Best Available Techniques (BAT) Reference Document for the Surface Treatment of Metals and Plastics

Colour code:
Black: Text from the original STM BREF (2006)
~~Black: Deleted text from the original STM BREF (2007)~~
Green: New text in D1
Yellow highlights are messages to the TWG, not part of the BREF

Directive 2010/75/EU on Industrial and Livestock Rearing Emissions (Integrated Pollution Prevention and Control)

JOINT RESEARCH CENTRE
Directorate B – Fair and Sustainable Economy
Circular Economy and Sustainable Industry Unit
European Bureau for Research on Industrial Transformation and Emissions (EU-BRITE)
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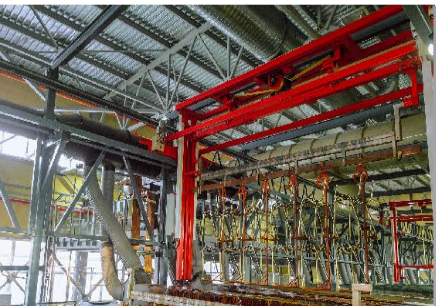

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WORKING DRAFT

This document is one of a series of foreseen documents as below (at the time of writing, not all documents have been drafted):

Reference Document on Best Available Techniques (BREF)	**Code**
Ceramic Manufacturing Industry	CER
Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector	CWW
Common Waste Gas Management and Treatment Systems in the Chemical Sector	WGC
Emissions from Storage	EFS
Energy Efficiency	ENE
Ferrous Metals Processing Industry	FMP
Food, Drink and Milk Industries	FDM
Industrial Cooling Systems	ICS
Intensive Rearing of Poultry and Pigs	IRPP
Iron and Steel Production	IS
Large Combustion Plants	LCP
Large Volume Inorganic Chemicals – Ammonia, Acids and Fertilisers Industries	LVIC-AAF
Large Volume Inorganic Chemicals – Solids and Others Industry	LVIC-S
Large Volume Organic Chemical Industry	LVOC
Management of Tailings and Waste-rock in Mining Activities	MTWR
Manufacture of Glass	GLS
Manufacture of Organic Fine Chemicals	OFC
Non-ferrous Metals Industries	NFM
Production of Cement, Lime and Magnesium Oxide	CLM
Production of Chlor-alkali	CAK
Production of Polymers	POL
Production of Pulp, Paper and Board	PP
Production of Speciality Inorganic Chemicals	SIC
Production of Wood-based Panels	WBP
Refining of Mineral Oil and Gas	REF
Slaughterhouses and Animals By-products Industries	SA
Smitheries and Foundries Industry	SF
Surface Treatment of Metals and Plastics	*STM*
Surface Treatment Using Organic Solvents including Wood and Wood Products Preservation with Chemicals	STS
Tanning of Hides and Skins	TAN
Textiles Industry	TXT
Waste Incineration	WI
Waste Treatment	WT
Reference Document (REF)	
Economics and Cross-media Effects	ECM
Monitoring of Emissions to Air and Water from IED Installations	ROM

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PREFACE

[Note to the TWG: This section has been completely rewritten compared to the original STM BREF]

1. Status of this document

Unless otherwise stated, references to 'the Directive' in this document refer to Directive 2010/75/EU as amended by Directive 2024/1785/EU of the European Parliament and of the Council on industrial emissions and livestock rearing emissions (integrated pollution prevention and control) (Recast).

This document is a working draft of the European Bureau for Research on Industrial Transformation and Emissions (EU-BRITE), formerly known as the European IPPC Bureau – EIPPCB, (of the Commission's Joint Research Centre). It is not an official publication of the European Union and does not necessarily reflect the position of the European Commission.

2. Participants in the information exchange

As required in Article 13(3) of the Directive, the Commission has established a forum to promote the exchange of information, which is composed of representatives from Member States, the industries concerned and non-governmental organisations promoting environmental protection (Commission Decision of 16 May 2011 establishing a forum for the exchange of information pursuant to Article 13 of the Directive 2010/75/EU on industrial emissions (2011/C 146/03), OJ C 146, 17.05.2011, p. 3).

Forum members have nominated technical experts constituting the technical working group (TWG) that was the main source of information for drafting this document. The work of the TWG was led by EU-BRITE (of the Commission's Joint Research Centre).

3. Structure and contents of this document

Chapters 1 and 2 provide general information on the Surface Treatment of Metals and Plastics and on the industrial processes and techniques used within this sector.

Chapter 3 provides data and information concerning the environmental performance of installations within the sector, and in operation at the time of writing, in terms of current emissions, the consumption and nature of raw materials, water consumption, use of energy and the generation of waste.

Chapter 4 describes in more detail the techniques to prevent or, where this is not practicable, to reduce the environmental impact of installations in this sector that were considered in determining the BAT and emerging techniques. This information includes, where relevant, the environmental performance levels (e.g. emission and consumption levels) which can be achieved by using the techniques, the associated monitoring and the costs and the cross-media issues associated with the techniques.

Chapter 5 presents the BAT conclusions as defined in Article 3(12) of the Directive.

Concluding remarks and recommendations for future work are presented in Chapter 6.
[This chapter will be drafted and shared for comments at a later stage.]

4. Information sources and the derivation of BAT

This document is based on information collected from a number of sources, in particular through the TWG that was established specifically for the exchange of information under Article 13 of the Directive. The information has been collected and assessed by EU-BRITE (of the Commission's Joint Research Centre) who led the work on determining BAT, guided by the principles of technical expertise, transparency and neutrality. The work of the TWG and all other contributors is gratefully acknowledged.

The BAT conclusions have been established through an iterative process involving the following steps:

- identification of the key environmental issues for the sector;
- examination of the techniques most relevant to address these key issues;
- identification of the best environmental performance levels, on the basis of the data available in the European Union and worldwide;
- examination of the conditions under which these environmental performance levels were achieved, such as costs, cross-media effects, and the main driving forces involved in the implementation of the techniques;
- selection of the best available techniques (BAT), their associated emission levels (and other environmental performance levels) and the associated monitoring for this sector according to Article 3(10) of, and Annex III to, the Directive.

Expert judgement by EU-BRITE and the TWG has played a key role in each of these steps and the way in which the information is presented here.

Where available, economic data have been given together with the descriptions of the techniques presented in Chapter 4. These data give a rough indication of the magnitude of the costs and benefits. However, the actual costs and benefits of applying a technique may depend greatly on the specific situation of the installation concerned, which cannot be evaluated fully in this document. In the absence of data concerning costs, conclusions on the economic viability of techniques are drawn from observations on existing installations.

5. Review of BAT reference documents (BREFs)

BAT is a dynamic concept and so the review of BREFs is a continuing process. For example, new measures and techniques may emerge, science and technologies are continuously developing and new or emerging processes are being successfully introduced into the industries. In order to reflect such changes and their consequences for BAT, this document will be periodically reviewed and, if necessary, updated accordingly.

6. Contact information

All comments and suggestions should be made to the European Bureau for Research on Industrial Transformation and Emissions (EU-BRITE) at the Joint Research Centre (JRC) at the following address:

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Best Available Techniques Reference Document for the Surface Treatment of Metals and Plastics

[Note to the TWG: please note that the colour code is not applied in the table of contents, list of figures and list of tables below]

List of figures

List of tables

SCOPE

[Note to the TWG: This section has been completely rewritten compared to the original STM BREF]

This BREF concerns the following activities specified in Annex I to Directive 2010/75/EU as amended by Directive (EU) 2024/1785:

2.3. Surface treatment of metals or plastic materials using an electrolytic or chemical process where the volume of the treatment vats exceeds 30 m^3.

6.11. Independently operated treatment of waste water not covered by Directive 91/271/EEC[1], provided that the main pollutant load originates from the activities covered by these BAT conclusions.

This document covers the porcelain (vitreous) enamelling of metals and also the following:

- The manufacturing of semiconductors covered by the activity description in point 6.7 of Annex I to Directive 2010/75/EU as amended by Directive (EU) 2024/1785.
- The combined treatment of waste water from different origins, provided that the main pollutant load originates from the activities covered by these BAT conclusions and that the waste water treatment is not covered by Directive 91/271/EEC[1].
- Combustion processes directly associated with the activities covered by these BAT conclusions provided that the gaseous products of combustion are put into direct contact with material.

This document does not cover the following:

- Waste water from indirect cooling systems. This may be covered by the BAT conclusions for Industrial Cooling Systems (ICS).
- On-site combustion plants generating hot gases that are not used for direct contact heating, drying or any other treatment of objects or materials. These may be covered by the BAT conclusions for Large Combustion Plants (LCP) or by Directive (EU) 2015/2193 of the European Parliament and of the Council[2].

Other reference documents which could be relevant for the activities covered by these BAT conclusions include the following:

- Surface Treatment Using Organic Solvents (STS);
- Waste Treatment (WT);
- Monitoring of Emissions to Air and Water from IED Installations (ROM);
- Economics and Cross-Media Effects (ECM);
- Emissions from Storage (EFS);
- Energy Efficiency (ENE).

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[1] Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment (OJ L 135, 30.5.1991, p. 40).

[2] Directive (EU) 2015/2193 of the European Parliament and of the Council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants (OJ L 313, 28.11.2015, p. 1).

1 GENERAL INFORMATION ON THE SURFACE TREATMENT OF METALS AND PLASTICS

Treating the surfaces of metals

The surface treatment of and by metals dates back to early man using gold decoratively before 4000 BC. Gold and silver plating (including their deposit from amalgams) was well-known by the 13th century AD, and tin plating of iron was carried out in Bohemia in 1200 AD. In the mid-19th century, the electrodeposition of metals was discovered enabling new possibilities, which are still being extended [4, Cramb, 1996], [5, Hook and Heimlich, 2003]~~, 41, 2003~~.

The surface properties of metals are typically changed for:

- decoration and/or reflectivity
- improved hardness (to maintain cutting edges and resistance to damage and wear)
- prevention of corrosion.

Currently, the main areas of application are: automotive and transportation, packaging, building and construction (for more information, see Section 1.1) [118, ESTAL, 2003]. Two further commercial areas of application have emerged since the 1960s:

- in microelectronics, especially with the advent of telecommunications and microprocessor controls in many common appliances. These demand mass-produced components with high conductivity capable of carrying very small electrical currents. This is achieved by applying precious metal plating on cheaper substrates
- in printing, where aluminium is usually the substrate of choice for lithographic plates. The aluminium is first treated by electrochemical graining and anodic oxidation (anodising) prior to photosensitive treatments.

Treating the surfaces of plastics

Plastics are now widely used in their own right and not only to replace metals. However, although they can be easily formed, may be flexible or rigid, and are corrosion-resistant and insulating, they lack other desirable properties. This has led to demands to change the surface properties of these new materials for:

- decoration, to achieve a high value, metal-like appearance similar to gold, brass, and chromium
- reflectivity, similar to chromium
- durability, as plastics are generally softer than metals
- electrical conductivity, usually in selected areas.

These requirements are met by depositing layers of metals on the surface of the plastic.

Printed circuit boards are a specific case, where intricate electronic circuits are manufactured using metals on the surface of a plastic – usually resin or glass fibre board but also plastic films. A complicated series of processes removes and adds successive layers of metals as circuits to connect small holes. The inside surface of these holes are also coated with metal during the processes to enable electronic components to be subsequently soldered into them.

Semiconductor manufacturings

A semiconductor is characterised by its electrical current conductivity, which is between an insulator and a conductor. With the help of doping, i.e. the introduction of impurities into the crystal lattice, the semiconductor's ability to conduct electrical current can be adjusted in such a way as to make it an ideal way to control electrical current. Diodes, transistors and integrated circuits are made of semiconductors, which are vital components of today's electronic equipment and devices such as LED lighting and photovoltaic cells. [https://www.techtarget.com/whatis/definition/semiconductor]

The most widely used semiconductor material is silicon (Si). The purification of metallurgical to polycrystalline Si is performed via the Siemens process. Subsequently, the polycrystalline Si is converted into a single crystal. Eventually, wafers, i.e. very thin slices of semiconductors with highly accurate dimensions, are produced from the single Si crystal, which is the most demanding step in the production of electronic-grade Si. [Winnacker, Albrecht. *The Physics behind Semiconductor Technology*. 2022. https://doi.org/10.1007/978-3-031-10314-8; Chapter 5]

The Si wafer is used as substrate and modified with several surface treatment techniques such as:

- photolithography to transfer the required pattern onto the wafer via a photomask;
- deposition to establish dielectric or metal films;
- etching to remove parts of dielectric or metal films;
- doping to form n-type and p-type regions.

[Lian, Yaguang. *Semiconductor Microchips and Fabriaction. A practical Guide to Theory and Manufacturing*. 2023. ISBN: 9781119867791; Chapter 11]

1.1 Industries using surface treatments

TWG please provide updated information

The surface treatment of metals and plastics does not itself form a distinct vertical industry sector. Surface treatments do not create products; they change the surface properties of previously formed components or products for subsequent use. Printed circuit boards as well as semiconductors might be considered products but are components manufactured for use in other products, and are made by a considerable number of interdependent manufacturing stages. The surface treatment of metals and plastics is therefore largely a service to many industries and examples of key customers are given below:

- automotive
- aerospace
- information systems
- telecommunications
- heavy engineering
- construction (building)
- bathroom fittings
- hardware
- food and drink containers
- printing
- domestic appliances
- jewellery, spectacles and ornaments
- furniture
- clothing
- coinage
- medical.

The market structure in volume is approximately: automotive 22 %, construction 9 %, food and drink containers 8 %, electric industry 7 %, steel semi product 7 %, electronic industry 7 %, industrial equipment 5 %, aerospace industry 5 %, unspecified 30 % [121, France, 2003]. Table 1.1 sets out examples of key treatments and their uses.

Table 1-1: Examples of key treatments and their uses

Treatment type	Substrate	Example workpieces	Effect achieved
Zinc plating and chromium passivation	Steel	Fastenings (nuts, bolts, screws, nails, specialist design, etc.) for construction, automotive, furniture. Automobile brake system components, windscreen washer system components. Chassis and casings for domestic goods (TVs, Hi-fis, videos, washing machines, fridges).	• corrosion protection • decoration
Hard chromium plating	Steel	Heavy duty engines (marine, etc.). Rolling mill bearings (steel and non-ferrous metal). Rollers (in paper mills). Aerospace undercarriage and control components. Medical equipment. Automotive shock absorbers [157, ACEA, 2004].	• durability • prevention of sticking • micro-smooth surface
Chromium plating	Steel coil	Food, domestic and commercial products packaging (cans)	• corrosion protection • decoration
Nickel, autocatalytic plating (for subsequent chromium plating)	Plastic, steel, aluminium, etc.	Bathroom fittings. Furniture fittings. Textile and printing machinery. Automotive trim [124, Germany, 2003].	• decoration • corrosion protection
Nickel, electrolytic	Steel	Coins (all EU currencies). Fittings (screws, etc.). Automotive trim [157, ACEA, 2004].	• corrosion protection • decoration
Copper and copper alloy (brass) plating	Steel	Coins (all EU currencies). Fittings.	• decoration
Cadmium plating	Steel	Aerospace fittings.	• corrosion prevention • prevention of sticking
Gold plating	Copper, printed circuit boards	Connectors and wires for telecommunications and IS hardware.	• corrosion prevention • high conductivity
Precious metal plating (gold, silver, iridium, platinum)	Steel, copper, brass, alloys	Jewellery, ornaments (hollowware), spectacle frames.	• decoration • corrosion prevention
Anodising	Aluminium	Automotive components [111, ACEA, 2003]. Aerospace wing and fuselage panels. Building door and window frames, cladding panels. Packaging and consumer goods.	• corrosion protection • decoration (with or without colour)
Hard anodising	Aluminium	Bearing surfaces in turbine compressor housings for automotive engines.	• durability, increased hardness
Conversion coatings, such as phosphating, chromating and others [118, ESTAL, 2003]	Steel, aluminium and other metals	Nuts, bolts, screws, tubes. Engine pinions, camshafts, pistons, gears, valves. Cold forming of wires, tubes, etc. Food and domestic goods packaging. Automotive bodies and panels [111, ACEA, 2003]. Domestic electrical goods, etc.	• corrosion protection • durability (surface lubrication for cold drawing, or forming) • overcomes surface irregularities • adhesion of paints

Treatment type	Substrate	Example workpieces	Effect achieved
Printed circuit boards (tin and copper plating, etching,etc.)	Copper on plastics	Control systems for aerospace, automotive products (engine management, braking, etc.), telecommunications and IS, domestic goods.	• circuit systems
Semiconductor manufacturing	Semiconductors, e.g. silicon, germanium, gallium arsenide	Electronic devices, including diodes, transistors and integrated circuits	• adjusted conductivity • circuit system

1.2 Industry structure and economic background

1.2.1 Equipment lifetime

The vast majority of process lines are modular and the actual plant life is difficult to quantify as individual modules are repaired or replaced as necessary. Typically, complete production lines are only replaced at long intervals (when maintenance of individual modules is no longer sufficient), or when radically new technology is introduced. However, for large scale surface treatment operations such as steel coil coating and treating automotive bodies and panels, capital investment can be many millions of euros (and up to EUR 500 million for a complete paint shop installation) with a lifetime of 20 to 40 years~~. Depreciation is usually over 20 years~~ [111, ACEA, 2003].

1.2.2 Type and size of installations

The surface treatment of metals and plastics discussed in this document is carried out in more than 18 300 installations (both IED~~IPPC~~ and non-IED~~IPPC~~) in Europe, ranging from small private companies to facilities owned by multinational corporations. The large majority are small or medium enterprises (SMEs, [61, EC, 2002]); in Germany the typical number of employees is between 10 and 80. Altogether, the industry for the surface treatment of metals and plastics employs about 440 000 people in Europe. These figures include manufacturers of printed circuit boards, but exclude the semiconductor manufacturing industry. While there are a relatively small number of semiconductor manufacturing installations in Europe, i.e. about 60 [https://www.dpsgroupglobal.com/news-and-insight/european-chips-act-and-upcoming-eu-semiconductor-projects-for-2023-2024/], approximately 200 000 jobs are directly linked to the semiconductor industry in the EU [https://www.eusemiconductors.eu/sites/default/files/20240131_EUTalentPool.pdf].

More than 10 000 (55 %) are specialist surface treatment installations (known as job or jobbing shops). The remaining 8 300 (45 %) are surface treatment shops within another installation typically also an SME. The majority of jobbing shops serve more than one industry (see those listed in Table 1.1). There is no installation typical of the whole range of activities, and even though there are strong similarities between sites engaged in the same activities, no two sites will be identical. [3, CETS, 2002], [104, UBA, 2003] For gathering economic statistics, electroplating, plating, polishing, anodising and colouring are classified under the Standard Industrial Classification (SIC) code 3471, but this includes establishments engaged in all types of metal finishing. Companies that both manufacture and finish (surface treat) products are classified according to the products they make. The semiconductor manufacturing industry is covered by the SIC code 3674. For data on sources of emissions, the industry is classed under general purpose manufacturing processes (for emissions, NOSE-P 105.01 [2, EC, 2000]). These groupings make the extraction of data for specific surface treatments or for the whole sector difficult as they cannot be differentiated readily from the other engineering activities.

Surface treatment is positioned between initial workpiece or substrate manufacture and final product assembly, completion and packaging. Treatment (both in jobbing shops and many in-house workshops) often has low priority in the production chain, although there are significant exceptions. Low priority can result in insufficient attention to correct and up to date specifications, insufficient attention given in product design to minimise and reduce consumptions, as well as a lack of investment.

Surface treatment is usually carried out after the primary metal or plastic has been formed into workpieces or shaped substrates, such as nuts, bolts, pressed or moulded components, sheets, or coils. They may even be sub-assemblies made of several components, often of different materials. These components and sub-assemblies can be complex shapes which have been pressed, cast and/or machined. However, in coil processing the surface treatment is applied before the substrate used. The size varies from wires to steel strip 2008 mm wide. In smaller scale reel-to-reel applications, copper, brass or other alloys are also coated. Printed circuit boards are made from plastic or glass fibre boards which are already laminated (usually with copper) or plastic films.

Process lines are usually modular, and small lines can be easily assembled as a series of tanks. However, large automated lines and the modules in those installations handling steel coil on a large scale, or large components such as parts of aircraft wings, are typically specialist, large and capital intensive. This also holds true for the manufacturing of semidconductors: the stringent requirements, for example on precision and cleanliness, make the sector highly specialised and cost-intensive.

Most installations, particularly the jobbing shops, will operate multiple lines side by side. This assists in increased capacity and reliability of delivery, and allows the installation to offer different treatments (jig, coil or small scale coil, see Chapter 2) for different products and prices and/or to offer different finishes. In these cases, ~~point 2 of~~ Annex I to the ~~IPPC~~ IED ~~Directive~~ states~~applies~~: "*Where one operator carries out several activities falling under the same subheading in the same installation or on the same site, the capacities of such activities are added together*" [1, COM 2024~~EC, 1996~~].As an example of geographic distribution and structure of the industry, in France the industry is widely spread, with concentrations in the south east (21 %) and the Paris area (24 %). The number of surface treatment installations where the volume of treatment vats exceed 1.5 m^3 is 2250 (the threshold level for French national legislation), and the number where the volume of treatment vats exceed 10 m^3 is 1260 [121, France, 2003].

1.2.3 Technical characteristics of installations

Due to the modular nature of the process lines, some techniques can be installed or changed relatively quickly and cheaply. For instance, some process solutions are changed on a regular basis, others are expensive with a long life and change is an investment decision. Some techniques may require alterations or extensions to production lines. Although the modular nature facilitates such changes, in many cases other factors will affect the ease of change, such as the limits of transporter mechanisms and control systems, and the space available in the installation. In-house operations tend to be for specific products. Introducing changes for these and for plants handling larger products such as steel coil coating, aerospace parts or automotive bodies may be technically more difficult and/or involve higher capital costs. For larger plants, depreciation is usually between 6 and 20 years [157, ACEA, 2004].

Because of overcapacity in the sector, it is rare for totally new plants for conventional surface treatment to be built. In existing installations, it is more common to replace modules or lines. In contrast, semiconductor manufacturing is a special case. As it is a strategic asset, the expansion of semiconductor manufacturing is targeted by the European Chips Act to decrease the global dependency on a limited number of suppliers [https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-chips-act_en]. Therefore, the semiconductor manufacturing industry is expected to grow significantly in Europe [https://www.dpsgroupglobal.com/news-and-insight/european-chips-act-and-upcoming-eu-semiconductor-projects-for-2023-2024/].

1.2.4 Market structure

1.2.4.1 Competition

The low cost and ease of modular construction of conventional surface treatment lines is a low barrier to entry. Businesses treating the surfaces of metals and plastics using only one or two process lines, often of small vat volumes, are frequently in direct competition for some customers with installations operating larger process lines utilising more abatement techniques.

Semiconductor manufacturing is characterised by significant barriers to entry, which results in a relatively small number of larger installations. However, these installations are in competition with other installations around the world.

While this industry serves several major manufacturing areas, there is a high concentration of customers in some areas (such as the automotive industry) with highly competitive markets, and surface treatment overcapacity. Very few jobbing shops are large enough to serve more than three or four industry types or provide more than three finish options, with most company business strategies focused on specialising in certain finish types. There are some limited opportunities to differentiate the business by providing specialist treatment finishes and/or by specialist quality standards, or for vertical integration such as manufacturing the components to be treated. The in-house installation is the complete vertical integration of the business. The large scale production lines depend on large volumes of very specific surface finishes, such as one type of coating for steel coil, and typically opportunities for diversification or new markets are extremely limited.

1.2.4.2 Extent of the market

The geographic size of the market is often proportional to the degree of specialisation of the treatment. Those treatments that are widely carried out by jobbing shops (such as zinc plating with chromium passivation) are carried out on a very local basis, with customers usually controlling the price. Other, more specialised, finishes where the higher price justifies transport costs (such as cadmium plating or anodising of large components to aerospace specifications) may be carried out on a national scale, or even between neighbouring countries. However, the concentration of surface treatment installations within Europe usually means physically extending markets brings more competitors within range.

The extent of the market for the customers' goods is also an important factor. During 2001 and 2002 the volume of business in the light engineering industries fell by 30 % across Europe. This was due to the increased exporting of the total manufacture of engineered components and assemblies to Asia (Verbal discussions, TWG).

~~Current predictions for printed circuit board (PCB) production are that by 2005/6 the worldwide PCB production may again reach the level of the boom year 2000. Due to the cost structure of Asian competitors, the long term competitiveness of high volume PCB production in Europe using standard technologies remains questionable with global customers. Worldwide overcapacity may result in further mergers and insolvencies, unless further growth is generated in Europe. [122, UBA, 2003]~~

Despite a constantly growing global PCB market, reaching almost USD 70 billion in 2023, the European PCB production industry has experienced a significant decrease in productivity over the last two decades. One reason for the decrease in PCB production in Europe is the availability and import of cheap PCBs from Asia, with China dominating PCB production. In 2022, Europe only contributed 2.3% to the global PCB supply, and further significant European PCB production sites in Germany, Czechia, France and Estonia stopped operations afterwards. The trend of declining PCB production in Europe is expected to continue, leading, on the one hand, to a further drop in the European PCB supply to 1.7%, and, on the other hand, an intensified reliance on PCB imports. (https://www.power-and-beyond.com/european-pcb-industry-crisis-a-bb7293096ca632378b998846d6e9f9ac/)

~~The percentage growth of multilayer boards (MLBs) and other high-tech products, including the disproportionate growth of HDI (high density interconnect) or microvia boards, demonstrates the technological development of European PCB production. It is expected that European PCB manufacturers will continue to move to high-tech areas, concentrating in segments such as sensor technology, industrial applications, telecommunications, automotive electronics, and medical and aeronautical industries (see Section 1.3.5).~~

Semiconductors are globally traded goods. Therefore, European semiconductor manufacturing installations, contributing 8% to the global commercial semiconductor fab capacity in 2022, compete with many other countries. Big players in the semiconductor manufacturing are China (24% of global commercial semiconductor fab capacity), Taiwan (18%), South Korea (17%), Japan (17%), and the US (10%). (https://www.semiconductors.org/wp-content/uploads/2024/05/Report_Emerging-Resilience-in-the-Semiconductor-Supply-Chain.pdf)

1.2.4.3 Market substitutes

Substitutes in this context [88, COM, 2006] means alternative, competing ways for the customer to achieve the desired result, and not the substitution for chemicals or other processes described in Section 4.2.6.9. Alternatives are readily available for many of the surface treatments of metals and plastics. The customer may change to one of these alternatives because of price or for design reasons. This type of substitution can take three forms:

- a different surface treatment system. For example, electrolytic or chemical treatments compete with surface treatments by solvent-painting: painted car door handles have largely replaced chrome-plated ones; lithographic printing from aluminium plates can be replaced by laser or ink jet for small runs
- component manufacture from a different material. The customer may redesign the products or components from alternative materials, reducing the need for surface treatment. For example, paint or foodstuffs can be sold in plastic containers instead of metal cans; lithographic plates can be produced with different substrates such as plastics
- a combination of the above. Car light reflectors can now be moulded from plastic with vapour deposition of a metal, instead of copper/nickel/chrome plating of a steel pressing.

Figure 1-1 and Figure 1.2 both show example activities where customers can switch between anodising and other coatings, according to design trends, customer specification requirements and cost.

1.2.5 Summary of general economic situation

Opportunities to pass increased costs to customers are limited because of:

- the large number of surface treatment installations competing for a decreasing number of customers
- the decline of engineering businesses in Europe
- the increasing substitution options (as described above).

1.3 Specific industry activities

1.3.1 Anodising of aluminium ~~architectural panels and profiles~~

[175, ESTAL 2024]
Anodic oxidation coating, or ‘anodising’, is an electrochemical process reinforcing the natural oxide film on the aluminium surface, increasing hardness and corrosion and abrasion resistance. Anodising gives a decorative silver matte surface finish, and coloured surfaces can also be obtained by sealing colorants into the anodised layer. Anodising is mostly a batch process, applicable to all types of aluminium semi-products (profiles, sheets, castings, etc.), but coiled sheets can also be anodised in a continuous process.

While there are only a small number of companies dealing with continuous coil anodising, there are about 150 aluminium-dedicated batch anodising plants in the EU, mostly SMEs, plus several general metal finishers that are also active in anodising as a complementary activity, even sometimes combining plating and anodising on the same line.

Most batch anodising lines are horizontal but vertical ones also exist. Vertical lines are used for a small variety of treated parts, but with a huge throughput, while it is the opposite for horizontal lines. From the point of view of consumption of materials, energy and water, vertical lines cannot be compared with horizontal ones.

Most aluminium anodising plants use the sulphuric-acid-based process. The chromic-acid-based process is also used, but limited to aerospace and military applications.

Quite different anodic layer thicknesses may be applied, varying from 3 µm to over 100 µm, depending on the alloy treated and customer (product) requirements. The thickness of the anodic layer influences the electricity consumption of the process.

The post-treatment sealing, which aims at plugging the pores of the anodic layer, can be done at various temperatures which have a significant impact on the energy consumption.

~~The surface treatment of aluminium predominantly for construction use as architectural profiles is carried out in more than 460 plants across the EU-15 and 6 non-EU-15 countries. Again, these are mainly small or medium enterprises [9, ESTAL, 2002]. In Europe, the consumption of anodised aluminium amounts to approximately one square metre per capita per year [118, ESTAL, 2003].~~

~~Figure 1.1 shows the total production for both anodising and other coatings for aluminium profiles in Europe.~~

~~Figure 1.2 shows the European production of anodising by batch (jig line, see Chapter 2), other coatings by batch, and other coatings on coils from 1996 to 2000.~~

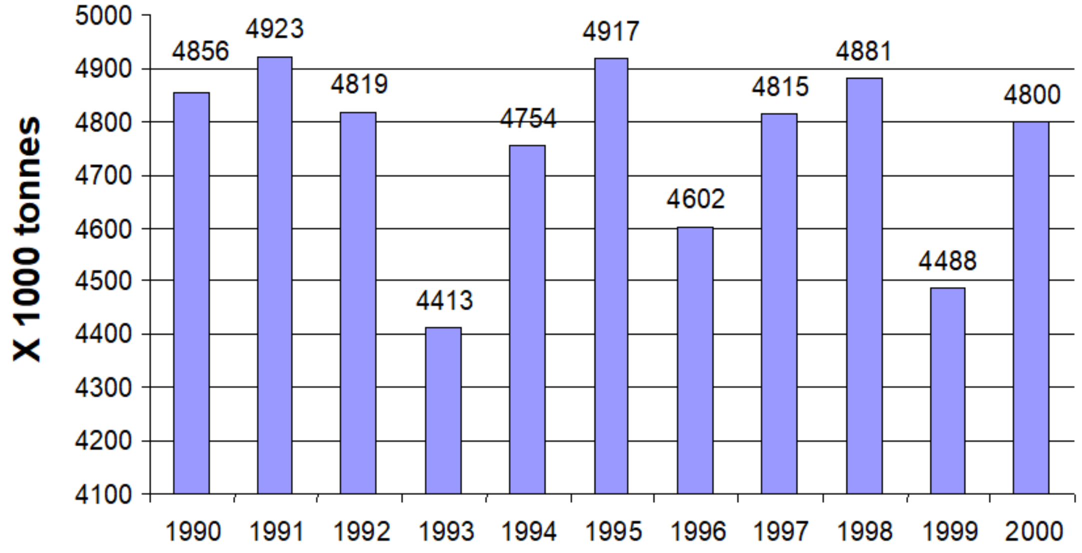
~~Figure 1.3 shows the production of the leading four European countries for anodising of profiles from 1996 to 2000.~~

1.3.2 Large scale continuous coating of steel

There are four types of electrolytic treatment systems applied to steel coil in the EU~~-15~~: tin plate, chromium (ECCS: electrolytic chrome coated steel), zinc or zinc-nickel alloy and lead [19, Eurofer, 2003]. In the Czech Republic, copper, brass, nickel, and zinc are applied to steel strip in widths of 145 – 265 mm. [116, Czech-Republic, 2003] No data are known for other European countries.

Electrolytic tin plate and electrolytic chromium coated steel (ECCS)

The main application for the substrate from this process is packaging. The production of continuous electrolytic tin plate and electrolytic chromium (ECCS) in EU-15 was 4800 kt in 2000. The trend in production for both tin plate and ECCS is shown in Figure 1-1 and by country in Table 1.2.



APEAL [19, Eurofer, 2003][3]

Figure 1-1: Steel for packaging (tin plate and ECCS) production in EU-15 (in kt)

Table 1-2: Production tonnages for the year 2000 for both tin plate and ECCS by country in EU-15

Country	**Production (kt) tin plate in 2000** nd = no data	**Production (kt) ECCS in 2000** nd = no data
Austria	nd	nd
Belgium	281	12
Denmark	nd	nd
Finland	nd	nd
France	886	207
Germany	802	147
Greece	69	nd
Ireland	nd	nd
Italy	283	67
Luxembourg	nd	nd
Netherlands	612	51
Portugal	76	nd
Spain	494	61
Sweden	nd	nd
United Kingdom	588	147
Totals for data given	**4091**	**692**
EUROFER STATS [19, Eurofer, 2003]		

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[3] APEAL: - The Association of European Producers of Steel for Packaging – a federation of four multinational producers of steel packaging for Europe across seven countries. This represents some 90 % of the total European production of steel for packing and hence of tin plate and ECCS lines.

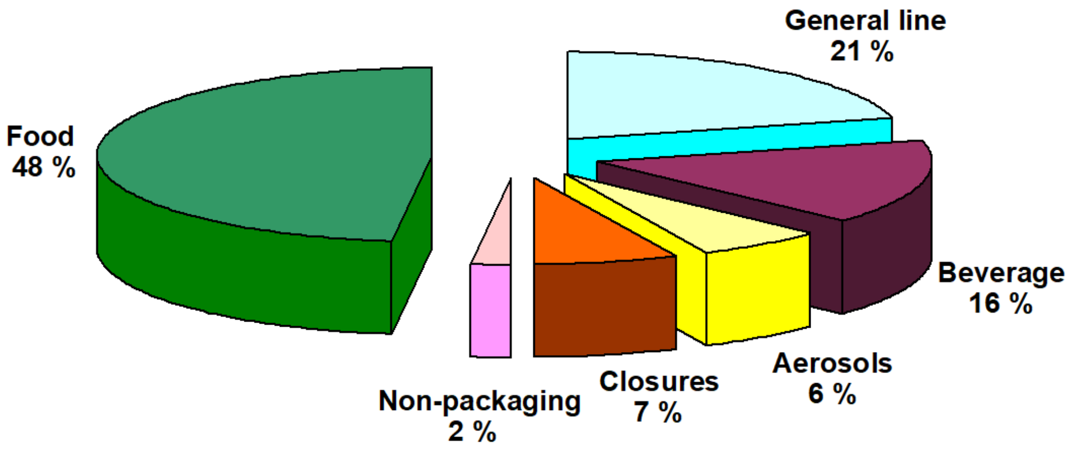
Tin plate and ECCS activities annual turnover is in the order of EUR 3 000 million and employs directly and indirectly 15 000 people (2003 data).

There are installations in nine Member States. The number of continuous coil production lines in EU Member States operating, under construction and planned is shown in Table 1.3.

Table 1-3: Number of continuous lines producing both tin plate and ECCS in EU-15

Country	No of tin plate lines nd = no data	No of ECCS lines nd = no data
Austria	nd	nd
Belgium	1	1*
Denmark	nd	nd
Finland	nd	nd-
France	5	5*
Germany	3	1
Greece	1	
Ireland	nd	nd
Italy	nd	nd
Luxembourg	nd	nd
Netherlands	4	2 including tinning*
Portugal	1	0
Spain	4	1*
Sweden	nd	nd
United Kingdom	2	1
* Indicates lines that can produce tin plate ECCS [119, Eurofer, 2003].		
[19, Eurofer, 2003]		

Figure 1-2 shows the share of tin plate and ECCS consumption by industries in the EU-15 with an average annual production close to five million tonnes. Steel packaging of human and pet food represent the main application with a 48 % share, followed by general production lines (for paint cans, industrial cans, etc.).

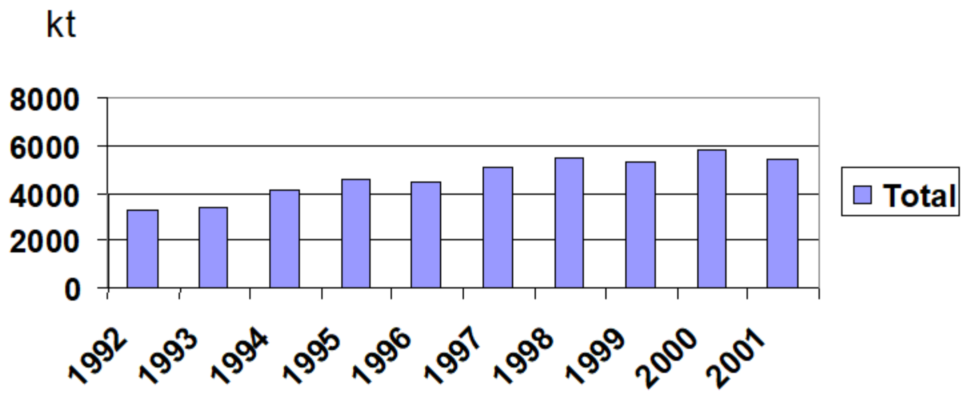


APEAL [19, Eurofer, 2003]

Figure 1-2: Main consuming industries for tin plate and ECCS outputs

Continuous electrolytic zinc and zinc nickel (Zn and Zn-Ni) coating of steel

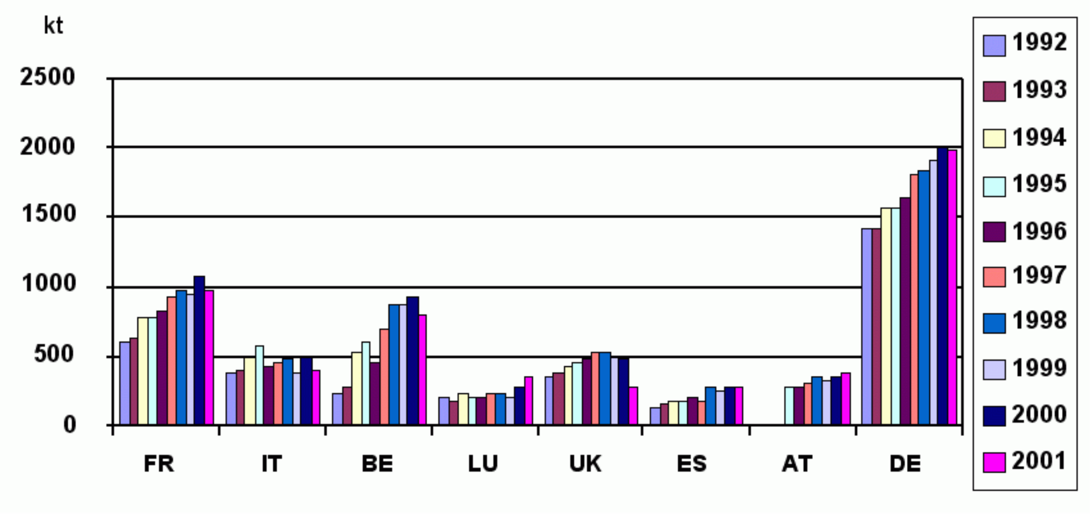
Since the 1970s, the production of zinc and zinc alloy-coated steel sheet has increased significantly. This has been largely for the automotive industry in response to the demand for anti-corrosion guarantees and longer vehicle lifetimes.



[19, Eurofer, 2003]

Figure 1-3: Production of continuous electrolytic zinc/zinc-nickel in EU-15 (in kt)

The production of continuous electrolytic Zn or Zn-Ni coating steel was 5.37 Mt in 2001. The evolution of the production in the EU-15 is shown in Figure 1-4, below.



[19, Eurofer, 2003]

Figure 1-4: Production of continuous zinc and zinc-nickel coating steel in EU-15 (in kt)

Continuous electrolytic lead coating of steel

There is only one continuous lead coating plant in Europe (Austria). This plant will lose key European automotive customers and is due to close by 2005 – 6. This is due to European legislation controlling the amount of lead in end-of-life vehicles [99, EC, 2000].

Other continuous electrolytic coating of steel

In the Czech Republic, there is an installation for the continual application of metallic coatings (copper, brass, nickel, zinc) on steel strip (width 145 – 265 mm) with a total capacity 8000 t/yr steel. [116, Czech-Republic, 2003]

1.3.3 Coil and sheet anodising for lithographic (offset) printing plates

Lithographic or offset printing uses an intermediate roller to transfer ink from a plate to paper. It requires plate-making that is simple, quick, and economical. Aluminium is the usual substrate of choice. There are two types of plates: [38, Ullmann, 2002/3]

- pre-sensitised (PS) plates (manufactured with a photosensitised finish). Current world sales are about 180 × 10^6 m^2
- wipe-on plates which are not pre-coated and are coated by the printer as required. They are still being used in some countries, mainly the United States and Eastern Europe. Worldwide consumption amounts to about 30 × 10^6 m^2.

1.3.4 Continuous coil processing of aluminium

~~Many hundreds of kilotonnes per year of aluminium coil are processed through lines of the main rolling mills and other companies. Processes include cleaning, pretreatment, etching, anodising, colouring, sealing, electrobrightening and tunnel etching [118, ESTAL, 2003].~~

Besides continuous coil anodising mentioned in Section 1.3.1 and continuous coil coating with wet paint, which is not within the scope of the current BREF (but in the STS BREF [90, COM 2020]), other continuous processes can be applied to aluminium coils.

These are mainly treatment process steps before coils are shipped to customers who will deal with the final coating step.

Such process steps can include various combinations of the following: degreasing, etching, application of conversion layer (e.g. Cr-III, Ti, Ti-Zr and/or other passivation processes (e.g. polymer), oiling.

Instead of treatment by immersion, spaying techniques, roller coaters or electrostatic applications are more and more widely used. In this case, there are no surface treatments vats.

Degreasing as such may not be considered a surface treatment because the altering of the substrate is not the purpose of the process.

Oiling may also not be considered a surface treatment because it does not alter the substrate.

Some lines include treatment steps that are not a surface treatment, e.g. tension levelling, metallurgical thermal treatment like annealing. These lines can also be operated without any surface treatment, e.g. tension levelling only.

The various combinations of the above-listed process steps are very heterogeneous because of the variety of customer requirements, and they are nearly always integrated in rolling mills where other activities possibly covered by other BREFs may take place.

1.3.5 Printed circuit boards

The world market for PCBs in 2023 was USD 69 690 million, while the market is projected to grow from USD 71.57 billion in 2024 to USD 113.49 billion by 2032, exhibiting an annual growth rate of 5.9%. Asia-Pacific dominated the global market with a share of 56.69% in

2023[4].~~down 24.3 % from the market peak in 2000 of USD 41824 million, which was a boom year for electronics (see Figure 1.8) [122, UBA, 2003]~~.
The figures below give an idea of the composition of the various segments of the industry[5]:

By type:

- Rigid PCBs: USD 43.6 billion (2020), growing to around USD 56.3 billion by 2025.
- Flexible PCBs: USD 14.5 billion (2020), growing to around USD 23.4 billion by 2025.
- HDI PCBs: USD 4.3 billion (2020), growing to around USD 7.3 billion by 2025.

By application:

- Consumer electronics: USD 23.4 billion (2020), growing to around USD 31.4 billion by 2025.
- Industrial electronics: USD 14.5 billion (2020), growing to around USD 20.5 billion by 2025.
- Automotive electronics: USD 8.5 billion (2020), growing to around USD 14.5 billion by 2025.
- Aerospace and defense: USD 4.3 billion (2020), growing to around USD 6.5 billion by 2025.

By region:

- Asia-Pacific: USD 55-60 billion (2020), growing to around USD 70-75 billion by 2025.
- Europe: USD 4-5 billion (2020), growing to around USD 5-6 billion by 2025.
- Americas: USD 3-4 billion (2020), growing to around USD 4-5 billion by 2025.

~~The European share of the world market in 2002 was 18.0 %. The shares of the other regions were: Africa and the Middle East: 1.3 %, South East Asia: 26.4 %, Japan: 25.1 % and the Americas 29.2 %.~~

Production of PCBs in Europe

The European printed circuit board (PCB) manufacturing industry is a significant sector that contributes to the region's electronics manufacturing capabilities. An overview of the industry in terms of the number of plants, revenue and employment in Europe and the EU-27 is given below:

Number of plants

There are approximately 150 PCB manufacturing plants in Europe, with around 120 of them located in the EU-27 countries[6]. The majority of these plants are small- to medium-sized enterprises (SMEs), with only a few large-scale manufacturers. The European PCB industry produced around 150 million square metres of PCBs in 2020.

The EU-27 countries accounted for around 80% of the European PCB market revenue, with Germany and France being the largest markets.

The European PCB manufacturing industry employs around 15 000 people directly, with a significant proportion of them working in the EU-27 countries.

The industry also supports a larger ecosystem of jobs in related sectors, such as electronics manufacturing services (EMS), original equipment manufacturing (OEM), and research and development (R&D).

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[4] https://www.fortunebusinessinsights.com/printed-circuit-board-market-104947

[5] https://www.researchandmarkets.com/report/printed-circuit#tag-pos-1 "Printed Circuit Boards: Technologies and Global Markets"

[6] European Institute for Printed Circuits (EIPC) https://www.ipc.org/europe

In terms of product type, the European PCB industry can be split into the following categories:

- rigid PCBs: around 70-80% of the market share;
- flexible PCBs: around 10-15% of the market share;
- rigid-flex PCBs: around 5-10% of the market share;
- HDI (high density interconnect) PCBs: around 2-5% of the market share.

~~In 2002, the total PCB production in Europe was EUR 3422 million, and employed 29000 people at 434 plants.~~
~~The number of European manufacturers has changed significantly. In 1999, there were 612 manufacturers, which reduced to 434 by 2002. More than 80 % of these have a turnover of less than EUR 7.5 million/yr showing the European industry is dominated by SMEs, despite the high level of technology (see Figure 1.9).~~

In Europe, the percentage of high-tech PCB production has grown as a proportion of the total, showing the technological strength of the European PCB industry. This underlines the trend to higher specification products, with ever-more detailed structures in the smallest possible dimensions (see Section 1.2.4.2).

1.3.6 Porcelain (vitreous) enamelling of metals

Porcelain enamelling, also known as vitreous enamelling, is a process used to coat metal surfaces with a glass-like layer for decorative and protective purposes.

The main production processes for porcelain enamelling of metals include the following:

1. Cleaning: The metal surface is cleaned to remove contaminants and prepare it for enamelling.
2. Application: The porcelain enamel is applied to the metal surface, usually by dipping, spraying or brushing.
3. Drying: The enamel is dried to remove moisture and prepare it for firing.
4. Firing: The enamelled part is heated in a furnace to fuse the enamel to the metal surface, creating a strong bond.
5. Cooling: The part is cooled to room temperature after firing.

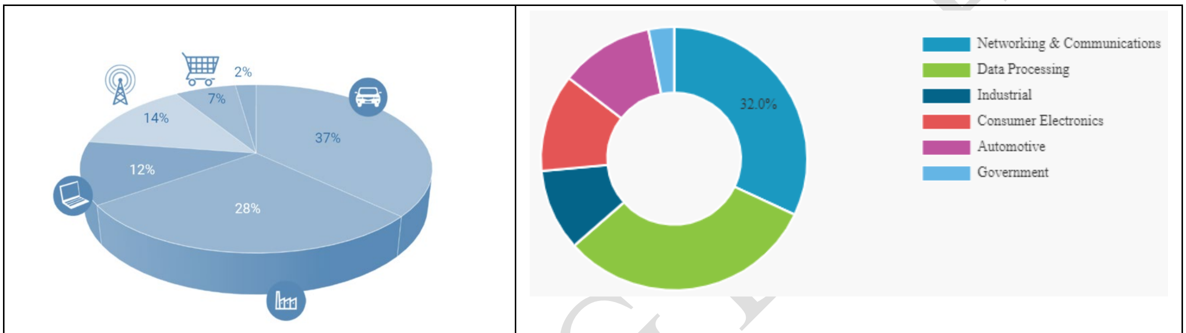
Porcelain enamelling is a widely used process in various industries, such as automotive, consumer goods, and architectural applications. Here are some estimates based on industry information:

- Automotive industry: Porcelain enamelling is commonly used for decorative and protective coatings on automotive parts, such as wheels, grilles and trim pieces. The automotive industry is a significant user of porcelain enamelling, with manufacturers and suppliers located in various countries, including in Europe, North America and Asia.
- Consumer goods: Porcelain enamelling is used for household appliances, cookware and decorative items. Major manufacturers and suppliers of porcelain enamelled consumer goods are located worldwide, including in Europe, North America and Asia.
- Architectural industry: Porcelain enamelled panels and cladding are used for building facades and interior design. Major manufacturers and suppliers of porcelain enamelled architectural products are located worldwide, including in Europe, North America and Asia.

1.3.7 Semiconductors manufacturing

Semiconductors are essential electronic circuits or units made of materials such as silicon, germanium, silicon carbide and others. Semiconductors are integral to electronic devices and systems comprising components such as memory devices, logic devices, analog integrated circuits, memory protection units, microcontroller units, discrete power devices, and others. The global semiconductor industry is growing with rising electronics use and integration across applications such as networking communication devices, data processing, industrial automation systems, consumer electronics, automotive, and government projects[7].

European semiconductor sales have reached over USD 51.2 billion in 2022. The biggest end-use segment in the European market is automotive chips (37%) followed by industrial applications (28%). In 2022, Europe and China were the biggest markets for automotive semiconductors, accounting for 25.4% and 26.2% of the global automotive market respectively. (https://www.eusemiconductors.eu/esia)



Source: https://www.eusemiconductors.eu/esia

Source: www.fortunebusinessinsights.com/semiconductor-market-102365

Figure 1-5: Semiconductor market share by application in Europe (year 2022, left) and in the world (year 2023, right)

There are 60 operating fabs in Europe, 7 in construction, and 8 more in the planning stages. Two of the seven fabs in construction and all eight in the planning stages have been enabled by the European Chips Act[8].

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[7] https://www.fortunebusinessinsights.com/semiconductor-market-102365

[8] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-chips-act_en

1.4 Key environmental issues

1.4.1 Overall

The STM industry plays a major role in extending the life of metals, such as in automotive bodies and construction materials. It is also used in equipment that increases safety or reduces consumption of other raw materials (e.g. plating of aerospace and automotive braking and suspension systems, plating precision fuel injectors for automotive engines to reduce fuel consumption, etc.). The main environmental issues arising from the surface treatment of metals and plastics relate to energy and water consumption, the consumption of raw materials, emissions to surface and groundwater, emissions to air and to water, solid and liquid wastes and the site condition on cessation of activities.

Surface treatments have traditionally been associated with large water usage creating a wet working environment, although many installations have moved away from this way of working. The chemicals used have the potential to cause environmental harm particularly to surface waters, groundwaters and soil. Metals removed from waste waters end up in solid wastes and, together with some used process solutions, may need special management for recovery or disposal. The industry can discharge fumes and dust to air, as well as generating noise. The sector is a significant user of electricity, water and non-renewable resources (metals). The following issues are crucial:

- minimisation of the consumption of raw materials, energy and water
- minimisations of emissions by process management and pollution control
- minimisation of waste production and its management
- improvement of chemical safety and reduction of environmental accidents.

The measures to achieve better environmental performance are frequently complex and have to be assessed in respect to their potential impacts on the product and other processes (both pre- and post-treatment), the age and type of installation as well as the benefits to the environment as a whole. Best available techniques will be balanced against these criteria and therefore include changes within process units as well as end-of-pipe abatement techniques.

Sophisticated process and treatment techniques play an important part in achieving improved environmental performance. Competent operation and regular maintenance are as essential as the choice of technology. Important considerations therefore include good management and working practices, good process and site design, education of the workforce on environmental and process performance, workplace safety and accident prevention, and finally, monitoring of the process and environmental performance.

1.4.2 Water

The activities covered in the scope of this document predominantly use aqueous solutions as the medium, therefore the management of water, its pathways and targets – the protection of surface water, groundwater and soils – are central themes. Both in-process techniques and end-of-pipe processes can affect the type and quantity of solid and liquid wastes produced (sometimes negatively), as well as changing the quality of waste waters.

Process waters are often treated in on-site waste water treatment plants. The discharge is then usually to municipal (urban) waste water (sewage) treatment plants, or if the effluent is treated to a suitable standard, directly to surface waters. This is the principal route for chronic pollution and can be caused by poor process controls and/or inadequate end-of-pipe controls. This may be due to poor management and maintenance, or lack of investment.

Although the industry has improved both its practice and infrastructure in many areas, it is still the source of a significant number of environmental accidents [44, France, 2003]. For France, from 1992 to 2002, 1.2 % of all serious industrial water pollution incidents were attributable to this sector, rising to 5 % for ‘near misses’ [121, France, 2003]. Thames Water plc in the UK has identified the sector as posing a high risk to sewage and water resource operations [Tempany, 2002 #18]. The impacts can include the loss of biological sewage treatment processes, disruption of sewage sludge management, as well as damaging water resources for drinking water use and aquatic ecosystems.

Poor housekeeping or accidents in handling and storing solutions, including the failure of storage containers and process tanks, cause acute polluting discharges to surface waters, as well as both chronic and acute pollution events affecting groundwaters and soils. The batch discharge of used process solutions without adequate treatment [113, Austria, 2003], or which overload treatment facilities, is also a cause of surface water pollution. Overload may be caused by poorly designed or out-of-date facilities, production capacity increasing beyond the projected design capacity, changes in process type and/or poor control of water and material usage in the processes [158, Portugal, 2004].

Water usage is also an important issue. The largest proportion of water intake is used in rinsing between process stages and then discharged. In some sites, significant amounts of water are used in cooling. There may be insignificant amounts of water in wastes and there are some losses in evaporation from drying components, hot solutions in open tanks and from some recovery processes. Some water is used in making fresh process solutions (make up); the service life of these solutions varies according to the activity and throughput.

1.4.3 Energy

Electricity is consumed in electrolytic and other electrochemical reactions (*inter alia,* electroplating and anodic oxidation). Electricity is also used to operate the process plant and equipment such as pumps, transporter equipment, other motors and compressors. It may also be used for supplementary vat heating (by immersion heaters) as well as space heating and lighting in the installation.

There are transmission losses when electricity is transformed from high to low voltages [111, ACEA, 2003]. Energy can also be lost when drawing from more than one phase (reactive energy), as well as in DC (direct current) supplies to the treatment lines. Energy is lost, too, as heat when electric current is passed through the treatment solutions: some process chemistries are less energy-efficient than others.

Energy is also consumed in raising the temperature of the process baths, in drying components and for other heating activities. Losses occur from evaporation and as radiant heat from equipment. Some process chemistries require more heat energy than others. Energy is also used in drying workpieces or substrate and in extracting process fumes. [158, Portugal, 2004]

Cooling can consume significant amounts of water in open flow or some cooling towers, and electricity is consumed by sealed refrigerating systems.

1.4.4 Substances of concern

Due the wide range of process activities, the range of substances used and emitted by the industry is substantial. However, most installations will only use or generate some (and not all) of these substances [111, ACEA, 2003]. Table 1.4 identifies key substances used and the media they may affect when emitted. As most substances are used in aqueous solutions, they will be found in process waste waters as well as in-plant leakages and spills. Very little is known of the breakdown products in the processes.

Table 1-4: Key substances of concern across the sector and media potentially affected

Principal substances of concern	**Medium affected**			
Note: It is unlikely that all substances will be used or arise in one installation, as they are process-dependent	**Water**	**Soil**	**Air**	**Other issues to be considered**
Metals:				See Annex 8.1
Zinc	√	√		
Copper	√	√		
Nickel	√	√		Health issues during use and in products
Chromium	√	√	√	Health issues with aerosols of Cr(VI) solutions
Lead	√	√		Pb and Cd are EU priority pollutants
Cadmium	√	√	√	
Non-metals:				
Cyanides	√	√	√	Toxic
Hypochlorite	√		√	Concern for formation of AOX with other substances. Can release chlorine under certain conditions
AOX (absorbable organic halogens)	√	√		May be formed in some effluent treatments
Peroxides				Oxidising agent: storage issues
Surfactants:				
Dispersing agents, emulsifiers, detergents, wetting agents (including nonyl and other alkyl phenyl ethoxylates (NP/NPEs) brightening agents (brighteners), ~~PFOS~~PFAS	√			NPE is banned. Health and environment issues with ~~PFOS~~PFAS, ~~see Annex 8.2~~
Complexing agents:				
EDTA	√			
Tartrate, EDDS, NTA, gluconate, Quadrole	√			
Sodium dithionite	√			Storage issues
Acids and alkalis:				
Hydrochloric, nitric, phosphoric, sulphuric, hydrofluoric, acetic	√	√	√	Acid fumes, particularly NO$_X$
Sodium and potassium hydroxides, lime	√	√	√	Dusts
Other ions	√	√		Local environmental issues
Solvents:				
Trichloroethylene (TRI)	√	√	√	Other legislation applies to air emissions
Tetrachloroethylene (PER)	√	√	√	
Trichlorotrifluoroethane (CFC-113)	√	√	√	
Methylene chloride	√	√	√	
Gases:				
Chlorine			√	Used in cyanide treatment
Dusts		√	√	From linishing and polishing
Wastes	√	√	√	

Process discharge problems with metals, cyanides, surfactants, complexing agents, acids, alkalis and their salts can be addressed by substituting processes and/or chemicals, and managing processes and rinsing systems to reduce the amount of chemicals dragged out of the solution on the substrates being treated. End-of-pipe treatment may also be applied.

1.4.4.1 Metals

The main impact of metals is as soluble salts. Metals are conservative materials, that is, they cannot be created or destroyed: they are neither created nor destroyed in the treatment processes or in waste water treatment. Their form may be changed and/or managed so they cannot readily access environmental pathways but their disposal means that the metals still remain in part of the environment. Options exist for maximising their in-process recovery and recycling as well as for external recovery. They can also be separated in end-of-pipe systems into sludge. Metals not removed from the effluent accumulate in sewage sludge or in aquatic ecosytems. Management routes for municipal waste water treatment sludges vary in all Member States and are strongly dependent on the acceptability of applying the sludges to agricultural land where the metal content is a key determining factor.

While all the metals used in surface treatment (including substrates) can have adverse effects, depending on their speciation, six metals are of most concern for their environmental and/or health effects: cadmium, lead, nickel, chromium, copper and zinc [114, Belgium, 2003]. A Commission Decision [2, EC, 2000] implementing an inventory of emissions and sources from IPPC installations requires the reporting of the quantities emitted above certain thresholds and the six metals are mentioned in key EU environmental directives, PARCOM (now OPSAR) [12, PARCOM, 1992] and four are restricted in product-related directives (see Annex 8.1).

Cadmium's toxic properties are well established and it is a priority hazardous substance according to the Water Framework Directive [93, EC, 2000]. However, it has certain key properties important in surface treatment (see Section 2.5.5), for applications with high fail-safe requirements such as aeronautical and aerospace, nuclear, mining, and communications applications. Its use is therefore restricted to these by the Marketing and Use Directive as amended [144, EC, 1976]. These controls have been in place for many years and emissions of cadmium have been considerably reduced from the surface treatment industry.

Hexavalent chromium has adverse health effects, causing skin and mucus membrane irritation and certain cancers. Aerosols are generated from the electroplating process solution by cathodic hydrogen evolution (see Section 2.2.1.3). Workplace health and safety regulations usually require measures to meet maximum allowable concentrations (MACs). Hexavalent chromium is also soluble at a wide range of pHs contributing to high aquatic toxicity. Due to its solubility and chemistry, it must first be reduced to trivalent chromium before precipitation in waste water treatment plants. Recent Directives [99, EC, 2000, EC, 2003 #98] limit the quantities of hexavalent chromium (but not the metal) in certain products treated by this industry.

Nickel metal and its salts have adverse health effects: nickel sulphate is currently classed as a category 3 carcinogen[9] [105, EC, 1967]. Aerosols and airborne particles can arise from electroplating and autocatalytic (electrocatalytic) as well as plant and solution maintenance operations. Again, workplace health and safety regulations usually require measures to meet maximum allowable concentrations (MACs). Nickel and its salts can cause allergic contact dermatitis and contact can be avoided by using good health and safety at work practices [144, EC, 1976, CETS, 2003 #115].

Lead is subject to a review for possible identification as a priority hazardous substance. Recent Directives [99, EC, 2000, EC, 2003 #98] also limit the quantities of lead in certain products treated by this industry.

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[9] R40: possible risk of irreversible effects. R42/43; may cause sensitisation by inhalation and skin contact.

1.4.4.2 Cyanides

Cyanides are well-known hazardous substances but are still essential in some processes. As well as their inherent toxicity, cyanides give off cyanide gas in acid conditions. Cyanides can cause problems in effluent treatment by strongly complexing some metals, such as nickel, and this interferes with both the easy oxidation of the cyanide and the separation by precipitation of the metal (see complexing agents, Section 1.4.4.5). There is a PARCOM recommendation for cyanide to be substituted [12, PARCOM, 1992].

1.4.4.3 Hypochlorite, chlorine and AOX

Hypochlorite and chlorine are used in the oxidation of cyanide in waste water treatment plants. They are capable of reacting with organic substances to form AOX (absorbable organic halogens). [104, UBA, 2003] Hypochlorite has been flagged by OSPAR as a candidate substance for prioritisation for cessation of emission [131, OSPAR, 2002 ongoing]. Chlorine is the only gas likely to be used in surface treatment installations for the oxidation of cyanide, and is not widely used. Hypochlorite can release chlorine in certain conditions, such as low pH.

1.4.4.4 Surfactants

Surfactants are widely used in many of the processes, such as in degreasing, in wetting surfaces and assisting other processes such as etching, and as brighteners by promoting finely divided metal deposition. Some surfactants have low degradability in aquatic systems, and the by-products of degradation may have adverse effects. Nonyl phenyl ethoxylate (NPE) is cited as being used in the industry. [38, Ullmann, 2002/3] For metal working, with effect from 17 January 2005 [115, CETS, 2003], NPE and nonylphenol are OSPAR chemicals for priority action and are banned except for uses in "*controlled systems where the washing liquid is recycled or incinerated*" [30, EC, 2003]. PFAS are used as foam suppressants and surfactants. ~~PFOS (perfluorooctane sulphonate) is widely used as a foam suppressant and surfactant, especially in preventing the formation of mists in hexavalent chromium electroplating and alkali non-cyanide/zinc baths. However, it is now under investigation (see Annex 8.2, [109, DEFRA, 2004]) and the OECD Task Force on existing chemicals has already agreed that it is persistent, bio-accumulative and toxic.~~

1.4.4.5 Complexing agents

Complexing agents [73, BSTSA,] including cyanides and EDTA retain metals as complexes and preventing the absorption the metal onto sediments or suspended sediments. The soluble metals may be carried through effluent treatment systems and into sewage and aquatic systems. EDTA is both a strong complexing agent and has low biodegradability. Excess uncomplexed EDTA carried into aquatic systems may remobilise metals from sediments with high metals loads [22, Fraunhofer, 2002].

1.4.4.6 Acids and alkalis

Acids and alkalis are commonly used industrial chemicals and their discharge without neutralisation may affect sewers or receiving watercourses. Spillage and leakage can also contaminate soils. When used in hot solutions, the resulting fumes may cause problems in the workplace or locally when extracted. Hydrochloric acid is the most commonly used acid and its fumes can also cause corrosion damage inside the installation, affecting equipment controls. Specific problems occur with nitric acid, as it can release NO_X when in contact with metals. This is a local environmental and workplace health issue, as most installations are not significant NO_X emitters. Sulphuric acid is widely used, particularly in anodising. However, concentrations are lower than the level for the emission of fumes.

1.4.4.7 Other ions

Chlorides, sulphates, phosphates and other salts are the necessary anions in treatment solutions and are not usually a problem when discharged to municipal waste water treatment plants. However, they may occasionally cause salinity problems, and phosphates and nitrates [121, France, 2003] contribute to eutrophication, especially if discharged directly to surface waters.

1.4.4.8 Solvents

Solvents are used for degreasing incoming components. 1,1,1,-trichloroethane used to be widely used, but is being phased out under controls as an ozone layer damaging substance. The heavier solvents trichlorothethylene and tetrachloroethylene can cause problems including accumulation into, and leakage from, sewerage systems [70, Ellis, 2001]. This can cause health and safety problems to maintenance workers and pollution problems to groundwater. Non-halogenated solvents are also used, but have lower environmental impacts. The Solvent Emissions Directive [97, EC, 1999] controls the use and emission of VOCs and the Reference Document on Surface Treatments using Solvents (the STS BREF) discusses BAT for solvent-based processes [90, COM 2020]. Organic solvents also have health and safety effects in use and the degree and type of control depends on the substance [113, Austria, 2003].

1.4.4.9 Dusts

Dusts are generated from linishing and polishing where these occur as directly related activities. They are usually a mixture of particles of abrasives with the abraded substrate. They may have health and safety impacts in the workplace, but can have adverse environmental impacts when extracted to the outside environment. The collected dusts require disposal as wastes, and may be hazardous.

1.4.4.10 Wastes

Much of the waste produced from process activities is likely to be classed as hazardous [92, EC, 1991, 100, EC, 2000]. The industry produces in the order of 300000 tonnes of hazardous waste a year in Europe[10] (approximately 16 tonnes a year per installation). Liquid wastes are spent process solutions that cannot be treated or discharged, and solid wastes are largely sludges from waste water treatment plants and treatments of process solutions. Metals may be recovered from both solid and liquid wastes. Other solid wastes include broken equipment such as jigs (which may contain recoverable materials), packaging for workpieces as well as used chemicals ~~(see Section 0)~~.

1.4.5 ~~Other~~ Emissions to air

There are two reasons for managing airborne emissions in surface treatment installations [111, ACEA, 2003]:

- Where health and safety legislation applies to the workplace atmosphere for the protection of the employees from dangerous substances in the workplace.
- Working atmospheres that are damp, acid, alkali or which contain other chemicals and/or particulates are likely to be corrosive to materials, workpieces and substrates,

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[10] This derived from an industry estimate of <1 % of hazardous waste in Europe and the Eurostat figures from hazardous waste management in the EU-15.

equipment and the fabric of buildings. This can lead to problems such as deterioration of raw materials, finished products becoming corroded and being rejected, equipment malfunctioning and buildings deteriorating at a high rate. Many installations extract water vapour, as well as acid, alkali and other gaseous or aerosol contaminants to prevent these problems.

Additional treatment of the exhaust gases may be required to meet emission values.

1.4.5.1 Emission sources and types

Airborne emissions include gases, vapours, mists and particulates [111, ACEA, 2003]. The main sources are highlighted throughout Chapter 2 and include layer stripping (such as pickling and stripping baths), electrolytic degreasing baths, individual treatment processes, as well as some drag-out and rinsing processes (especially where the rinses are heated and/or sprayed). Particulates can be from mechanical processes such as linishing and polishing, or form from some mists containing chemicals where water vaporises from the droplets leaving airborne chemical particulates.

Harmful substances can be emitted to air as gases from relevant processes (e.g. NO_X, HF, HCl) as well as aerosols loaded with caustic, acids or other chemicals (e.g. caustic soda solution, sulphuric acid, chromium (VI) compounds, cyanide), see Table 1.4.

Emissions of solvents from solvent degreasing or drying of organic coatings (such as electropainting or lacquering) are discussed in [90, COM 2020].

1.4.5.2 Measures for reducing emissions

Measures can be taken to minimise pollutant emissions from sources. For example:

- air agitation of process solutions can be replaced with other methods such as:
  - circulating the process solution by pumping;
  - mechanisms to move the jigs;
- baths not in constant use can be kept covered;
- additives can be used to suppress aerosol formation, such as for chromium plating; see Sections 1.4.4.1 and 2.5.3.

1.4.5.3 Extraction systems

Extraction systems can be installed for the capture of the emissions. Although some shops will have general extraction of the workspace, edge or lip extraction at the emitting vat is a widespread procedure. Lines may be fully enclosed with extraction systems. Transporter systems can include an integral lid which is put in place with the flight bar.

The quantity of exhaust air caught by the edge exhaust and the quantity of pollutants contained depend on several parameters:

- bath size;
- continuous or intermittent operation of the bath;
- bath temperature;
- physico-chemical characteristics of the specific chemicals;
- classification and permissible concentration values in the workplace;
- use of additives for the decrease and/or avoidance of the emissions to HF, NO_X and Cr (VI);
- other emission control procedures;

- fully enclosed treatment lines.

1.4.5.4 Waste gas treatments

The following cleaning systems are used:

- Droplet separators which use a fill material to condense aerosols and droplets. Condensate is usually treated in a waste water treatment plant.
- Exhaust air wet scrubbers. These may be:
  - fibrous packing scrubbers with mats of fibrous packing;
  - moving bed scrubbers with a zone of mobile packing, usually low density plastic spheres which are free to move between support grids;
  - packed bed scrubbers containing a fixed bed of variously shaped packing material;
  - impingement plate scrubbers;
  - spray towers.

Water or specific chemical solutions are sprayed into the wet scrubbers usually (but not always) countercurrent to the gas flow.

Reduction of NO_X could be achieved by selective reduction using NH_2-X compounds (with X = H, CN or $CONH_2$) injected into the gas stream. The most common reducing agent is ammonia. Both non-catalytic (SNCR) and catalytic (SCR) techniques exist.

These techniques and devices are described in more detail in the reference document on BAT in the waste water and waste gas treatment/management systems in the chemical sector [87, EIPPCB,]

1.4.6 Noise

Surface treatment is not a major noise emitting industry. However, some activities and associated activities do generate significant noise. These can be as peaks, such as unloading of metal components in stillages, or continuous noise from linishing and polishing or fans and motors sited externally.

1.4.7 Odour

Again, odour is not a major factor for this industry. However, odour can be associated with some activities, particularly acid fumes and especially when stripping metal layers. The impact will depend on the type and size of activity carried out, the design and operation of any extraction system (e.g. chimney height) and the proximity of receptors, such as housing.

2 APPLIED PROCESSES AND TECHNIQUES

[Note to the TWG: This section has been completely reordered compared to the original STM BREF and relevant contents were reallocated to their relevant sections]

2.1 General processes

[Note to the TWG: This section was created by extracting relevant pieces of information from Chapter 2 in the existing BREF]

Despite the~~is~~ complexity and the range of activities described in this chapter, all workpieces or substrates pass along a common route of activities~~, described in~~. The first activity on-site is the delivery and storage (Section 2.1.1) of incoming workpieces, substrates and raw materials. Workpieces or components are loaded onto the appropriate transport systems (see Section 2.1.2) prior to pretreatment, such as degreasing. Most workpieces or substrates are given more than one pretreatment (see Section 2.1.4), and some of these may be prior to loading to a process line. The workpieces or substrates are then surface treated with one or more of the activities described in core processes. Rinsing, (see Section 2.1.5), is usually carried out between processes steps, whether they are pretreatment and/or core processing steps. Treatment is followed by after treatments such as drying, (see Section 1.1), and the workpieces or substrates are stored and dispatched (described in Section 2.1.1, together with incoming goods).

2.1.1 Delivery and storage – workpieces and consumable raw materials

2.1.1.1 Incoming workpiece and/or substrates to be treated

The workpiece and/or substrates to be treated are delivered in different ways according to size, substrate material, quality and cost, and whether they are intended for in-house treatment or for external shipment to another site or a subcontractor. Jig treatment is most costly, and workpieces may be packed in bulk in stillages for cheaper steel components but are more carefully packaged for more valuable workpieces: from layering in stillages with protective inter-layers (to protect against physical damage and/or corrosion) to high value components such as aluminium alloy aircraft wing sections being individually packed in robust boxes. Automotive bodies are moved individually before and into processes on large jigs (or sleds) see Figure 2.4 [111, ACEA, 2003]. Handling of workpieces can be mechanical or manual. Barrel plating tends to be cheaper, where the quality of the finish is less critical and substrate is robust, and here workpieces are usually transported loose in stillages and often emptied mechanically. For coils, the external initial layers protect the rest of the coil. While small coils (in reel-to-reel processing) can be moved by hand, large scale coils (because of their weight) need specialist equipment, such as air flotation rafts and overhead cranes.

Environmental considerations
The amount and type of packing used and the minimisation of loss of materials by damage to workpieces or substrate.

[ACEA]

Figure 2-1: Automotive body undergoing spray pre-treatment

2.1.1.2 Consumable raw materials

Raw material inputs will vary according to the installation and will depend on the chemistry the various processes carried out and the workpiece or substrate condition, shapes and surface area throughput. Larger sites will receive some liquid chemicals in bulk by tanker, ~~most IPPC~~ IED sites will receive at least some chemicals in IBC (Intermediate Bulk Containers) and all will receive liquids in sizes from 2.5 to 210 litre containers, or larger. Bulk liquid storage is in bulk tanks or in IBC ~~containers~~, with smaller quantities being stored ‘as delivered’ and used from the delivery containers.

Large scale solids deliveries may be by bulk tanker, but are more usually in the form of big bags. Most commonly, 25 kg sacks, bags, drums and other containers including disposable packaging, are used for powders, pellets and flakes. Storage of bulk solids may be in silos. Other solids are stored in the containers they are delivered in. [111, ACEA, 2003].

Metals for deposition are usually delivered as anode bars or anode balls, or as salts (see solids, above) but may be in proprietary solutions for chemical treatments (including autocatalytic processes) or precious metal plating.

Smaller quantities of chemicals are used in laboratories and for replenishing costly ingredients, such as in gold solutions or some trace components of process solutions.

The largest amount of chemicals in an installation are usually stored in use in the process line vats and the containment of these chemicals, the use of chemicals in maintaining the solutions and leakage issues are analogous to those for the incoming raw materials.

A description of the storage and handling of chemicals is given in the reference document on BAT for emissions from storage [23, EIPPCB, 2002].

Environmental considerations
Prevention of unplanned releases to surface and groundwaters, and soils.

2.1.2 Handling techniques for processing and loading for processing

When workpieces are in a suitable state for the core treatments, they are loaded for processing using one of the three transport types described below: [104, UBA, 2003]

- jigs or racks – frames carrying the workpieces singly or in groups;
- barrels – plastic cylinders holding many workpieces;
- coil – coils or reels of substrate working on a continuous basis.

Specific manual or automatic handling techniques may be used in PCBs manufacturing and semiconductors manufacturing.

In a limited number of cases, components are treated *in situ* (see brush electroplating and anodising, below).

2.1.2.1 Jigs or racks

Jigs (also known as racks or frames) provide both physical support for handling during processing, as well as electrical contact when needed in electrolytic processing. Jigs may be used for all sizes of components from small, such as jewellery and small precision engineered components, to large installations handling parts of aircraft and automotive bodies (see Figure 2.4). Small components are secured by hand on jigs, either by being clipped onto spring retainers forming part of the jig or fixed using copper wire: both systems carry the current in electrolytic processes. Jigs are hung on flight bars: these assemblies are used both to move the jigs through the core process steps and (where the processes depends on electrical current) to carry the electrical current to the jig [128, Portugal, 2003]. Where current is carried, the flight bars need to make good electrical contact: for example, the jigs are hung in each process vat from copper U- or V-shaped cradles. For very large components, the jig may be a large platform or frame without a separate flight bar, and electrical connectors are attached to the jig where necessary.

Figure 2.5 shows finished gold plated components being unloaded from jigs with spring retainers, visually inspected and packed in specialised plastic trays. There are two jigs suspended from a flight bar.

Flight bars can be moved by two types of mechanism:

- transporters, which are hoists travelling on rails running the length of the process line. This is the most flexible type of system and can be programmed for various finish options, with different dwell times in different vats, or operated manually;
- beams, where the flight bars are hung on a beam. The beam moves up and down at present intervals. In the up position, the flight bars are moved to the next process vat position. However, the only way of varying the process time in different vats is to change the tank length.

In process lines with low throughput, or small components, jigs may also be moved by hand. Large, individual components, such as aircraft parts or automotive bodies may be moved on conveyor systems or by overhead transporters.

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Figure 2-2: Jig or rack plating: unloading finished components

2.1.2.2 Barrels

Barrel lines tend to be used for high volume, lower cost work such as nuts and bolts, and can only achieve lower quality finishes than jigs. Barrels are usually hexagonal or octagonal plastic drums, with many holes in the long panels allowing access for the process liquids. The barrels are usually moved by transporter systems, although for very small components (such as contact pins being gold plated) small barrel units can be moved by hand. They are loaded from stillages of components. Usually workpieces are emptied from stillages onto the floor, and the barrels are then loaded manually using a shovel. Large scale barrel operations may use a mechanical loader or a mechanised system. The barrel hangs from cradles which carry current at the appropriate process vats. The barrel spindle carries current to a flexible electrode which trails in the barrel from the central spindle and carries current to the loaded components in the relevant process vats. The barrel is constantly rotated usually via a drive mechanism on the side. The current is then passed through a flexible inert anode which trails in the rotating barrel and current is passed through the contacting workpieces.

2.1.2.3 Coils

Steel coils
Coils can be up to 32 tonne rolls of steel up to 2080 mm wide [119, Eurofer, 2003]. Coils are loaded in an entry loader section and welded onto the end of the preceding coil, see Section 2.3.

Aluminium coils
Aluminium coils up to about 25 tonnes, up to 2200 mm wide and up to about 3 mm thick are processed [118, ESTAL, 2003].

2.1.2.4 Other manual or automatic handling systems

Printed circuit boards and semiconductors
The transport of boards can vary during production. They are moved manually or automatically both as individual boards across rollers in some parts of the process lines and in other parts they are moved in sets on jigs.

Brush electroplating and anodising
This is a specialised technique, developed for selective plating using portable equipment and anodes surrounded by absorbent material that do not require immersion of the part. The method is not generally used for production, but repair of worn or defective parts, e.g. large printing rollers, large bearings, military and aviation parts, statues and other parts too large to process by immersion techniques. [38, Ullmann, 2002/3]

2.1.3 Type of processes

2.1.3.1 Continuous processing

Continuous surface treatment is characterised by the surface treatment of metal coils with various substrates: copper and copper alloys, steel and steel alloys, and aluminium.

The dimensions of the coils or rolls are also variable: standard widths are between 10 mm and 400 m with metal thicknesses ranging from 0.1 mm to 4 mm.

The particularity of continuous surface treatment lies in the applied process: the coils or rolls are loaded on an unwinding plate causing the longitudinal movement of the metal strip to be treated before successively crossing the various baths. Coils pass through the different baths, with quenching or spraying steps, and they can also pass through reducing rolls. The strip is rewound at the end of the line into a roll or coil on a rewinding plate.

In order to guarantee the consistency of continuous surface treatment, the coils or rolls are joined together by welding, riveting or stapling, so that the beginning of one treatment corresponds to the end of another.

The coils or rolls to be processed are presented in two distinct forms: solid metal strips called strip and metal strips more or less cut according to the complexity of the final part. This process allows the rapid treatment of a large number of units.

(FR contribution to [170, TWG, 2023])

2.1.3.2 Barrel processing

[Note to the TWG: This section corresponds to the Section 2.8 of the original STM BREF]

~~The use of barrels is described in 0 and 2.2 above.~~
~~Processing is carried out as described in the generic jig Sections 2.4 to 2.6.~~ The following sections refer specifically to activities normally associated with barrel treatments.

2.1.3.2.1 Workpiece preparation

Deburring and tumbling, as well as degreasing workpieces for barrel treatment by centrifuging are described in Section 2.1.4 .

2.1.3.2.2 Core activities

Core activities are the same as for jigs or racks, except chromium and anodising where barrel use is impossible. Workpieces should be small and without flat areas to prevent the flat surfaces adhering during treatment. This can cause marking, or in some cases burning, from uneven surface treatment [121, France, 2003].

2.1.3.2.3 Drying for barrelled components

Barrel plants use centrifugal drying or hot air drying depending upon the type of component. Centrifugal drying is effective and energy-efficient.

2.1.4 Workpiece or substrate pretreatment

Workpieces or substrates to be surface treated must be clean from dust, swarf and moulding flash, as well as being corrosion- and grease-free to ensure uniform application and permanent adhesion of the surface treatment. Many workpieces or substrates are oiled to prevent corrosion in transit or from a previous operation such as pressing. Usually (but not necessarily) the workpieces will need to be totally smooth to produce a high quality treated finish. Some preparation of the workpieces may be carried out at the site producing them, but these activities are also carried out at the surface treatment installation [6, IHOBE, 1997].

~~Activities preparing steel coil and wires prior to surface treatment in coil coating process lines are described in the BREF on the ferrous metals processing industry [86, EIPPCB,].~~

While virtually all process lines include cleaning or degreasing, where components are heavily oiled or surface preparation is critical, it may be necessary to supplement this by an additional pre-degreasing step [104, UBA, 2003].

The pretreatment steps not only remove greases and oil, but also remove oxides and provide chemically active surfaces for the subsequent treatment [73, BSTSA,].

Overall environmental considerations
If cleaning is a separate activity to the main processing, the increased handling (such as emptying containers, etc.) may give rise to additional noise [73, BSTSA,].

2.1.4.1 Mechanical pretreatment

2.1.4.1.1 Linishing and polishing

Mechanical polishing produces a flowed amorphous surface under the influence of pressure and high local temperatures [121, France, 2003], [120, Finland, 2003]. Individual components are linished using abrasive belts, and then polished with an abrasive paste applied on fabric mops, which removes fine marks and gives a highly polished finish. These activities are carried out less frequently as modern production techniques produce better engineered components than in the past, or use alternative materials such as plastics which can be precision moulded. Where large numbers of workpieces are handled, the linishing and polishing are usually automated.

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Figure 2-3: Linishing

Environmental considerations
Noise and dust are associated with this activity.

Wastes may be hazardous depending on the substrate.

2.1.4.1.2 Abrasive blasting

This traditionally uses sand or grit, but may use softer, finer abrasives such as ground nut shells. These techniques may be used to de-stress the surface of the workpieces.

Environmental considerations
Noise and dust are associated with this activity.

Abrasive blasting creates solid wastes. With non-ferrous metals, the wastes (a mixture of abrasives and abraded material from the metals) may be hazardous [113, Austria, 2003].

2.1.4.1.3 Deburring and/or tumbling

Applied to smaller, mass-produced components often followed by barrel treatment. The workpieces are mixed with abrasive stones and tumbled or vibrated for up to several hours [73, BSTSA,]. These techniques can also be used in aqueous media with chemical additives to clean, deburr and pickle the parts.

Environmental considerations
Noise and dust are associated with this activity.

Wastes generated directly may be contaminated with oils, surfactants and abrasive particles, particularly vibratory finishing [73, BSTSA,].
Where used with an aqueous system, the effluent may require specific treatment to eliminate metals in solution and COD. This effluent is often recycled after centrifugation, simple filtration or ultrafiltration. The residues from treatment may be treated off-site in a suitable waste treatment plant or on-site in a physico-chemical waste water treatment plant. The residues may be hazardous waste [121, France, 2003].

2.1.4.2 Electrolytic and chemical polishing

As well as the mechanical methods, electrolytic and chemical processes are employed in the production of smooth, bright surfaces. Although their function in industry is similar, the principle by which polishing is carried out is very different. While mechanical polishing produces a flowed amorphous surface under the influence of pressure and high local temperatures, chemical and electrolytic polishing are selective dissolution processes where the high points of the rough surface are dissolved faster than the depressions. The potential advantages of these methods are [118, ESTAL, 2003, Finland, 2003 #120, P G Sheasby, 2002 #132]:

- being similar in operation to anodising and electroplating processes, they can be employed together in a single production line, with considerable reduction in plant and simplified control, while mechanical polishing may often be replaced entirely;
- they are suitable for bulk treatment and labour costs are appreciably lower, particularly on components not suited to automatic polishing machines;
- the surface is clean and gives better subsequent deposit adhesion as well as high corrosion resistance;
- the reflectivity and colour are often superior and there is no tendency to ‘bloom’.

Overall environmental considerations
Some of the chemicals used in electropolishing are toxic and this should be taken into account both in the workplace and when disposing of spent baths. For chromium compounds, see Sections 1.4.4.1 for health effects, and Section 2.5.3 for overall environmental considerations.

Spent electrolytes and acids have a low pH and high concentration of dissolved metals including chromium and nickel and may need to be treated before disposal as effluent (see Section 4.16.2). Alternatively, spent electrolytes may be managed as hazardous wastes. Electrolytes for stainless steels deteriorate due to excessive iron in solution [73, BSTSA,].

Rinsing waters may also require treatment for the same reasons.

Acid fumes, particularly those containing hexavalent chromium, may need extraction and treatment. Where nitric acid is used, an air-scrubber may be used to remove nitrogen oxides (NO_X).

There is no associated dust and noise, unlike mechanical polishing processes.

2.1.4.2.1 Electropolishing

Electropolishing is a commonly used electrochemical method for smoothing, polishing, deburring and cleaning various metals, generally steel, stainless steel, copper and its alloys and aluminium and its aluminium alloys. It is widely used in food equipment, surgical equipment and implants, the pharmaceutical, paper, pulp and food industries, as well as in automotive and architectural applications. Electropolishing removes a fine surface layer electrolytically, and is often used in cases where very smooth and bright finishes are needed. In electropolishing, the workpiece (anode) is immersed in electrolyte and electric current (usually DC) is connected between the workpiece and the cathode. The workpiece becomes polarised and metal ions start to diffuse to the cathode, and metal is removed from the anode. The reaction can be controlled by adjusting bath and process parameters and by choosing the metal or alloy being electropolished.

In these electropolishing processes, different electrolytes are used. Electrolytes are usually mixtures of various acids (sulphuric acid, chromic acid, citric acid, and/or phosphoric acid) and sometimes organic compounds (such as glycerine or diethyleneglycolmonobutylether) are added. [133, Hensel, 2002], [134, CEN/BSI, 1997], [135, Swain, 1996], [136, Webber and Nathan, 2000], [137, ISO/BSI, 2000].

Environmental and other considerations
During electropolishing of stainless steels, hydrogen is formed, which mixes with oxygen at the solution surface. If ignited by a spark, this can produce an explosion. It is therefore advisable to extract gases forming on top of the solution. This is vital when processing the internal surfaces of enclosed vessels, otherwise a serious, possibly fatal, injury may occur. Repeated noise of this type may have an impact beyond the perimeter of the installation (as well as being an occupational health issue).

2.1.4.2.2 Electropolishing with electric discharge (also known as plasma-electrolytic polishing)

Plasma-electrolytic polishing is an alternative method for some applications. The process differs from conventional electropolishing mostly because of its electrolytes and process parameters used. Instead of mixed acids, these electrolytes are different salt solutions and far more friendly for employees and for environment. In this process, the used electric potential between anode and cathode is in the range of 200 – 400 V DC depending on the solution and temperature (40 – 95 °C) used.

The same process can be used also for plasma-electrolytic oxidation in order to get hard oxide-ceramic coatings.

2.1.4.3 Solvent degreasing

Solvent degreasing is usually by means of chlorinated hydrocarbons (CHC), alcohols, terpenes, ketones, mineral spirits or hydrocarbons [90, COM 2020], [104, UBA, 2003], [73, BSTSA,]. CHCs are used because of their good cleaning efficiency and universal applicability, as well as their quick drying and incombustibility, but their use is restricted by environmental and health legislation. All solvents affect the central nervous system and exposure should be controlled (see environmental considerations, below) [73, BSTSA,], [90, COM 2020]].

There are two types of process:

- **cold cleaning:** The workpieces and/or substrates are immersed in the solvent or cleaned in a stream of solvent. In some cases, the solvent is pumped round taking the liquid from near the top of a holding tank, leaving dirt to settle at the bottom. The tank is cleaned periodically;
- **vapour phase:** The solvent is vaporised in a purpose-built bath and the cold component suspended in the vapour. The vapour condenses on the component dissolving grease and drained off with the dirt and grease, leaving the component clean and dry. The most common solvents are CHCs. As the vapours are heavier than air they are contained in the bath. Hydrocarbon solvent may be used.

The choice of solvents will depend on a number of factors including the substrate to be cleaned, the type of oil or grease to be removed, the previous manufacturing process and the requirements of the subsequent surface treatments. Chlorinated ethanes and ethylenes attack aluminium and should not be brought into contact with substrate, tanks, containers, valves, etc. made of aluminium. Dichloroethylenes in contact with copper should be avoided under all circumstances as explosive acetylides may be formed.

Chlorinated solvents have no flashpoints [73, BSTSA,]. Ketones and mineral spirits may be used, but are flammable. Higher hydrocarbons with a narrow distillation range give the highest flashpoints commensurate with solvent drying from the workpieces and/or substrate.

Environmental considerations
Because of the classification of certain CHCs as potentially carcinogenic materials, their water-endangering potential and problems with emissions to the air, their use is strongly regulated [[93, EC, 2000, 97, EC, 1999]. Most other solvents are either inflammable or not self-drying [73, BSTSA,].

2.1.4.4 Aqueous cleaning

The workpieces are placed in this process solution for several minutes, or placed in a spray bath. The solution is usually alkaline or neutral but may be acidic and usually working at increased temperatures (40 – 90 °C) because of the improved cleaning effect. The main components of the aqueous cleaning system are alkalis or acids, silicates, phosphates and complexing and wetting agents. Aqueous cleaning systems work either by forming unstable emulsions (known as weak emulsion systems) or stable emulsions. [3, CETS, 2002, 104, UBA, 2003]

Aqueous chemical systems avoid the use of solvents. The cleaned items can remain wet if the subsequent treatment is water-based, such as electroplating. Process solutions have a short life, dependent on throughput and the amount of oil or grease on the workpieces. The efficiency of aqueous cleaning systems depends on the type and concentration of chemicals, the mechanical effect, the temperature and the time. The mechanical effect can be applied by spray pressure or flowrate, agitation of parts or solution, or by using ultrasonics.

Hot water is used effectively to remove oil and grease, especially from steel panels. It is widely used in the automotive industry.

Strong alkalis and silicates are not suitable for aluminium. Complexing agents (tensides) are not used in aluminium cleaners. For wetting agents, only very specific agents can be applied (for instance, non-anionic agents). Cleaning at a low temperature is possible, from 40° upwards [160, ESTAL, 2004].

Environmental considerations
Energy usage: process tanks operate at 50 – 90 °C and may require fume extraction to remove water vapour and alkaline or acid fumes.

Rinse-waters (including those from air scrubber units) may require simple pH treatment in waste water treatment plants.

Metals can be stripped from the substrate surface (including trace elements such as lead which may have toxic effects). They can be separated after pH adjustment.

Alkaline degreasing agents may contain small amounts of substances of concern, such as nonyl phenols [161, Assogalvanica, 2004].

Used acid or alkali solutions are often treated separately as they create a large pH change which may not be accommodated by continuous flow waste water treatment plants.

Solution maintenance by replacing consumed components and removing the accumulated oil dirt, oil and grease can greatly increase the solution life by various options [73, BSTSA,].

Cleaning solutions may need to be separated from other process effluents to avoid interference with the waste water treatment plant by excess surfactants. Cleaning solutions containing complexing agents should be separated from other waste water streams containing metal ions [73, BSTSA,], see Section 4.16.2.

2.1.4.5 Other cleaning techniques

2.1.4.5.1 Air knives

Air knives can be used to remove excess oil and grease from parts [73, BSTSA,]. They are low pressure, high volume systems where air is emitted through precision slits, giving a laminar air curtain, through which components can be passed, either manually or on a conveyor belt. The air heats up due to compression and movement in the system, and this warms oils and greases, assisting their removal. Both the laminar air movement and the temperature also facilitate drying of components.

2.1.4.5.2 Centrifuges

Centrifuges are used on a batch basis to remove excess grease, and usually applied to smaller workpieces prior to barrel treatment.

2.1.4.5.3 Dry ice

Blasting with pellets of dry ice by a process called ‘Cryoclean’ can be used to remove oil and grease as well as particles, paint, etc. The cleaning effect comes from cooling and cracking of contaminant layers, mechanical impact and lifting by the gas formed from sublimation of the dry ice. [115, CETS, 2003], [116, Czech-Republic, 2003]

Pellets are made from liquid CO_2 with a diameter of 3 mm and length of 8 mm at a temperature of-78 °C. They are accelerated by air to a velocity of 100 to 300 m/s. The pellets release kinetic energy at the surface. On impact, they sublimate immediately. The surface is locally cooled and due to different thermal expansion coefficients of the substrate and any coating and/or contaminants, the cleaning ability is increased.

After use, the pellets of dry ice evaporate so the only waste formed is the solid waste of the stripped coatings. This method is used mainly for cleaning pressing forms and other special parts. In special cases, it is used to strip coatings (organic and metallic).

Environmental considerations
The method is noisy, and requires protection of workers. The waste may contain toxic compounds (such as paints with heavy metals, lead, cadmium, etc.). Workers must protect eyes and respiration. Air extraction and filtration may be necessary.

2.1.4.5.4 Hand wiping

Hand wiping uses a clean cloth and solvent, or an absorbent such as ground chalk or limestone. This is carried out on large, high value workpieces such as aerospace components. It is also used for small, quality critical components [73, BSTSA,].

2.1.4.6 Pickling, descaling and desmutting

Pickling and descaling are chemical metal-stripping procedures used to brighten and/or remove oxides from the degreased metallic surface prior to other surface treatment processes [73, BSTSA,]. The bulk pickling of steels is described in the BREF on ferrous metals processing [86, COM, 2022]. During the pickling processes disturbed or adhering layers, such as scale, oxide films and other corrosion products of the metal, are removed by chemical reaction with an acid-based pickling agent. In order to remove strong oxide layers effectively, specified acid concentrations, temperature and pickling times must be adhered to. Hydrochloric or sulphuric acids are normally used. In special cases nitric, hydrofluoric or phosphoric acid, or mixtures of acids are used. Solutions containing fluorides are necessary for reliably pickling certain alloys. The typical pickling reaction is described by the following chemical equation:

- metal oxide + pickling solution → metal ion + water

Some erosion of the metallic surface is desirable, but excessive attack of the acid on the basic material is unwanted. Hydrogen is usually formed:

- metal + pickling solution → metal ion + hydrogen

The attack can be reduced by using so-called pickling inhibitors. These also cause an inhibition of hydrogen development, thus minimising so-called hydrogen (or pickling) embrittlement (or brittleness), caused by entrapment of hydrogen in the metal crystalline structure at the surface and diffusion of hydrogen to stress concentration sites in the material. This may cause catastrophic failures in high strength steels [73, BSTSA,].

The concentration of the ions of the dissolved metal increase in the pickling solution while the strength of the free acid declines. The acid consumption associated with the dissolution of metal and metal oxide can be supplemented by adding fresh pickling solution [73, BSTSA,]. However, this technique is limited by the constantly increasing metal content. A maximum iron content of 8 % is recommended for sulphuric acid, 12 % for hydrochloric acid and 2.5 % for phosphoric acid. When the limiting concentrations are reached, the pickling solution must be disposed of completely or partly. [104, UBA, 2003]

The workpieces to be pickled must be completely grease-free, otherwise uneven pickling will occur as the acid attacks grease-free areas only. The use of wetting agents accelerates the pickling procedures as the workpieces are wetted better and more quickly. Iron materials can be de-rusted and descaled in so-called acid degreasing agents without prior degreasing. The commercial acid degreasing agents contain mixtures of wetting agents and emulsifying agents, which can support the emulsification of fats and oils in strong acid media.

The pickling time is reduced with increasing acid concentration and temperature. A maximum pickling effect is reached with a sulphuric acid concentration of 25 %. Above this, the pickling speeds decrease. The optimal temperature is at 60 °C.

The pickling effects can also be accelerated by movement of the workpieces in the pickling solution or movement of the pickling solution by solution injection [159, TWG, 2004].

Hydrochloric acid is also good for descaling and pickling. It works rapidly in most cases, with a concentration of 18 – 22 %. However, its disadvantage is aggressive vapours. Heating up to 30 – 35 °C not only increases the pickling effect, but also the formation of hydrochloric acid air emissions.

Hydrofluoric acid is nearly exclusively used for the pickling of cast iron, for example engine blocks. A concentration of 20 – 25 % (as HF) and temperatures of 35- 40 °C are generally preferred.

~~For aluminium, the process is called desmutting, and nitric acid is at concentrations below 150 g/l~~

In the aluminium anodising context (and sometimes before conversion coating), a desmutting process is applied to remove alloy second-phase constituents that were insoluble in the caustic etch. Thus, it is different to pickling, the purpose of which is to dissolve oxides [175, ESTAL 2024].

Desmutting of aluminium is also performed in sulphuric acid which preferably originates from the reuse of spent anodising baths [175, ESTAL 2024].

Environmental issues

Process tanks may need to be equipped with fume extraction to remove generated aerosols and hydrochloric acid gas and nitrous oxides if nitric acid is used.

For desmutting of aluminium, the use of sulphuric acid instead of nitric acid eliminates such emissions, therefore no exhaust is necessary for such baths [175, ESTAL 2024].

Spent pickling solutions require either treatment and disposal through an effluent treatment system or disposal as liquid wastes. Excessive attack of the metal surface removes a significant amount of iron, which can have adverse effects on the waste water treatment systems, such as significantly increased sludge production [158, Portugal, 2004].

Effluents can easily be treated in typical waste water plants.

Maintenance of ~~pickling~~ electrolytes by acid retardation and diffusion dialysis is used in Germany in some cases, ~~such as anodising;~~ it is not widely used in electroplating [124, Germany, 2003], [175, ESTAL 2024].

2.1.4.7 Electrolytically assisted pickling, activation and degreasing

Pickling can be enhanced by making the substrate anodic. The non-electrolytic pickling of metals is often followed by electrolytic activation to remove the remains of unwanted residues from the surface, such as oil and dirt, which remain trapped in the micro-roughness of the substrate surface. These are removed by the formation by electrolysis of H_2 at the surface of the cathode and O_2 gas at the surface of the anode [73, BSTSA,]. The basic composition of the solution is similar to alkaline degreasers, although the chemical concentration is generally twice as high. Wetting agents are omitted to prevent foaming; however, cyanides or other complexing agents may be added to improve the activation of steel items. For normal applications, cyanide- and chelating-agent free electrolytes are sufficient. The solution lifetime is mainly determined by dilution through drag-in of rinse-water and drag-out of process solution. [3, CETS, 2002]. This process is not used in anodising [159, TWG, 2004].

Environmental considerations
Process tanks may be equipped with fume extraction to capture vigorously generated aerosols.

Rinse baths are rapidly saturated with dirt, fats and oils.

Rinse effluents and used solutions can be treated as alkaline or cyanide solutions in waste water treatment plants. The waste water can upset the waste water installation because of the amount of oils and grease, and the composition and concentration of components, e.g. phosphates and surface active agents which can interfere with settlement processes [20, VITO, 1998].

2.1.4.8 Metal stripping

Metal stripping is necessary for the processing of defectively electroplated components without losing the properties of the base material [73, BSTSA,]. It may also be used [73, BSTSA,] for the new treatment of nascent workpieces. It may be also used for the recovery of expensive metals (such as the precious metals), both from the base metals and the coating materials. Often scrap iron substrate metal can only be regenerated if certain metal coatings which cause problems are removed. The metal stripping of jigs and/or of jig contacts used in the electroplating process extends the life of the jigs and recovers the metal deposited.

To preserve the form of the surface to be stripped, the metal stripping techniques should remove the coating material quickly and safely and not attack the base metal. In exceptional cases, [73, BSTSA,] electrolytic activation of the coat can be necessary, for example with chemical chrome stripping. Chemical procedures are simple in application and they require less expenditure on plant equipment. On the other hand, electrolytic procedures usually work more quickly, more economically and with more control. They are therefore preferable for activities such as the metal stripping of rack contacts.

Environmental considerations
The use of strong acids can generate spillage capable of attacking concrete floors and subsequently polluting the soil and any groundwater beneath with acid and the dissolved metals. The disposal of used acid stripping solutions may exceed the treatment capacity of effluent systems. Acid fumes and mists are caused by reaction with the metals and substrate. These can cause local air problems, health effects in staff and deterioration of equipment in the installation.

Stripping of previous treatments is often carried out as a batch process outside of the normal process controls of an installation. They are a potentially significant source of breach of permit conditions and pollution from the industry.

There can be increased waste production (in sludges from treatment and used acids), as well as wasted energy, water and raw materials where defective components are stripped for reworking.

2.1.4.9 Pretreatment of plastics (etching)

Pretreatment is essential in the surface treatment of plastics by autocatalytic plating (see Section 2.5.8) and printed circuit boards (see Section 2.11).

2.1.4.9.1 Conditioning of plastics

This provides wetability of the surface as a prerequisite for subsequent voidless covering and good adhesion of metal layers [3, CETS, 2002], [77, BSTSA,].

The process solution contains sulphuric acid (<20 % by volume) or sodium hydroxide and carbonate (<10 % by volume), water soluble organic biodegradable solvents (alcohol, glycol derivatives).

For PCB boards, cleaning using a mix of pumice and water may be used to provide a micro-rough surface for the subsequent adherence of layers [125, Ireland, 2003].

Environmental considerations
Acid effluents may require pH adjustment in waste water treatment plants.

2.1.4.9.2 Etching or pickling of plastic

The pickling of plastic is a prerequisite for good metal adhesion. It is carried out in an aqueous mixture of chromic acid (up to 380 g/l) [73, BSTSA,] sulphuric acid (380 g/l) and wetting agent. It is applied to ABS-type plastic surfaces to oxidise and dissolve the butadiene component, thus generating a micro-rough surface [3, CETS, 2002].

Environmental considerations
Process tanks may be equipped with fume extraction to remove small amounts of generated aerosols and acid gases.

The solution lifetime can be extended by membrane electrolysis to oxidise Cr(III) to Cr(VI).

Effluents can easily be treated in a similar manner to other solutions containing hexavalent chromium in waste water treatment plants.

2.1.5 Drag-out and rinsing

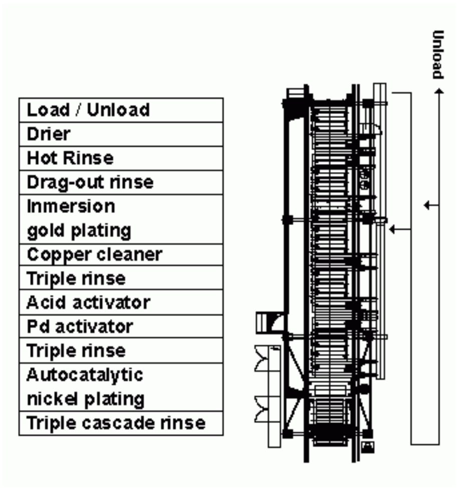
Drag-out is the liquid from the previous process which adheres to the workpiece or substrate surfaces. Rinsing is necessary:

- between most process steps to prevent cross-contamination of process solutions;
- to ensure there is no deterioration of the workpiece and/or substrate surface by residual chemicals, such as by over-reaction or by staining by the drying of dissolved chemicals.

A reduction of drag-out is a primary measure for minimising losses of chemicals, operating costs and environmental problems in rinse-waters. In some processes, such as etching in anodising, a certain amount of drag-out is used to maintain the solution by preventing the build-up of by-products, such as in aluminium etching [159, TWG, 2004].

Rinsing is therefore a common activity carried out after nearly all process steps in surface treatment [3, CETS, 2002]. Figure 2.7 shows a section through a typical jig plating line with six rinsing stations [65, Atotech, 2001].

Rinse-water may vary in quality depending on the process requirements ~~(see Section 0)~~. Many rinsing techniques have been developed to reduce water consumption to a minimum, and some of these are discussed in Sections 4.2.6.7 and 4.2.6.8. There is usually a balance to be sought between achieving the requisite cleanliness of the surface, the quality and quantity of the water used, and the way rinsing is carried out.



(Atotech Deutschland GmbH)

Figure 2-4: Section through a jig plating process line for PCB production

Environmental considerations
Rinsing is one of the largest potential sources of waterborne contamination as rinse-waters carry all the process chemicals from an activity. In many cases rinse-waters are treated prior to discharge (treatment options are discussed in Section 4.2.10). Key issues are:

- minimisation of the loss of materials, including possible re-use of rinse-water;
- metals: these are conservative, i.e. can only be treated and moved to another waste stream, but cannot be destroyed;
- cyanides: these are usually treated by oxidation;
- complexing agents: (including cyanides) these may need to be treated separately to enable metals to be successfully treated subsequently;
- surfactants, brighteners and other additives may interfere in waste water treatment or have their own environmental impacts;
- other cations may have local water quality effects.

Rinsing is also one of the two largest water usages in installations (the other large use is cooling).

2.1.6 ~~After~~ Post treatment activities

[Note to the TWG: This section corresponds to the Section 2.6 of the original STM BREF]

2.1.6.1 Drying using hot water

[3, CETS, 2002] After all wet processing operations have been completed, the workpieces or substrates need to be quickly and effectively dried in order to avoid staining and corrosion. The simplest method of drying is by immersing the components in hot water for a few seconds and then allowing them to dry-off in the air.

The disadvantage of hot water drying is the high energy loss from the tank surface. It is, however, common practice in surface treatment shops moving jigs manually (and hence low throughput of workpieces).

The water temperature needs to be carefully controlled. The temperature must be limited to 60 °C for plated plastic components in order to avoid deformation. Zinc plated and passivated

components also are limited to 60 °C to avoid dehydration of the coating and loss of corrosion protection of the passivate film. Chrome plated components can be dried at up to 90 °C.
Deionised water is usually used to prevent drying stains. Some plants use a continuous trickle feed of deionised water, the water overflow is then used to provide a feed for a preceding cascade rinsing system. The hot water stage may also be a final rinsing step.

Environmental considerations
Energy efficiency can be low.

2.1.6.2 Drying using hot air

Drying in automated jig plants is most easily accomplished on automatic lines using hot air. The jigs are placed in a tank-shaped drier at the end of the process line; the tank has the same dimensions as the vats in the line to fit into the transporter system. Hot air is evenly re-circulated from the top to the bottom of the tank at temperatures of 60 – 80 °C. Hot air escaping from the top of the drier tank makes the equipment thermally inefficient.
In some cases, such as the new thick film passivations or to reduce drying times, it is necessary to heat the substrate or workpieces to 80 °C and higher. The temperature of the air circulating in the tank-shaped driers then needs to be above 100 ºC. The air is normally heated by circulation or heat-exchangers using steam or hot oil. Direct heating systems are an alternative, using a special gas burner with an open gas flame in the circulating air. The burning gas heats the air directly with an efficiency of nearly 100 % of the energy input [124, Germany, 2003].

Environmental considerations
There is a potential for poor energy efficiency if air is not retained and recirculated effectively.

2.1.6.3 Drying using air knives

There is a growing use of localised air drying by means of precision nozzles or ‘air knives’ that is more energy-efficient than hot air tank drying. See Section 2.3 for a description.

2.1.6.4 Heat treatment for hydrogen de-embrittlement

Heat treatment to avoid the hydrogen embrittlement formed in pickling, cathodic cleaning, and the electrodeposition of metal where the current efficiency is less than 100 %, or in chemical deposition (phosphating). The temperature and time of the de-embrittlement process depend on the substrate [159, TWG, 2004].

Environmental considerations
Energy consumption [124, Germany, 2003].

2.2 Electroplating and chemical plating activities

General description of activities

The surface treatments of plastics and metals described in this document are mostly water-based and the installations carry out activities sequentially, usually in process lines made up of a series of vats or activities. Figure below shows a simplified process workflow of a typical process line. ~~All l~~Lines ~~(except some simple iron phosphating lines, see Section 1.1.1)~~ contain often more than one treatment or activity type, usually with rinsing vats in between. Some activities are waterless, such as drying. ~~and, for printed circuit boards, drilling.~~The size of an individual vat can range from a few litres for precious metal coating, to 500 m^3 or more for some installations processing aerospace workpieces. Historically, the surface treatment industry has been characterised by the large volumes of water used in processing, and these were often visible running across process area floors: this is no longer usual [124, Germany, 2003] [111, ACEA, 2003].

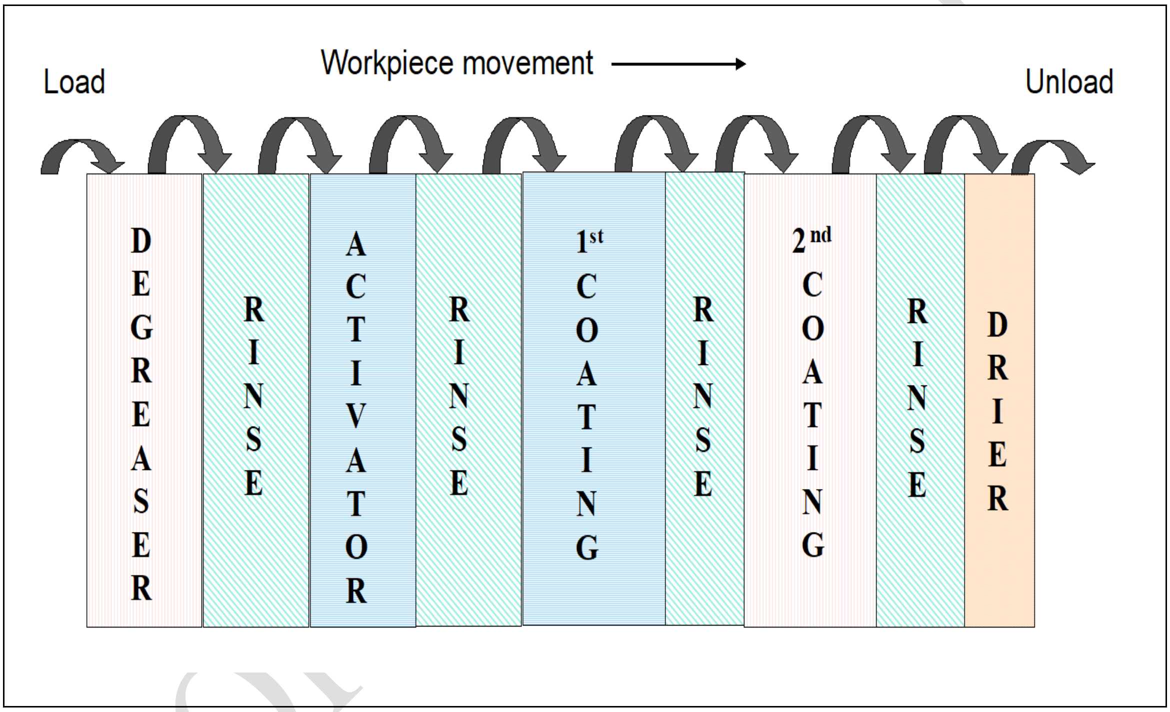


Figure 2-5: A simplified process line workflow diagram

A common feature of surface treatment installations is the large number and complex mix of processes and activities carried out in an installation, particularly in jobbing shops (as shown in Figure 2-6), as well as in single purpose installations (see Figure 2-30). Figure 2-4 shows a section through a typical jig plating process line with multiple processes and activities (note the activities are not carried out in numeric order because of transporter programming) and Figure 4-49 shows two large scale jig lines in an installation.

The size and complexity of the installation, the core activities and associated activities are dictated by:

- the type of surface treatments to be carried out;
- the quality standards being worked to;
- the type, size and amount of workpieces (substrates) to be treated;
- the transport systems required to handle the workpieces.

These all also impact on the pollution potential from the installation.

Before and after the activities described here, subsequent operations may be performed on the workpiece or substrate such as pressing, forming, bending, crimping, drilling, welding, soldering, etc. These subsequent operations, as well as the final use of the treated product, will be critical factors in determining the specification and type of surface treatment to be applied.

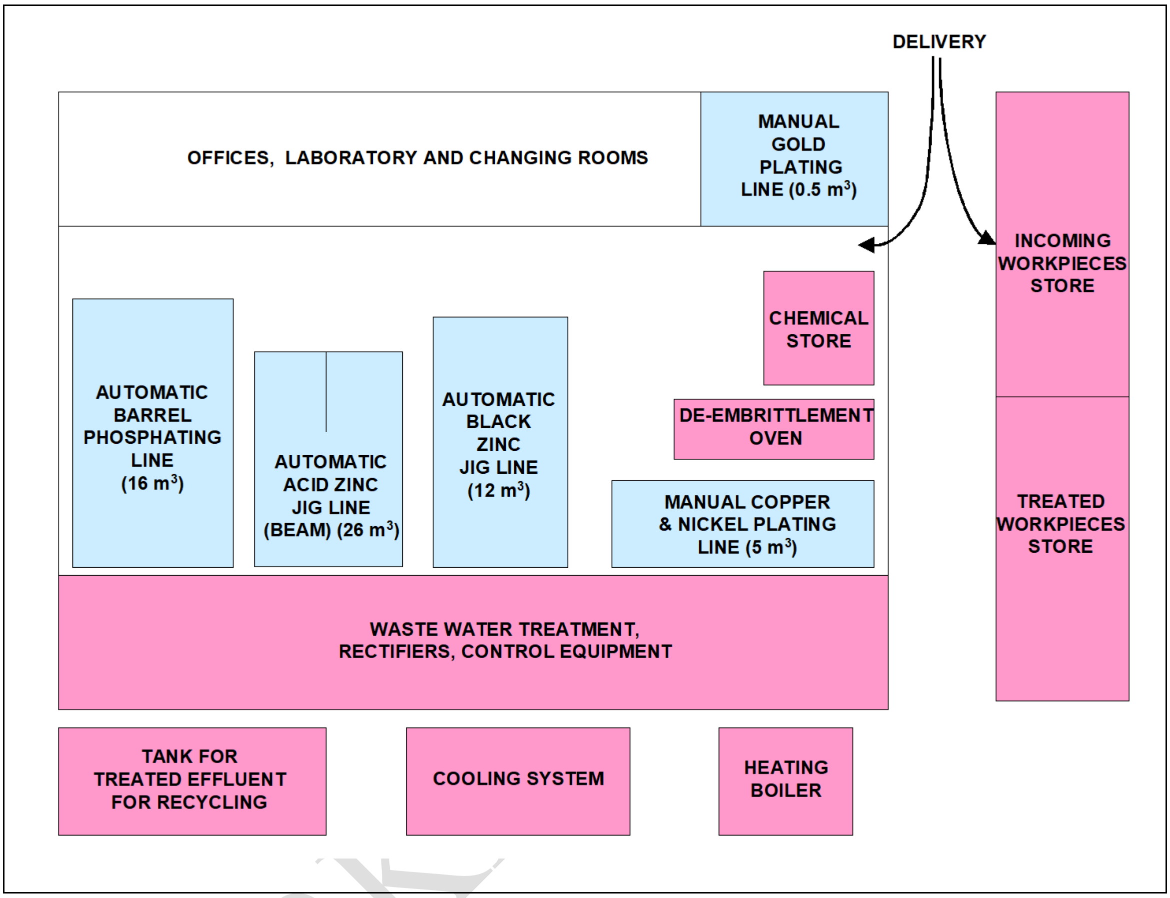


Figure 2-6: Example of a jobbing shop layout

All the core electroplating or chemical treatment processes and other activities have historically been developed for jig lines. Indeed, jig lines still carry out the widest range of activities. The treatments are therefore described generically for jig lines. ~~Specific issues for barrel and coil processing and printed circuit boards are described subsequently: barrel processing in Section 0, coil processing for large scale steel coils in Section 2.4, coil and sheet processing for aluminium lithographic plates in Section 2.5, and printed circuit boards in Section 2.6.~~

There are also utility inputs- energy and water- to surface treatment installations (described in Section 3), as well as the use of abatement techniques for the treatment of water, waste and air emissions (see Section 4).

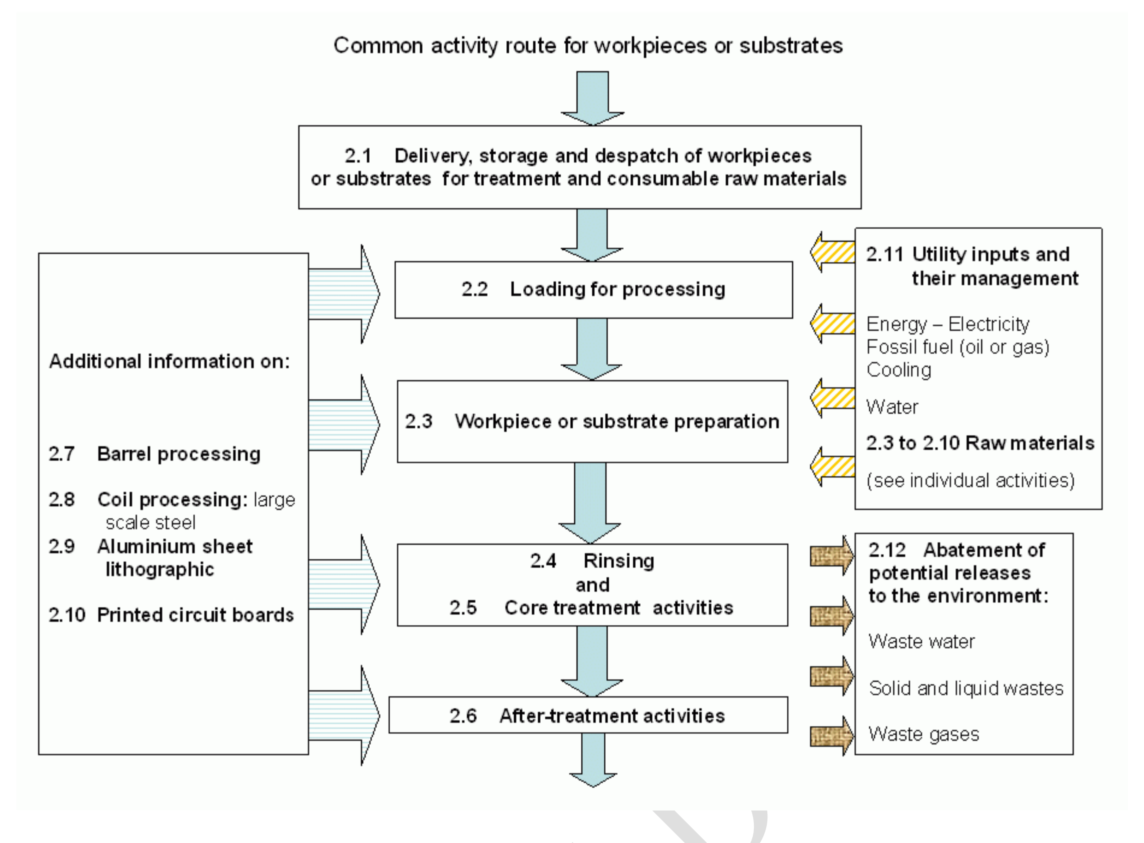


Figure 2-7: Common route in Chapter 2 for workpieces and substrates and the activity descriptions

Electrolytic processes

An electrolytic process needs:

- a solution of electrolytes, i.e. capable of carrying a current;
- at least two electron conductors (electrodes) and the ability to form a circuit;
- a current – usually direct current (DC), although the voltage can be AC or reversing DC in specific cases.

The electrolytic process requires the electrolyte to complete an electric circuit between the electrodes. When the electrodes are connected to a source of direct current (DC), one electrode, the cathode, becomes negatively (−ve) charged while the other, the anode, becomes positively (+ve) charged. The positive ions (cations) in the electrolyte will move towards the cathode and the negatively charged ions (anions) toward the anode. This migration of ions through the electrolyte constitutes the electric current in that part of the circuit. The migration of electrons into the anode, through the wiring and an electric power supply (supplied by rectifiers), and then back to the cathode constitutes the current in the external circuit. Electrolysis therefore converts electrical energy into chemical energy [11, Tempany, 2002, 34, Brett, 2002, 35, Columbia, 2002, 36, IUPAC, 1997].

Chemical energy in electrolytic reactions is associated with changes in the oxidation state in part of the circuit (in the electrolyte, at the anodes or at the interface) and can be manifested as some or all of the following:

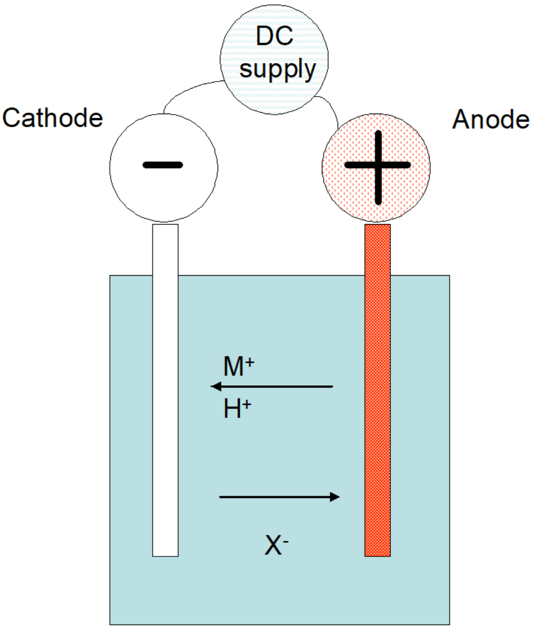
- the dissolution of metal ions into electrolyte;
- the deposit of metal from the electrolyte;
- some layer conversion coatings, e.g. anodising, change the oxidation state at the anode surface (see Section 2.5.13);

- the release of gases. In the circuits discussed here, hydrogen and/or oxygen are the gases usually released.

Electrolytic cells and reactions

When the workpiece or substrate is connected to the circuit in the electrodeposition cell, the cations (in the example, M^+ and H^+) move towards the cathode (–ve). The metal is deposited while hydrogen is generated as a secondary cathodic reaction. The anions (e.g. Cl^-) move towards the anode (+ve) [118, ESTAL, 2003, Ireland, 2003 #125].

As a simple example, M is the metal being electroplated, and X is the anion in solution:



- in acid solution:

  anode reaction: $2H_2O \rightarrow 4H^+ + O_2\uparrow + 4e^-$ Electrolysis of water

  cathode reaction: $M^+ + e^- \rightarrow M\downarrow$ Reduction to metal

- in alkali solution:

  anode reaction: $4OH^- \rightarrow O_2\uparrow + 2H_2O + 4e^-$

  cathode reaction: $M^+ + e^- \rightarrow M\downarrow$

The choice, design and sizing of the other line components and associated activities are dependent on the choice of the electrolytic cell and its components. The choice of an electrolytic cell depends on:

- the industrial applications the producer intends to supply;
- the layer type and thickness required (deposit and/or conversion) and of the throughput capacity required;

- the type of substrates (workpieces) to be treated;
- the transport type required to move them: jig, barrel or coil.

Electrolytic cells may be classified in function by four main parameters:

- electrolytic cell geometry;
- current density;
- types of electrolyte bath (described for each process, below);
- anode types.

Two families of anodes are available:

- Soluble anodes which have two functions: to provide metal ions to the electrolyte bath and to repel the positive ions towards the substrate (forming the cathode). The anodes are consumed during the process and need to be replaced regularly to maintain the solution strength. They are fixed on a supporting rail which carries the current to them.
- Insoluble anodes have only one function: to repel the positive ions towards the steel strip (cathode). They are constructed of current carrying materials that do not take part in the solution reaction. They are used in electrochemical processes where the anode material does not take part in the process, such as electrolytic degreasing. Where there is deposition of material, process solution strength is maintained by additions as make-up, often from a separate feed tank, e.g. a zinc dissolution tank.

2.2.1 Core metal plating activities

2.2.1.1 Copper and copper alloy plating

[3, CETS, 2002] Copper plating is common for items in daily use, such as coins, and buttons or zip fasteners with a patina for haberdashery. These types of workpieces can be plated on jigs or in barrels. ~~Copper plating is also essential in printed circuit board manufacture, see Section 2.6.~~

2.2.1.1.1 Cyanide copper

Cyanide copper low temperature electrolytes are necessary for strike plating on steel and zinc die casts to prevent spontaneous cementation of copper and poor adhesion of the subsequent metal deposit. This type of solution is based on copper cyanide and sodium cyanide, with a copper concentration of 15 – 20 g/l. Copper strike layers are usually no thicker than 2- 3 µm.

Thicker layers (6- 8 µm) are achieved with potassium cyanide and potassium hydroxide based high performance electrolytes at a metal content of 25 – 50 g/l, mainly for barrel plating and others.

Another high performance electrolyte is based on copper cyanide and sodium cyanide with potassium sodium tartrate providing higher current densities system, enhanced brightness of layers and reduces the tendency to anode passivation. The metal content is 40 – 60 g/l.

Potassium carbonate is generated in potassium-based systems during processing. This disrupts bright copper deposition and causes roughness at concentrations beyond 90 g/l.

Environmental considerations
Process tanks may be equipped with fume extraction to remove generated aerosols.

Sodium-based solutions can be regenerated by batch or continuous precipitation of sodium carbonate.

Potassium-based electrolytes have to be discarded as soon as the content of potassium carbonate exceeds 90 g/l.

Effluent can be treated in typical waste water plants, with a cyanide oxidation stage.

2.2.1.1.2 Acid copper

These solutions are now the usual choice for copper plating [124, Germany, 2003]. Due to their excellent levelling capability, acid copper electrolytes based on copper sulphate and sulphuric acid are used to make polishing and buffing redundant prior to decorative bright nickel and copper plating on furniture frames, bathroom fittings, wire work, etc. The normal copper content is 50 – 60 g/l and sulphuric acid is 60 – 90 g/l.

The solutions are also cyanide free, do not suffer from carbonate build-up and are more electrolytically efficient.

Environmental considerations
Process tanks may need to be equipped with fume extraction to remove aerosols generated by air agitation of the plating solution.

Effluents can be treated in typical waste water plants for low pH and to remove copper.

2.2.1.1.3 Pyrophosphate copper

Pyrophosphate copper electrolytes no longer play an important role. They are based on copper pyrophosphate (110 g/l) and potassium pyrophosphate (400 g/l). Additives are citric acid (10 g/l) and ammonia (3 g/l) [124, Germany, 2003].

They are used for special technical applications such as shielding on heat treated parts, as a drawing aid for wires, and for other thick bright layers that need little or no polishing, to prevent hydrogen embrittlement and as an intermediate layer below nickel and silver.

~~Pyrophosphate electrolytes can also be used for through-hole and panel plating of printed circuit boards and multi layers, but are currently substituted mainly by acid copper electrolytes.~~

Pyrophosphate is continuously decomposed by hydrolysis if pH is not maintained sufficiently, shortening the lifetime of the process solution. Appropriate regeneration means are not currently available. However, properly maintained baths can last more than 10 years [129, Spain, 2003].

Environmental considerations
Fume extraction is normally used at process tanks.

Effluents have to be treated with lime, as sodium or potassium hydroxides do not precipitate copper from the pyrophosphate.

Due to the ammonia content, separate treatment from other effluents containing metals is required.

2.2.1.1.4 Brass

Brass is predominantly an alloy of copper and zinc although nickel, tin, or lead may be added. A mixture of copper and zinc cyanides in solution are widely used to deposit copper and zinc alloys for decorative purposes. They are alkaline electrolytes containing between 8 – 15 g/l copper and 5 – 30 g/l zinc (depending on the formulation used). The total sodium cyanide content can vary from 70 to 90 g/l and working pH around 10. The deposited alloy contains 65 to 80 % of copper and the colour is light yellow. It can be used as a flash over a bright substrate or if heavier deposits are used then different finishes can be obtained through a subsequent chemical colouring of the deposit.

2.2.1.1.5 Bronze

Bronze is copper alloyed with tin and zinc. Cyanide bronze alloy is used as a decorative plating process. It is used as a substitute for nickel in jewellery as a ‘nickel free’ coating to avoid skin allergy effects. Acid bronze is under development [124, Germany, 2003].

The metal concentration in this stannate and cyanide-based electrolyte is 4 – 10 g/l of stannate, 4 – 20 g/l copper, and 1 – 4 g/l zinc, with 6 – 10 g/l potassium cyanide. It is used in two different colours: white or yellow bronze.

Lead is used in low concentration as a brightener in some electrolytes. Its future use in many products is banned by new directives [98, EC, 2003, 99, EC, 2000].

Cyanide oxidises with the passage of current to carbonate. Solutions have to be discarded as soon as the carbonate level exceeds 40 g/l.

Environmental considerations
Process tanks may need to be equipped with fume extraction to remove generated aerosols.

Effluent can be treated for pH, cyanide and metals in a typical waste water treatment plant with a cyanide oxidation step.

2.2.1.2 Nickel electroplating

[73, BSTSA,] Nickel electroplating and electroless plating processes are used in a wide range of industrial and consumer applications. Although the prime function of these processes is to improve the resistance of substrates to corrosion, wear and abrasion, nickel provides a smooth, highly reflective and corrosion-resistant coating below a range of other coatings for decorative finishes.

Nickel plating processes- including both electrolytic and electroless (autocatalytic) systems- can conveniently be considered in seven separate categories.

Nickel/chromium electroplating
The most important application of nickel is in nickel/chromium electroplated coatings, commonly called ‘chrome plating’. They consist of a very thin chromium topcoat (1 %) over an undercoat of nickel (99 %). Nickel provides a very smooth, brilliant corrosion-resistant finish.

Nickel electroplating with other topcoats
Brass, gold and silver topcoat systems are used as alternatives to chromium.

Nickel electroplating
Nickel can be used on its own without any topcoat. Generally, this is only for engineering purposes, such as refurbishment of worn components.

Nickel composite electroplating systems
Almost uniquely, nickel matrixes can be formed in which inert, non-metallic particles, such as silicon carbide, diamond or PTFE are incorporated by co-deposition to improve engineering properties such as hardness, abrasion resistance and coefficient of friction.

Nickel alloy electroplating
Electrodeposited nickel alloys of commercial significance include zinc-nickel, nickel-cobalt, and nickel-iron.

Nickel electroforming
Nickel electroforming is a unique process that allows articles to be produced by the electrodeposition of relatively thick nickel layers- it is a vital part of the process of manufacturing compact discs, DVDs, holograms and screen printing cylinders.

Electroless nickel plating
This is a chemical process giving hard uniform coatings. They can also be deposited on materials that cannot be electroplated, such as plastics and some alloys. A full description of these processes is given in Section 2.5.8.

Overall environmental considerations
The health issues related to nickel metal and its soluble salts, and the principal areas of concern are described in Section 1.4.4.1.

Nickel solutions are likely to require agitation and the choice of agitation can affect the amount of airborne pollutants, see Section 4.3. Effectiveness of distribution can be improved by the addition of wetting agents.

Exhaust extraction is regularly used and mist eliminators are often employed and the effluents may be treated with other waste waters (see below).

Waste waters can be treated in a typical waste water treatment plant. However, waste waters containing nickel must be separated from cyanide-bearing waste waters, as nickel forms stable complexes with cyanide which are difficult to treat. Contact with other complexing agents should also be avoided.

Solid residues will require management as a hazardous waste [92, EC, 1991], [100, EC, 2000].

Substrate considerations
Nickel is regularly deposited onto a wide range of metallic substrate materials commonly used in manufacturing processes such as steel, copper, brass, zinc alloys, aluminium, and magnesium as well as onto a range of plastics substrates.

It can successfully be plated directly, achieving good adhesion, onto some of these substrates (steel, copper and lead-free brass) if the correct cleaning and other pretreatment processes (see Section 2.3) are properly carried out.

Zinc alloys are, however, susceptible to corrosive attack in acidic nickel plating solutions and consequently require a layer of copper deposited from a cyanide solution (see Section 2.5.1) before nickel can be successfully deposited.

With aluminium and its alloys, because of their very high surface reactivity, it is necessary to deposit a layer of zinc (produced by non-electrolytic chemical treatments known as the ‘zincate’ or ‘double zincate’ processes) before a layer of copper can be applied, again from a cyanide-based solution. Magnesium alloys require similar treatment.

2.2.1.2.1 Watts-type nickel solutions

Watts-type nickel solutions account for the majority of solutions used in the nickel plating industry, including those used for nickel-chromium plating, nickel with other topcoat systems and composite nickel plating. Nickel sulphate (240- 375 g/l) is used with nickel chloride (35- 60 g/l) and boric acid (30- 45 g/l). Operating temperatures can range from 25 to 70 °C although the more restricted range of 50 to 60 °C is more common. The pH is normally 3.5- 4.5. Formulations with a nickel chloride content at the higher end of the range may be used to achieve increased deposition rates.

Watts-type solutions can be used without any additions to produce dull nickel deposits, although wetting agents are almost always added to reduce gas bubble retention on the nickel surface which would result in 'pitting'. However, Watts-type solutions are most frequently employed with the addition of organic compounds. These modify the metallurgical structure of the nickel to produce either a lustrous and fully bright appearance or alternatively semi-bright or satin nickel deposits. As well as altering the visual appearance of the nickel, these additives also inevitably bring about changes in deposit ductility, hardness and internal stress. Typical additions depend on the required function of the nickel deposit and varies from a small amount of organic semi-brightener (<1 ml/l) and wetting agent (<1 ml/l) for a semi-bright finish to primary and secondary brighteners at 10- 20 ml/l and <10 ml/l wetting agent for a bright finish.

There are many types of organic compounds used to modify the properties of deposits produced from Watts-type solutions. In general, they are added as proprietary mixtures.

If regularly analysed, used and maintained with care, Watts-type solutions can have an almost indefinite working life. Nickel metal deposited at the cathode is rather more than fully replenished by that dissolved at the anode since the cathode efficiency is normally only between 96 – 98 %, compared to an anode efficiency of 100 %. This small difference in efficiencies is normally compensated for by removal ('drag-out') of solution from the process tanks by work being carried forward into the rinsing system. In systems where 'drag-out' is low, the solution concentration may actually increase; this may require treatment to keep the concentration within operating limits.

The problem most likely to shorten the working life of the nickel solution is the introduction of contamination which can be either inorganic or organic in nature.

Inorganic contaminants can be introduced by an impure water supply, solution carried forward into the nickel solution from those preceding it in the process chain (e.g. cleaning solutions) or metallic components accidentally dropped into the nickel solution, such as work falling from jigs, subsequently dissolving into the process solution. Some inorganic contaminants (Fe) can be removed by measures such as high pH precipitation and others (Cu and Zn) by low current density electrolysis known as 'plating out', see Section 4.11.9.

A considerable number of organic contaminants can be removed simply by filtration over activated carbon or using adsorber polymers. Others may require additional treatment either with hydrogen peroxide or with potassium permanganate in order to break down the compound into simpler ones that can then be removed by active carbon treatment.

Environmental considerations
See overall environmental considerations.

~~The~~ Some wetting agents used ~~do not usually~~ may interfere with typical waste water treatments. [176, CETS, 2024].

With suitable maintenance and rinsing measures, closed loop operation can be achieved, reducing effluent treatment requirements and increasing raw material and water conservation.

2.2.1.2.2 Nickel sulphamate-based solutions

These solutions are widely used, and most frequently in electroforming applications where the low internal stress of the deposits they produce is absolutely vital. In these cases chloride-free solutions can be used (but only if a form of sulphur-activated nickel anode material is employed) to reduce deposit stress to a minimum. They are also used in barrel plating operations and reel-to-reel, since their higher electrical conductivity allows faster deposition rates to be used, and for thicker layers (> 2 000 µm).

Generally, sulphamate-based solutions are not used in situations where Watts-type solutions will prove effective due to their higher cost.

The solutions are based on nickel sulphamate (rather than nickel sulphate) in concentrations ranging from 350 to 600 g/l of the tetrahydrate salt, allowing a higher current. These solutions always contain boric acid (35 – 45 g/l) and frequently nickel chloride (1- 15 g/l).

These solutions normally operate in similar temperature and pH ranges as those used for Watts-type solutions although high concentration sulphamate solutions that are used to achieve high metal deposition rates, using current densities up to 35 A/dm^2, are often operated at around 70 °C.

Sulphamate-based solutions are frequently used without any additions, other than wetting agents to reduce ‘pitting’. However, selected organic compounds, such as saccharin and naphthalene tri-sulphonic acid, can be added to the solution to increase deposit hardness or to control deposit internal stress.

Like Watts-type solutions, those based on nickel sulphamate can have an almost indefinite life if analysed regularly and carefully maintained. There is, however, an additional complication to be considered in relation to the chemical and electrochemical stability of the sulphamate anion. At higher temperatures and lower pH values this will hydrolyse to produce sulphate ions plus ammonium ions in solution. The ammonium ion increases the deposit stress and hardness to unacceptable levels and, furthermore, cannot be removed from the solution. In addition, if the anodes in the process solution become passive, the sulphamate anion will undergo electrochemical oxidation to produce an unspecified mixture of by-products that radically and detrimentally affect deposit properties.

The avoidance of inorganic and organic contamination and treatment are as for Watts-type solutions.

Environmental considerations
Issues relating to solution loss by ‘drag-out’ and effluent treatment are the same as for Watts-type ones.

2.2.1.2.3 Nickel chloride-based solutions

Solutions based on nickel chloride have very limited uses due to the very high internal stresses of the deposits they produce. One exception is the Woods nickel strike solution which normally consists of 240 g/l of nickel chloride hexahydrate plus 125 ml/l hydrochloric acid and is operated at 20- 30 °C. It is used for one specific purpose only: to provide an initial adherent nickel layer on the surface of materials, such as stainless steel and nickel-chromium alloys, where it is difficult to achieve adhesion due to the naturally forming passive oxide film.

2.2.1.2.4 Nickel sulphate-based solutions

Solutions based on nickel sulphate and not containing nickel chloride are only rarely used as they do not promote good dissolution of the nickel anode material. Formulations similar to the Watts-type solution (but without chloride) can be used when it is vital to use inert anodes in order to deposit into highly inaccessible recesses.

A sulphate-based (70 g/l nickel sulphate plus 100 g/l sulphuric acid) nickel strike solution is sometimes used for a similar purpose as the Woods solution (see above).

2.2.1.2.5 Nickel phosphorus-based solutions

[Note to the TWG: Please complement the description below]

Solutions based on nickel phosphorus are used in an electroless plating process that involves the deposition of a nickel-phosphorus alloy onto a substrate. The solution is typically based on a nickel sulphate or nickel chloride formulation, with sodium hypophosphite (NaH_2PO_2) as the primary phosphorus source. The solution also contains other additives, such as complexing agents, stabilisers, and pH adjusters, to maintain the stability and performance of the bath.

In terms of specific applications, such coatings are commonly used in the electronics industry for components such as connectors, switches and contacts. They are also used in the aerospace industry for corrosion-resistant coatings on aluminium alloys.

In contrast to nickel-cobalt and nickel-iron alloys, phosphorus-based coatings do not require special additives to stabilise the ferrous ions in solution, as they do not contain iron. However, the plating solution does require careful control of pH, temperature and chemical composition to maintain optimal performance and prevent spontaneous decomposition.

Overall, the plating process using a phosphorus-based solution offers a versatile and effective method for depositing corrosion-resistant, wear-resistant coatings onto metal and plastic substrates. [170, CETS, 2022]

2.2.1.2.6 Other nickel plating solutions

Solutions based on nickel fluoroborate are mentioned in literature but currently find little, if any, commercial application.

2.2.1.2.7 Nickel alloy plating solutions

Nickel-cobalt alloys are used in electroforming because they are harder than pure nickel and nickel-iron alloys find applications in the electronics industry, generally related to their magnetic properties. Solutions used for depositing both types of alloy are normally based on the standard Watts-type or nickel sulphamate formulations, with the same issues of operation and maintenance.
Nickel-iron processes, however, require special additives to stabilise the ferrous ions in solution and prevent spontaneous oxidation to the ferric state.

Nickel-zinc alloy plating processes that produce alloys containing 10- 14 % nickel have been developed recently and are becoming increasingly important since they can provide almost 10 times the level of corrosion protection that can be achieved with pure zinc (see Section 2.5.4.).

2.2.1.2.8 Thermochemical diffusion processes

[Note to the TWG: Please complement the description below]

One common application of thermochemical diffusion processes is after electroless nickel plating. Electroless nickel plating is a process that involves the deposition of a thin layer of nickel onto a substrate material using a chemical reaction. However, the nickel layer can be prone to corrosion and wear and may not provide adequate protection for certain applications.

To address this issue, thermochemical diffusion processes can be used to diffuse atoms or molecules into the nickel layer at high temperatures, creating a thin, uniform layer of material that enhances the properties of the nickel. There are several types of thermochemical diffusion processes, including the following:

- Pack cementation: This process involves the use of a pack of powder or granules to diffuse atoms or molecules into a substrate material.
- Gas-phase diffusion: This process involves the use of a gas to diffuse atoms or molecules into a substrate material.
- Ion implantation: This process involves the use of high-energy ions to diffuse atoms or molecules into a substrate material.

[170, CETS, 2022]

2.2.1.3 Chromium plating

[Note to the TWG: This Section is not updated yet as regards the use of Chromium in plating activities]

Chromium plating has found wide usage both as a decorative surface finish (bright chromium plating) and as a functional coating (hard chromium plating), because of its typical high hardness and wear resistance properties. It is also widely used in packaging applications (see Section 1.3.2). [3, CETS, 2002]

For decoration, often referred to as bright chrome or bright chromium, it is usually applied as a thin layer to prevent the corrosion of the very level and bright surfaces generated by bright nickel undercoats. Deposit thickness is generally in the range 0.1 to 0.4 µm [73, BSTSA, 124, Germany, 2003], with a treatment time from 2 to 13 minutes [73, BSTSA]. The finish has a typical silver-bright colour and has a very high resistance to tarnishing.

Bright chromium can be plated either from a hexavalent or trivalent chromium electrolytes [122, UBA, 2003].

Hard chromium plating (usually known as hard chrome) consists of heavy deposits applied on particular components (drive shafts, hydraulic cylinders, aircraft landing gear [73, BSTSA,] pins, valves, etc.) to give high resistance to mechanical and wear damage. Hard chromium plating can only be plated from hexavalent chromium electrolytes.

Aerosols are generated from the hexavalent process solution by significant cathodic hydrogen evolution. The health effects of hexavalent chromium are described in Section 1.4.4.1. Theoretically, trivalent processes based on a chloride solution may produce hazardous organic halogens (AOX) and chlorine gas, but production solutions prevent this by additives reducing the chlorine. There is no problem with sulphate-based solutions.

Further issues relating to Cr(III) and Cr(VI) are discussed in Section 4.9.6.

~~Annex 8.10 contains a spreadsheet setting out all the comments received and their validation.~~

Overall environmental considerations for hexavalent chromium

Process tanks are normally equipped with fume extraction to remove hexavalent chromium aerosols.

Fume suppressants may be used to control foaming and to reduce the amount of aerosol, whether in conjunction with fume extraction or not [73, BSTSA,]. However, ~~the~~ suppressants ~~are~~ may be based on PFAS~~PFOS~~, which are ~~is~~ toxic and persistent [73, BSTSA,]. [176, CETS, 2024]

Extracted vapours may be treated through a suitable mist eliminator and the wash liquor treated with other chromium effluents.

Effluents may be treated in a typical waste water treatment plant, with reduction of Cr(VI) to Cr(III) followed by flocculation and precipitation.

Cr(III) solutions do not require separation and reduction prior to treatment.

2.2.1.3.1 Bright chromium plating (hexavalent chromium electrolytes)

Bright hexavalent chromium plating electrolytes are based on chromic acid (80- 400 g/l), sulphate as the primary catalyst (0.8- 5.0 g/l) such as fluoride ions (<2 % of the concentration of the chromic acid). Where high corrosion protection is required so-called ‘micro-cracked or micro-porous’ chromium coating can be applied using readily available techniques, with a thickness from 0.7 to 0.8 µm, and a treatment time of 7- 8 minutes [113, Austria, 2003].

Decorative chromium coating properties are determined by the characteristics of the nickel underlayer, by the CrO_3/catalyst ratio and by the operating temperature (20 – 45 °C) [73, BSTSA,]; [124, Germany, 2003].

Environmental considerations
See overall environmental considerations for hexavalent chromium, above.

2.2.1.3.2 Bright chromium plating (trivalent chromium electrolytes)

Bright trivalent chromium electroplating electrolytes are based on chromium III compounds, such as sulphate or chloride, together with proprietary chemicals. The electrolyte contains only about 20 g/l of the trivalent chromium, compared with about 200 g/l of chromic acid in the hexavalent chromium process.

Currently, trivalent chromium can only be used for decorative finishes, and cannot replace hexavalent chromium for hard chrome plating (see Section 4.9.8.3) [124, Germany, 2003]

The use of trivalent chromium eliminates the carcinogenic and other hazards associated with hexavalent chromium in the workplace. Fume extraction and scrubbing, or fume suppressant are not required for hexavalent chromium. However, additives are required to prevent the formation of free chlorine and AOX.

The lower electrolyte concentration has a lower viscosity than the hexavalent electrolyte. This results in better draining of plated parts, and subsequently less drag-out, less loss of electrolyte, less effluent treatment required and less chromium-containing waste being produced.

Environmental considerations
There is no hexavalent chromium aerosol to control, but fume extraction may be required to deal with any acid fumes [115, CETS, 2003, 124, Germany, 2003].

Fume extraction will assist with, providing evaporation and sufficient volume reduction for additions made during solution maintenance [124, Germany, 2003] or returned drag-out from rinsing processes. However, evaporation may be needed.

The significantly reduced drag-out losses result in much reduced associated effluent treatment and sludge disposal requirements: up to 90 % reduction is possible.

The waste water requires less chemical treatment as the chromium is already in the trivalent state and will precipitated at a suitable pH.

2.2.1.3.3 Black chromium plating

Black chromium finishes can be achieved for decorative black pieces and on the same substrates as for bright chromium plating. They are also plated onto a preceding nickel layer. Usually, they are treated in emulsions to achieve a decorative finish after the plating process (see Section 2.5.11).They are based on hexavalent chromic acid electrolytes (350- 520 g/l) and catalysts (nitrates, fluorides). The layers are porous and <1 µm. [113, Austria, 2003]

Environmental considerations
See overall environmental considerations for hexavalent chromium, above.
Although not usually required, there may be a need to treat nitrates and/or fluorides in any waste waters.

2.2.1.3.4 Hard chromium plating

Hard chromium plating electrolytes are based on chromic acid (180 – 350 g/l) and on one of the following catalysts:

- sulphate ions (1.8 – 6.0 g/l);
- mixed sulphate and fluoride ions (<2 % of the content of the chromic acid);
- pre-prepared proprietary fluoride-free (<2 % of the content of the chromic acid).

The catalyst choice is fundamental to the efficiency of the electrolyte (from 25- 33 % [73, BSTSA,] for the sulphate catalyst to 25 – 27 % for the pre-prepared proprietary fluoride-free type). The type of catalyst used, and the operating temperature have a great influence both on the physical properties (cracked, micro-cracked and crack-free coatings) and on the chemical and mechanical properties, e.g. the corrosion and wear resistance, the mechanical workability, etc. [3, CETS, 2002, 74, BSTSA,]

Environmental considerations
See overall environmental considerations for hexavalent chromium, above.

Due to the long plating times and high process temperatures (50- 60 °C) there is usually sufficient evaporation to use rinse-water returned from the subsequent rinsing station. This may enable closed loop operation, with or without an evaporator. Alternatively, there may be high water consumption [73, BSTSA,].

2.2.1.3.5 Passivation with chromium-free processes

[Note to the TWG: Please complement the description below]

Passivation is used to prevent corrosion and improve the durability of metal components. Traditional passivation processes often involve the use of chromium-based treatments, which have provoked environmental and health concerns. As a result, chromium-free passivation processes have been developed, including zirconium-based treatments.

Zirconium-based passivation processes involve the use of zirconium salts or compounds to create a protective layer on the surface of metal components. The zirconium layer is oxidised to form a stable and durable oxide layer, which provides corrosion protection.

Zirconium is one of the alternatives to the use of chromium, e.g.in the following:

- Aerospace: For passivating aluminium and other metal components used in aircraft and spacecraft.
- Automotive: For passivating metal components used in vehicles, such as brake components and fuel systems.
- Medical: For passivating medical implants and equipment, such as surgical instruments and hospital furniture.
- Food processing: For passivating metal components used in food processing equipment, such as stainless steel and aluminium.

In addition to zirconium-based treatments, other chromium-free passivation processes are being developed, including: titanium-based treatments, silicon dioxide, aluminium oxide, and polymer-based treatments using for example polyurethane and polyethylene. [170, CETS, 2022]

2.2.1.4 Chromium conversion coatings

[Note to the TWG: This section corresponds to Section 2.5.17 of the original STM BREF]
[Note to the TWG: This section is not updated yet as regards the use of Chromium in plating activities]

[3, CETS, 2002, 104, UBA, 2003]
Chromium conversion coatings are used to enhance corrosion protection on various metal surfaces, including electroplated zinc and cadmium, zinc die castings, tin, aluminium, magnesium and magnesium alloys, copper, brass and bronze, nickel, silver and stainless steel. Without such protection, zinc electroplated steel surfaces have a strong tendency to white (zinc oxide) corrosion. Often referred to as ‘chromating’ because the process originally used only hexavalent chromium as the chromate ion ($Cr_2O_4^{2-}$), it is used in nearly all areas of the steel processing industry and is an essential post treatment step in zinc plating. The wide spread use of the original yellow chromating was increased by the development of further layer systems of blue and black chromating, which have decorative effects in addition to corrosion protection.

Phospho-chromating exists with both hexavalent chromium (Cr(VI)) and trivalent chromium (Cr(III)) versions and is used in the treatment of aluminium prior to painting in special applications ~~[118, ESTAL, 2003]~~.

The layer thicknesses of the chromating coats lie between 0.1 and 2 µm. They are well suited as adhesion mediators for subsequent treatment with paint layers or synthetic material coatings. Lubricants can be included in order to decrease the friction values of treated pieces.

The corrosion protection of the chromium coatings can be increased by further sealing layers, described in topcoatings, Section 2.5.17.7.

The typical composition of solutions are chromic acid, dichromate, chloride, fluorides, sulphates, borates, nitrates and acetates, which are used in different combinations and concentrations to produce different colours and layer characteristics.

Overall environmental and health considerations
For health issues relating for Cr(VI), see Section 1.4.4.1.

For Cr(VI) aerosols and effluents, see Section 2.5.3.

2.2.1.4.1 Chromium (VI) conversion coatings

Conventional processes are all based on the use of acid oxidising solutions, the oxidant being hexavalent chromium (Cr(VI)). The protection mechanism is based on the dissolution of the Cr(VI) present at the surface of the film. The presence of chromate works locally to inhibit any corrosive action on the exposed metal surface.

2.2.1.4.2 Chromium (VI) conversion coatings on electroplated zinc layers

Coatings are applied by chemical reaction in aqueous solutions. Numerous proprietary conversion coating processes are available, producing decorative and protective films with colours ranging from clear through iridescent yellow to brass, brown, olive drab and black. Broadly, the deeper the colour the better the corrosion resistance.

2.2.1.4.3 Chromium (VI) conversion coatings on copper, brass and bronze

Chromate solutions to treat copper and copper alloys are prepared with proprietary materials. The treatment not only passivates the surface but also provides effective chemical surface polishing. Consequently, chromate treatments on copper and copper alloys are used both as a final finish and as a whole or partial substitute for mechanical buffing prior to nickel or chromium plating. The passivity obtained is effective in reducing corrosion and sulphide tarnishing.

Environmental considerations
Chromate bright dipping solutions are preferred because of their non-fuming nature.

Increased effluent treatment may be required because of the dissolution of copper in the process bath.

2.2.1.4.4 Chromium (VI) conversion coatings on magnesium and its alloys

Because of their corrosion characteristics, chromate treatment is still the only common method to treat magnesium and magnesium alloys. This treatment is often applied at the raw material source, in order to ensure good storage characteristics. Chromate treatment is also used to prepare magnesium and magnesium alloys for subsequent plating, particularly for nickel autocatalytic plating.

There are two typical process methods in use:

- pickling is mainly used to protect parts during storage and shipment
- dichromate treatment provides maximum corrosion protection and improved adhesion properties for paint.

2.2.1.4.5 Trivalent chromium (Cr(III)) conversion coatings on ~~aluminium and~~ electroplated zinc

Trivalent chromium (Cr(III)) conversion coating processes were first developed about 20 years ago as a more environmentally acceptable alternative to hexavalent chromium (Cr(VI)) processes, mainly on electroplated zinc. These conversion coating systems and treatment baths do not contain hexavalent chromium and therefore avoid the environmental or health problems associated with hexavalent chromium. [118, ESTAL, 2003]

Trivalent chromium-based blue coating processes can produce the appearance traditionally associated with hexavalent processes over acid, cyanide or alkaline non-cyanide zinc plating systems.

Trivalent chromium conversion coating processes usually produce clear or blue conversion coatings only. Recently, trivalent chromium passivates producing a higher film thickness and greater corrosion resistance have been developed that perform well in comparison with iridescent hexavalent chromium passivation.

At least one process is available with coatings that are Cr(VI)-free. They have a unique light green, yellow iridescent colour and provides up to 120 hours to first white corrosion when barrel processing and up to 240 hours when rack processing. These numbers vary depending on the process and if a topcoat or sealer has been added. This passivation can be used on all zinc plating (acid, alkali non-cyanide and cyanide) as well as zinc alloys (Zn-iron, Zn-cobalt and Zn-Nickel). It is claimed that treated parts can be baked at 200 °C for four hours and still retain up to 90 % of their corrosion protection abilities.

Black Cr(VI)-free passivations have also been developed which, with sealers, give the comparable corrosion test results [124, Germany, 2003].

However, the thickest conversion coatings, olive drab, that give greater corrosion protection for zinc can only be achieved using hexavalent chromium conversion coating processes.

Compared to hexavalent chromium conversion coating processes, the trivalent chromium conversion coating:

- can provide equal or more corrosion-resistant for the same colour finish [124, Germany, 2003]
- does not require a running in period for freshly prepared passivation solutions
- the colour and performance of the processes are more uniform throughout the solution life
- solution is normally at least twice that of conventional hexavalent chromium and limited by impurities rather than consumption of the active chromium compounds, resulting in less solution disposal
- cannot produce the range of colours and corrosion resistance given by hexavalent coatings
- requires more process control
- may require a top coating or sealer to produce similar corrosion performance to darker Cr(VI) passivations.

Environmental considerations
There are no specific health and safety considerations for Cr(III).

Reduction of Cr(VI) to Cr(III) is not required during waste water treatment.

Cr(III) processes generally contain approximately ten times the concentration of chromium to Cr(VI) baths. The zinc removal from zinc plating is twice that of Cr(VI). Cr(III) may therefore generate more waste in waste water treatment [113, Austria, 2003].

Cr(III) processes with a similar corrosion resistance to Cr(VI) processes are usually heated baths with a higher energy consumption than the corresponding Cr(VI) processes [73, BSTSA,].

2.2.1.4.6 Topcoatings for chromate conversion coatings

Both hexavalent and trivalent chromate conversion films are porous and adsorbent in nature and their thickness is very limited. Their protective action can be enhanced by applying a subsequent top coating film, either organic (e.g. methacrylate, see electropainting, Section 2.5.10 and lacquering, Section 2.5.11) or inorganic (e.g. metasilicate) and/or mixed inorganic-organic. These topcoatings have additional functions: a self-healing effect, providing protection against local mechanical scratches due to improper handling during processing; a substantial reduction in the quantity of Cr(III) leaching out from the treated surface, and a reduction in friction parameters [124, Germany, 2003]. Top coating protection is mainly due to the physical barrier of the coating itself.

2.2.1.5 Zinc and zinc alloy plating

Zinc and zinc alloy coatings are the most widely used electrolytic surface treatment, providing corrosion resistance and/or cheap decorative coating to a very wide variety of iron and steel items for the automotive, construction and other industries. For example, they are used for steel sheet or wire, screws, washers, nuts, bolts, shopping trolleys, construction frames (chassis) and casings for domestic appliances (such as washing machines) and many other kinds of applications (see Section 1.1). [3, CETS, 2002, 78, BSTSA,]

Zinc layers require post-treatment (see Section 2.5.17): in conjunction with various coatings, zinc layers of only 2.5 –18 µm thick will be sufficient to protect parts for their whole working lifetime [159, TWG, 2004].

Zinc plating has been in existence for a hundred years and because of its wide application, many different electrolyte systems are in use. The most common ones are described below.

Overall environmental considerations
Zinc ores contain cadmium. At the purity used for zinc electroplating, anodes contain about 1 gram of cadmium per tonne of zinc or 0.0001 %. EN 1179: requires a zinc purity of 99.995 %. The maximum amount of cadmium allowed is 0.003 %, although in practice, this is about 0.0003 % or 3 g per tonne [124, Germany, 2003] Trace quantities of cadmium may therefore appear in the effluent. These traces are largely removed in typical waste water treatment plants, and will be in the sludge produced. The quantities in either treated effluent or wastes are not usually significant. Treatment to remove zinc to regulatory levels are usually sufficient to remove this incident cadmium. If necessary, additional steps such as filtering may be added (see Section 4.16.10 [124, Germany, 2003].

2.2.1.5.1 Alkaline cyanide zinc

This is used mainly for technical (non-decorative) corrosion-resistant layers. The process electrolytes are easy to operate, and have compositions of zinc oxide (10 – 30 g zinc/l), sodium hydroxide (80 – 120 g/l) and sodium cyanide (5 – 100 g/l). They operate at pH values close to 14, using both soluble and insoluble anodes.

Alkali zinc gives coating with good post-forming properties. Some sources suggest this is due to a fine structure of the deposit, others that is due to the cleaning action of the cyanide solution giving good adhesion [73, BSTSA,].

The cyanide-based electrolyte has good throwing power into holes and blind spaces.

The plating solution has low conductivity, thus a higher voltage (6- 8 V for jig plating, 10-15 V for barrel plating) and a higher energy demand is needed. [73, BSTSA,] Carbonate build-up from cyanide decomposition can be dealt with by crystallising out (see Section 4.11.4), which also removes metallic impurities in the electrolyte.

The current efficiency is from 50 % to 75 % on a well-run process at an average current density of 2A/m^2 [73, BSTSA,], but decreases with increasing current density.

Fume extraction of the process tanks to remove aerosols may be used.

Environmental considerations
There is an industry tendency towards decreasing the cyanide content because of environmental and safety reasons.

Cyanide in rinse-waters can be readily oxidised by several methods in the waste water treatment plant.

Zinc can be readily removed in a typical waste water treatment plant.

2.2.1.5.2 Alkaline cyanide-free zinc

These are mainly applied for technical corrosion-resistant layers (non-decorative). The process solutions contain zinc oxide (5 – 15 g zinc/l) and sodium hydroxide or potassium hydroxide (100 – 150 g/l). This process may require better pre-cleaning treatment than for cyanide solutions [73, BSTSA,]. The process can give better metal distribution than cyanide electrolytes.

The plating solution has a low conductivity, thus a higher voltage (6- 8 V for jig plating, 10- 15 V for barrel plating) and higher energy demand is needed.

Current efficiency 65- 70 %, decreasing with increasing current density. 70 – 85 % is achievable at 2A/m^2 for well-managed processes [129, Spain, 2003, CETS, 2003 #115].

Environmental considerations
Zinc from rinses can be readily removed in an waste water treatment plant.

Aerosols from the bath can be reduced by using wetting agents, which create a foam blanket over the bath.]. However, ~~the~~ suppressants may be based on PFAS~~PFOS~~, which are ~~is~~ toxic and persistent [73, BSTSA,]. [176, CETS, 2024]

Air extraction may be required from the plating vats and any external dissolution tank for zinc metal (see Section 2.13.3[113, Austria, 2003].

This process has a much higher energy demand than other zinc-processes (cooling, lower current efficiency). Potassium electrolytes have better current efficiency than sodium electrolytes [113, Austria, 2003].

2.2.1.5.3 Acid zinc

Acid zinc electrolytes give bright decorative layers, and used, for example, on furniture frames, shopping trolleys and baskets. In conjunction with post-treatments, they provide corrosion resistance comparable with finishes from alkaline-type electrolytes. Metal distribution is poor to acceptable, but this improves with warm electrolytes.

Electrolytes contain zinc chloride (30 – 55 g zinc/l), potassium and/or [124, Germany, 2003] sodium chloride (130- 180 g/l) [116, Czech-Republic, 2003], boric acid (10 – 40 g/l) and wetting agent. Only soluble anodes are used. The solutions have good conductivity and high cathode efficiency, typically 93- 96 %. It has a lower energy demand than alkali processes[73, BSTSA,].

Plating tanks may be equipped with fume extraction hoods to remove chloride-containing mists, thus preventing the corrosion of equipment.

Environmental considerations
Current efficiency of the electrolyte means lower power consumption.

If the extracted air is passed through mist elimination, effluents may require treatment to adjust pH and remove zinc.

Effluents may be easily treated in typical waste water treatment plants.

Acid zinc electrolytes generate more solids in effluent treatment than alkali cyanide processes, resulting in possibly four times as much solids. This may be due to increased dissolution of steel substrates, where the iron both bulks and acts as a flocculant in waste water treatment ~~(Personal communication, D. Hemsley)~~.

2.2.1.5.4 Zinc alloy plating

Zinc alloy coatings provide extended corrosion resistance and the main use is for automotive applications (see Sections 1.1 and 2.9).

The main zinc alloys deposited are:

- zinc-iron (<1 % Fe), from alkaline cyanide-free electrolytes;
- zinc-cobalt (<3 % Co), from acid or alkaline cyanide-free electrolytes;
- zinc-nickel (<15 % Ni), from acid (ammonium chloride-based) or alkaline cyanide-free electrolytes. Alloys containing 10 %- 14 % nickel have been developed recently and are becoming increasingly important since they can provide almost 10 times the level of corrosion protection than can be achieved with pure zinc. They can be deposited either from acidic chloride-based solutions or from alkaline solutions where the relatively low concentration of nickel in solution (1- 2 g/l) is stabilised by the addition of small amounts of amines. The alkaline solutions are becoming the preferred formulations since they give a more consistent alloy composition on complex work geometry [115, CETS, 2003].

Environmental considerations
Plating tanks may be equipped with fume extraction hoods to capture aerosols or ammonium chloride fumes.

The extracted air may be passed through mist elimination.
Alkaline cyanide-free effluents are treated in typical waste water plants.

Treatment of effluents from ammonium chloride-based electrolytes is difficult and has to be effected separately. Recovery of drag-out can be close to 100 % (closed loop operation) and this facilitates effluent treatment.

For zinc-nickel, the dilution factor that occurs in rinse-waters generally overcomes the complexing effect of the amines so that special treatment is not required to remove the nickel from the effluent. If it is necessary to dispose of quantities of undiluted process solution, however, chlorination treatment will be necessary be to destroy nickel amine complexes before the nickel can be precipitated from the effluent stream [73, BSTSA,].

2.2.1.5.5 Sealing following passivation

[Note to the TWG: Please complement the description below]

Sealing is a process used to enhance the corrosion protection of zinc-plated and zinc-alloy-plated components. After passivation, a sealant is applied to the surface of the component to fill in any pores or gaps in the passivation layer, providing an additional layer of protection against corrosion.

The zinc-plated or zinc-alloy-plated component is passivated using a chromate-based or non-chromate-based solution.

There are several types of sealants used in zinc plating and zinc alloy plating, including the following:

- Wax-based sealants: These sealants are based on natural or synthetic waxes, such as beeswax or paraffin wax.
- Oil-based sealants: These sealants are based on mineral oils or synthetic oils, such as silicone oil.
- Water-based sealants: These sealants are based on water and a variety of additives, such as polymers or surfactants.
- Solvent-based sealants: These sealants are based on organic solvents, such as toluene or xylene.

[170, CETS, 2022]

2.2.1.6 Cadmium plating

[114, Belgium, 2003, 115, CETS, 2003, 121, France, 2003] Cadmium is mainly used to protect parts made of steel, and aluminium or titanium alloys. It has particular properties: a low risk of hydrogen embrittlement, a low friction coefficient and constant torque for fasteners, and has better throwing power and penetration as well as better corrosion resistance than zinc. Its toxicity has resulted in it being restricted to specific ~~vital~~ technical uses where it is difficult to replace in aviation and aerospace, military equipment, mining and nuclear industries and some safety critical electrical contacts (see Section 1.4.4.1, ~~Annex 8.1,~~ [105, EC, 1967])

Cadmium plating can be performed in acidic as well as alkaline cyanide baths. The pretreatment is the same as for zinc plating. After plating the coating is often given a passivation treatment in chromic acid. High strength steel parts are heat treated to minimise the hydrogen uptake and then activated in diluted nitrous acid before chromating. Cadmium covering layers can be chromate plated.

Electrolytes may be based on cyanide, fluoroborate, sulphate or chloride:

- electrolyte based on cyanide:
  NaOH: 20 g/l; NaCN: 120 g/l; cadmium: 20-30 g/l; temperature: 20- 35 °C
- electrolyte based on fluoroborate:
  Cadmium fluoroborate: 250 g/l; ammonium fluoroborate: 60 g/l; boric acid: 25 g/l; temperature: 20- 35 °C
- electrolyte based on sulphate:
  Cadmium sulphate: 52- 85 g/l; sulphuric acid: 50- 120 g; temperature: 18- 30 °C
- electrolyte based on chloride:
  Cadmium chloride: 114 g/l; ammonium chloride: 112 g/l; complexing agent (EDTA, NTA): 180 g/l

Environmental considerations
The toxic effects of cadmium are well-known. [114, Belgium, 2003]~~, see Annex 8.1~~.

~~Discharge levels from waste water treatment plants are likely to be orders of magnitude lower than for other metals (such as zinc, see Annex 8.3).~~ Effluent may be treated by chemical-physical treatment. The precipitation of cadmium can be to improve by adding Fe^{2+} during the coagulation step, when there is a co-precipitation of cadmium and iron. It can be very difficult to obtain very low emission values for cadmium by precipitation. Additional treatment may be required, such as separate treatment at the point source prior to mixing with other effluents: e.g. electrolysis, mobile ion exchangers, evaporation [114, Belgium, 2003, 121, France, 2003].

2.2.1.7 Tin and alloy plating

Tin plated metal is widely used in many applications because of its unique properties. Plated tin coatings are non-toxic, ductile, resistant to corrosion, easy to coat, and have high throwing and good distribution properties. This makes it possible to plate items with complex shapes to a uniform thickness compared with hot tin dipping methods. Tin finishes are also subsequently easier to solder components onto[73, BSTSA,].

The main applications of tin are the coating of steel coil for packaging of food, beverages and aerosols, etc (see Sections 1.3.2 and 2.9.9). It is also widely used in printed circuit boards (see Section 2.11), electronic components [73, BSTSA,], appliance chassis, as well as for kitchen utensils.

Several different electrolytes are available, such as acid stannous sulphate, acid tin fluoroborate, alkaline sodium or potassium stannate and more recently the stannous systems based on organic acids, such as methane sulphonic acid, (MSA) and accounts for 13 % of European tin plate production [73, BSTSA,]. The simpler sulphate baths containing stannous sulphate, sulphuric acid and addition agents (antioxidants for stannous tin, plus grain refiner) are the most popular in rack and barrel applications because of their high current efficiency [73, BSTSA,].

Tin lead plating is the most commonly tin plated alloy. It is used as solder coat in different alloy ratios (60/40, 90/10, 95/5) traditionally using stannous, and lead fluoroborates with fluoroboric acid and additives[73, BSTSA,].

Non-fluoroboric tin lead electrolytes are now available based on the organic methane sulphonate acid They have improved stability, low sludge formation, higher plating rates, [73, BSTSA,] better deposit properties and structure of the deposit. They are widely-used in reel- to-reel machines, as well as in barrel processing.

Tin-nickel has high throwing power, good distribution of metal, ductile, non-toxic, and is readily soldered to.

Environmental considerations
Process tanks may be equipped with fume extraction to remove aerosols generated during the electrolysis.

Effluents may be treated in typical waste water plant.

The MSA-based process is fully biodegradable, contains no chelates, complexing agents or phenols, has low COD and simple waste treatment (neutralisation and filtration) [73, BSTSA,].

Fluoroborate bath effluents should be pretreated separately to a typical waste water treatment plant.

The organic load from MSA-based processes is usually biodegradable [73, BSTSA,].

2.2.1.8 Precious metal plating

Silver and gold have been deposited electrolytically since the first half of the nineteenth century. More recently, processes for the so-called platinum metals (palladium, rhodium, ruthenium and platinum) have also been developed. Thin layers of less than 1µm are used to make a wide range of items appear valuable without commensurate cost. They also provide stain and corrosion resistance. Other specific technical properties such as conductivity, hardness and wear resistance have led to their wide-spread application in the electric and electronic industries. [3, CETS, 2002, 75, BSTSA,]

2.2.1.8.1 Silver

The silver plating of cutlery and hollowware is one of the oldest decorative applications of electroplating (see Chapter 1). Bright silver deposits are widely used for jewellery as well as on ornaments, trophies, giftware, etc. Due to its high conductivity and mechanical and chemical properties, silver layers are found on many components of electrical and electronic devices. Also, silver-palladium layers as a substitute for gold on electrical connectors have recently gained importance. [73, BSTSA,]

The majority of silver electrolytes are based on potassium-silver cyanide (potassium dicyano-argentate). A silver content of 30 – 65 g/l with free potassium cyanide of 100 – 160 g/l and potassium carbonate (15 – 20 g/l) is necessary for good plating performance. However, a potassium carbonate concentration of over 200 g/l makes it necessary to discard the electrolytes.

Attempts to replace cyanide, for example by thiosulphate and alternative complexing agents, have had limited success due to lower stability of the bath, high cost and cosmetic differences of the deposit.

Environmental considerations
The cost of silver makes recovery economic. Residues of silver may be recovered from rinse-water through electrolysis or ion exchange. Recovery of silver from spent electrolytes may be achieved through precipitation with zinc powder.

Plating tanks may be equipped with fume extraction hoods to remove cyanide fumes.

Cyanide can be readily oxidised in typical effluent treatment in waste water treatment plants.

2.2.1.8.2 Gold

Gold can be plated using rack, barrel or high speed equipment either as a very pure metal or as an alloy. It finds use in a wide range of industries such as connectors, printed circuit boards, integrated circuits, semiconductor manufacture, bathroom fittings, giftware, tableware, buttons, watches, pens, jewellery, and spectacle frames. [73, BSTSA,]

The majority of gold plating solutions in commercial plating facilities, whether the deposit has a decorative or a functional requirement are based on mildly acid solutions of gold potassium cyanide as potassium cyanoaurate, $KAu(CN)_2$. These solutions typically contain 2- 6 g/l of gold together with buffering agents to maintain the pH. These solutions often contain alloying metals such as cobalt, nickel, iron or indium. These harden, increase the wear resistance, and brighten the deposit. They also give distinctive colours.

A gold strike solution is often used to deposit the initial layer of gold to promote adhesion. Strike solutions usually based on gold potassium cyanide at 1- 2 g/l but may use gold (III) potassium cyanide ($KAu(CN)_4$) at a pH of around 1. These are often used on difficult to plate base materials such as stainless steel.

Alkaline solutions containing free cyanide are occasionally used for jewellery plating and for electroforming.

There are non-cyanide gold electrolytes, which are based on one of the gold sulphite complexes, which generally operate in mildly alkaline conditions, these typically contain 8- 15g/l of gold together with organic or inorganic brightener systems.

Environmental considerations
Drag-out recovery and gold recovery with electrochemical reactions on ion exchangers from the rinse-water is economically viable.

Chelating agents resistant to degradation have been largely substituted by biodegradable ones.

Effluent treatment is similar to other electroplating rinse streams in typical waste water treatment plants.

Air emissions from potassium gold cyanide plating operations can give rise to emissions of hydrogen cyanide. The levels of emissions can be significant depending on the size of operation when considered in conjunction with emission limits contained in the revised TA Luft guidelines for air emissions regulation (inorganic gaseous substances Class II). [125, Ireland, 2003]

2.2.1.8.3 Palladium and alloys

Layers of palladium-nickel alloy (75 – 80 % Pd/25 – 20 % Ni) are hard, extremely ductile [73, BSTSA,] and have a white colour with good corrosion resistance. They are suitable for coating spectacle frames and writing implements.

Pure palladium deposits are also used to substitute for nickel as a diffusion barrier below a final gold flash on spectacle frames, jewellery and buttons. Sandwich layers of nickel, palladium or palladium/nickel alloy and gold flash have proven applicability on printed circuit boards and connectors as substitutes for hard gold layers.

The most common formulation is based on the complex tetraamine palladium (II) dichloride (4- 20g Pd/l), [73, BSTSA,] containing ammonia. Alloying metals are nickel, cobalt and silver.

Environmental considerations
Besides drag-out recovery, electrolytic and ion exchange recovery of palladium are normally practical.

Tanks for ammonia-containing electrolytes may be equipped with fume extraction hoods to capture ammonia escaping from the plating electrolyte.

Effluents may be treated in typical waste water treatment plants.

2.2.1.8.4 Rhodium

Very thin rhodium deposits on silver have a silvery-white colour and are used to prevent staining. Their hardness and wear resistance properties are suitable for technical applications such as on reed contacts and on heavy duty connectors. Rhodium is also applied on reflectors for optical equipment and in aerospace applications.

Electrolytes are based on rhodium (III) sulphate or rhodium (III) phosphate, with a rhodium content of 2.5 – 20 g/l depending on their application for decorative (thickness of layer 0.05- 0.5 µm) or for technical purposes (thickness of layers 0.5- >8 µm), where selenium and sulphites are added to prevent cracking.

Environmental considerations
Besides drag-out recovery, electrolytic and ion exchange recovery of rhodium are normal practice.

Tanks for sulphuric acid-containing electrolytes may be equipped with fume extraction hoods to remove acid fumes.

Effluents may be treated in typical waste water treatment plants.

2.2.1.8.5 Platinum

Thin platinum layers are applied for decorative purposes, with thicker layers on electrical devices and on equipment for the chemical industry. Non-soluble platinised titanium anodes and anode baskets are in common use in electroplating.

Acid electrolytes are based on chloride, sulphate, nitrate and nitrite complexes of platinum, alkaline electrolytes on phosphate, ammonia and sodium hydroxide complexes, with metal contents of 6 – 40 g/l.

Environmental considerations
Besides drag-out recovery, electrolytic and ion exchange recovery of platinum are normal practice.

Effluents may be treated in typical waste water treatment plants.

2.2.2 Other plating types

2.2.2.1 Autocatalytic plating (catalytic chemically reduced coatings)

This is also known as electroless plating according to BS EN ISO 4527: 2003, [73, BSTSA,] but the term should be avoided, according to [101, CEN, 2000]. The fundamental reaction requires the presence of a catalytic metal – the metal being deposited- that allows the reaction to proceed. The advantages of the system are:

- provided there is sufficient agitation to maintain fresh undepleted solution in contact with all surfaces at all times, the deposit is uniform over the entire surface even if the shape is highly complex;
- deposits are usually less porous than the same metal deposited electrolytically;
- racking or fixing is greatly simplified;
- non-conductors (such as plastic) are coated;
- deposits often have special chemical or physical properties since the deposit is an alloy of the metal and a compound formed from the reducing agent. For example, with hypophosphite [73, BSTSA,] the deposit is an alloy of the metal and the metal phosphide, and with boron reducing agents the metal and the metal boride.

Overall environmental considerations:
Autocatalytic coatings commonly generate more waste than other plating techniques, but efficiency can vary significantly between facilities [69, NCDPPEA, 2003].

Improvement in process efficiency and a reduction in waste can be achieved by the use of electrodialysis to continuously remove the by-products from the plating solutions during operation [73, BSTSA,].

2.2.2.1.1 Autocatalytic nickel on metals

Autocatalytic nickel electrolytes are based on nickel sulphate and nickel chloride (nickel 2- 10 g/l). Sodium hypophosphite (10 – 50 g/l) is the most often used reducing agent [73, BSTSA,]. Solutions also contain chelating agents (organic carboxylic acids 10- 50 g/l) and buffers as sodium hydroxide and sodium carbonate. Cadmium may be present in some formulations as a brightener, 1- 5 mg/l giving approximately 0.03 % in the deposit. [73, BSTSA,] Lead may be used in some formulations as an alternative up to 3mg/l. Modern formulations are available which avoid the use of both cadmium and lead, in line with the requirements of the End-of-Life Vehicles Directive [99, EC, 2000].

Autocatalytically deposited nickel-alloy layers contain 2 – 15 % phosphorus.
Their key properties are:

- uniform thickness of deposit irrespective of the size and shape of items to be plated, provided that the plating solution can freely circulate around all surfaces of the components to be treated;
- deposit thickness can be controlled accurately;
- surface hardness as high as electroplated finishes and within the range 350- 750 Knoop;
- high resistance against wear and abrasion;
- inherent high resistance to corrosion resistance;
- good adhesion on base material;
- special properties such as natural lubricity, easily soldered to, magnetic properties.

Applications include (among many others):

- data storage devices as rigid memory discs;
- components for chemical and oil and gas industry;
- automotive, machine tool and electronics industries;
- plastics molding tools.

Environmental considerations
See overall environmental considerations for Section 2.5.8.

Fume extraction may be required at process tanks including mist elimination to remove nickel containing aerosols.

The solution working life is short (6- 8 MTOs, metal turnovers) due to the formation of reaction by-products. Process performance deteriorates requiring frequent discarding of used solutions. The working bath then requires disposal as a hazardous waste.

Effluents may have to be pretreated before discharge to the waste water treatment plant. Ammonia, which can complex other metals, and can be oxidised. Hypophosphite ions and phosphite ions can be oxidised to phosphates. The phosphate ion can be precipitate by adding calcium ions during the neutralisation. Metals can be separated from effluents by precipitation, plate-out or ion-exchange.

The strong chelating agent may require separate waste water treatment.

There may be trace amounts of cadmium and lead in the effluent. [124, Germany, 2003]

2.2.2.1.2 Autocatalytic nickel coating for plastics

Similarly to autocatalytic copper, electroless nickel solutions are used for generating a first conductive metal layer on plastic surfaces prior to further electrolytic metal (copper, nickel) deposition. [73, BSTSA,]

Plastics require etching (see Section 2.3.10.2) before deposition. Process solutions contain nickel sulphate or nickel chloride (nickel 2- 5 g/l), reducing agents e.g. sodium hypophosphite (5 – 20 g/l), dimethylaminoborane (>10 g/l) and optionally, chelating compounds such as organic acids. Both weakly acidic (sulphuric acid at pH 3- 6) and alkaline solutions (sodium hydroxide or ammonia hydroxide at pH 8- 10) are in use.

An example of a process line plating on plastics (PCBs) using autocatalytic nickel [73, BSTSA,] is shown in Figure 2.7

Environmental considerations
See overall environmental considerations

Fume extraction may be used for alkaline or high temperature processes. Typical effluent treatment will remove metals except where effluents contain strong chelating agents, which may have to be treated separately.

2.2.2.1.3 Autocatalytic copper on metals and plastics

Autocatalytic copper plating is still a key process for the metallisation of plastics [73, BSTSA,]. The main properties of the copper layers are uniform thickness, and fine crystalline, ductile layers with low internal stress. Copper layers are applied on small items such as buttons, fashion jewellery as well as on plastic housings and for electric shielding.

Plastics require etching (pretreatment, see Section 2.3) before deposition. Copper deposition starts on metal nuclei such as palladium and continues autocatalytically, thus providing an initial conductive layer. The deposition rate is 5- 8 µm/h. The solution has a copper content of 2 – 5 g/l, with sodium hydroxide (15 – 20 g/l), chelating agents such as EDTA or similar (10- 15 g/l) or tartrates (5 – 10 g/l) and reducing agents, e.g. formaldehyde (3 – 5 g/l).

The process solution lifetime is limited by the build-up of reaction products.

Environmental considerations
See overall environmental considerations.

Fume extraction for the process tanks may be necessary to remove gases (formaldehyde and others).

Effluent containing EDTA requires separate treatment as EDTA will prevent the precipitation of metals in the treatment process. There was an industry trend to replace EDTA as a chelating agent, although high specification work may require its use and the trend is currently being reversed [22, Fraunhofer, 2002]. Some parts of industry report the trend is being maintained [73, BSTSA,].

2.2.2.2 Self-Assembled Monolayers (SAMs)

[Note to the TWG: Please complement the description below]

Self-Assembled Monolayers (SAMs) are used to create a thin, ordered layer of molecules on a specific surface. This process involves the spontaneous organisation of molecules into a monolayer, which provides a stable and uniform coating.

During pretreatment, the surface is cleaned and prepared to ensure a strong bond between the self-assembled monolayers and the substrate. Then, the molecules are deposited using various methods, such as dipping, spraying or vacuum deposition.

The molecules spontaneously assemble into a monolayer on the surface, driven by intermolecular forces such as van der Waals and hydrogen bonding. This is followed by an annealing step to optimise the ordering and stability of the monolayer.

There are several types of SAMs used in surface treatment, including the following:

- Alkanethiol SAMs: These SAMs are formed from alkanethiol molecules, which are commonly used for gold and silver surfaces.
- Silane SAMs: These SAMs are formed from silane molecules, which are commonly used for silicon and glass surfaces.
- Phosphonic acid SAMs: These SAMs are formed from phosphonic acid molecules, which are commonly used for metal oxides and ceramic surfaces.
- Polymer SAMs: These SAMs are formed from polymer molecules, which are commonly used for a wide range of surfaces.

This process provides a uniform and ordered coating, which is ideal for applications requiring precise control over surface properties. These coatings are highly stable and resistant to degradation, making them suitable for applications in harsh environments. They can provide a low surface energy, which is beneficial for applications requiring low adhesion or wettability. They can also be designed to be biocompatible, making them suitable for biomedical applications, such as implants and biosensors.

Compared to other surface treatment processes, such as chemical vapour deposition (CVD) and physical vapour deposition (PVD), Self-Assembled Monolayers provide more uniform, ordered, stable and durable coatings. [170, CETS, 2022]

2.2.2.3 Sol-gel coating

[Note to the TWG: Please complement the description below]

Sol-gel coating is based on the hydrolysis and condensation of metal alkoxides or other precursors to form a sol, which is then deposited onto the surface and gelled to form a film. The metal alkoxide or other precursor is mixed with a solvent and water to form a sol, which is deposited onto the surface to form a film. Then the film is dried to remove any excess solvent, and cured at elevated temperatures to densify and stabilise the coating.

There are several types of sol-gel coatings used in surface treatment, including the following:

- Silica sol-gel coatings: These coatings are formed from silica precursors and are commonly used for applications requiring high scratch resistance and durability.
- Titania sol-gel coatings: These coatings are formed from titania precursors and are commonly used for applications requiring high UV resistance and photocatalytic activity.
- Alumina sol-gel coatings: These coatings are formed from alumina precursors and are commonly used for applications requiring high wear resistance and thermal stability.
- Hybrid sol-gel coatings: These coatings are formed from a combination of different precursors and are commonly used for applications requiring unique properties, such as self-cleaning and antimicrobial activity.

[170, CETS, 2022]

2.2.2.4 Deep spin coating

[Note to the TWG: Please complement the description below]

Deep spin coating is based on spinning at high speed a liquid solution onto a surface and then removing the excess liquid to create a thin, even layer. The thickness of the coating can be precisely controlled; however, deep spin coatings can be difficult to apply to surfaces with complex geometries.

These coatings are based on organic materials, such as polymers or waxes, or inorganic materials, such as metals or ceramics.
[170, CETS, 2022]

2.2.2.5 Immersion or displacement coatings – non-catalytic chemically reduced coatings

Non-catalytic chemically reduced coatings have been in use for many years, and are often known as immersion or displacement coatings. [38, Ullmann, 2002/3] They are formed when the metal to be deposited is precipitated on its reduction in solution either (i) chemically from solution, or (ii) the metallic substrate is more active than the ions in the solution in terms of the electromotive or electrochemical series, e.g.

$$Cu^{2+} + Fe^0 \rightarrow Cu^0 + Fe^{2+}$$

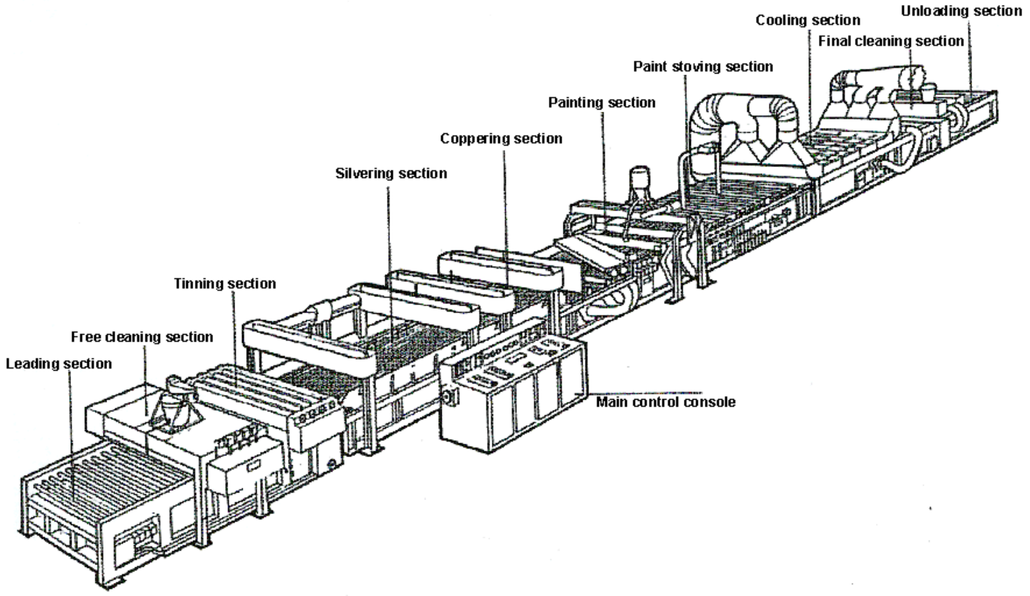
Although these deposits are often non-adherent and of poor physical quality, careful attention to solution composition and operating conditions can produce deposits that are acceptable for certain purposes. The zincate and stannate solutions used for plating aluminium are examples of special finishes producing acceptable deposits.

~~**Printed circuit boards**~~
~~High purity deposits, usually only of gold, silver and tin, are widely used on printed circuit boards. Thickness does not exceed 0.1 – 0.2 µm. [121, France, 2003] (see Section 2.11.3.2).~~

Mirrors
Their best known use is in producing mirrored surfaces from silver, although other techniques can now be used (such as vapour phase deposition). Their two main drawbacks are that only relatively thin coatings can be deposited and that all surfaces, including the container, receive a coating. While these solutions are sometimes used by immersion, they are now more often applied by spraying the solutions from a dual spray gun.. [38, Ullmann, 2002/3] [116, Czech Republic, 2003] The first step in silver coating of mirrors is the activation of the glass surface by stannous chloride ($SnCl_2$). This is followed by the application of a solution of silver nitrate ($AgNO_3$) and a reducing agent (usually glucose) by spraying. The precipitated silver (about 12 – 17 µm thick is rinsed by deionised water. The Ag coating is fixed by cementing copper with iron or zinc, forming a layer several µm thick: the copper is precipitated from solution by contact with the more electropositive silver deposit. This technique was discovered in 1835 and is still the best one. Some years ago a Belgian patent was given for a technique which used tin for fixation of Ag coating solution of Sn. This process is used by the largest producer of mirrors in the Czech Republic. Passivation using mercaptosilanes is also used.

The metallic layers are protected by a 50- 70 µm of solvent-based lacquers. Replacement by water-based lacquers has so far been unsuccessful.

Figure 2.8 shows an example of a mirror processing plant.



(SVUOM, Czech Republic)

Figure 2-8: Example of mirror processing line

Environmental considerations
For mirrors: copper from the cementation process can form a complex in the waste water s, and is difficult to precipitate in a typical waste water treatment plant. [116, Czech-Republic, 2003]

~~For printed circuit boards, the environmental considerations for gold and silver are as for tin [73, BSTSA,] (see Sections 2.5.6 and 2.5.7) Tin concentrations are low, and are treated in a typical waste water treatment plant.~~

2.2.2.6 Immersion painting

[Note to the TWG: Please complement the description below]

Immersion painting, also known as dip painting or immersion coating, is used to apply a layer of paint or coating to metal and plastic components. This process involves submerging the components in a paint bath, where the coating is deposited onto the surface through a combination of capillary action, gravity and wetting.The immersion painting process typically involves the following steps:

- Pre-treatment: The components are cleaned and degreased to ensure a strong bond between the coating and the substrate.
- Immersion: The components are submerged into the paint bath, which is typically a tank filled with a liquid coating material, such as paint, varnish, or a specialised immersion coating.
- Dipping: The components are slowly dipped into the paint bath, allowing the coating to flow onto the surface through capillary action.
- Coating deposition: The coating is deposited onto the surface of the components, forming a uniform layer.
- Draining: The components are removed from the paint bath, allowing excess coating to drip back into the tank.

- Curing: The coated components are then cured in an oven or using other specialised equipment, such as ultraviolet (UV) light or infrared (IR) radiation, to harden the coating.

There are several types of immersion paints used, including the following:

- Solvent-based paints: These paints use a solvent as the carrier for the coating material.
- Water-based paints: These paints use water as the carrier for the coating material.
- Powder coatings: These coatings use a powder as the coating material, which is applied electrostatically and then melted and formed into a uniform layer.
- Specialised immersion coatings: These coatings include materials such as silicone, polyurethane, and epoxy, which are used for specific applications, such as corrosion protection or thermal insulation.

Immersion painting offers several advantages, such as a uniform coating thickness and coverage, even on complex shapes, a fast and efficient process, making it suitable for high-volume production, and the possibility of automatisation.

Environmental considerations
Immersion painting can reduce waste and emissions, as excess coating material can be reclaimed and reused.
[170, CETS, 2022]

2.2.2.7 Electropainting or electrocoating

Also known as: electrophoretic painting, E-coat, Elpo, electrodeposition.

Electropainting is covered in detail in [90, COM 2020].

The activity is increasingly found alongside surface treatment activities covered in this document, both for subsequent painting and/or in conjunction with other coatings described here. It is used to apply a protective coating after decorative finishes (for example, applying a lacquer coat to brass plating) and as an alternative or supplement to corrosion-prevention layers, such as replacing hexavalent chromium conversion coatings on its own or used in conjunction with trivalent chromium systems, discussed in Sections 2.5.17 and 4.9.10.2. They may also reduce friction, and enable parts to be evenly or readily distributed without surface damage [124, Germany, 2003].

Common issues discussed in this document are:

- rinsing and drag-out control techniques (Sections 2.4, 4.6 and 4.7);
- solution maintenance (Section 4.11);
- water usage (Sections 2.12.2 and 4.4.5);
- electricity supply to the process and the workpieces (Sections 2.12.1.1 and 4.2.3);
- waste water treatment (Sections 2.13.1 and 4.16).

2.2.2.8 Lacquering

Lacquers are applied to protect and enhance decorative coatings (such as copper plating of hollowware) or to supplement corrosion protection systems such as chromating (see Section 2.5.17). They also reduce friction, and enable parts to be evenly or readily distributed without surface damage [124, Germany, 2003]. They can be applied by dipping in a proprietary water-based solution or by electropainting (see Section 2.5.10) [76, BSTSA,].

Topcoatings are applied immediately after chromate or trivalent chromium conversion coatings, by dipping in an appropriate proprietary medium or by electropainting (electrophoretic painting), see Section 2.5.10.

It should be underlined that ‘lacquering’ is not a synomym for powder coating. Lacquering is a wet painting process [175, ESTAL 2024].

Environmental considerations
Effluents have no impact on typical waste water treatment plants. Rinsing waters may need to be treated separately to reduce BOD or TOC levels in the discharged effluent.

2.2.2.9 Oiling

[Note to the TWG: This section corresponds to the Section 2.9.5 of the original STM BREF]

A wet film of oil is applied to the surface by spray, by wringer rolls or by an electrostatic oiler. This provides a coating for improving protection against white rust (e.g. oxide layers on zinc plating) corrosion. It can also act as a lubricant film to minimise subsequent damage by abrasion, to facilitate sorting and to aid in subsequent lacquering and printing operations. ~~See coil coating, Section 2.9.5, for electrostatic oiling.~~

2.2.2.10 Waxing

[Note to the TWG: Please complement the description below]

A layer of wax is applied to provide a barrier against corrosion, wear and tear.

The wax may be applied to the surface of the component using a brush. The wax is melted and forms a uniform layer on the surface before being cooled and hardened, forming a solid surface layer.

The waxed component may be cured in an oven or using other specialised equipment, such as ultraviolet (UV) light or infrared (IR) radiation, to harden the wax and improve its adhesion to the substrate.

[170, CETS, 2022]

2.2.2.11 Phosphating layer conversion coatings

[Note to the TWG: This section corresponds to the Section 2.5.16 of the original STM BREF]

[38, Ullmann, 2002/3, 71, BSTSA,]Phosphate coatings are the most widely used conversion coatings and probably the most widely used surface treatment. They are used to treat steel, aluminium and zinc for the following:

- Cold forming: this involves very high surface stresses and phosphating is used in all types of cold forming operations, i.e. drawing of wire, tube, or profile; deep drawing; cold heading, cold extrusion, cold forging. These applications are described in the reference [86, COM, 2022].
- Coil coating: steel strip electroplated with zinc is phosphated in the process line to improve formability in subsequent drawing operations, such as steel can forming, as well as for corrosion resistance and subsequent paintability, see Sections 2.9.6 and 2.9.8.9. Hot dip galvanised steel strip is discussed in [86, COM, 2022].
- Rustproofing: heavy zinc and manganese phosphate coatings retain a protective oil film and provide substantial corrosion prevention, e.g. for nuts, screws, bolts, and tubes.

- Bearing surface lubrication: manganese phosphate improves the retention of lubricant and shortens running-in periods. It is used for pinions, camshafts, pistons, gears, and valves.
- Paint base: phosphating enhances the adhesion and corrosion protection of paints, see [90, COM 2020].
- Electrical insulation: phosphate layers can be used to coat the silicon steel sheets forming the cores of electric motors, generators or transformers. A phosphate coating of 1- 6 µm thickness is sufficient insulation to prevent eddy currents.

There is a wide variety of phosphating processes, but the most important are alkali (iron) and zinc phosphating. The surface weight of layers is 0.05 – 5 g/m^2.

Methods of application
The phosphating solutions are generally applied by spraying or by immersion depending on the number, size, and shape of the parts to be treated. The type of application may lead to differences in the composition and morphology of phosphate coatings. Coiled strip is also coated by the roll-on, dry-in-place process, in which phosphating solution is applied to the strip and, without rinsing, is dried to form the phosphate coating, see Section 2.9.6.

Phosphating requires workpieces or substrates to be degreased and pickled see Section 2.3. [116, Czech-Republic, 2003] Activation prior to phosphating may be with hot water or with special proprietary titanium or manganese phosphate dispersions to induce the formation of a fine-grain phosphate coating in the subsequent step. Final rinsing may be with deionised water or passivating chemicals based such as Cr(VI) and Cr(III) compounds. Rinsing with water is needed between the processing stages as described in Section 2.4.

Overall environmental considerations for all phosphating processes
Effluents may require pH control and may [124, Germany, 2003] contain nickel, manganese, as well as zinc (according to solution make-up), which can be dealt with in a typical waste water treatment plant. Anions that may be of concern include nitrite and fluoride, which may require additional treatment.

Sludges formed in the process solutions require removing as wastes as part of the solution maintenance.

Health and environmental concerns have instigated the development of:

- nitrite-free processes with hydroxylamine, nitroguanidine, or hydrogen peroxide as accelerators
- nickel-free processes
- chromium-free after-rinses based on organotitanium, inorganic zirconium, or polymeric compounds
- effluent-free phosphating lines using ultrafiltration for cleaning, hydrogen peroxide acceleration in phosphating, and precipitation plus ion exchange for chromium-free after-rinses, without compromising the performance of the subsequently painted parts.

2.2.2.11.1 Alkali phosphating

This is mainly used when corrosion protection does not have to satisfy stringent requirements. For steel substrates, the solutions (pH 4- 6) consist of acid alkali phosphates, free phosphoric acid, and small amounts of additives; oxidising agents (e.g. chlorates, chromates, or nitrites), condensed phosphates (e.g. pyrophosphate or tripolyphosphate), and special activators (e.g. fluorides or molybdates). The first reaction is the pickling reaction which produces Fe^{2+} ions from the substrate (steel). These ions react with phosphate ions from the solution to form sparingly soluble iron phosphate that precipitates and adheres strongly to the metal surface. Iron phosphating processes may not require acceleration. The coating weight varies with the bath composition. Coatings formed on ferrous surfaces contain iron oxides and phosphates. Iron phosphating solutions normally contain surfactants for cleaning and oily surfaces may thus be treated in one step (so-called ‘cleaner-coater’).

On zinc surfaces, zinc phosphate layers are formed in an analogous reaction sequence. Aluminium is usually treated with solutions containing fluoride; thin, complex coatings are formed that contain aluminium, phosphate, and fluoride. The baths are adjusted to a concentration of 2 – 15 g/l. Treatment may be by spraying, flooding, or dipping. The bath temperature is normally 40- 70 °C, but can be lowered to 25- 35 °C with special bath compositions. Treatment times are 5- 10 seconds (spraying of strip material) and 1- 3 minutes (spraying or dipping of individual parts). Iron phosphating includes both thin-coating (0.2- 0.4 g/m^2) and thick-coating methods (0.6- 1.0 g/m^2). The colour of the layers is blue-green, but may be reddish iridescent. The surfaces become more matt and grey with increasing coating weight.

2.2.2.11.2 Zinc phosphating

Zinc phosphating is primarily used for the surface treatment of steel and zinc (or zinc coatings on steel) as well as composites of these metals with aluminium. Application may be by spraying or immersion. Essential constituents are zinc, phosphate ions, and an oxidizing agent, often sodium nitrite. The pH value is between 2 and 3.5. Concentrations vary considerably; additives such as nitrate, fluoride, silicofluoride, nickel ions, or manganese ions are common.

The following is an example of a process suitable for the phosphating of steel sheets as a pretreatment prior to painting:

$$Zn^{2+}\ 1.2\ g/l,\ Ni^{2+}\ 1.0\ g/l,\ H_3PO_4 + H_2PO_4^-\ 15\ g/l,\ \text{and}\ NO_2^-\ 0.1\ g/l$$

A pH of 3.2 is achieved with sodium hydroxide. The process is usually carried out at up to 95 ºC. For cold forming applications total concentrations may well be ten times higher.

Typically, the phosphating reaction may be broken down into five steps:

Pickling reaction
Part of the metal surface is dissolved by the acid:

$$Fe + 2H^+ \rightarrow Fe^{2+} + H_2 \text{ for Fe} \quad \textit{or} \quad Zn + 2H^+ \rightarrow Zn^{2+} + H_2 \text{ for Zn}$$

The phosphating of aluminium requires fluoride ions to attack surface oxides which only slowly dissolve in phosphoric or nitric acid:

$$AlOOH + 3HF \rightarrow Al^{3+} + 3F^- + 2H_2O;\ \ Al + 3H^+ \rightarrow Al^{3+} + 3/2H_2$$

Acceleration
The pickling reaction is accelerated by oxidising agents called accelerators, which also prevent the evolution of excessive amounts of molecular hydrogen thus minimising hydrogen embrittlement: [159, TWG, 2004]

$$H_2 + 2O_x \rightarrow 2HO_x;\ Fe^{2+} + H^+ + O_x \rightarrow Fe^{3+} + HO_x \text{ for Fe}$$

Complexation
When coating aluminium, sufficient fluoride ions must be available for complexation of surplus Al^{3+} ions as, in concentrations as low as 3 mg/l, they prevent the formation of zinc phosphate

coatings. If different metals including aluminium are to be treated, the use of fluoride-free phosphating solutions may allow phosphating of steel or zinc without coating the aluminium:

$$Al^{3+}+6F^{-} \rightarrow AlF_6^{3-} \text{ for Al}$$

Coating formation
Metal dissolution in the pickling reaction results in a significant increase of the pH value close to the metal surface. Consequently, the equilibrium constant for the precipitation reaction is exceeded and zinc phosphate is precipitated as the metal surface offers favourable nucleation sites. Once the whole metal surface is covered, the reaction ceases:

$$3Zn^{2+} + 2H_2PO_4^{-} + 4H_2O \rightarrow Zn_3(PO_4)_2 \cdot 4H_2O + 4H^{+}$$

$$2Zn^{2+} + Fe^{2+} + 2H_2PO_4^{-} + 4H_2O \rightarrow Zn_2Fe(PO_4)_2\, 4H_2O + 4H^{+}$$

Sludge formation
Dissolved iron and AlF_6^{3-} ions from the pickling reaction do not accumulate in the phosphating solution but are precipitated as iron(III) phosphate or trisodium hexafluoroaluminate, respectively. When treating galvanised surfaces and in spraying processes, relatively small amounts of tertiary zinc phosphate sludge are formed as well. Nitrate-accelerated processes often do not involve sludge formation. Iron(II) nitrate accumulates until equilibrium is reached between iron dissolution and drag-out.

$$Fe^{3+}+H_2PO^{-}_4 \rightarrow FePO_4 + 2H^{+} \text{ for Fe; or } AlF_6^{3-} + 3Na^{+} \rightarrow Na_3AlF_6 \text{ for Al}$$

The sludges formed must be removed either periodically or continuously.

Pre-paint processes
Zinc phosphating processes carried out prior to painting can be classified as high zinc or low zinc processes. High zinc processes operate at 3- 4 g/l Zn^{2+} and low zinc processes at 0.7- 1.5 g/l Zn^{2+}, the upper limit for dip applications. Low zinc concentration, i.e. high phosphate to zinc ratio, improves corrosion protection. Coatings on steel produced by low zinc processes consist mainly of phosphosphyllite and show superior paint-base performance to the high zinc processes with their hopeite coatings, such as stone chipping resistance and wet adhesion on galvanised substrates. Performance has further increased with the introduction of trication processes, which contain zinc, nickel, and manganese both in solution and in the coating. These processes have become commonplace in, for example, the automotive industries. [38, Ullmann, 2002/3]

For powder coatings, iron phosphate often gives optimum results [90, COM 2020].

Low temperature processes for cold forming
These are accelerated by nitrate, and the iron(III) concentration in the bath is limited to 5- 8 g/l by oxidation with air, preferably continuously in a separate reaction tank. The operating temperature has thus been lowered by about 30 °C to 50- 60 °C, and the phosphating tank remains virtually free of sludge.

2.2.2.11.3 Manganese phosphating

This is performed by dipping only, and iron(II) nitrate is often used for acceleration.

2.2.2.12 Metal colouring

[Note to the TWG: This section corresponds to the Section 2.5.18 of the original STM BREF]

It is possible to obtain a wide range of shades and colours over different metals by heat treatment, chemical dip or electrolytic treatment. These processes are used for brass, copper and steel parts. The most commonly used system is chemical dipping. The results obtained will depend more on the practice of the operation and process parameters than on the formula used. Originally, sulphide and polysulphide solutions in alkaline media using sodium, ammonium or barium salts from room to high temperatures were used. It is now more usual to use solutions containing metallic ions (copper, selenium, molybdenum, etc.) in an acid medium and at room temperature. [3, CETS, 2002]

Small articles may be coloured in bulk, then proud surface areas relieved by tumbling with an abrasive media, see Section 2.3. All sulphide treated workpieces require wet or dry scratch-brushing and must be protected by a topcoat of clear lacquer.

Environmental considerations
Depending on the precise formulations used, effluents may need to be pretreated separately prior to typical waste water treatment.

~~2.2.2.13 Bright dipping~~

[Note to the TWG: This section corresponds to the Section 2.5.19 of the original STM BREF. It is proposed to merge with Section 2.2.2.16]

~~For all substrates including aluminium, this term is synonymous with ‘brightening’ and ‘chemical polishing’, see Section [118, ESTAL, 2003, 159, TWG, 2004].~~

2.2.2.14 Chemical blacking – oxide coatings

[Note to the TWG: This section corresponds to the Section 2.5.20 of the original STM BREF]

Immersion-type chemical oxidation coatings are used mainly for appearance, as a paint base, or for their oil-retention characteristics. [38, Ullmann, 2002/3]

Environmental considerations ~~for all chemical blacking processes~~
Fumes from processes containing alkali and chromium may require extraction and possibly scrubbing. Scrubber effluents may require treatment in a waste water plant.

Rinsing waters may require treatment for pH. Other materials such as nitrogen-containing compounds, other oxidising agents and sulphides may require additional treatments to those found in a typical waste water treatment plant.

Steel
Steel may be blackened in a high temperature bath containing 480 – 840 g/l of a mixture of about 75 wt-% sodium hydroxide and 25 wt-% sodium nitrate. The solution is operated at the boil between 121 – 149 °C. Instead of 25 wt-% sodium nitrate, a mixture of 12 wt-% sodium nitrate and 13 wt-% sodium nitrite may also be used.

Lower boiling points are obtained by including various additives containing sulphur.
The resulting oxide coating is somewhat less corrosion-resistant because of the inclusion of iron sulphide in the film. Some of the sulphide-modified materials may also be used to blacken stainless steel.

Following thorough rinsing, the oxide film is normally coated with an oil, wax, or lacquer.

Stainless steel
Stainless steel can also be blackened in molten sodium/potassium dichromate at about 370 °C provided the parts are not adversely affected by the high temperature. The resulting oxide has good corrosion resistance, and the procedure is covered by military specifications.

The 'Inox' process, dipping in chromic acid and sulphate at 60 – 90 °C can be used, and chromium-nickel steel can be coloured black by dipping in $NaOH/NaNO_2$ at 125- 130 ºC [113, Austria, 2003].

Copper
Copper may be blackened in a bath containing 120 g/l of a mixture of 75 wt-% sodium hydroxide and 25 wt % sodium chlorite at 93 – 100 °C. The black copper (II) oxide produced has a fuzzy appearance. On bright finished parts, this fuzzy nap disappears when lacquer is applied, restoring the lustrous appearance, or it may be laid down (not removed) by gentle buffing or tumbling in sawdust or other soft abrasives (see Section 2.3).

Brass
Brass may be blackened in the same solution but may not respond, depending on the zinc content and metallurgical history. Activation may be carried out by immersion in a bath containing 120 g/l of a mixture of 85 wt-% sodium hydroxide and 15 wt-% sodium chlorite operated at 93- 100 °C for 5- 10 min to dezincify the surface, after which the blackening bath will usually function normally.

Aluminium
Aluminium may be given an oxide coating by immersion by a number of different processes including the ~~Alzac and~~ ~~Juratka~~ Jirotka process~~es~~. Electrolytic processes (anodising) are generally preferred.

2.2.2.15 Brightening and bright dipping

[Note to the TWG: This section corresponds to the Section 2.5.21 of the original STM BREF]

In the brightening of steel, concentrated nitric acid is used to form a very clean surface. Note that this process forms nitrous gases in the exhaust gas. [104, UBA, 2003]

Copper and brass are brightened by oxidising a surface layer.

~~Aluminium and some of its alloys can be brightened by chemical or electrochemical processes for special applications such as lighting and decorative finishes [118, ESTAL, 2003, 132, Sheasby and Pinner, 2002].~~

Phosphoric acid pickles have specific uses such as chassis parts and bicycle frames. It is usually used at a concentration of 10- 15 %, at temperatures of 40- 50 °C and sometimes as high as 80 °C.

Metal surfaces must be degreased thoroughly. Poor results, such as uneven attack or stained surfaces after brightening, are frequently due to insufficient pre-degreasing.

Environmental considerations
Spent brightening solutions may require treatment for low pH and possibly metal content prior to disposal as effluent. Alternatively, they may be disposed of as liquid wastes.

Acid fumes, particularly those containing NO_X may require extraction, possibly with treatment.

2.2.2.16 Chemical milling

[Note to the TWG: This section corresponds to the Section 2.5.23 of the original STM BREF]

Chemical milling is a process used to remove metal on workpieces by dissolution in a caustic or acid bath without an external source of energy (mechanical or electrical). Metal is removed off the whole surface of the part dipped in the milling bath provided this surface is in contact with the solution. Areas to remain are masked. The speed of the chemical dissolution is low, processing 0.5 to 3 mm/h compared with mechanical processes. The thickness removed is almost constant all over the surface, but with a roughness created which varies with the process used. [47, France, 2003]

The most important uses are on aluminium alloys for the aeronautical and aerospace industry. It is generally used on sheets that have been previously curved to save weight in specific areas of the part ~~and where it is necessary to save weight~~. Chemical milling can also be used on titanium alloys, stainless steel and some special alloys with a nickel, cobalt or magnesium base.

It is important to note that, although similar in principle (i.e. caustic soda with additives used for aluminium), chemical milling is not used as an etching pretreatment before anodising of aluminium. The process parameters are different.

Process chemistries used are:

- for aluminium: caustic soda with additives (sodium gluconate, sodium sulphide);
- for titanium: hydrofluoric acid (20 – 50 g/l) with nitric acid (50 – 70 g/l);
- for stainless steel: hydrochloric acid with nitric and phosphoric acid.

The main control parameters for aluminium and aluminium alloys are:

- concentration of the bath: from 100 to 150 g/l of free NaOH;
- temperature: 80 °C for older processes, types up to 110 °C for high speed processes;
- concentration of dissolved metals: 70 to 90 g/l Al;
- composition of the alloy chemically milled.

All these parameters affect the speed of processing, the thickness regularity and roughness of the finish.

Generally, the entire surface is not milled. In order to prevent milling on some areas it is necessary to mask those areas with protecting layers such as neoprene. The usual technique is to mask the whole part and then remove the mask from the areas to be milled. The mask is cut by scalpel or laser beam.

A typical process sequence is:

- solvent degreasing;
- alkaline etching;
- rinsing;
- pickling (e.g. sulphochromic pickling);
- rinsing;
- drying;
- masking;
- removal of mask on surface to be treated;
- attack;
- rinsing;
- surface passivation: (e.g. sulphochromic or nitric acid);
- rinsing;
- removal of mask;
- quality control.

Environmental issues
The main problem for this treatment is the large quantity of sludge due to the dissolved metals. The concentration of the chemical milling bath is generally kept below 70 g/l of aluminium and so used solutions are discarded beyond this concentration. Normal waste water treatment may be used and the principle component of the sludge is $NaAlO_2$.

2.3 Anodising

The anodising of metals is an electrolytic surface oxidation process which enhances the natural aptitude for the metal to oxidise; coatings can be 1000 times thicker than the natural layer Aluminium is the most important material to be anodised, with alumina (Al_2O_3) formed at the surface: magnesium, titanium, tantalum and niobium are also anodised in smaller quantities [3, CETS, 2002, 45, France, 2003] [118, ESTAL, 2003].

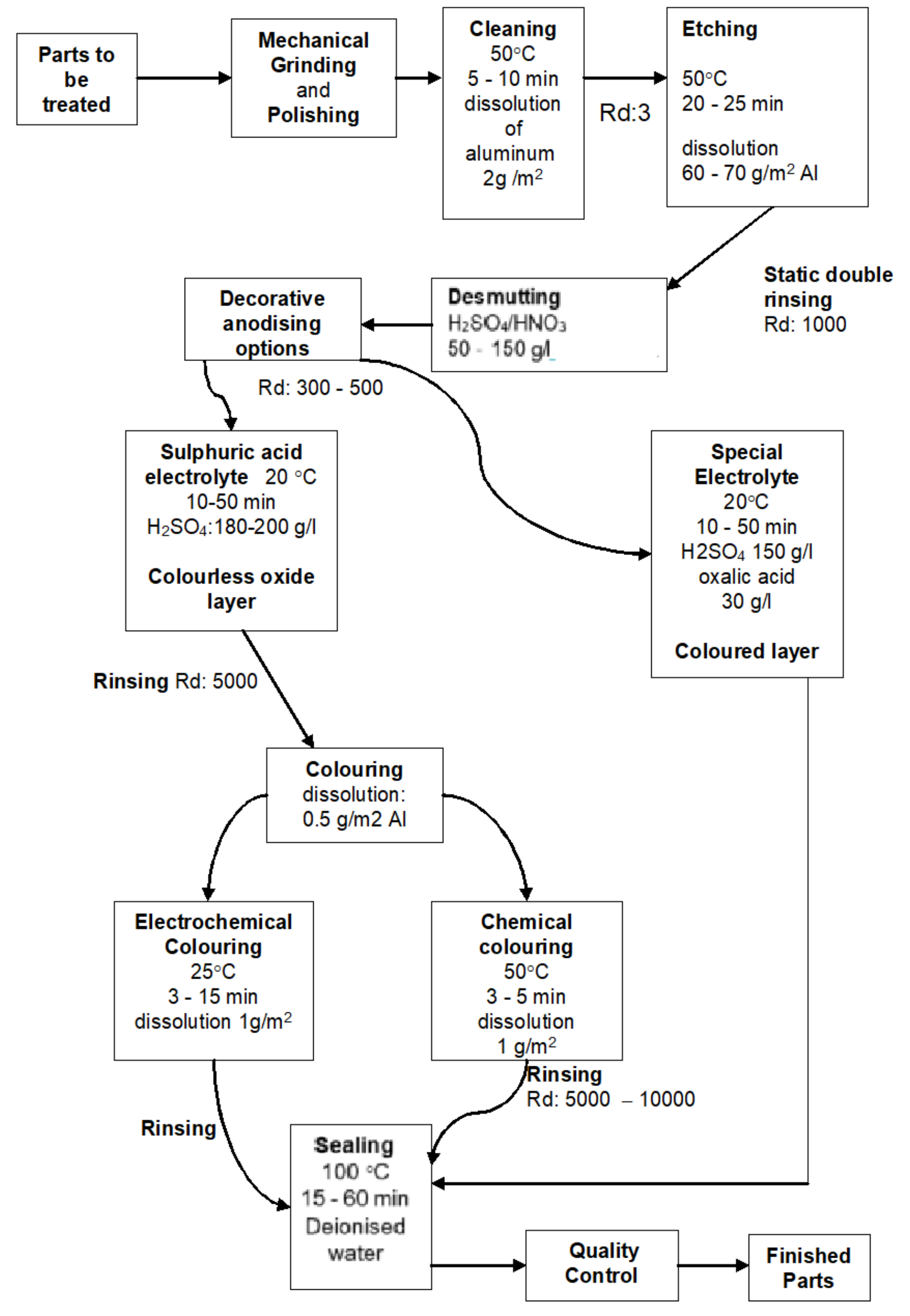
Aluminium is normally (90 % of cases) anodised in sulphuric acid electrolyte. For special applications, aluminium may be anodised in many different types of process solution: phosphoric acid, sulphuric/oxalic acids, sulphuric/salicylic acids and chromic acid electrolytes. [73, BSTSA,].

So-called TSA electrolytes consisting of tartaric/sulphuric acid have been successfully introduced in many applications to replace chromic acid [175, ESTAL 2024].

A wide variety of current forms and wave shapes may be used for the process, depending on the solution selected and the purpose of the anodic film. Direct current (DC), alternating current (AC), and DC with superimposed AC. are all used in various processes.

The workpiece or substrate to be treated is made anodic. During the anodising process the negatively charged anion migrates to the anode where it is discharged with a loss of one or more electrons. The metal reacts with the oxygen of the anion and a layer of oxide forms on the surface.

Figure 2-9 shows examples of decorative anodising options and Figure 2-13 shows a typical anodising line layout.



[45, France, 2003]   Note: Rd means rinsing ratio

Figure 2-9: Example of decorative anodising process options

The alumina coating is sealed to improve corrosion resistance and retain any surface colouring (see Section 2.3.6). Sealing is described in Section 2.3.7.

Overall environmental considerations for all anodising processes

Anodised aluminium (coloured or not) is very easily recycled for metal recovery, i.e. anodising processes have no significant effect on the recovery of aluminium metal, and other metals are not added.

Typical emission levels after typical waste water treatment are given in Section 3.3.1

2.3.1 Workpiece or substrate pretreatment

2.3.1.1 Electrolytic and chemical polishing processes for aluminium

[This Section moved here from Section 2.3.2.3 of the current STM BREF]

Industrial electrolytic and chemical polishing processes for aluminium are of two types:

- processes designed to replace or reduce mechanical polishing. These provide a smooth, bright, though not a ‘mirror’, finish, and are characterised by high dissolution rates (between 2.5 and 5.0 µm per minute). In most cases, the best results are obtained on high purity aluminium or its alloys, but some processes may be employed on commercial purity based grades of aluminium, producing a correspondingly lower grade of finish

- processes employed after mechanical polishing. These processes have a low rate of attack and are employed on aluminium reflectors and other components which require a higher specular reflectivity than is obtained by mechanical methods alone. Their use is generally restricted to high purity based materials as reflectivity falls off sharply as the quantity of second-phase constituents present increases.

Hot, highly concentrated acid mixtures are normally used, especially phosphoric acid, sulphuric acid and sometimes nitric acid. The temperature is > 80 ºC in chemical polishing, while it is about 60 °C for the acids used in electrolytic polishing (brightening) [175, ESTAL 2024].

2.3.1.2 Desmutting

[175, ESTAL 2024]
In the aluminium anodising context (and sometimes before conversion coating), a desmutting process is applied to remove alloy second-phase constituents that were insoluble in the caustic etch. Thus, it is different from pickling, the purpose of which is to dissolve oxides.

Desmutting of aluminium is also performed in sulphuric acid which preferably originates from the reuse of spent anodising baths.

Environmental issues
Process tanks may need to be equipped with fume extraction to remove generated aerosols and hydrochloric acid gas and nitrous oxides if nitric acid is used. For desmutting of aluminium, the use of sulphuric acid instead of nitric acid eliminates such emissions, therefore no exhaust is necessary on such baths.

2.3.1.3 Etching ~~and descaling~~ of aluminium

[This Section has been moved here from Section 2.3.7 of the current BREF]
[175, ESTAL 2024]

The purpose of etching aluminium before anodising for decorative and decorative/protective applications is to produce a desired matte and uniform surface appearance. As the anodic oxidation coating is transparent, the topography produced by etching is critical to the final product.

Although it is not its objective, the etching process also removes the natural oxide layer on aluminium, which is very thin, unlike that of steel.

Therefore, descaling and pickling are not necessary before anodising aluminium.

~~Descaling and pickling are not normally applied to aluminium processing because the natural oxide on aluminium is very thin, unlike that on steel. Aluminium oxide removal may not be necessary as part of a pretreatment but as a consequence[118, ESTAL, 2003].~~

The etching of aluminium and its alloys is usually carried out in sodium hydroxide solutions. It is also sometimes carried out in acid solutions, fluorides being added as necessary. Zincate treatment is necessary for good adhesion prior to autocatalytic or electrolytic metal plating. This solution is based on sodium hydroxide containing <20 g/l zincates.

Etching aluminium is also a common practice before batch conversion coating, with the aim of removing undesired elements that concentrate on the surface of the metal and therefore to obtain a more chemically uniform substrate.

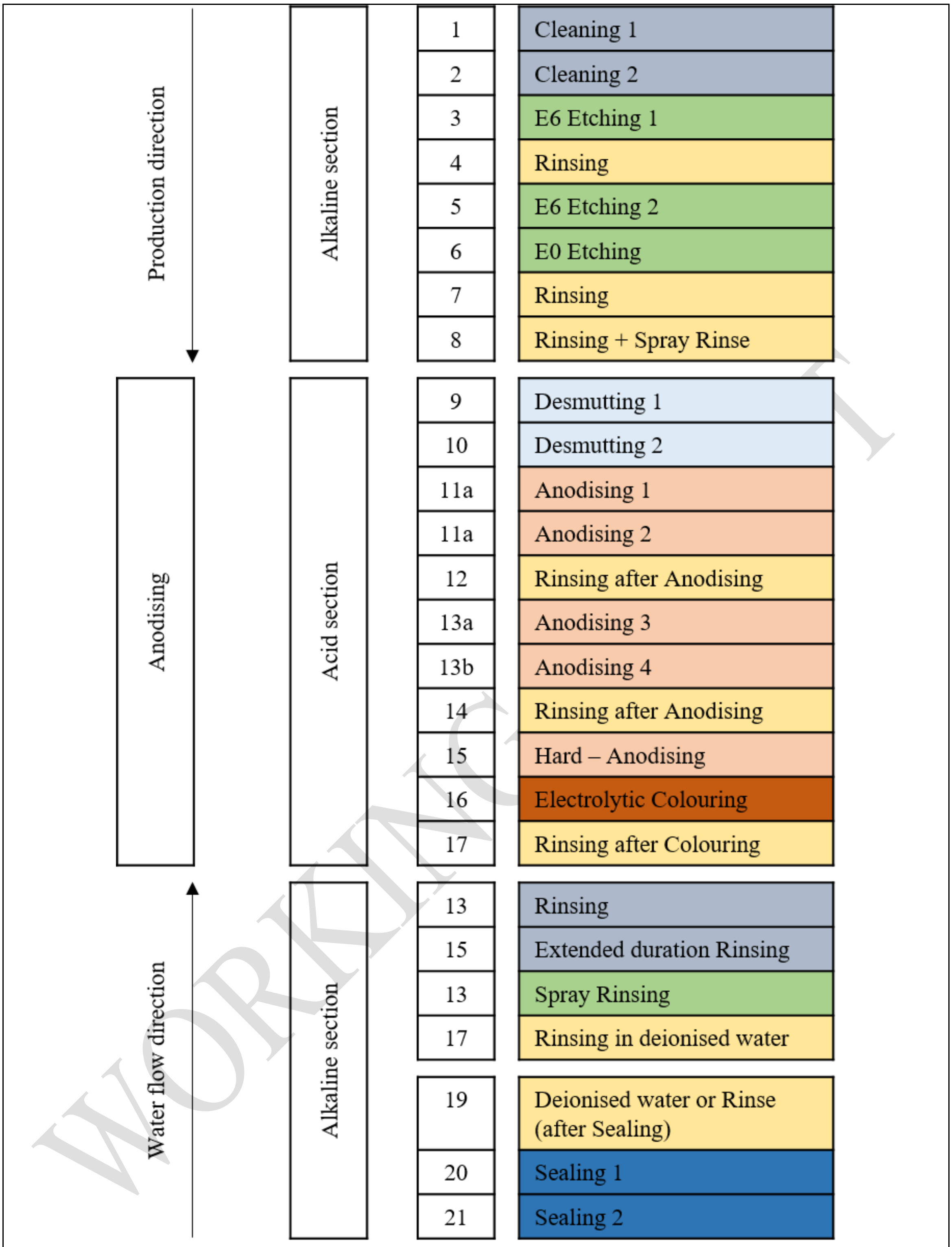
2.3.2 Sulphuric acid anodising of aluminium

On most aluminium alloys a colourless, transparent aluminium oxide is formed, but alloys containing high quantities of elements such as iron, manganese, silicium and others [118, ESTAL, 2003] tend to give greyish or brownish coloured layers. The anodising voltage is in the range of 17 – 22 V and the temperature of the electrolyte. is generally 20 °C ± 5 °C and electrolyte concentration is generally 190 g/l ± 40 g/l H_2SO_4. A film thickness of 5- 30 µm is used for decorative and protective sulphuric acid anodising. The working parameters may vary according to the application, especially in architectural anodising. Sulphuric acid anodised coatings are often coloured by special colouring processes. (See Figure 2.10). The oxide coating is sealed to obtain improved corrosion resistance (see Section 2.5.15).

In hard anodising, a film thickness of 25 – 250 µm is obtained. The electrolyte is operated at-below 5 °C [73, BSTSA,]. Processes with oxalic acid and sulphuric acid with organic additions can also be used for hard anodising. The hard anodising layer is normally not sealed. In this state it can be impregnated with lubricants.

Environmental considerations
Acid concentrations and operating temperatures are low. If necessary, aerosols can be minimised by a layer of foam or by mechanical devices, for example cathode enclosures [175, ESTAL 2024]. . ~~[118, ESTAL, 2003]. However, the suppressants may be based on PFOS, which is toxic and persistent see Annex 8.2, [109, DEFRA, 2004], although alternatives to PFOS exist and are used successfully [159, TWG, 2004].~~

Effluent may be treated in typical waste water treatment plants.



1	Cleaning 1
2	Cleaning 2
3	E6 Etching 1
4	Rinsing
5	E6 Etching 2
6	E0 Etching
7	Rinsing
8	Rinsing + Spray Rinse
9	Desmutting 1
10	Desmutting 2
11a	Anodising 1
11a	Anodising 2
12	Rinsing after Anodising
13a	Anodising 3
13b	Anodising 4
14	Rinsing after Anodising
15	Hard – Anodising
16	Electrolytic Colouring
17	Rinsing after Colouring
13	Rinsing
15	Extended duration Rinsing
13	Spray Rinsing
17	Rinsing in deionised water
19	Deionised water or Rinse (after Sealing)
20	Sealing 1
21	Sealing 2

Source: [175, ESTAL 2024]

Figure 2-10: Typical anodising plant layout

2.3.3 Chromic acid anodising of aluminium

This forms an aluminium oxide film on most aluminium alloys ranging from a light to dark grey. The process is mainly used for aerospace and military applications. Parts can be treated after joining since residual chromic acid in the joins does not cause corrosion and the process gives very limited degradation of fatigue properties of the materials [73, BSTSA,].

]

The electrolyte contains 30 – 100 g of chromic acid per litre. The temperature is kept within the range of 38- 42 °C for most aluminium alloys. The voltage cycle used depends on the alloy treated and must be closely followed to avoid etching. The coating is thin with an average of 2- 5 µm and is relatively soft. Its corrosion resistance is good and the coating is normally not sealed.

The regeneration of anodising baths using a retardation process extends the electrolyte life by reducing its aluminium content.

Environmental considerations
Effluent may be treated in typical waste water plants.

Process tanks may to be equipped with fume extraction to remove generated acid aerosols and gases. Section 1.4.4.1includes a discussion of the health effects of chromium and Section 2.5.3 for environmental considerations for hexavalent chromium solutions. [118, ESTAL, 2003],. [116, Czech-Republic, 2003]

2.3.4 Anodising of magnesium, titanium, tantalum and niobium

[73, BSTSA,] Anodising of magnesium gives the best protection for abrasive wear. The coatings are relatively porous and contain crystalline phases like $Mg(OH)_2$ and MgO. The oxide layer can be 25 µm or more.

Anodising of the DOW-17 type is dark grey or green and has very good adhesion. Alternating current is preferable. The coating has an attractive appearance and is well suited for being coated by for example a transparent paint. The oxide layer is soluble in the acid electrolyte meaning that the deposition rate decreases until a steady state condition is reached. Thorough rinsing is required and if the parts are not to be painted a sealing in 50 g/l $Na_2Si_4O_9$ at 93- 100 °C for 15 minutes can be performed.

Anodising of the HAE (Harry A. Evangelides) type gives the hardest oxide and is well suited for protecting against abrasion. It has very good adhesion and gives good protection against corrosion. The coating is from light to dark brown, depending on alloy and thickness and the best properties are achieved by using alternating current. Dipping in a $Na_2Cr_2O_7/NH_4HF_2$ solution at 20- 30 °C for 40- 60 seconds can seal the coating.

For titanium anodising, there are two commonly used types: Type 2 and Type 3. Type 1 is far less common, and is used in specialised high-temperature treatments.

Type 2 is mainly for wear purposes: It protects the metal surface against the effects of wear. When untreated titanium parts rub against each other, they produce titanium dust – a result that is not desirable in biomedical products (e.g. orthopedic implants). Type 2 anodising provides a wear-resistant surface and helps prevent seizing or friction between sliding titanium surfaces.

It should be noted that Type 2 titanium anodising requires additional processing in comparison to Type 3. After Type 2 titanium anodising, the parts will come out with a white film. Bead blasting is a necessary final step to remove the white film and achieve the characteristic grey finish on the titanium part.

Type 3 titanium anodising is also called titanium colour anodising. Type 3 colour anodising is widely used in the medical sector for quick visual identification of parts. Type 3 titanium colour anodising is less common in the aerospace industry, but is sometimes used for quick visual identification in complicated assemblies. Type 3 coloured titanium finishes are also used in jewellery manufacturing (https://www.besttechnologyinc.com/surface-finishing/titanium-anodizing-equipment/).

Tantalum anodising is an electrochemical process that creates a protective oxide layer on tantalum surfaces. The process involves immersing the tantalum part in an electrolyte solution and applying a voltage to form a thin, dense and uniform oxide layer on the surface. The layer provides excellent corrosion resistance, making it suitable for use in demanding environments, such as in aerospace, medical and electronic industries.

Niobium anodising forms a protective oxide layer on niobium surfaces. The process involves immersing the niobium part in an electrolyte solution and applying a voltage, which creates a thin, dense and uniform oxide layer on the surface. This layer offers excellent corrosion resistance, making it suitable for use in various applications, including aerospace, chemical processing and medical industries. The anodising process can also create various colours on the niobium surface, providing aesthetic appeal.

Environmental considerations
High temperature, toxic and aggressive electrolyte (for DOW-17) require good ventilation.

2.3.5 Phosphoric acid anodising

Phosphoric acid anodising is being increasingly used as a preparative treatment for subsequent applications of organic or plated coatings. Phosphoric acid anodising produces a relatively thin, porous oxide that is used for bonding, painting, plating and printing applications. [132, Sheasby and Pinner, 2002].

This process has been originally developed by the aerospace industry and is presently used mainly as a pretreatment for preparing adhesively bonding aluminium structures in the aerospace industry~~, for painting aluminium in architectural applications~~ and for the printing industry.

Phosphoric acid anodising produces a porous, hydration-resistant oxide and increases fracture toughness. The anodic coatings resulting from phosphoric acid anodising have a high porosity compared to those produced with other processes.

2.3.6 Colour anodising on aluminium

[118, ESTAL, 2003]

Aluminium can be coloured in many shades and colours in conjunction or after sulphuric acid anodising and is normally referred to as ‘colour anodising’. Normally colouring methods are identified as ‘dip dyeing’, ‘electrolytic dyeing’ or ‘two-stage colour anodising’, ‘self-colouring process’, or ‘integral colour process’. [118, ESTAL, 2003]. There are four methods [3, CETS, 2002, 45, France, 2003].

A common colouring technique features a combination of immersion colouring (see Section 2.3.6.1) and electrolytic colouring (see Section 2.3.6.2). It can produce a great variety of colours [175, ESTAL 2024].

2.3.6.1 Immersion colouring

This is the most widely used colouring method with a large range of dyes giving good light resistance. The anodised aluminium workpieces or substrate are immersed in a water-based organic or inorganic dye solution before sealing. The pores in the oxide layer adsorb the dye and then sealing is carried out to achieve durability. For colouring the oxide, thickness depends on the type of product and on the colour required. For a good corrosion protection and weather resistance, at least 15 µm minimum is needed. [118, ESTAL, 2003, Sheasby, 2002 #132].

Environmental considerations
Some organic dyes may require additional waste water treatment.

2.3.6.2 Electrolytic colouring

The anodised aluminium is placed in an acid solution containing metal salts and an alternating current (AC) is applied. This deposits oxide of the other metal which penetrates 1- 5 µm deep into the pore of the alumina, with the residual oxide layer remaining on top. The film obtains a colour characteristic of the metal salts used. The metal salt most commonly used in Europe is tin. For special applications, nickel, cobalt and copper can be used. Tin sulphate gives shades from light bronze to black depending on the process time, of 0.5 to 15 minutes. A major use is for architectural panels. Electrolytic and immersion colouring can be combined to form new shades. [73, BSTSA,] [118, ESTAL, 2003]

Environmental considerations
The other metals used may require treatment in a waste treatment plant prior to discharge.

2.3.6.3 Interference colouring

Interference colouring is a special technique based on the electrolytic colouring principle. The appearance is produced by interference effects between two light-scattering layers: the electrochemically deposited metal layer at the bottom of pores and the aluminium oxide/aluminium interface beneath.

2.3.6.4 Integral colouring

With integral colouring, the aluminium oxide layer is coloured itself during the anodising process. Colouring occurs either by anodising in a solution of special organic acids or by normal anodising in sulphuric acid of special aluminium alloys with substances that are not oxidised such as Al-Si or Al-Fe-Mn. The oxide layer appears with a colour ranging from light bronze, through dark bronze to black, depending on the layer thickness. This technique has almost entirely been replaced by electrolytic colouring [73, BSTSA,]

2.3.7 Sealing following anodising

~~Sulphuric acid anodising is normally followed by a sealing process. Sealing improves the corrosion and stain resistance of the oxide layers. It also prevents organic dyes from leaching out and improves the light fastness. Sealing may be carried out in hot or cold processes. (For architectural applications see ref [138, QUALANOD, 1999, ESTAL, 2003 #118])~~
Sulphuric acid anodising is normally followed by a sealing process. ISO 7583 defines sealing as a treatment applied to an anodic oxidation coating on aluminium to reduce its porosity and absorption capacity. Thus, it improves the corrosion and stain resistance of the oxide layers. It also prevents organic dyes from leaching out and improves the light fastness. Sealing may be carried out in hot or cold processes. ISO 7583 identifies a number of different types of sealing as follows:

- Hydrothermal sealing is either steam sealing not below the saturated steam temperature or sealing in an aqueous solution at a temperature no lower than 95 °C.

- Cold sealing (cold impregnation) is a sealing process carried out using an aqueous solution at a temperature no higher than 35 °C.
- Medium-temperature sealing is a sealing process carried out using an aqueous solution at an intermediate temperature generally no lower than 60 °C.

[175, ESTAL 2024]

2.3.7.1 ~~Hot~~ Hydrothermal sealing

~~With hot sealing, the pores in the oxide layer are closed by hydrating the aluminium oxide to boehmite: the pores are close by the increased volume of the boehmite structure. The sealing process is carried out by dipping the anodised parts in hot or boiling (minimum 95 - 96 °C) deionised water for three minutes per µm thickness. Sealing with steam achieves the same effect. [118, ESTAL, 2003, CETS, 2003 #115]~~

With hydrothermal sealing, the pores in the oxide layer are closed by hydrating the aluminium oxide: the pores are closed by the increased volume of the hydrous oxide structure. The sealing process is carried out by dipping the anodised parts in hot or boiling deionised water for a time dependent on the coating thickness. Sealing with steam achieves the same effect. [118, ESTAL, 2003], [CETS, 2003 #115], [175, ESTAL 2024]

2.3.7.2 Cold sealing

~~Sealing methods at lower temperatures have been developed. So-called mid-temperature sealing processes are also available operating at about 60 °C. These are not based on the hydrothermal conversion of aluminium oxide for closing the pores, but by the use of nickel salts, such as the fluoride or silicate. In the past, in the European market, there was some concern about long term properties such as light fastness and corrosion resistance. However, such processes have now been proven and accredited for outside use (see Qualanod [138, QUALANOD, 1999, ESTAL, 2003 #118])~~

~~There are also processes working at 25- 35 °C. Advantages with cold processes are lower energy consumption and shorter process times[73, BSTSA,].~~
Sealing methods at lower temperatures have been developed. These are not based on the hydrothermal conversion of aluminium oxide for closing the pores, but on the precipitation of other compounds derived from the sealing solution. Qualanod recognises nickel-based two-step cold sealing as an established process. The nickel salt is a fluoride while the second step is a higher-temperature sealing process. For the first step, an aqueous solution containing nickel fluoride is used at a temperature below 35 °C. The second step is hydratation in hot water above 70 °C or 80 °C. Qualanod requires other cold sealing processes to be tested before its licensed architectural anodisers may use them. (See Qualanod [138, QUALANOD, 1999, 118, ESTAL, 2003]), [175, ESTAL 2024].

The latest developments in the industry are aimed at replacing the nickel.

Advantages with cold processes are lower energy consumption and possibly shorter process times [73, BSTSA]. However, the use of heavy metal salts can be a disadvantage.

2.3.7.3 Medium-temperature sealing

So-called medium-temperature sealing processes are also available. These are not based on the hydrothermal conversion of aluminium oxide for closing the pores, but often on using nickel salts, such as acetate. In the European market, there is some concern about long-term properties such as light fastness and corrosion resistance. Qualanod requires such sealing processes to be tested before its licensed architectural anodisers may use them. [138, QUALANOD, 1999], [118, ESTAL, 2003], [175, ESTAL 2024].

~~**Environmental considerations**~~
~~Hot water sealing may also require ventilation and have very high energy consumption. However, this can be reduced by covering the tanks or with proper insulation [159, TWG, 2004]. There is lower energy consumption with cold sealing [73, BSTSA,].~~

2.3.8 Chromium (VI) conversion coatings on aluminium

[This Section has been moved here from Section 2.5.17.4 in the current BREF]

Chromate or phospho-chromate conversion films, ranging from clear yellow for chromate to green for phospho-chromate [118, ESTAL, 2003] can be produced on aluminium. The film colour depends on the immersion time, pH, solution concentration and, to some extent, on the composition of the alloy to be treated. Due to the REACH Regulation, these are now only used in the treatment of aluminium prior to painting in special applications.~~The main use is as a pretreament prior to painting or powder coating, although it is used for components in aerospace, electronics and other applications [118, ESTAL, 2003, CETS, 2003 #115].~~
The ability of the treatment to provide corrosion resistance without a corresponding loss of conductivity is particularly useful for electronic applications.

Solutions containing low Cr(VI) are available ~~(Personal communication, ESTAL)~~.

Environmental considerations
Low Cr(VI) solution reduce drag-out and typical waste water treatment requirements.

2.3.9 Trivalent chromium (Cr(III)) conversion coatings on aluminium

Trivalent chromium (Cr(III) conversion coatings on aluminium (free of Cr(VI)) are based on Cr(III) and Zr(IV) salts and other additives, and used for corrosion protection of unpainted surfaces and to meet the electrical conductivity properties required for aerospace and other industrial applications and as preparation for paint adhesion and corrosion protection in architectural and decorative applications. The working conditions are dependent on the aluminium alloy used and the application.

2.3.10 Chromium(VI)-free conversion coatings on aluminium

The European regulation REACH (Regulation on Registration Evaluation, Authorisation and Restriction of Chemicals) has induced major changes in some of the finishing processes (e.g. chromate conversion, chromic acid anodisation and chromate sealing).

Regarding chromium(VI)-free conversion coatings, different technologies have been developed and have been used in the market (paint pretreatment in architectural, automotive, transportation and others) since several years ago. The different technologies substituting chromium(VI) in aluminium pretreatment are based on Zr, Ti, Zr/Ti, Ce, Si, pre-anodisation, and others.

European standards and quality organisations' specifications define the requirements, performances and application methods that these Cr(VI)-free technologies have to fulfil.

2.3.11 Chemical blacking – oxide coatings

Aluminium

Aluminium may be given an oxide coating by immersion by a number of different processes including the ~~Alzac and~~ ~~Juratka~~ Jirotka process~~es~~. Electrolytic processes (anodising) are generally preferred.

More information on chemical blacking – oxide coatings for various metal substrates is given in Section 2.2.2.14.

2.3.12 Brightening

Aluminium and some of its alloys can be brightened by chemical or electrochemical processes for special applications such as lighting and decorative finishes [118, ESTAL, 2003], [132, Sheasby and Pinner, 2002]. To do so, electrolytes of sulphuric and phosphoric acid are commonly used today. Although no longer common, nitric acid is also still in use [175, ESTAL 2024].

More information on brightening for various metal substrates is given in Section 2.2.2.15.

2.3.13 Etching – Alkaline etching of aluminium

[Note to the TWG: This section corresponds to the Section 2.5.22 of the original STM BREF]

The most frequently used method for etching aluminium is aqueous solutions of caustic soda, with or without other additives. This process takes place after cleaning (degreasing) of the surface to avoid slowing down the process and prevent an uneven finish. ~~It can be used for general cleaning purposes where oxide, grease of subsurface detritus may be removed.~~ With more prolonged etching, it can produce a ~~stain~~ satin or matte finish for nameplates or decorative architectural work; or for deep engraving and chemical milling. ~~It is a relatively cheap and easy method of etching but the details can be exceedingly complex.~~

Solutions for decorative etching may contain from 4- 10 % or more caustic soda, used at 40- 90 °C, possibly with a wetting agent to disperse grease and give a light foam blanket.

The most common are ‘long-life~~term use~~’ etch processes operated on a never-dump basis. These processes contain special additives, which stabilize the aluminate solution. Etch rate must be controlled to get a constant etch finish. Important parameters are: temperature, free sodium hydroxide, aluminium and additive content.

Alkaline etches with increased etch rates are used to remove the anodised film from aluminium jigs before the next jigging.
[118, ESTAL, 2003], [132, Sheasby and Pinner, 2002], [138, QUALANOD, 1999] [175, ESTAL 2024].

Environmental considerations
Spent alkali etch baths may be re-used in municipal waste water treatment [159, TWG, 2004].

2.3.14 Chemical milling

See Section 2.2.2.16.

2.4 Continuous coil – large-scale steel

The coating of large steel coils is traditionally associated with the production of the coil. Coils weigh up to 32 tonnes and can be up to 2080 mm wide [119, Eurofer, 2003], [73, BSTSA,], [86, COM, 2022].

Finished cold-rolled steel (pickled, cold-rolled, annealed and tempered) is a material with mechanical characteristics that make it suitable for use in many industrial applications. Unfortunately, it suffers the major disadvantage of low corrosion resistance. The use of surface treatments to improve the corrosion resistance of the coiled steel substrate is described in this document.

Electroplating is a major surface treatment for large scale steel coil production. Other surface treatment options of printing and painting are discussed in [90, COM 2020].

The electrolytic coating procedure is fundamentally the same as that used in jig and barrel processes, even using similar solution chemistries. It is also preceded by the same type of pretreatments such as cleaning and pickling, and followed by post-treatments including layer conversion techniques such as chromating and phosphating. The specific activities for steel coil are described below.

There are two key differences for large-scale steel coil:

- the size and nature of the coils and the equipment used to handle and process them. These require:
    - coil handling equipment;
    - loading and unloading systems (entry and exit loopers);
    - equipment to keep the coil in process at the right tension and flat (to prevent coil distortion and contact with anodes);
    - edge trimming to size.
- the continuous nature of the substrate, with only small thickness and limited width changes. This allows the use of some techniques that cannot be used for jig and barrel systems (which have constantly changing shapes of components), such as:
    - brushes to assist with activities such as degreasing and wringer rolls to reduce process solution drag-over;
    - the continuous nature of the strip and the type of plant layout also lends itself to the widespread use of other techniques such as spray rinses and electrostatic oiling which are used less frequently in other transport systems.

A typical process outline is described in Figure 2.11. Details for specific process lines are described in the following sections.

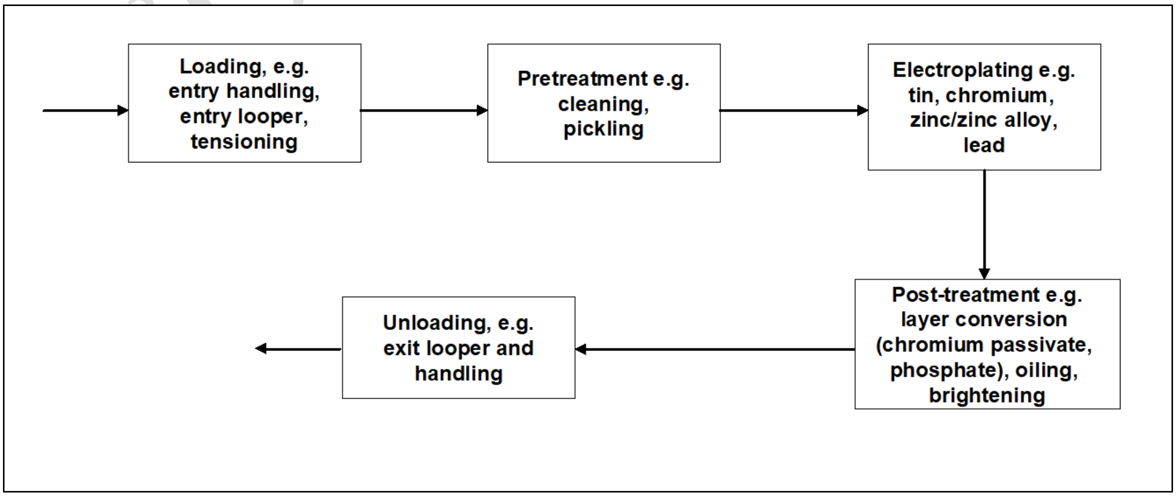


Figure 2-11: Outline of typical coil coating process

2.4.1 Entry equipment

The reception of coils, the uncoiling and welding of the coil end with the start of the next coil allows for a continuous process. The entry equipment involves the following:

- transport between the storage of uncoated steel coils to the uncoilers by means of a transfer chain, fork lift or an air-cushion vehicle;
- uncoiling of the strip (including uncoiler, magnetic strip and pressure rolls);
- the entry looper guarantees that the strip can go on moving at a constant speed in the processing section even during welding when the strip end is held still at the entry section. The looper stores coil by running it through a series of vertical or horizontal loops. These are then used when the coil end is held still for welding on a new coil;
- shearing of coil tails and scrap collection;
- seam welding of the coil end with the start of the next coil;
- continue strip thickness measurement;
- tension leveller: used at the entry section or prior to any point where flatness is essential such as running between anodes or edge trimming knives. This flatness is corrected continuously by traction and flexion.

Environmental considerations
Power consumption can be assisted by maintenance of correct settings and ensuring bearings are free running.

2.4.2 Rinsing and drag-out

These activities are described in Section 2.4. Specific control techniques for coil processing are described for the individual processes.

2.4.3 Pretreatment

Activities preparing steel coil and wires prior to surface treatment in coil coating process lines are described in the BREF on the ferrous metals processing industry [86, COM, 2022].

[Note to the TWG: This content was moved from Section 2.3 of the original STM BREF]

2.4.3.1 Degreasing and cleaning

The coiled blackplate is usually contaminated with fatty residues (oil and grease) and mill dirt (amorphous carbon or abraded iron fines) left over from the rolling process. It is essential that the surface of the steel strip is free of these impurities to ensure the entire surface is exposed to the treatment activities to ensure strong adhesion of the coatings is achieved.

Aqueous systems are now standard, and solvent degreasing is no longer used.
The cleaning is usually a combination of soak and electrolytic activities, see Section 2.3. Cleaning solutions are usually based on sodium hydroxide, phosphate or polyphosphates and wetting and complexing agents.

Electrolytic cleaning
Impurities such as grease, oil, amorphous carbon or abraded iron fines may exist in the depressions of the surface roughness after the degreasing treatment. It is essential that these impurities are removed to ensure a strong adherence of the coating and it is achieved by electrolytic cleaning.

The polarisation of the uncoiled strip can be achieved in two different ways~~either~~:

- Directly, where the strip passes over a conductor roll and then travels between two pairs of mild steel electrodes. The current passes from the conductor roll via the strip and electrolyte to the electrodes.
- Indirectly by grid electrodes, where the steel strip travels between two pairs of mild steel plates which form two electrodes of opposite polarity. The current passes from one pair of electrodes via the electrolyte and the strip to the other pair of electrodes.

The electrolysis of the alkaline solution produces the release of H_2 gas at the cathode and of O_2 gas at the anode. The polarity of the electrodes is inverted after each coil or after a certain time to avoid polarisation.

Environmental considerations
See Section 2.1.4.4 and the individual processes.

Where oily waste is collected from the activities, it is usually treated off-site.

2.4.3.2 Pickling

Although the strip should be free of surface oil and dirt as it leaves the cleaner rinse, oxides formed during the various stages of steel processing are not removed. The purpose of acid pickle is to remove these oxides and lightly etch the strip to present as clean a steel surface as possible to the plating section. Strip pickling can be carried out by immersion, spraying or more commonly by electrolysis, with the same electrical arrangements as for cleaning, i.e. contact rollers or grids. See also Section 2.3 and [86, COM, 2022].

Lead anodes are used because of the 50 g/l (max) concentration of the sulphuric acid electrolyte.

Electrolytic pickling (bipolar action) in neutral electrolyte (Na_2SO_4) may also be used in treating steel coil [113, Austria, 2003].

Environmental considerations
See Section 2.1.4.6.

2.4.4 Coating activities – electroplating

The materials commonly used for electroplating steel strip because of their special characteristics are: tin, chromium, zinc, copper, lead and some of their alloys. Electrolytic reactions are described at the start of Chapter 2.

Electrolytic cells for continuous steel coil
The cleaned and pickled strip is fed through electrolytic cells. The electrolytic cells are the heart of an electrolytic line. The choice, design and sizing of the other line components and supplying sections are dependent on the choice of the electrolytic cell and its components.

The main components of a continuous coil electrolytic cell are as follows:

- Conductor roll: this gives the steel strip a negative electrical charge. The voltage is transformed into current by means of a rectifier. The negative pole of the rectifier is connected to the carbon brushes of the conductor roll.
- Press roll: provides good contact and high electric conductivity between conductor roll and steel strip.
- Anode: repels the positive ions towards the steel strip (cathode). The positive pole of the rectifier is connected to the anode.

- Sink roll: turns the steel strip by 180°.
- Wringer rolls or squeeze rolls: minimise the drag-over (drag-in) into the next cell.
- Edge masks: prevents zinc edge overthrow (build-up of zinc preferentially at the edge of the coil where charge density is highest).
- Conductor roll cleaning device: cleans the surface of the conductor roll to avoid surface defects on the steel strip.

The choice of an electrolytic cell depends on the industry applications the producer intends to supply, on the layer thickness they intend to deposit and on the capacity they intend to install. Electrolytic cell type is a function of four main parameters:

- cell geometry;
- current density;
- electrolytic solution type;
- anode type.

Cell geometry
The three main types of cell geometry are as follows:

Vertical cell
The two strip sides may be coated simultaneously in one cell. On entry to the cell the strip runs from top to bottom, from the conductor roll through one pair of guiding rolls and the first anode pair down to the sink roll. From there it runs to the exit side, upwards through to the second electrode pair and wringer rolls and on to the next conductor roll.

Conventional cells are filled in with electrolyte and the sink roll and the two pairs of anodes are submerged in the electrolyte bath. In the Gravitel cell, the electrolyte enters via a weir in the narrow gap between the insoluble anode and the strip, holding only a small amount of electrolyte in contact with the strip. In this case, neither the anodes nor the sink roll are submerged in the electrolyte.

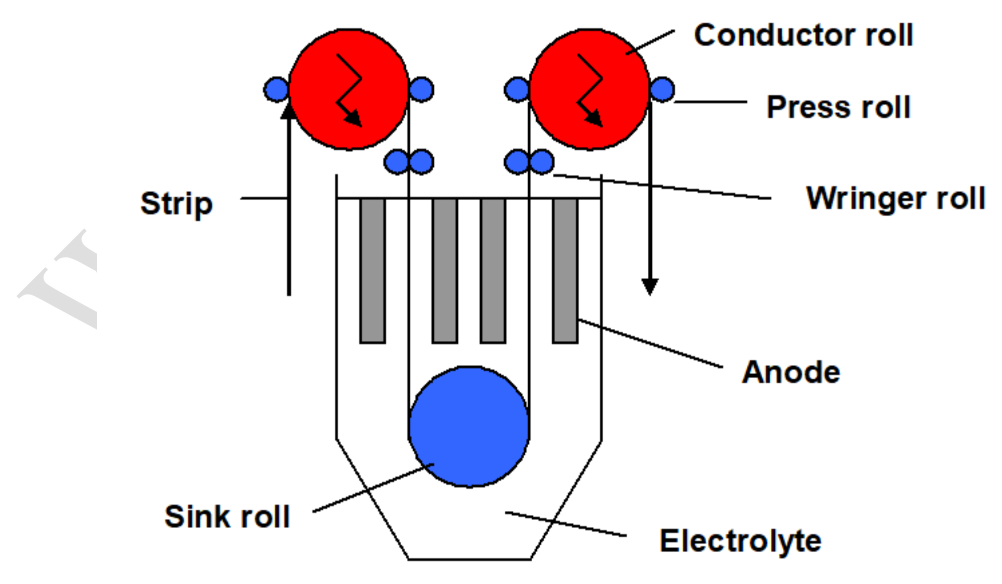


Figure 2-12: Vertical cell

Radial cell

Only one side of the strip may be coated at a time in one cell. On entry to the cell, the strip runs from the top to the bottom, from the conductor roll through one pair of wringer rolls down to the sink roll. From there the strip runs to the exit side, upwards through the wringer rolls and on to the next conductor roll. Only the lowest part of the sink roll is plunged in the electrolyte bath.

In a variant, the carousel cell, the top rolls have the function of deflector rolls while the sink roll, equipped with a metallic winding, combines the functions of deflector roll and conductor roll.

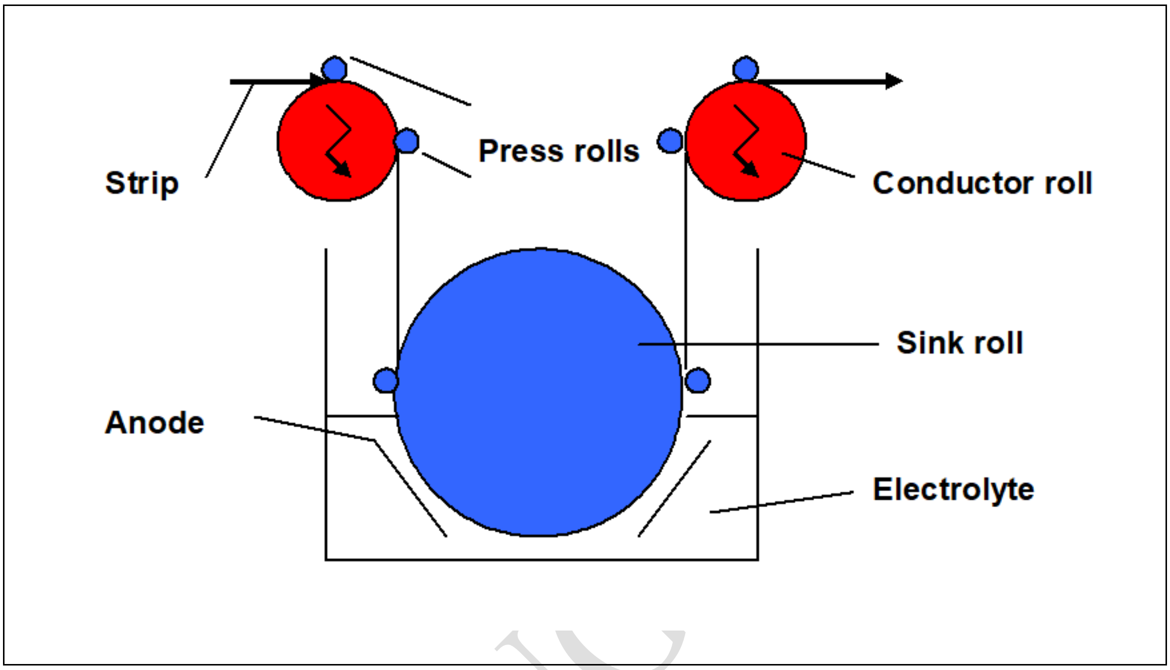


Figure 2-13: Radial cell

Horizontal cell
Both strip sides may be coated simultaneously in one cell. The strip runs horizontally through the cells. At the entry to the cell, the strip leaves the conductor roll and runs through one pair of wringer rolls, then between a pair of anodes and from there to the exit side, onwards through a another pair of wringer rolls to the next conductor roll. The electrolyte is continuously injected between the two anode pairs, thereby only holding a small amount of electrolyte in contact with the strip at any one time.

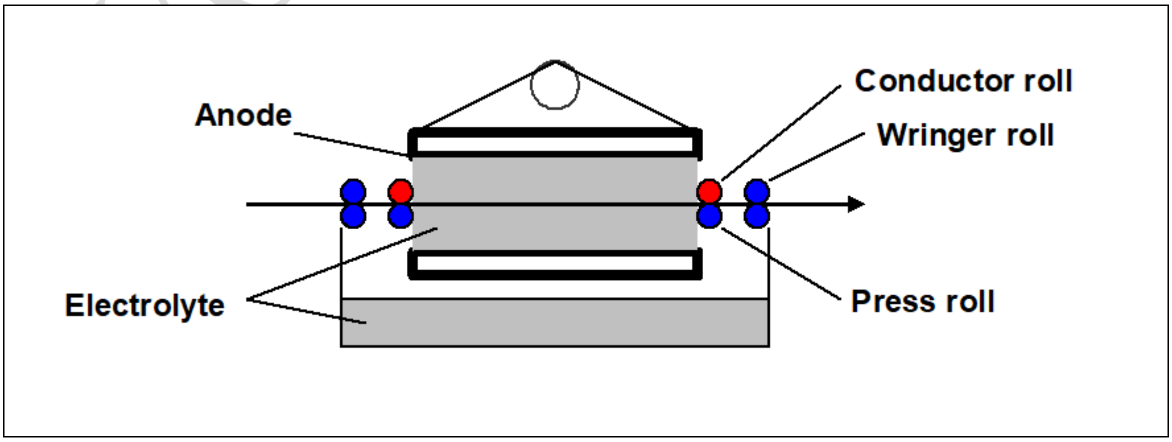


Figure 2-14: Horizontal cell

Current density

Installations normally working at low current density can be differentiated from those normally working at high current density. The current density will depend on the main industrial application, the normal metal thickness required and the normal steel substrate thickness. Table 2.1 shows thicknesses for zinc and zinc alloy coil coating applications. A high current density allows a thicker metal layer to be plated onto the steel substrate with a shorter anode length.

Table 2-1: Zinc and zinc alloy layer thickness as a function of industry application

Current density (A/dm$^{2)}$	Main industrial applications	Zinc layer thickness (µm)	Steel thickness minimum (mm)	Electrolyte relative speed (m/sec)
60 to 120	Vehicle	5 to 12	0.5	1.0 to 4.0
30 to 90	White goods	2.5 to 3.5	0.3	<1.0
30 to 90	Others	2.5 to 3.5	0.3	<1.0

High current density cells are equipped with systems such as electrolyte injection devices to realise a high relative electrolyte speed (electrolyte speed versus strip speed). These systems assure a sufficient supply of metal ions to the polarisation layer at the steel strip surface to carry the current.

Electrolyte bath

These are described for each process separately, see Sections 2.9.8, 2.9.9 and 2.9.10.

Anode type and gap

Two families of anodes are available: soluble anodes and insoluble anodes, see the introduction of Chapter 2, Electrolytic cells and reactions.

The gap between the anode and the steel strip differs as a function of the cell geometry and of the maximum steel strip width.

Table 2-2: Gaps between anode and steel strip for different electrolytic cell types

Electrolytic cell	Minimum gap (mm)
Vertical	16 to 26
Vertical gravitel	7 to 14.5
Radial	7 to 15
Horizontal	10 to 20

~~2.4.5 Coating activities – oiling~~

~~A wet film of oil is applied to the surface by spray, by wringer rolls or by an electrostatic oiler. This provides a coating for improving protection against white rust (oxide layers on zinc plating) corrosion. It can also act as a lubricant film to minimise subsequent damage by abrasion, to facilitate sorting and to aid in subsequent lacquering and printing operations.~~

[Note to the TWG: This section above was moved to Section 2.2.2.6]

2.4.6 Layer conversion activities

In order to prevent surface damages and flaws during storage and transportation, such as white rust (zinc corrosion) caused by water condensation where there is insufficient air access, the deposited layer may be subsequently phosphated (see Section 2.5.16), passivated with a chromate treatment (see Section 2.5.17) and/or oiled prior to recoiling (see Section 2.9.5). These layers also significantly improve the processing properties, during these and subsequent processes, such as painting or deep drawing.

2.4.7 After treatment activities

2.4.7.1 Drying

The strip is dried by means of hot air drying devices. The hot air temperature depends on the process stage. The drier device is usually situated at the end of the post-treatment; the same type of device is used for the phosphate and the chromate sections. See Section .

Environmental considerations
Energy efficiency according to type of drier and the installation.

2.4.7.2 Unloading- exit looper

The exit looper allows the strip end to remain at standstill in the exit section during the cutting of a completed coil. It stores sufficient coil for the strip to continue moving at a constant speed in the processing section. Construction and operation is the same as for an entry looper, with the coil running in the reverse direction.

Environmental considerations
Power consumption which will be minimised by maintenance of correct settings and ensuring bearings are free running.

2.4.8 Continuous electrolytic zinc or zinc nickel plating activities

This is the electrolytic deposition of a thin layer of pure or alloyed zinc onto the surface of a steel strip substrate.

On continuous electrolytic zinc plating line, the cold-rolled, annealed and tempered steel strip is passed continuously through degreasing and pickling pretreatments, then through a series of electrolytic cells containing a zinc electrolyte. It is then passed through one or more post-treatments, either layer conversion such as chromating or phosphating, or through an oiling step.

Plating lines layout may vary in design. As an example, Figure 2.15 shows a typical layout of a continuous electrolytic zinc plating line.

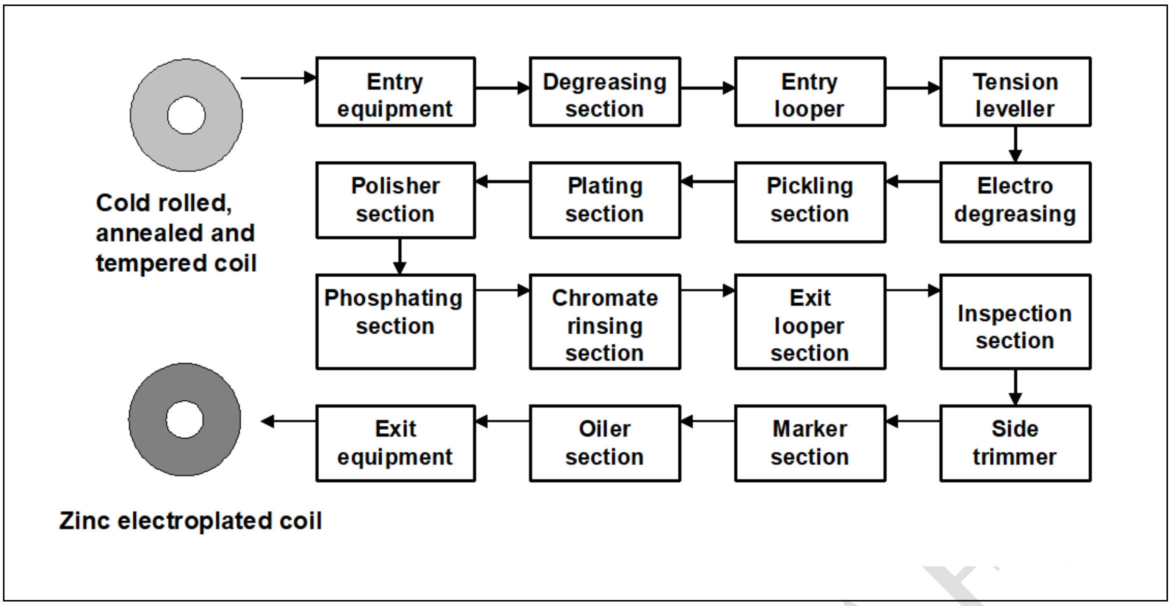


Figure 2-15: Schematic of an electrolytic zinc coating line layout

2.4.8.1 Entry equipment

See Section 2.9.1.

2.4.8.2 Degreasing

Degreasing of steel strip surface is by means of both chemical action (alkaline agent) and mechanical action (spray and brushes).

The cleaning process involves the following steps:

- alkaline degreasing via immersion or by spraying. This may be coupled with brushing;
- rinsing with water and brushing between intermediate rinsing tanks;
- drying.

The degreasing and rinsing sections may be in horizontal or vertical tanks.

Alkali degreasing
A typical horizontal spray degreasing section for the treatment of oiled coils consists of three successive stages:

- stage 1: spray nozzles and brushes;
- stage 2: spray nozzles;
- stage 3: spray nozzles and brushes.

Cascade degreasing has the advantage of achieving a high cleaning rate using only a small amount of degreasing solution. Degreasing is performed in counter-flow direction to the steel coil movement, which means that clean degreasing solution is used in the third (final) stage where it becomes slightly contaminated. This degreasing agent is used for cleaning in the second (more contaminated) stage and subsequently in the first (most contaminated) degreasing stage. The degreasing agent overflows between any two stages are controlled by means of wring rollers.

Section 2.9.3.1 describes typical chemical degreasing systems. In steel coil coating, the degreasing agent is usually an alkaline containing phosphate (a non-siliceous solution) containing mainly sodium hydroxides, orthophosphates and surfactant compounds with a concentration of 5 to 40 g/l, a temperature between 60 and 85 °C and a pH of about 13. The degreasing solution may be used first in the electrolytic degreasing section and be moved to the chemical degreasing stage to replace the spent chemical degreaser.

Environmental considerations
The use of cascade degreasing minimises the amount of raw materials and water used.

When the cleaning solution has reached the maximum oil content it is regenerated by centrifuges.

The solution may be used first in the electrolytic degreasing section.

Fumes generated in degreasing and brushing are normally collected, scrubbed and treated prior to release.

Spent degreasing agent is sent to waste water treatment before release.

The oily waste is treated off-site.

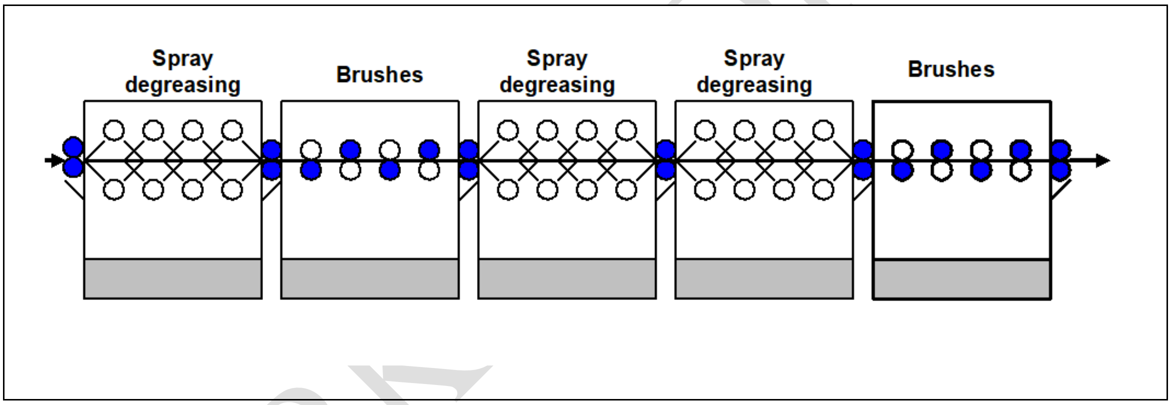


Figure 2-16: Spray degreasing and brushing

Rinsing
See Section 2.4. The alkaline degreaser is completely removed by cascade rinsing in three stages. Cascade rinsing has the advantage of achieving a high cleaning rate using only a small amount of rinsing water. Rinsing is performed in a counter-flow direction to the movement of the steel strip: the clean water is used in the third stage where it consequently becomes contaminated. This slightly contaminated water is then used for cleaning in the second stage and subsequently in the previous rinsing stage. The water overflows between two stages are controlled by means of wring rollers. The rinsing equipment involves the following steps:

- stage 1: spray nozzles and brushes;
- stage 2: spray nozzles;
- stage 3: spray nozzles.

The process solution in the first stage is demineralised water at a temperature of 70 to 85 °C.

Quality control techniques are used to determine the oil content in the water which gives the required standard of cleaning with minimum water usage. During processing, when the oil content in the water has reached this maximum allowed concentration, the water is sent to waste water treatment before discharge.

Environmental considerations
Countercurrent rinsing optimises process efficiency and minimises use of heated demineralised water.

Used water is treated to remove oil prior to discharge.

Water vapour and/or fumes generated in rinsing and brushing are collected and injected into the rinsing tanks.

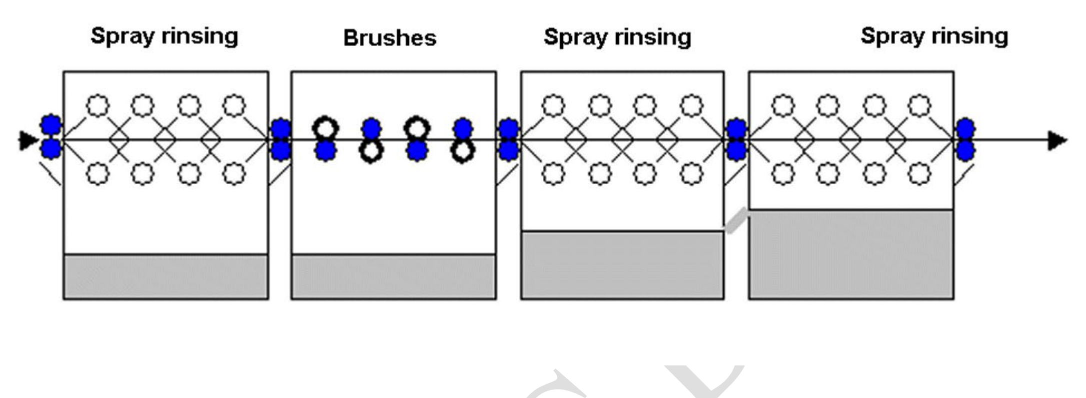


Figure 2-17: Spray rinsing

2.4.8.3 Drying

The degreased strip is dried by means of a hot air drying device. The hot air temperature lies between 100 and 120 °C.

Environmental considerations
Energy efficiency.

2.4.8.4 Entry looper and tension leveller

See Section 2.9.1

2.4.8.5 Electrolytic degreasing

The final degreasing of steel strip surface is carried out by means of chemical (alkaline agent) and mechanical (sprays and H_2 and O_2 gases bubbles generated by electrolysis at the strip surface) actions, see Section 2.3.8.

The electrolytic degreasing section involves the following steps carried in cells:

- alkaline degreasing by an electrolytic system;
- rinsing with water, possibly coupled with brushing.

The degreasing and rinsing sections may be in horizontal or vertical tanks.

The electrolytic degreasing is carried out by the electrolysis of the alkaline solution releasing H_2 gas at the cathode and O_2 gas at the anode. The polarity of the electrodes is inverted after each coil or after a certain period in order to avoid polarisation. The solution drag-out to the next stage is controlled by means of wringer rollers.

The degreasing solution is usually the same as that used in the degreasing section. Once the solution has reached a certain oil level it is re-used on the degreasing section (cascade use). The operating temperature of the solution lies between 60 and 85 °C.

Environmental considerations
Re-use of the solution in the more contaminated degreasing section is possible.

Alkali fumes generated in electrolytic degreasing cells are usually collected, scrubbed and treated prior to release to maintain a healthy working environment and to prevent corrosion of equipment and substrates.

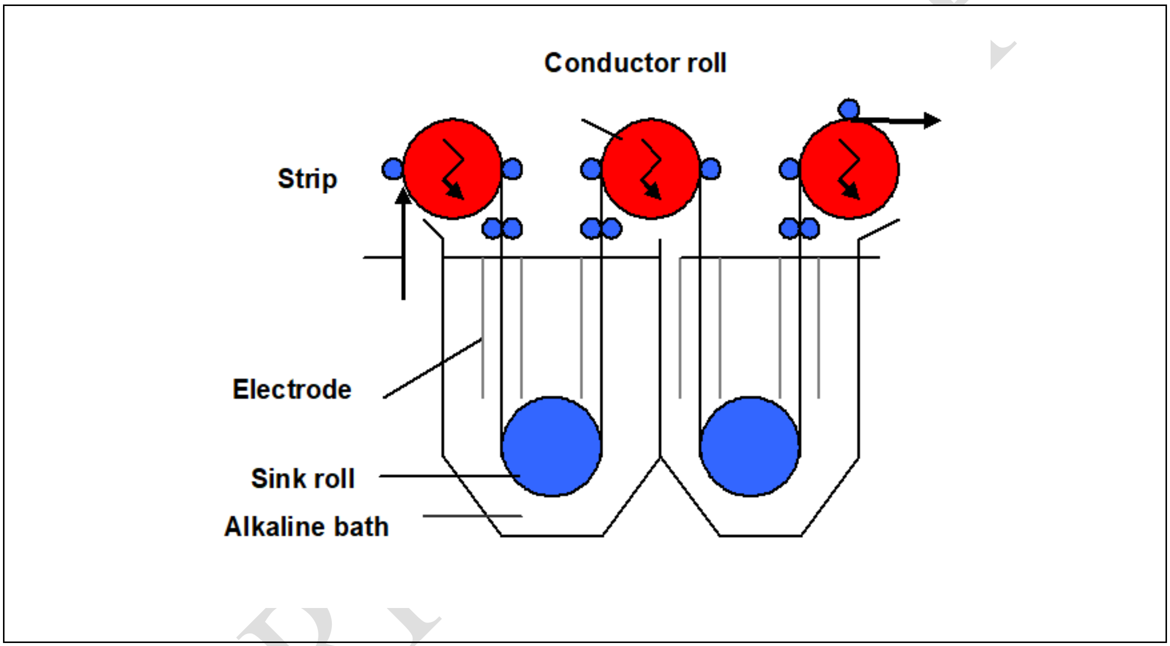


Figure 2-18: Electrolytic degreasing

Rinsing
Cascade rinsing in two stages completely removes the alkaline solution. Cascade rinsing has the advantage of achieving a high cleaning rate using only a small amount of rinsing water. Rinsing is performed in the counter-flow direction (i.e. the water flows in the opposite direction to the coil). This means that clean water is used in the last stage where it consequently becomes contaminated. This slightly contaminated water is used for cleaning in the second stage and subsequently in the previous rinsing stage. The water drag-over between two stages are controlled by means of wringer rolls. The rinsing equipment involves the following steps:

- stage 1: spray nozzles and brushes
- stage 2: spray nozzles.

Demineralised water having a temperature of 70 to 85 °C is used in the first stage.

Environmental considerations
Use of countercurrent rinsing to minimise use of heated demineralised water.

Water vapour and alkali fumes generated in rinsing and brushing are usually collected and injected in the rinsing tanks.

When the water has reached the maximum allowed oil content commensurate with process quality, it is sent to waste water treatment before release.

2.4.8.6 Pickling

Pickling removes any oxides formed during the various stages of steel processing and prepares a reactive steel surface for the plating section. For further information, see [86, COM, 2022].

Coil pickling can be carried out by spraying, or immersion with or without electrolysis.
Typical pickling sections involve the following steps:

- stage 1: pickling;
- stage 2: rinsing.

Spray pickling
Two types of pickling solution may be used:

- sulphuric acid at a concentration within a range of 10 to 60 g/l with a temperature range of 25 to 60 °C;
- hydrochloric acid at a concentration within a range of 100 to 150 g/l with a temperature range of 20 to 40 °C.

Both the temperature and the acid concentration are dependent on the available pickling time (which is a function of the contact length and the maximum strip speed).

Environmental considerations
Fumes generated in pickling are usually collected and scrubbed prior to release. In some lines, the contaminated water of the scrubber is treated together with the fumes from the electroplating cells in an evaporator and both the concentrate and the evaporated water are returned to the process.

Spent pickling solution is sent to waste water treatment before release.

Spray rinsing
The same system is used as for degreasing (see Section 2.9.8.5).

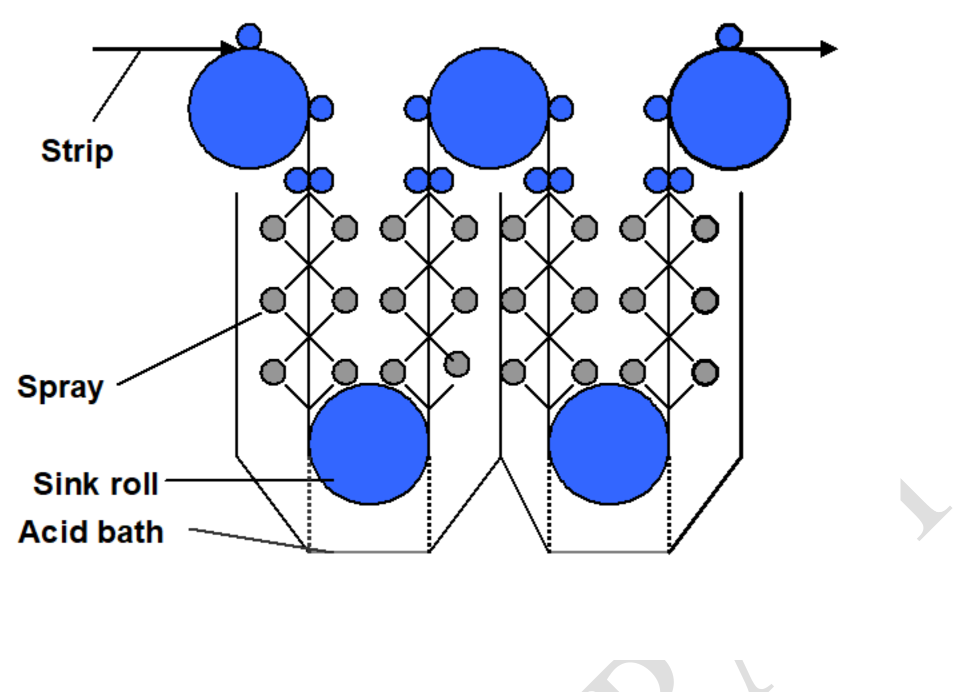


Figure 2-19: Pickling section

2.4.8.7 Electroplating

In this section, thin deposits of pure or alloyed zinc are electrolytically deposited onto the surface of a steel strip substrate. A typical plating section involves the following steps:

- stage 1: plating through several electrolytic cells;
- stage 2: rinsing.

Sections 2.9.4 discuss the process and describe types of electrolytic cell. Current density for various zinc and zinc alloy thicknesses, and the industries they are used in are set out in Table 2.1.

Types of electrolyte bath
Electrolyte baths in continuous electrolytic zinc plating lines are predominantly acid-based. Alkaline-based electrolytes are no longer in common use. Electrolytes can be sulphate-based or chloride-based. The sulphate-based bath is used with soluble and insoluble anode processes. The chloride-based bath is only used with soluble anodes as chlorine gas is generated with insoluble anodes. In both baths, ionic additions are made to increase the conductivity of the electrolyte bath (e.g. sodium sulphate, aluminium sulphate, sodium chloride). Buffer additions are made to stabilise the pH (e.g. CH_3COONa).

Typical sulphuric base electrolytic bath compositions are:

zinc	70- 120 g/l
free H_2SO_4	3- 25 g/l
Na_2SO_4	0- 100 g/l
pH	1.0- 3.0 pH units.

Anodes types
These are generally described at the start of Chapter 2. For this process:

- soluble anodes: the zinc anodes are fixed on a supporting rail and, as they are consumed during the process, they are displaced from the entry side rail to the exit side rail;
- insoluble anodes: two materials are used for the anode plate: a plate substrate in titanium coated with a thin layer of tantalum oxides or iridium oxides and a plate in lead alloyed with Sn or with Ag and In.

Rinsing step
The coil is then rinsed to completely remove the electrolyte from the strip surface. Also, in some cases where the coil is coated only on one side, the rinse may be used to pickle the zinc residues on the non-coated side. Rinsing can be carried out by immersion or by cascade spraying, and in horizontal or vertical tanks depending on the available surface. The same cascade principles described in the degreasing section are applied here, see Section 2.9.3.1.

Demineralised or fresh water is used, with a temperature of between 20 – 50 °C and a pH 0.3 to 3 (among other control parameters).

When the water has reached the maximum allowed contaminant (electrolyte) content determined by quality control, it is sent for waste water treatment before discharge. In some lines, the contaminated water is treated in an evaporator. The evaporated water can be re-used for rinsing and the concentrate re-used in the process electrolyte.

Environmental considerations
Counter-flow cascade rinsing can maximise the rinse efficiency and minimise the use of hot demineralised water.

Re-use of the water outputs distilled from evaporators.

2.4.8.8 Strip polisher

The strip polisher is used to clean the tarnished/oxidised uncoated side of the strip and to remove any stray coating particles which may have been deposited. When producing single sided coated material, some lines omit the polishing technology.

A typical polishing section involves the following stages:

- stage 1: polishing;
- stage 2: rinsing;
- stage 3: drying.

Polishing
Brushes are used to polish the cold reduced surface on the uncoated side. Demineralised water is used. The metal particulates are filtered from the used water.

Environmental considerations
The used water is sent to waste water treatment before release.

Rinsing
The strip is passed through a hot water rinse to remove any debris, before being dried. Rinsing can be carried out by immersion or by cascade spraying, in horizontal or vertical tanks depending of the available surface. The same principles as described for the degreasing section are applied. See Section 2.9.8.2.

Environmental considerations
The used water is sent to waste water treatment before release.

Drying

The polished strip is dried by means of a hot air drying device. The hot air temperature lies between 100 and 120 °C. The drier device is usually situated at the end of the post-treatment; the same type of device is used for the phosphate and the chromate sections. See Section 2.6.

Environmental considerations
Heat efficiency and losses.

2.4.8.9 Phosphating

This process forms a high quality light phosphate coat with the hopeite chemical structure which is widely used in the automotive industry and for household appliances. Phosphating can improve the performance of the zinc-coated strip with regard to drawability, corrosion resistance and subsequent paintability. See Section 2.5.16.

The strip is treated after zinc coating using spray banks in a two-stage process:

- stage 1: activation;
- stage 2: phosphating.

Activating
The first stage consists of spray of a titanium refiner, which provides activation sites for the second stage of phosphate coating. The activation solution circulates in a closed loop. The pH lies in a range of 8 to 10, and the temperature is maintained below 40 °C. Spent (used, out of specification) solution it is treated in the waste water treatment section.

Phosphating
Phosphate coatings are described in Section 2.5.16. A phosphate coat of approximately 1- 1.8 g/m^2 is applied. The phosphate system used can either be single or tricationic, depending on customer requirements. The hopeite crystal $Zn_3(PO_4)_2.4H_2O$ incorporates approximately 1 % Ni and 5 % Mn. A refiner is added to ensure that the phosphate crystals deposited are small, uniform and tight, which enhances the performance of the coating.

Following phosphating, the strip is rinsed in a spray of dilute chromate solution to form a chromate seal. This seal further enhances the corrosion performance of the phosphate coating. The strip is then dried.

The phosphate solution circulates in a closed loop at a temperature below 40 °C.

Environmental considerations
See Section 2.5.16.

Spent solution is treated in the waste water treatment section.

Effluents may contain traces of nickel and manganese.

2.4.8.10 Full chromating and chromate rinsing

This is described in Section 2.5.17. A typical chromating section involves the following steps:

- stage 1: chromating;
- stage 2: rinsing;
- stage 3: drying.

Chromating
Full chromating or chromate rinsing of the strip after zinc coating is achieved using spray banks. Chromate rinse or passivation is a spray treatment with solvents containing chromic

acids. A coat of 10 – 35 mg/m^2 per side is applied. During passivation, Cr(VI) is largely converted to Cr(III). The strip is treated with solutions between 0.5 – 2 % of chromium and at temperatures below 40 °C. The chromate solution circulates in closed loop.

Environmental considerations
General health and environmental issues for chromium passivation are described in Sections 1.4.4.1 and 2.5.17.

Spent (used, out of specification) solution may be treated in a typical waste water treatment plant or disposed of as hazardous waste.

Rinsing
Rinsing can be carried out by cascade spraying in horizontal tanks. The same principles as described for the degreasing section are applied. See Section 2.9.8.2

Environmental considerations
The used water is sent to waste water treatment before release.

Drying
The chromate rinse strip is dried by means of a hot air drying device. The hot air temperature lies between 100 and 120 °C which is necessary for the chemical reaction of the excess Cr(VI) with the solution additives to become Cr(III).

Environmental considerations
Heat efficiency and losses.

Anti-finger marking section
This provides a chromate coating for improving protection against white rust corrosion. This coating has the advantage of not showing fingerprints, which is critical for some customers.

A typical chromating section involves the following steps:

- stage 1: coating. The chromate coating is applied via a roller coater system, similar to that used in paint lines;
- stage 2: drying. The wet coating is passed through an air oven to dry.

Environmental considerations
The coating is dried in place with no rinsing, so no effluent arises.

Heat efficiency and losses may need to be addressed for the oven.

2.4.8.11 Oiling

A wet film of oil is applied on the surface of the strip, see Section 2.9.5. The oiling coat is between 0.25 – 3 g/m^2/side, applied in an electrostatic oiler, with the oil circulating in close loop.

2.4.8.12 Exit looper

See Section 2.9.7.2

2.4.9 Continuous electrolytic tin plating activities

Mild low carbon steel can be coated with tin either with equal or different thicknesses on either side, and in a range of thicknesses.

On a continuous electrolytic tin coating line, the blackplate strip is passed through cleaning and pickling pretreatments, then through a series of tanks containing a tin electrolyte. This process electrolytically deposits a light layer of pure tin onto the strip, which may be subsequently reflowed, then passivated and oiled prior to recoiling.

Plant layouts vary in design; some modern lines now incorporate a side trimming unit prior to pretreatment. Figure 2.20 shows a typical layout of a continuous tin coating line.

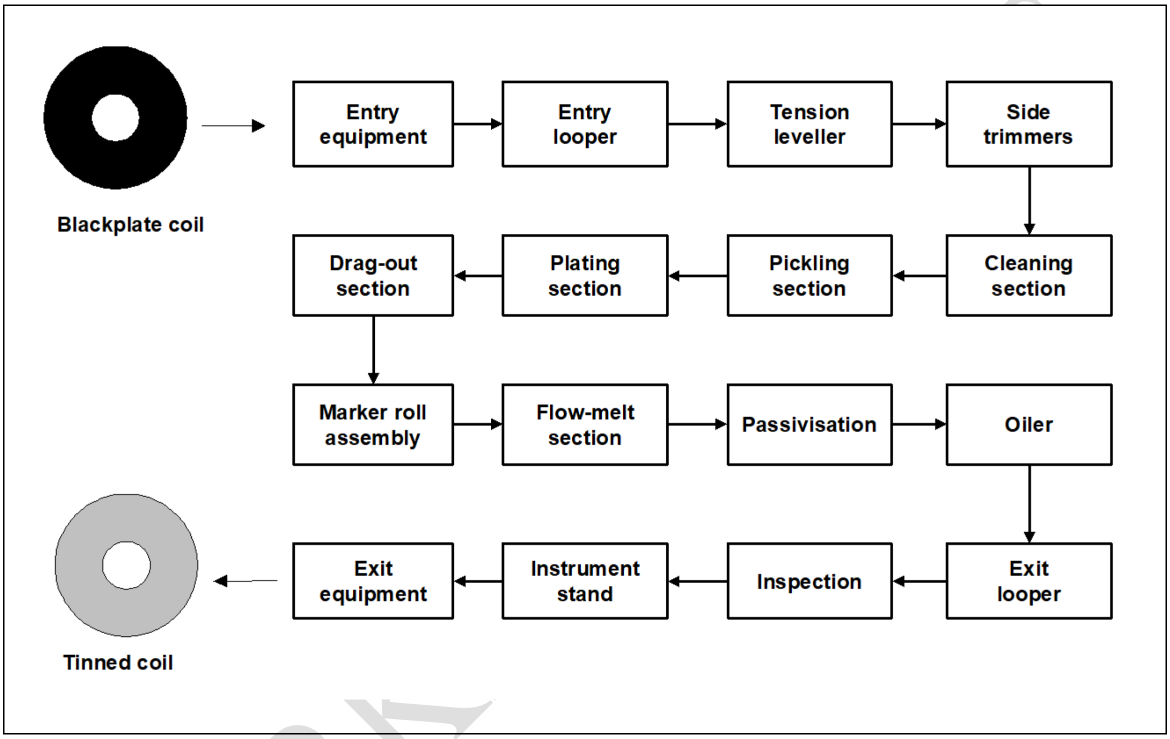


Figure 2-20: Schematic of a tin coating line layout

2.4.9.1 Degreasing and cleaning

As with other surface treatments, tin plating requires appropriate preparation of the substrate as poor surface condition can lead to inadequate adhesion of the tin or even dewetting during the remelting operation. See Sections 2.3 and 2.9.3.1. Cleaning solutions are usually proprietary mixtures of polyphosphates, sodium hydroxide and wetting agents. The chemical action of the bath is enhanced by electrolytic treatment. Concentrations range from 7 to 50 g/l and the solution is operated at a typical temperature of about 90 °C maintained by circulating the solution through a heated reservoir storage tank. Additions of water and cleaning compound are made as required. Figure 2.21 shows a typical cleaner section with rinsing.

The strip is polarised using one of the following two methods:

- directly- where the strip passes over a conductor roll, and then travels between two pairs of mild steel electrodes. Current passes from the conductor roll via the strip and electrolyte to the electrodes
- indirectly- by grid electrodes where the steel strip travels between two pairs of mild steel plates which form two electrodes of opposite polarity. Current passes from one pair of electrodes via the electrolyte and the strip to the other pair of electrodes.

The polarisation of the strip can be achieved in two different ways~~either~~:

- Directly, where the strip passes over a conductor roll and then travels between two pairs of mild steel electrodes. The current passes from the conductor roll via the strip and electrolyte to the electrodes.
- Indirectly by grid electrodes, where the steel strip travels between two pairs of mild steel plates which form two electrodes of opposite polarity. The current passes from one pair of electrodes via the electrolyte and the strip to the other pair of electrodes.

Rinsing
Rinsing is as thorough as possible to avoid contamination of the pickle liquor pretreatment by the cleaning solution. It is carried out by spraying hot water, typically between 150 – 400 l/min.

Environmental considerations
Alkali fumes generated during cleaning are typically collected and scrubbed prior to release.

Spent cleaning agent and waste water from rinsing can be treated in a typical waste water treatment plant.

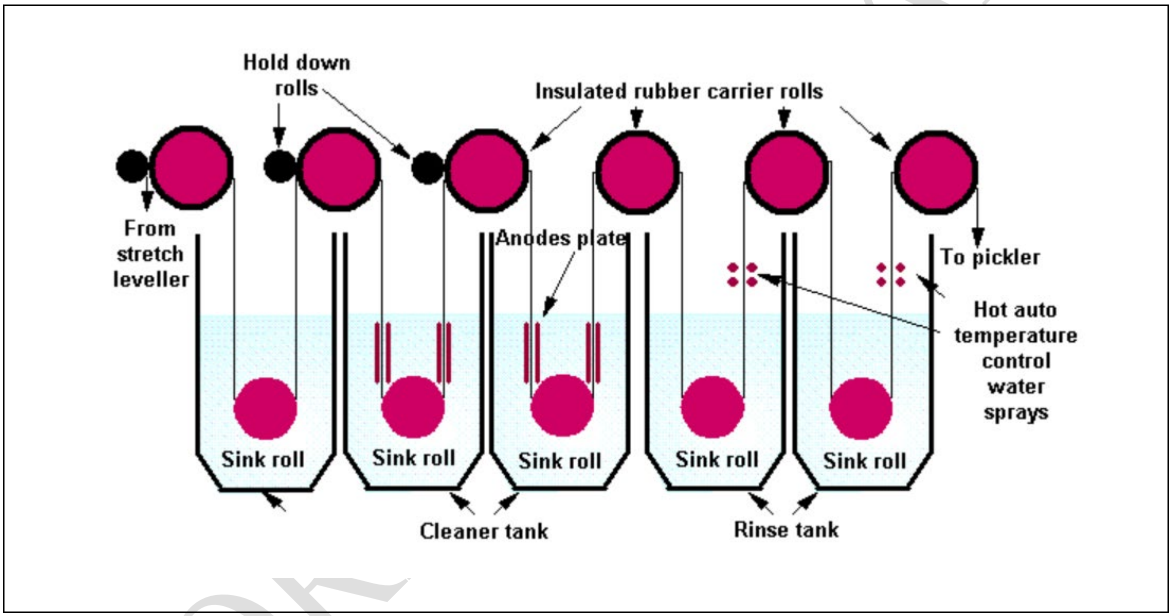


Figure 2-21: Schematic of a cleaner section

2.4.9.2 Pickling

See Section 2.4.3.2. Lead anodes are used because of the 50 g/l (max) concentration of the sulphuric acid electrolyte. The acid is deliberately not heated, but the process current induces an equilibrium temperature of 25 to 40 °C, depending on operating conditions.

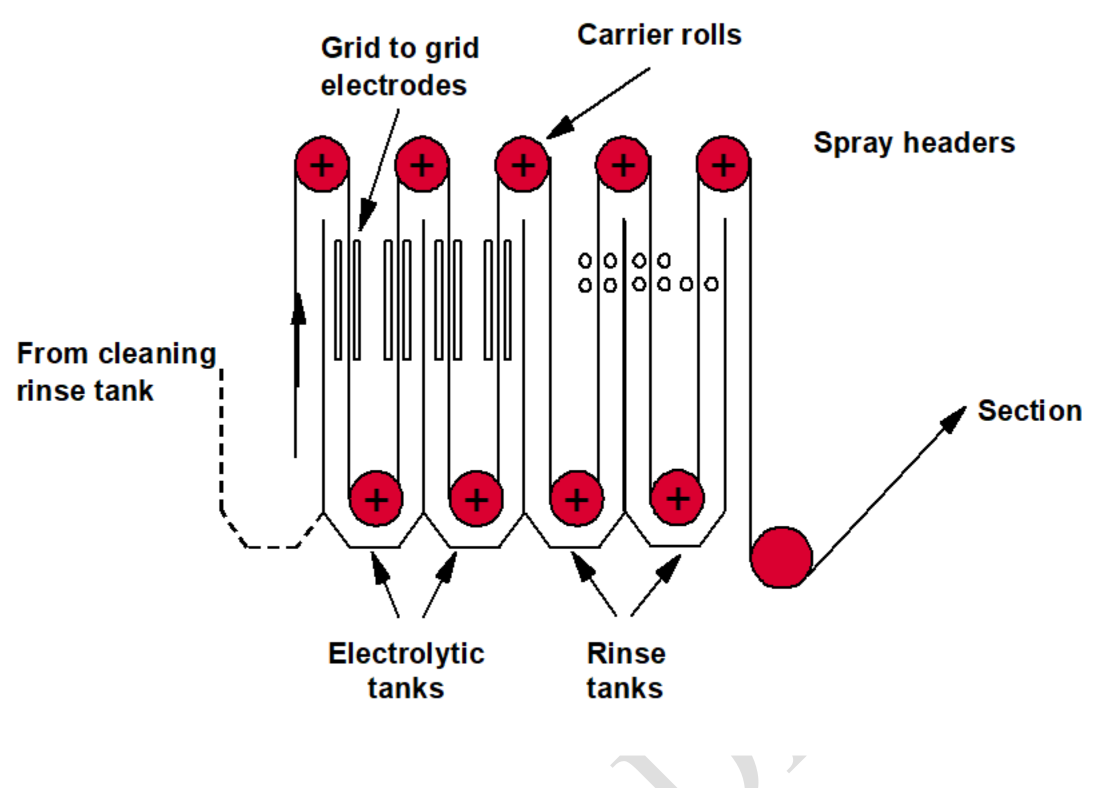


Figure 2-22: Schematic of a pickler section

Environmental considerations
Acid fumes generated during pickling are usually collected and scrubbed prior to discharge. Spent acids and rinse waste water are sent for waste water treatment prior to discharge.

2.4.9.3 Tin plating

There are two widely used tinning processes:

- The 'Du Pont' process which represents 20 % of worldwide tin plate production. It has the ability to accept high current densities. However the electrolyte composition is complex, with high chloride and fluoride contents making it highly aggressive to plant materials.
- The 'Ferrostan' process is the most widely used, with between 75 and 80 % of worldwide tin plate production. This is due to the use of less hazardous and corrosive chemicals.

Other electrolytes are based on tin sulphate, tin fluoroborate or tin methyl sulphonate [113, Austria, 2003].

The plating section of a tinning line consists of several rubber-lined steel vertical tanks arranged in tandem. Each tank contains a rubber driven sink roll at its base and two chromium plated copper conductor rolls above the electrolyte surface. Current is transferred from the roll to the strip so that the strip becomes cathodic. Soluble tin anodes are hung from bridges across the vats into the plating electrolyte. Anodes are cast from electrorefined tin which is typically more than 99.85 % pure.

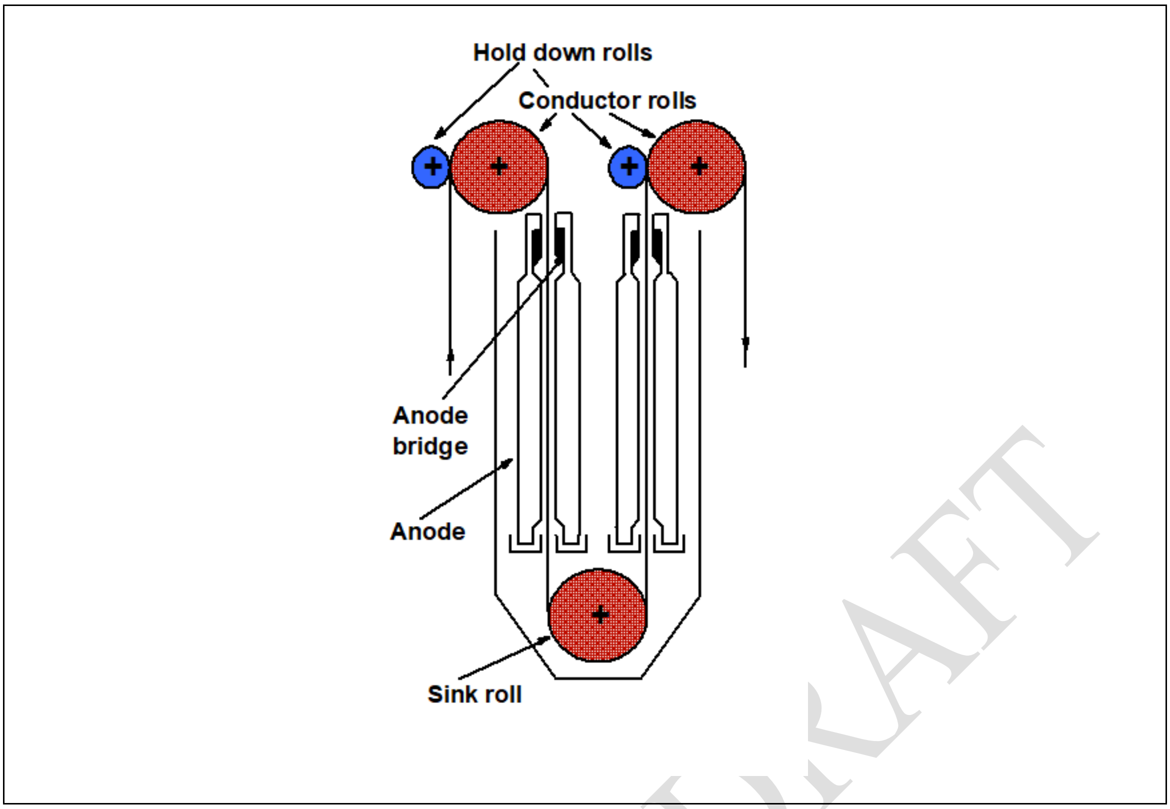


Figure 2-23: Schematic of a plating tank – vertical cell

The plating electrolyte consists of stannous sulphate, phenolsulphonic acid (PSA) and an organic addition agent. The stannous sulphate provides an initial source of tin ions in solution; the PSA makes the solution highly conductive and the addition agent ethoxylated alpha-naphthol sulphonic acid (ENSA) aids uniform and consistent tin deposition. This is essential for making the plate bright at after the later flow-melting stage.

Typical composition and temperature of tin electrolyte to ensure good plating conditions is:

stannous tin	25 – 45 g/l
phenol sulphonic acid (PSA)	20 – 27 g/l
ENSA	1.5- 6.0 g/l
at temperatures of	30 – 55 °C.

The plating electrolyte is circulated through heat-exchangers, the rate of circulation being high enough to maintain a constant plating temperature for all coating weights.

2.4.9.4 Drag-out

After plating, the strip goes through a series of drag-out and rinsing operations.

At the drag-out tank, electrolyte is spray-rinsed with a dilute solution of PSA and a tin compound, and then returned to the electrolyte circulation tank. This tank is connected to an evaporator and the dilute electrolyte is concentrated by evaporation then recirculated back to the plating tank.

The exit squeeze rolls on the drag-out recovery tank leave the optimum amount of electrolyte on the strip required for ‘fluxing’ of the tin coating during melting. The film only needs to be dried before the strip enters the flow-melting or brightening unit which is accomplished by passing the strip through a series of hot air jets.

On high speed lines, a second drag-out recovery unit is provided to increase the dilution ratio. This means a recovery ratio of more than 90 % of the drag-out electrolyte is accomplished.

Environmental considerations
Dragged over plating solution can be concentrated and returned to the plating process.

Acid fumes generated during plating and drag-out may be collected by an extraction unit and are usually scrubbed prior to discharge.

2.4.9.5 Differential marking

Differential coatings are shown by marking one side of the strip usually with a solution of sodium dichromate. This is printed onto the strip in a pattern of diamonds, circles or, more commonly, lines. The solution is dried onto the strip and after melting will leave a dull, non-lustrous finish in the areas that have been in contact with the printer.

Environmental considerations
As for other chromium coatings, see Section 2.9.8.10.

2.4.9.6 Reflow – tin brightening

The tin coating deposited on the strip has a dull matt appearance. Reflowing or flow melting is the process used to give a bright lustrous finish. The strip is heated to above 232 °C (the melting point of tin) and then quickly cooled to solidify the coating. Melting is achieved by resistive heating (applying a voltage between two conducting rolls supporting the strip), supplemented by induction heating (which provides 20 % of the total energy).

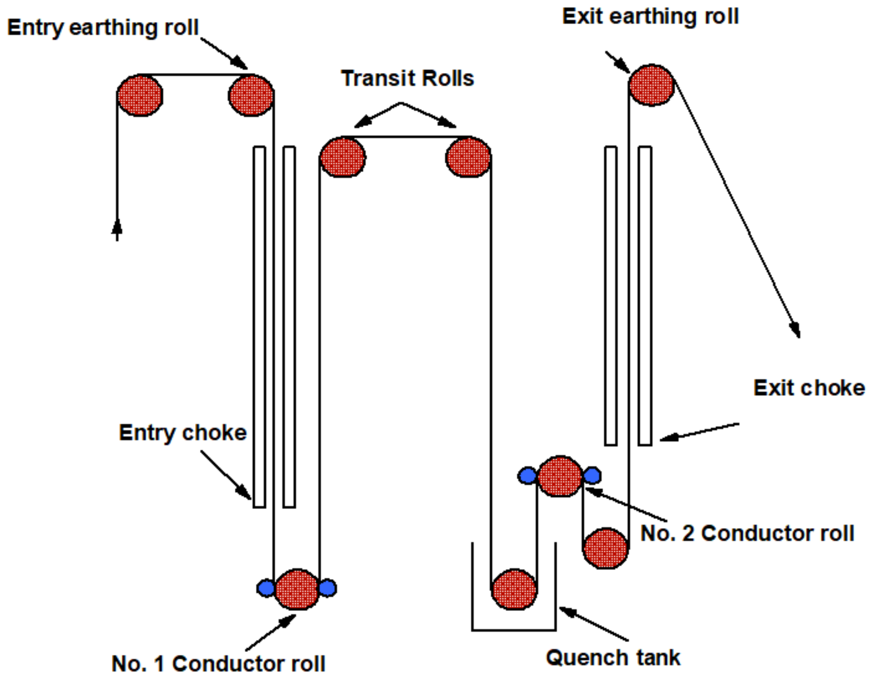


Figure 2-24: Schematic of flow-melt section

The mixed resistive and inductive heating makes it easier to obtain stable melting conditions, avoiding certain cosmetic coating defects.

Environmental considerations
Energy efficiency and energy losses.

2.4.9.7 Passivation treatments

Passivation is carried out by a chromating treatment, in order to reduce the thickness of tin oxides formed during remelting. The treatment electrolytically produces a layer containing chromium which prevents subsequent oxidation in air and also improves adhesion of the paint layer.

The operation is performed in a solution of sodium dichromate

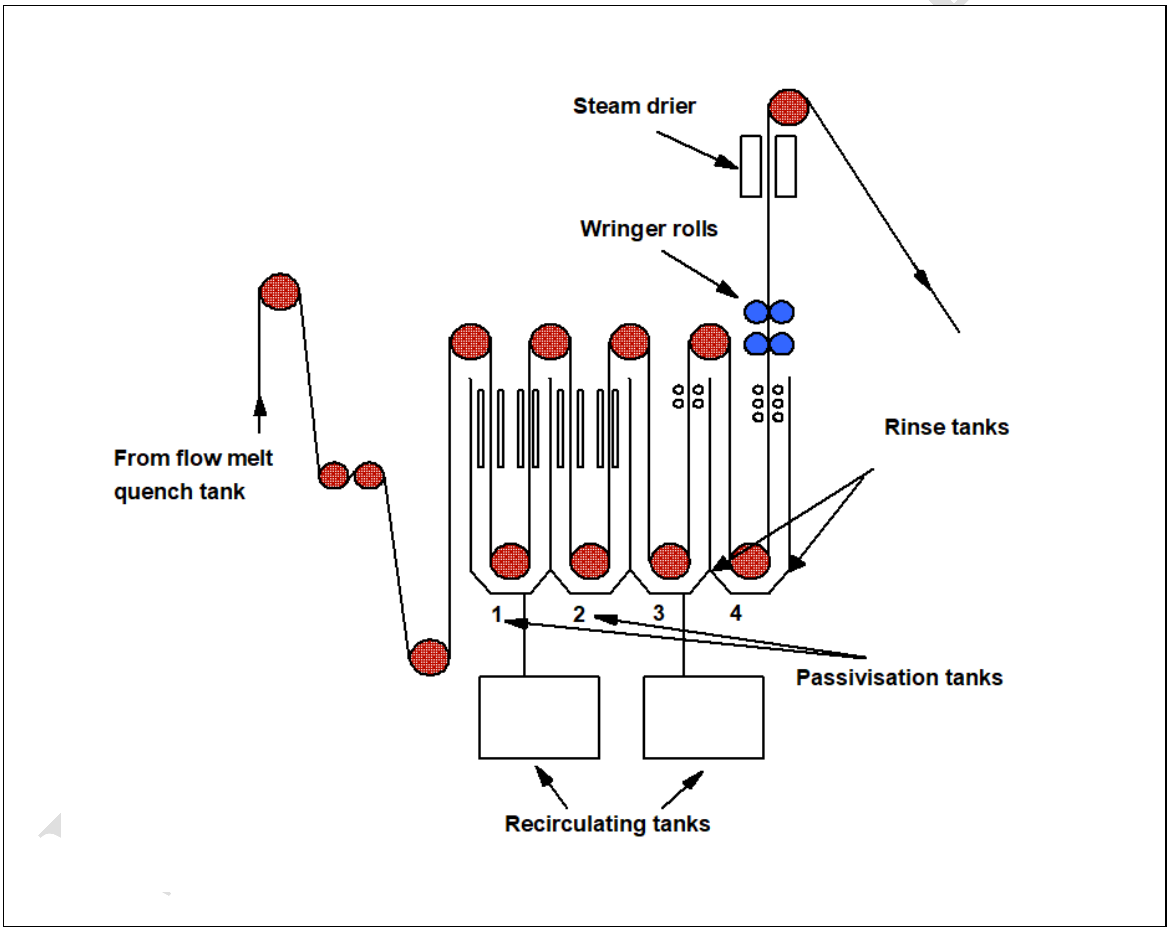


Figure 2-25: Schematic of passivation treatment

Environmental considerations
General health and environmental issues for chromium passivation are described in Section 1.4.4.1.

Spent (used, out of specification) solution may be treated in a typical waste water treatment plant or disposed of as hazardous waste.

2.4.9.8 Oiling

Prior to recoiling the treated coil, a thin film of lubricant is applied to the tin plate surface. This film minimises subsequent damage by abrasion, facilitates sorting and aids subsequent lacquering and printing operations.

A pure grade of either dioxyl sebacate (DOS) or acetyltributyl citrate (ATBC) is used. The oil can be added by two methods:

- electrostatically, where a negatively charged oil mist is driven away from similarly charged repeller plates onto the surface of the strip;
- emulsion oiling, where a thin, uniform oil film is applied by flooding the surface of the tin plate with a dilute oil-in-water emulsion.

The total oil levels on the strip range typically from 6.0 to 12.0 mg/m^2.

2.4.10 Continuous electrolytic chromium plating activities (electrolytic chromium coating of steel – ECCS)

This is also known as tin-free steel: a low carbon, mild steel, coated equally on both sides with a complex layer of metallic chromium and chromium hydroxides. The processes are described in general in Section 2.2.1.3, along with the health and environmental issues. Figure 2-26 shows a typical process line layout and Figure 2-30 gives a cross-section through a line. The chromium plating of the steel strip is performed electrolytically in a chromic acid bath. The coating is applied equally to both sides as a complex layer of chromium metal and chromium oxides. The overall process is similar to the electrolytic tin process – the steel strip is passed through the entry section of the line, cleaned, pickled and then treated electrolytically in a solution containing chromic acid, rinsed thoroughly, dried, oiled and then recoiled.

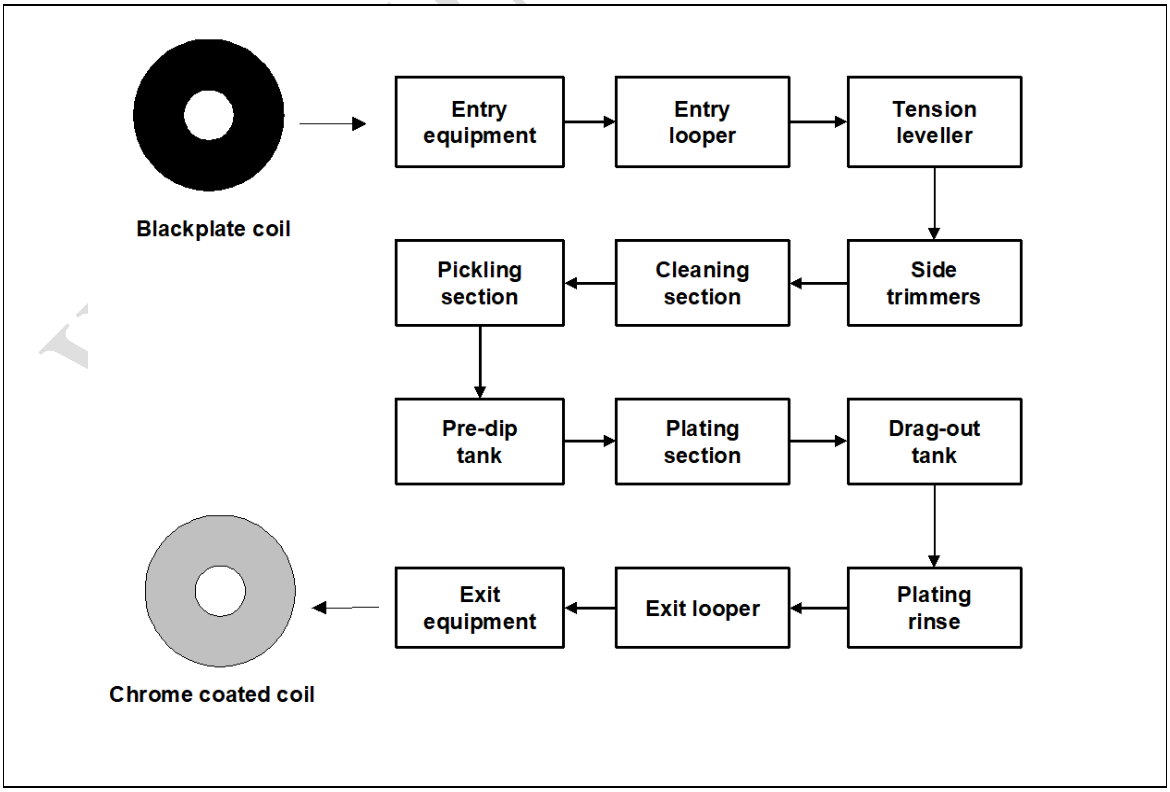


Figure 2-26: Chrome coating line layout

2.4.10.1 Degreasing and cleaning

Cleaning is performed electrolytically in an alkaline bath (see Section 2.3.8) and sodium hydroxide is generally used at concentrations of typically 50 to 90 g/l. Wetting agents and chelating agents are also added to the cleaning agent to improve cleaning performance.

- sodium hydroxide 60- 65 %
- sodium phosphate 30- 35 %
- wetting agent 0- 2 %
- chelating agent 2- 5 %.

Electrodes

Electrodes are made of mild steel plates. The polarity of the strip can be selected from anodic, cathodic or any combination of the two. The polarisation of the strip can be achieved in two different ways, ~~either~~:

- Directly, where the strip passes over a conductor roll and then travels between two pairs of mild steel electrodes. The current passes from the conductor roll via the strip and electrolyte to the electrodes.
- Indirectly, by grid electrodes where the steel strip travels between two pairs of mild steel plates which form two electrodes of opposite polarity. The current passes from one pair of electrodes via the electrolyte and the strip to the other pair of electrodes.

See Figure 2.18: Electrolytic degreasing.

The temperature of the cleaning solution is kept constant by circulating the solution between the cleaning tank and the storage tank with a steam heater coil.

Rinsing

This is thorough to avoid contamination of the pickle liquor pretreatment by the cleaning solution. It is carried out by spraying heated water typically between 150 – 400 l/min.

Environmental considerations

Alkali fumes generated during cleaning are typically collected and scrubbed prior to release.

Spent cleaning agent and waste water from rinsing are sent for waste water treatment before discharge.

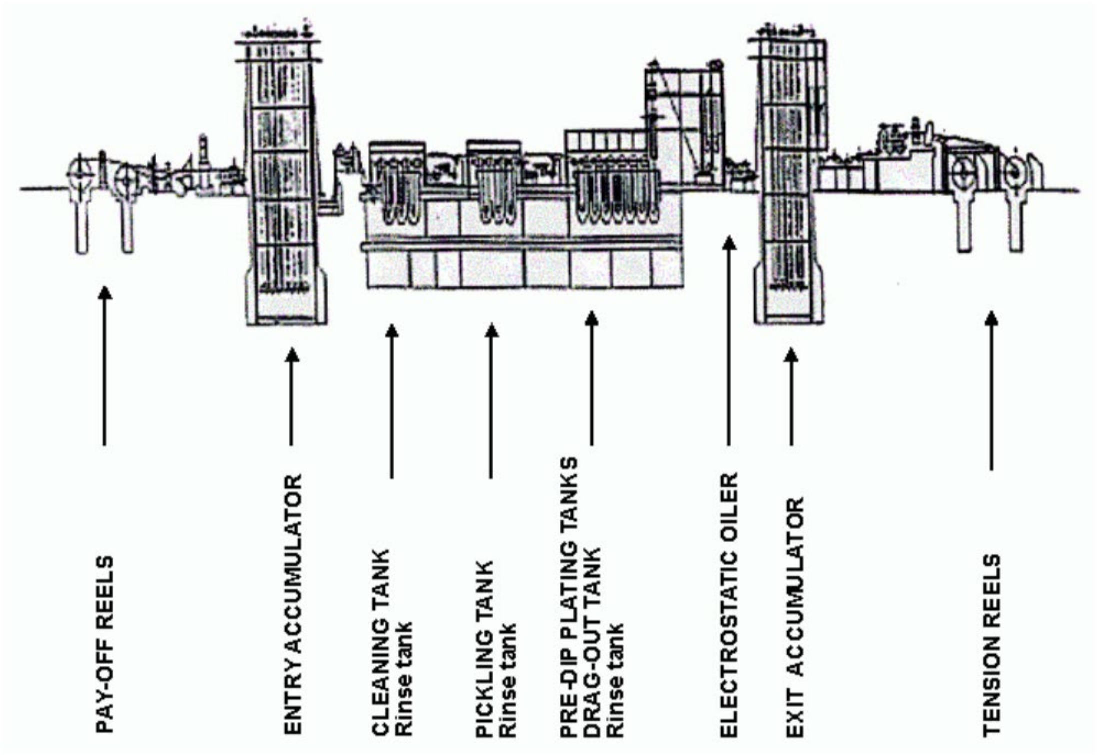


Figure 2-27: Typical arrangement of ECCS line

2.4.10.2 Pickling

Sulphuric acid is used for the pickling solution at concentrations of 60 to 115 g/l at ambient temperature. See Sections 2.3 and 2.9.3.2.

Environmental considerations
Acid fumes generated during pickling are usually collected and scrubbed prior to release.

Spent pickling agents and waste water from rinsing are sent for typical waste water treatment before discharge.

2.4.10.3 Chromium plating

See Section 2.5.3 for a general description of chromium plating and the health and environmental considerations.

Pre-dip
Before chrome plating takes place, the strip is passed through a pre-dip tank. This is essential to prepare the surface of the strip for electrodeposition and prevents stains and other surface defects forming on the surface of the strip. It is carried out in a sulphuric acid solution of 0.3 – 0.5 g/l at ambient temperature.

Electroplating
The strip is passed through an electrolyte containing Cr(VI) ions, which are reduced cathodically on the strip surface to form a duplex layer of hydrated chromium oxide and metallic chromium. The current applied is determined according to the strip width, line speed,

current efficiency and aimed film weight and flows from the insoluble electrodes to the strip through the electrolyte, and then returns to rectifier through the conductor rolls.

The plating solution is pumped from a circulation tank, passed through a heat-exchanger and then travels up into the bottom of the coating tanks, which contain inert anodes of lead-antimony. It is overflowed from the top part of the tank and then returned to the circulation tank.

A typical plating electrolyte will consists of:

chromic acid	110- 130 g/l
hydrofluoroboric acid (HBF_4)	0.30- 0.44 g/l
sulphuric acid (H_2SO_4)	0.60- 0.80 g/l.

The hydrofluoroboric and sulphuric acids both act as catalysts: they improve the efficiency of the plating process but are not themselves consumed in the process. In the US, the solutions are more usually Cr/sulphuric acid only [73, BSTSA,]. Temperature can have a marked effect on the electrolyte efficiency; the solution is far more efficient at lower temperatures. However, because the electrolyte is heated by the electric current passing through it, the temperature has to be kept constant by the heat-exchanger which cools the solution. In operation the optimum temperature of the electrolyte is 58 +/- 2 °C.

Environmental considerations
The health and environmental issues are described in general in 2.5.3.

Acid fumes are generally collected and scrubbed prior to discharge. The scrubbing solutions may need treatment prior to discharge.

2.4.10.4 Drag-out and rinsing

At the drag-out tank, electrolyte is spray rinsed away and the washings are returned to the electrolyte circulation tank. This is connected to an evaporator where the diluted electrolyte is concentrated and returned the process tank. The amount of spray rinse at the drag-out recovery tank and the capacity of the evaporator are decided from the chromic acid concentration in the effluent.

The chromic acid treated strip must be fully rinsed with water before drying, oiling and recoiling. The strip is sprayed with hot water at the entry and exit ends of the rinse tank to remove any carry-over of electrolyte or water-soluble constituents in the oxide film. Spraying is carried out at 50 – 60 °C with a flowrate of about 5000 – 10 000 l/h. Spraying at higher temperatures and pressures could damage the freshly formed film.

Environmental considerations
The health and environmental issues are described in general in Section 2.5.3.

Chromium and other electrolyte components may be recovered by countercurrent rinsing and evaporation of drag-out.

Fumes generated during electrolytic plating and drag-out are collected by an extraction unit and typically scrubbed prior to discharge.

2.4.10.5 Oiling

Prior to recoiling, a thin film of lubricant is applied to the chrome-plated surface. The function of this film of lubricant is to minimise subsequent damage by abrasion, to facilitate sorting and to aid in the lacquering and printing operations. A pure grade of either dioxyl sebacate (DOS) or acetyltributyl citrate (ATBC) is used. The oil is usually applied by an electrostatic oiler. See Section 2.9.9.8.

The aim weight of oil film on the strip is 3.0 – 7.0 mg/m^2

2.4.11 Continuous electrolytic lead coating of steel

The only plant operating in Europe is due to close by 2005 or 2006. No specific information has been exchanged. General information on analogous coil and jig processes can be used for the majority of the activities and issues.

2.5 Sheet processing for aluminium lithography plates

Substrates for lithographic plates (see Section 1.3.3) must be easily and cheaply prepared, chemically resistant to acid and alkali solutions, and solvents in inks or for cleaning. They must also be flexible for fixing to rollers, physically robust and stable in use for print runs of thousands of copies, with a well defined microroughness and hydrophilicity for retaining and spreading the dampening agent. Aluminium is the substrate of choice as it can be easily prepared by the processes described in Sections 2.10.1, 2.10.2, 2.10.3 and 2.10.4. [118, ESTAL, 2003], [38, Ullmann, 2002/3]

2.5.1 Surface graining

Although the surface can be prepared mechanically, it is now more usual to use electrochemical graining. The raw aluminium surface is first degreased (see Section 2.3) and then uniformly corroded by using an AC treatment in dilute nitric acid, hydrochloric acid, or mixtures of these with other acids. This process of graining is a type of pitting corrosion which attacks the entire surface of the aluminium leaving a very uniform rough surface. The depth of roughness can be controlled within wide limits (2.5- 9 µm) by varying the electrical parameters. Both processing speed and the uniformity of the resulting substrates depend on temperature, flowrate of the electrolyte, geometry of the tank, and other parameters. Combination processes have also been used in graining. In these processes, mechanical graining is followed by electrochemical treatment.

Graining with wire brushes produces the lowest increase in surface area of the plate, and electrochemical graining, the highest. This influences, not only the quality of reproduction and the optical resolution, but also the printing properties (water spreading and length of run). The finer the graining of an aluminium surface, the lower is the mechanical resistance. With wire-brushed aluminium, a second hardening step is not required. However, an anodic oxidation step is essential for electrochemically grained aluminium.

2.5.2 Anodic oxidation (anodising)

Anodic oxidation (as described in Section 2.5.13) involves conversion of the uppermost layer of the aluminium workpiece to aluminium oxide, without affecting the surface topography significantly. Two processes are in general use: sulphuric acid or a phosphoric acid electrolyte. The former leads to smaller pores and thicker oxide layers than the latter.

In general, not more than 5g of oxide is produced per square metre; depending on the roughness of the surface, this corresponds to a layer thickness of about 1 µm. The oxide formed during anodising is X-ray amorphous and an extremely strong adsorbent. The properties of the substrate are greatly improved during this step, i.e. the adhesion to the light-sensitive coating; resistance of the surface to chemicals; its hydrophilicity, hardness and abrasion resistance, and thus the potential of running length. However, the extent to which the aforementioned aspects can be effective depends on process parameters and on the process itself.

2.5.3 Post-treatment

Post-treatment of the oxide with certain hydrophilising solutions has proved advantageous in the production of pre-sensitised (PS) plates. The main purpose of this treatment is to improve the hydrophilicity of the aluminium oxide surface. However, the adhesive properties, the ability to be photo-developed and shelf-life of the plates are all influenced at the same time. Solutions of the following substances have been proposed for this purpose: alkali silicates, phosphonic acids, hexafluorometalates of group 4 elements (titanium, zirconium, and hafnium), heteropolyacids, oxy acids of pentavalent phosphorus, and hydrophilic colloids. All of these compounds coat the surface of the aluminium oxide to generate a very polar covering layer, which improves the hydrophilicity of the surface.

2.5.4 Coating and further processing

Preliminary treatment of the carrier is followed by in-line coating of the plate in a fully continuous process. A solution of the components of the light-sensitive coating in a more or less volatile solvent mixture is applied to the carrier in a defined wet film thickness. The coatings are generally applied with a fishtail die, with a roller coater, or by spraying. The thickness of dry coatings is 0.3 – 5 mm.
The line speed in modern plants is <1 m/s. The length of individual steps is adjusted to this process speed. After drying, the web is automatically inspected for coating defects. It is cut apart, and defective plates are removed. Cutting of the plates requires special attention. Pre-sensitised lithographic plates are available in many sizes up to about 3 m^2 (1500 × 2000 mm).

The finished faultless plates are stacked by using a suitable interleaving paper and packed in lightproof wrapping paper (if necessary, after shrink-film packaging).

The shelf-life required for these pre-sensitised lithographic plates depends on the extent of their distribution. Also, the more diverse the climatic conditions under which the plates are to be stored and used, the more diverse are the requirements.

2.6 Printed circuit board manufacturing

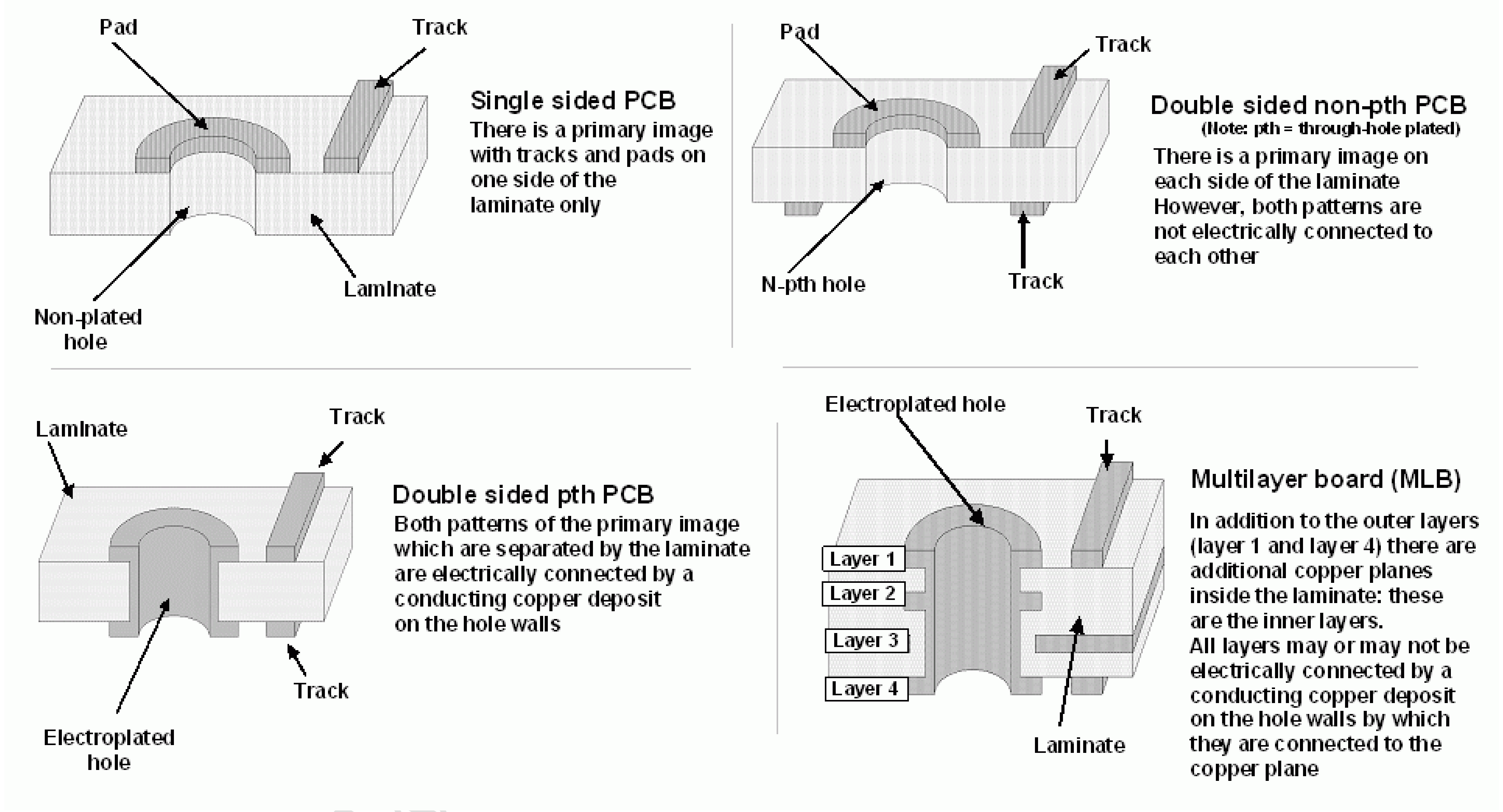
Printed circuit boards are the basis of electronic sub-assemblies. They are electronic circuits, often complex, with the thin layers of tracking printed onto thin, non-conductive layers. Components such as resistors, capacitors, semi-conductors, mounts for processing chips and memory chips, etc. are added in subsequent operations (not described in this document). Modern electronic equipment demands a very high tracking density which is achieved in ‘multilayers’ or ‘multilayer boards (MLBs)’ where multiple conductive layers (cores) are separated by insulating layers called prepregs. A further development of this technique is the HDI (high density interconnect) board. [73, BSTSA,]

Processing is a complicated set of individual operations and will vary to produce any specific design of board. Over 40 activity stages may be used in the production of boards, although not all of them will be used for any one board design. Some activities are waterless, such as drilling. Many of these stages have little or no environmental impacts and are only described briefly in the following sections.

In general, the base materials are phenolic paper, epoxy paper or epoxy glass laminates. For special applications, ceramic materials, flexible or flex-rigid materials are used. The base material is clad with copper on one or both sides, with a thickness usually between 5 and 105 µm, depending on design requirements. Copper plating is ~~also~~ essential in printed circuit board manufacture. Metals other than copper may be occasionally used for specific applications, such as aerospace. Examples of the construction of PCBs are shown in Figure 2.27.

The cores are laminated with prepregs, with copper foil outer layers. The cores and the copper foil are patterned and processed in similar ways, and some stages may be repeated to complete a complex multilayer board.

[Note to the TWG: This part was updated with Section 2.5.12 in the existing BREF]



Single sided PCB
There is a primary image with tracks and pads on one side of the laminate only

Double sided non-pth PCB
(Note: pth = through-hole plated)
There is a primary image on each side of the laminate However, both patterns are not electrically connected to each other

Double sided pth PCB
Both patterns of the primary image which are separated by the laminate are electrically connected by a conducting copper deposit on the hole walls

Multilayer board (MLB)
In addition to the outer layers (layer 1 and layer 4) there are additional copper planes inside the laminate: these are the inner layers.
All layers may or may not be electrically connected by a conducting copper deposit on the hole walls by which they are connected to the copper plane

Figure 2-28: Examples of printed circuit board construction

Over 90 % of European production is made by a subtractive method, where copper is removed from the base layer to leave the conducting track. called a connect. Additive or semi-additive processes, which lay down a conductive track are not used often, and are not described.

The following Figure 2.28 shows the production steps involved in creating a typical multilayer board, as shown in Figure 2.35.

The overall process is complicated, with many of the steps being repeated.

The diagram shows first the ancillary operations essential to all PCB manufacture, such as production of the design and preparation of phototools.

The inner layers are created, assembled and the outer layers created around them.

Holes (called vias) may be:

- buried: not visible from the outside and drilled in the inner layers;
- blind: visible from one side only and drilled from the outside;
- visible and drilled right through.

The holes may be plated on the inside (known as through-hole plating, abbreviated to pth) to provide a connection between layers, see Figure 2.28. Non-plated holes are referred to as non-pth.

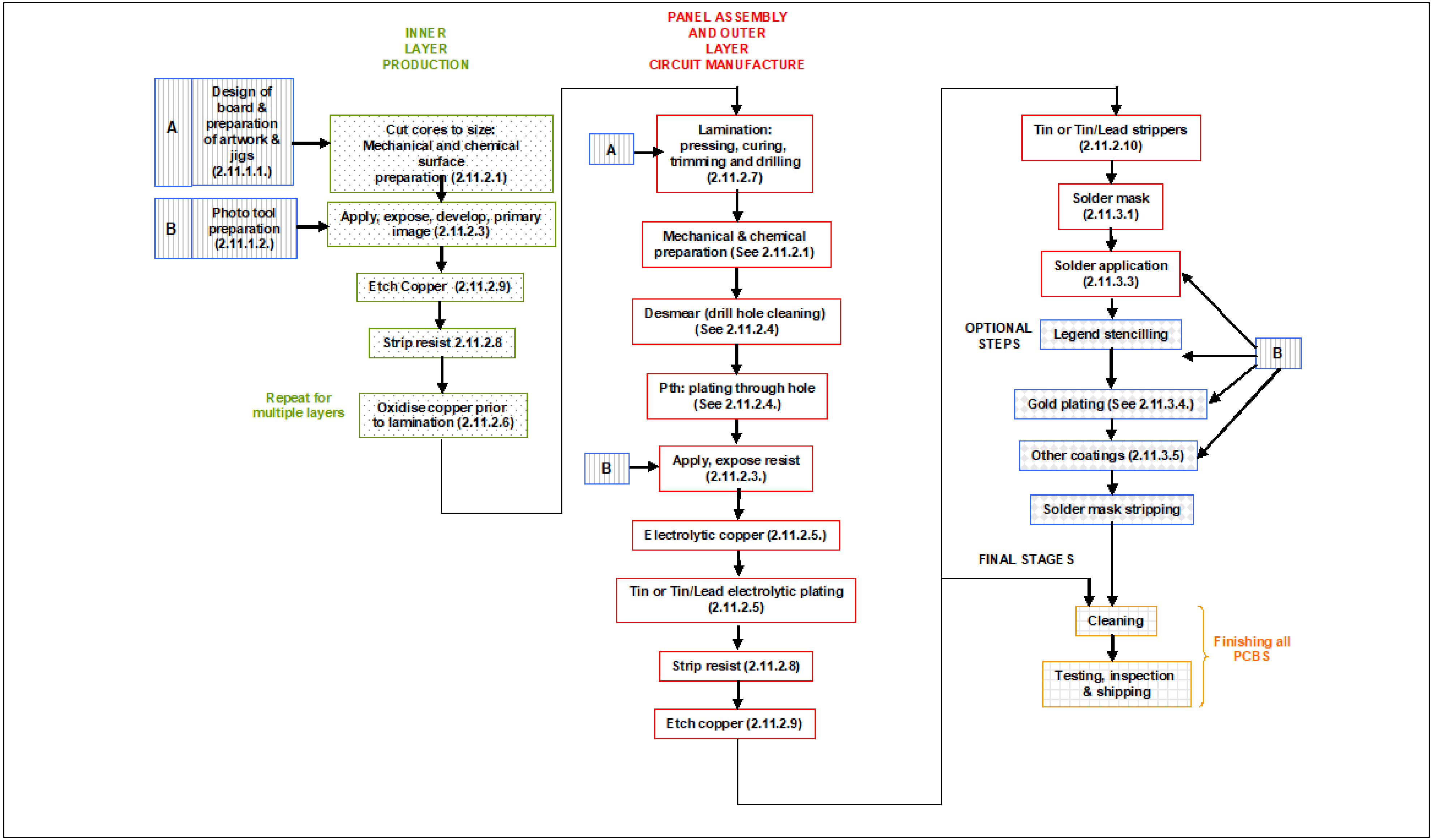


Figure 2-29: Flow diagram of typical printed circuit board production process sequence

2.6.1 Preparatory operations

2.6.1.1 Design of board

The printed circuit design is normally developed on CAD software, including reference marks such as locating holes for jigs to hold the board during the various processes such as drilling. The design is transferred to an artwork template called a phototool.

Environmental considerations
Removing large areas of copper slows production, wastes etchant and increases waste and copper concentration in effluents. Also, a PCB etches more consistently if all regions of the board have the same ration of copper to bare substrate. Therefore designs may widen connects, leave unconnected copper in place, or leave large areas of board covered with arrays of small, electrically isolated copper diamonds or squares [139, Wikipedia, 2004].

2.6.1.2 Generation of phototools (photo lab)

There are two ways of applying a design to a PCB: screen printing or photo-printing. Phototools are used in both processes and are made of polyester, or, for extremely high dimensional stability and accuracy, glass. The images are either dia positive (the tracking is shown as a positive image) or dia negative (the tracking is shown as a negative image). The phototools are coated with silver-halide emulsion produced by two techniques, although the photo technique or photo plotting have largely replaced screen printing technology.

Photo plotting uses laser plotters with high resolution to trace the design onto the film with an accuracy of up to 15 µm for trace and space. A development and fixation process follows in a continuous horizontal line.

Environmental considerations
To use as much of the raw laminate as possible, multiple sets of small designs are generated on the phototool by repeat processes. This will result in multiple images on each laminate panel processed.

Film generation: due to the silver content, revenues can be generated of wastes originating from films and developer solutions. Diazofilms, however, are disposed of, as they are not suited for recycling. Alternative processes, such as direct imaging, are ~~not commercially viable~~ already used in various installations across Europe [168, TWG, 2023].

When using the screen printing process sodium hydroxide solution, aldehydes, dispersions of polyvinyl alcohols, toluene and xylene may be discharged into the effluents.

2.6.1.3 Screen printing

Screen printing is based on the well-known printing technique [90, COM 2020]. An ink-permeable screen is stretched on a frame, degreased, rinsed and dried. A photo-sensitive emulsion based on a silver halide and polyvinyl alcohol/acetate is applied and dried. The film is cured with ammonium hydrogen dichromate. The image is applied and developed. If the screens are used again, they are cleaned by an oxidative cleaning process using stripping solutions such as enzymes, sodium hypochlorite, and periodate. Residues may be removed using toluene, xylene or butyl acetate.

Due to higher resolution requirements for the track pattern, the screen printing process is increasingly losing its importance against the photo printing process.

Environmental considerations
Wastes cannot be recovered.

Water-based effluents may be treated if necessary.

Solvents may be used in cleaning the screens.

2.6.2 Production steps

2.6.2.1 Mechanical and chemical preparation

Cut laminates to size
Prior to the application of the photoresist (see Section 2.11.2.3), the blank laminate has to be cut or punched to size and shape, and preliminary holes drilled for locating and initial contact through the board, see board design, Section 2.11.1.1.

The laminate is cleaned to remove the corroded copper surface. A pre-cleaning process provides a clean face for subsequent treatments (as in Section 2.3.4), but for PCBs a level surface is also essential for the high-accuracy circuitry. The cleaning processes are typically set up sequentially in horizontal continuous production lines.

Cleaning
The copper surface is initially cleaned with NaOH or a mixture of tensides and acids (H_3PO_4). This is followed by three further processes [159, TWG, 2004]:

- **Brushing**
  Brushing stations then roughen the board surface with roller brushes of bristles or non-woven abrasives under a water spray to wash away the abraded copper. Bristles can also be nickel silver or bronze. Problems caused by uneven wear can be overcome by oscillating rollers. The surface roughness should be between 1.5 and 2.5 µm. The subsequent adhesion of dry or liquid resists depends on the number of grooves and pores per surface unit.

  The surface is subsequently cleaned (usually on a conveyor system) by spraying in a rinsing cascade (see Section 4.7).

- **Abrasion**
  An inert pumice slurry (SiO_2 72.0 %, Al_2O_3 13.0 %, K_2O 4.2 %, Na_2O 3.5 % (unknown 7.3 %) is sprayed at high pressure to restructure the copper surface to a surface roughness of Rz = 1.6 to 1.9 µm, rather than to remove copper. Following this treatment the surface is rinsed under high pressure (10 bar) and subsequently dried.

- **Chemical roughening or microetching**
  This is spray etching using either copper chloride or a pickle of an acidic sodium persulphate, and for very thin inner cores, is the preferred method, as no mechanical damage of the cores should occur. The persulphate pickle consists of approximately 100 ml/l sulphuric acid and between 70 and 120 g/l sodium persulphate. During the microetch process, the copper value rises continuously. The performance of the etchant is reduced as soon as the concentration exceeds a value of approximately 30 g/l and the solution has to be prepared afresh. During a batch process, the concentrate is either precipitated as copper hydroxide slurry in an alkaline solution, pressed out and discarded as waste, or is recycled electrolytically.

The surface is rinsed in a cascade followed by a drying process.

Excess water is removed from the boards by squeegee rollers, and then residual humidity is evaporated by an almost pressureless preheated airflow.

Environmental considerations
The effluent from the rinsing cascade may be treated through an in-line neutralisation module prior to discharge.

Copper may be mechanically recovered by centrifuging or filtration, and this, coupled with cascade rinsing, can enable recycling of the waste water, and near-closed circuit operation of rinsing.

Where effluents are discharged, they can be treated in a typical waste water treatment plant. However, it is important to remove as much particulate copper as possible at source, as the copper can readily dissolve. If dissolved in acid solutions, it requires neutralisation, flocculation and precipitation; if complexed, it can be more difficult to treat (see Section 2.13.1.1).

Laminate and PCB wastes and off-cuts can be collected by specialist companies for recycling of the metals.

2.6.2.2 Drilling

In modern high density boards, holes are to be drilled as small as possible, often below 0.5 mm. NC controlled single spindle machines are used, but are increasingly replaced by the CNC/DNC controlled multi-spindle machines, as well as laser and the X-ray drilling machines used to generate very high hole densities for HDI technology.

Multi-spindle CNC drilling machines have table constructions which are extremely warp-resistant, relatively light and in addition fast to accelerate and to position. Spindles with air bearings can achieve more than 100000 rpm with individually controlled Z-axis modules.

Environmental considerations
The compressors and air drives produce noise, often at high frequencies. Modern drilling machines are usually contained in cabinets to reduce noise and maintain clean room working conditions.

Wear resistant tungsten carbide drill bits are breakage resistant, and can be resharpened, achieving high drill counts.

The swarf from drilling and routing is only generated in small quantities and cannot be recycled as the metal content is too low.

Entry boards made of aluminium which are commonly used and drills (for which resharpening no longer is possible) can be recycled 100 %. Drill-back boards are either disposed of or returned to the manufacturer. Dusts generated in drilling and routing operations with a remaining content of metals between 10 and 25 % are disposed of as wastes.

2.6.2.3 Generation of the primary image

There are two types of photoresist (or resist) used to produce the track image including the reference marks on the laminates from the phototools (see Figure 2.27):

- liquid resist applied by roller coating;
- dry resist applied by lamination.

Inner layers for MLBs may be either structured by screen printing or by dry resist (dry film). The pattern of the outer layers is generally structured by dry resist. In isolated cases, a third process, screen printing, may be used. For photo-printing the three process steps are coating (liquid or dry), exposure and developing. These process steps may be automated and conducted in a continuous process.

Coating

During the first step, the pretreated surface is coated with a photosensitive layer (photo resist) which is available either as liquid resist or as dry resist. For the coating, two different important processes are available: roller coating for liquid resists and lamination for dry resists. Table 2.3 shows the advantages and the disadvantages of both systems.

Table 2-3: Comparison of resist layer types for primary imaging

Process	Advantages	Disadvantages
Roller-coating (liquid resist)	Low film thickness (approximately 2- 12 µm)	Risk of pinhole formation
	Lower pollution in effluents due to lower material usage	Contain more than 50 % VOC-based solvents which may require reduction under Solvent Emissions Directive
	High yield from material used	Potential problems during ultrafiltration of effluents from developer and stripper
	Lower investment	Higher energy requirement
	Low under-etching of copper	Risk of involuntary bonding of inner layers
Lamination (dry resist)	Constant coating thickness because of dry film	Film thickness is generally 37.5 µm, more resist removed creating more effluents and resist waste
	No pinholes	Higher investment
	Low energy consumption as no drier is needed	
	No VOC emissions	
[122, UBA, 2003]		

- Roller coating (liquid resist). The liquid resist consists of acrylates, photo-initiators and fillers and is dispensed through a metering gap and spread under pressure by a corrugated rubber roller onto the surface of the laminate. Because of the corrugation of the roller, the contact pressure and the solid content of the liquid resist, the coating thickness is adjusted to a thickness of between 2 to 12 µm. The resist is continuously filtered and monitored in its viscosity while being circulated through a storage tank. The condition of the rollers is important as damaged rollers produce defective coatings. The inner layers are coated on both sides and then dried with on-line infrared driers. The conveyor speed is about 2 – 4 m/min with a high yield from the liquid resist. Material losses occur only during the cleaning of the equipment or when changing the resist.
- Lamination (dry resist) (Figure 2.30). Dry resists are structured in several layers. In clean room conditions with only yellow light, the photo sensible emulsion is applied by curtain coating on a polyester carrier foil of 25 µm thickness, dried and covered with a polyethylene protective layer. This sandwich can be rolled onto a paper or a plastic roll core from which it is laminated to the surface of the inner layer. Either manual or fully automatic laminators are used, the centre core of which is the roller system. Principal factors influencing the process are: laminating rollers with an aluminium core to maintain dimensional stability, temperature, contact pressure, waviness of the laminate surface, laminating speed and the pretreatment method of the copper surface.

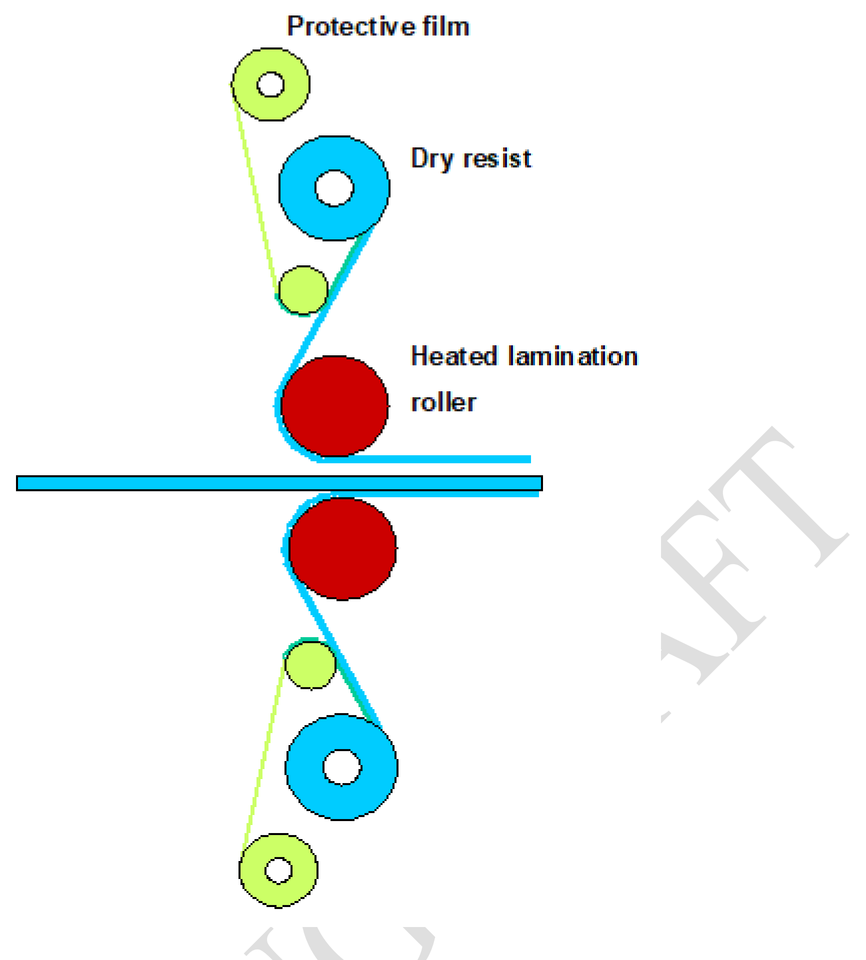
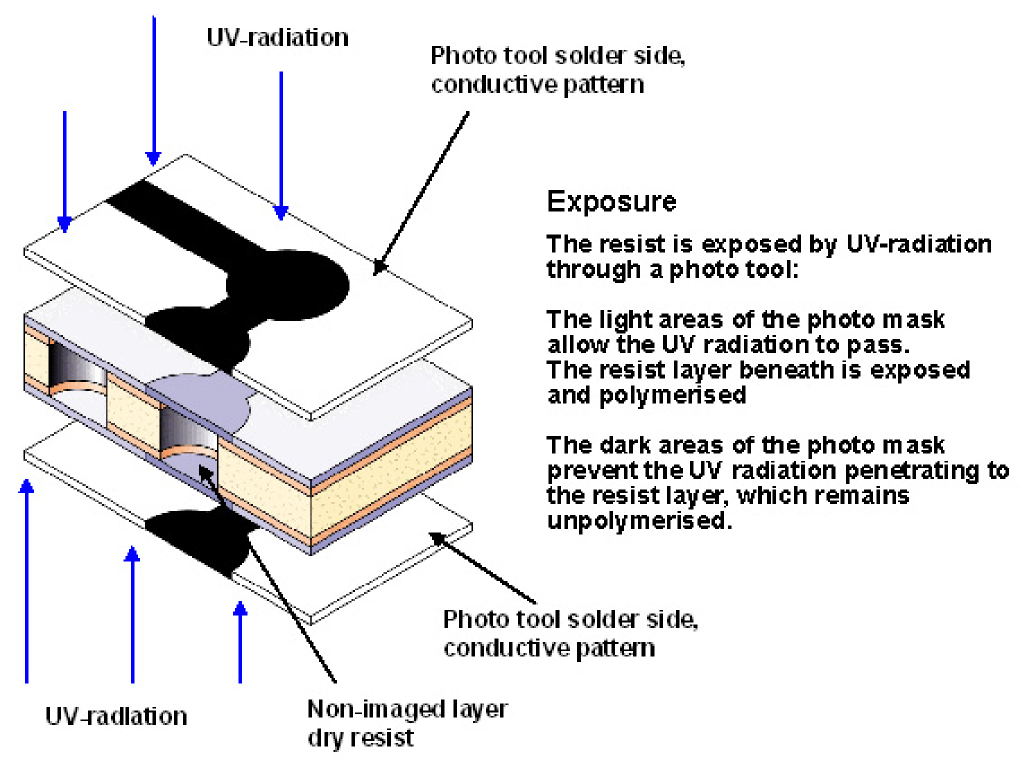


Figure 2-30: Application of dry resist

Exposure
The image is photo-printed onto either type of photoresist– either manually or automatically- in imaging equipment in clean rooms under amber light conditions. In Figure 2.30, the phototool (see Section 2.11.2.3) is exposed to UV light which passes through the transparent areas of the phototool, and polymerises the monomer components of the resist by cross-linking. The resulting polymer is resistant to the following development process.



Exposure

The resist is exposed by UV-radiation
through a photo tool:

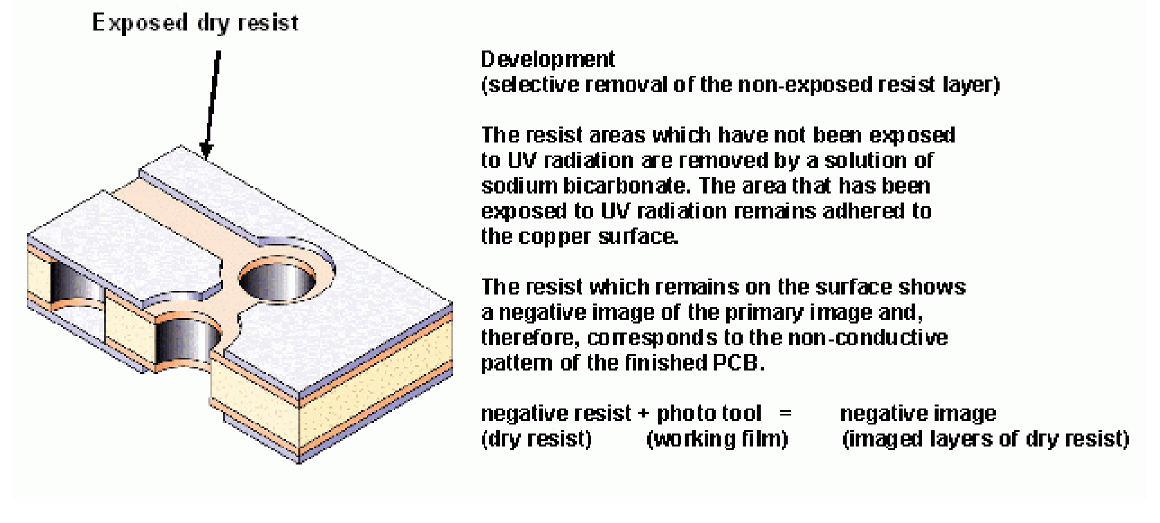
The light areas of the photo mask
allow the UV radiation to pass.
The resist layer beneath is exposed
and polymerised

The dark areas of the photo mask
prevent the UV radiation penetrating to
the resist layer, which remains
unpolymerised.

Figure 2-31: Exposure of resist

Developing

The laminate (resist) is developed by spraying with a sodium carbonate solution while passing along horizontal continuous line. This step exposes the final track pattern (tracks, pads with holes, pads for SMDs (surface mount device) and ground planes for the following process (Figure 2.32).



Development
(selective removal of the non-exposed resist layer)

The resist areas which have not been exposed
to UV radiation are removed by a solution of
sodium bicarbonate. The area that has been
exposed to UV radiation remains adhered to
the copper surface.

The resist which remains on the surface shows
a negative image of the primary image and,
therefore, corresponds to the non-conductive
pattern of the finished PCB.

negative resist + photo tool = negative image
(dry resist) (working film) (imaged layers of dry resist)

Figure 2-32: Development of resist

The typical development line consists of the main development chamber, followed by a smaller chamber(s) with fresh sodium carbonate supply. This enables the panel surface to be rinsed with clean development solution, reducing the drag-out of contaminated solution into the following fresh water rinsing zone. The development chamber may be equipped for the first 60 % with cone nozzles and for the remainder with fan jet nozzles. The manifolds are equipped with an oscillation to bridge the mechanical effect of the spray nozzles and a better exchange of solution. The fan jet nozzles are to be installed at an angle of approximately 30- 40° transverse to the direction of the process. In case of multiple nozzle bars, these may be installed against each other.

Screen printing process
In isolated cases non-pth PCBs are still manufactured using screen printing technology. The copper surface of the panel is coated with a special ink applied through a screen, described in Section 2.11.1.3. The exposed copper surfaces will be removed during the following etching process. The pattern is finished; although further processing with solder mask can follow (see Section 2.11.2.11). Screen printing inks may be removed either by solvents or sodium hydroxide solution.

Environmental considerations
Table 2.3 sets out the advantages and disadvantages of the two layer coating techniques.

Liquid resists contains more than 50 % solvents that evaporate causing VOC emissions, which may require reduction by the Solvent Emission Directive [97, EC, 1999, TWG, 2004 #159].

The exposure stage generates no waste or waste water. Cooling water can be recirculated. The development stage can use successive static rinses of developer to reduce drag-out, and use of fresh rinsing water (see Section 4.7).

Removed resist can be filtered from the effluent from the developer stage.

Screen printing inks that have to be removed (stripped) by halogenated solvents can now be substituted by alternatives.

Process tanks are usually equipped with fume extraction and scrubbing to remove generated aerosols.

Waste water s may need treatment including neutralisation and settlement.

Packing and protection of dry resists generates significant volumes of waste. Different types of plastic are used, making separation and return difficult. Some material may be separated and returned for recycling. Due to the elaborate packing requirements, a return to the suppliers is generally not possible. It is possible to minimise the incurring wastes by using liquid resists for inner layers.

2.6.2.4 Plating through holes (pth, through hole plating)

Plating through the holes provides electrically conductive connections between the conductor tracking planes on both sides of a double sided board or between the multiple tracking planes of MLBs. There are usually three stages, desmearing, activation and electroless (autocatalytic) copper plating. However, there is a tendency to replace autocatalytic copper by direct plating (see environmental considerations at the end of this section).

Note: do not confuse this process with through hole construction, which is a type of PCB construction where the wires of components are placed through holes drilled through the board. This has now largely been superseded by surface mounted components.

Desmearing- removal of the smear film
The high drilling and advance speeds cause the drill bits to heat up, causing the drilled polymer residues to smear as films in the barrel of the holes. It is essential to remove these residues or

there will be poor adhesion of the metal layer to be deposited. Remaining residues may also lead to later problems by vaporising during the soldering process (out-gassing).

The desmear process is best accomplished by using either potassium or sodium permanganate in several working steps:

- degreasing with phosphoric acid;
- deburring with abrasive rollers;
- swelling with sodium hydroxide, butyl diglycol and additives;
- permanganate process with permanganate and sodium hydroxide;
- cleaning process with hydrogen peroxide to prevent undesirable reoxidation.

The etch-back process using concentrated sulphuric acid (96 %) is being superseded by the permanganate process.

A plasma etch process exists but is rarely used.

Table 2-4: Comparison of desmearing processes

	Process		
	Desmear (frequently used)	**Etch-back (less frequently used)**	**Plasma (rarely used)**
Equipment used	Horizontal in-line module	Horizontal in-line module	Vacuum chamber
Operation	Continuous	Continuous	Batch process
Medium	Potassium permanganate, alkaline	Sulphuric acid (96 %)	O_2/F_2/HF/Freon
Reaction type	Oxidising	Resin-solvent, sulphonating	Radical reaction
Residues	Potassium permanganate	Dissolved resin (sludge)	Fluorinated surface ‘ash’
Speed of action	Fast	Fast	Medium to slow
Number of process steps	3 – 4	2	2 – 3
Effect on adhesion glass fibre/resin	None	Strong	Medium
Suitable for	Epoxy	Epoxy	Polyacrylates, polyester, epoxy
Adhesion of low built copper	Good	Satisfactory	Adequate
Adhesion of high built copper	Satisfactory	Inadequate	Problematic
[122, UBA, 2003]			

Environmental considerations
Table 2.4 compares the processes and residues.

Activation and electroless (autocatalytic) copper plating
See Section 2.5.8.

Direct plating
In direct plating, a conductive polymer layer is applied instead of a copper layer. The usual processes are based on either polymer-carbon or palladium deposition.

The following list shows the sequence and conditions of one of the possible processes (DMSE, direct metallisation system evaluation):

- DMSE conditioner 60 °C, 3 to 5 ml/l

rinsing	ambient temperature	
oxidative conditioning ($KMnO_4$, NaOH)	90 °C	50 g/l of each
catalysing (catalyst DMSE)	20 °C	65 %
fixing (H_2SO_4)	20 °C	100 g/l
drying	high temperature.	

During the first process steps (conditioning with subsequent oxidation with potassium permanganate) manganese dioxide is formed. Manganese dioxide reacts with a monomer compound (a thiophene derivate) during catalysis. In the fixing bath, the sulphuric acid causes the monomer compound and manganese dioxide to react to form a conductive polymer layer. This layer serves as a conductive layer during the subsequent electrolytic copper plating process.

Environmental considerations
Autocatalytic copper baths have a limited lifetime before they require complete replacement. Disposal of the baths is difficult (see Section 2.5.8). They are difficult to use, inherently unstable and use formaldehyde and complexing agents including EDTA, which are carried over in waste waters. While autocatalytic copper, especially with EDTA, was being replaced by ‘direct plating’, the high technical standards required for modern HDIs has lead to a resurgence in the use both of the autocatalytic process and the use of EDTA. However, the use of direct plating is increasing again, and about 60 % of the autocatalytic copper baths have been replaced by direct plating [122, UBA, 2003].

Desmearing has used chromium salts. However, they can now be substituted with potassium or sodium permanganate (see the direct plating process description in the paragraph above).

The direct plating baths containing complexing agents have to be batch treated or segregated and treated separately. Rinse-waters containing palladium are treated to extract the metal. The rinsing water can be countercurrent cascade (see rinsing, Section 4.7). After dealing with the complexing agents, effluent may treated in a typical waste water treatment plant. The hydroxide sludge may be recycled as it has a high metals content (see Section 4.17).

2.6.2.5 Electroplating of conductive pattern

Following the structuring process of the primary image, electroplating processes are used for:

- build-up (increasing of layer thickness) of conducting structures (primary image);
- protection of a copper surface against the etching medium (etch resist);
- plating of contact fingers with precious metals.

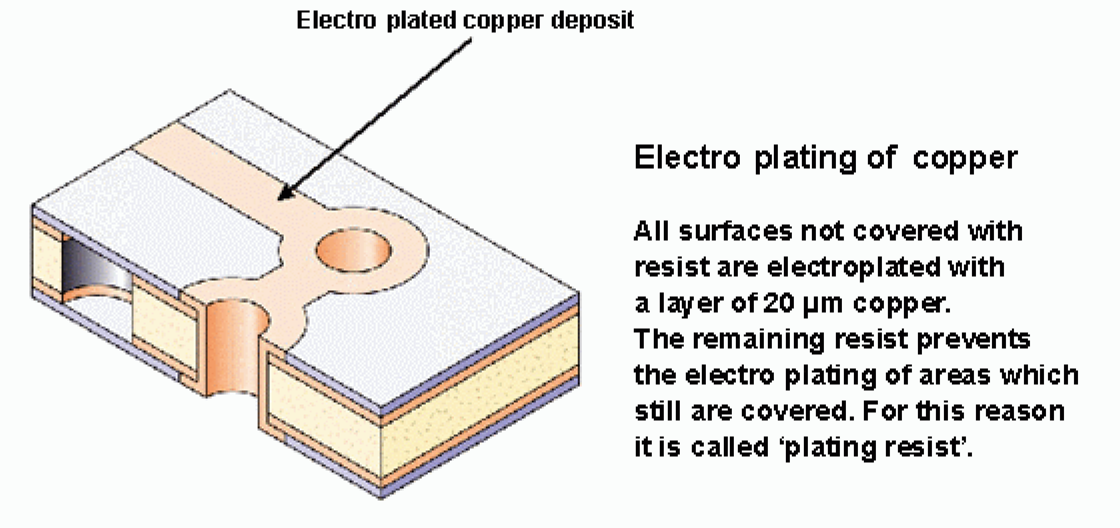


Figure 2-33: Copper electroplating

Pre-cleaning, deoxidation and acid

The panels that so far have been processed either by screen or by photo printing are now treated to eliminate any residues of grease, finger prints, etc.(see Section 2.3) They are first pre-cleaned in acidic, in alkaline or in neutral solutions. The open copper surface (conductive pattern) is then deoxidised either with sodium persulphate solutions or sulphuric acid/hydrogen peroxide solutions. Between 0.5 and 1 µm copper are removed. The copper surface is finally acid dipped to provide a freshly activated surface for plating.

Electrolytic deposition of copper

Generally, the primary image is built up by a minimum of 20 µm on top of the base copper surface where the surface is not protected by the plating resist, see Figure 2.33 (proportionately less within the barrel of the holes). For details, see Section 2.5.1

[Note to the TWG: The part below was moved from Sections 2.5.12 and 2.5.8.3 in the existing BREF]

An important technical application of acid copper electrolytes is for through-hole, panel and pattern plating of printed circuit boards and multilayers. Sulphuric acid enhances the conductivity, the macro-throwing power and provides fine crystalline and ductile layers. In such electrolytes, the concentration of sulphuric acid is in the range of 180 – 200 g/l and the copper concentration is 20 g/l. Pyrophosphate electrolytes can also be used for through-hole and panel plating of printed circuit boards and multi layers, but are currently substituted mainly by acid copper electrolytes.

Autocatalytic copper plating is still a key process in printed circuit boards. High purity deposits, usually only of gold, silver and tin, are also widely used on printed circuit boards. Thickness does not exceed 0.1 – 0.2 µm. [121, France, 2003]

For printed circuit boards, the environmental considerations for gold and silver are as for tin [73, BSTSA,] (see Sections 2.5.6 and 2.5.7) Tin concentrations are low, and are treated in a typical waste water treatment plant.

Etch resist – tin electroplating

In order to protect the electroplated primary image against the attack of etching media the copper surface is covered with a tin layer (Figure 2.34), described in Section 2.5.6.

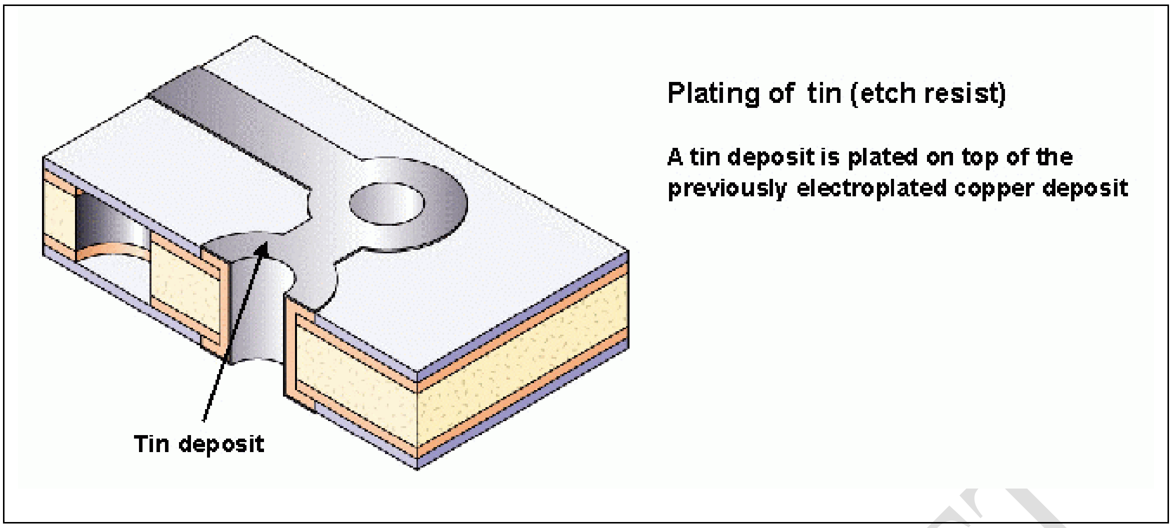


Figure 2-34: Tin electroplating

Electroplating with gold or other precious metals
Contact fingers for plug connectors are frequently gold plated. In rare cases, they are finished with rhodium, ruthenium or palladium. See Section 2.5.7.

Environmental considerations
Electrolytes for etch resists were generally based on lead- and tin fluoroborate solutions. Several Directives restrict the use of lead in products, and by 1 July 2006 lead additives in electroplating baths for PCB production will removed to use 100 % tin depositions. (The Directives are:

- the End-of-Life Vehicles (ELV) Directive [99, EC, 2000];
- the Waste Electrical and Electronic Equipment (WEEE) Directive [96, EC, 2003]; and
- the Directive on the Restriction and Use of Certain Hazardous Substances in Electrical and Electronic Equipment (ROHS Directive) [98, EC, 2003]).

In order to satisfy customer requirements for niche products (reflow boards) with 10 µm deposits of tin/lead (60/40 %) electrolytes are still used, but with reduced lead content.

The manufacturers of PCBs and their chemical suppliers are in a position to change to lead-free electrolytes rapidly.

Chemical coppering may be replaced by palladium, graphite or conducting copolymers, which are so-called ‘clean technology’ techniques.

To prevent deterioration of the workplace atmosphere, process tanks may be equipped with fume extraction to remove generated aerosols.

Effluents may require treatment in a waste water treatment plant. These treatments include filtering, neutralisation and settlement.

2.6.2.6 Inner layer bonding adhesion

Oxide processes have been commonly used and are described below. However, other processes are now emerging (sometimes referred to as oxide alternative treatments). One type creates a copper azole complex at the surface. Developments of these processes are rapid and driven by ever-increasing higher technical requirements [159, TWG, 2004].

The copper surface on inner layers is oxidised to Cu(I) to improve the adhesion between cores and prepregs and to prevent subsequent delamination (separation of multilayer boards). The oxide layer of 0.5 – 5 µm is formed by one of two processes:

- the brown oxide process is most commonly used and consists of hydrogen peroxide, organic additives (for passivation) and chloride (in mg quantities only), running at 30 °C;
- the black oxide process is carried out in a solution of sodium phosphate (Na_3PO_4), sodium hydroxide ($NaOH$), and sodium chlorate ($NaClO_2$) or hypochlorite ($NaOCl$) at 80 °C.

Effluents can be minimised by ensuring the concentration of the individual components is maintained by additions equalling the evaporation rate.

Thorough rinsing is necessary after the process (see Section 2.4).

Environmental considerations
The brown oxide process is increasingly used as it runs at lower temperatures and does not use chlorate or hypochlorite.

The process may need air extraction.

Effluents can be minimised (see above) and treated in a typical waste water treatment plant.

A new bath is made up at approximately 24 months intervals, and can be discarded after batch treatment by alkaline precipitation.

Oxide alternative treatments reduce consumptions of chemicals and water and generation of waste.

2.6.2.7 Lamination

Both the laminates and the insulating layers (the prepregs) have to be bonded strongly and using oxidised copper surfaces (see Section 2.11.2.6) prevents delamination of the finished board. The pre-oxidised cores of the multilayer are laminated with bonding sheets (prepregs) and copper foils (outer layers), see Figure 2.35.

The prepregs are shaped sheets of pre-polymerised epoxy resin reinforced with glass fibre. They liquefy under the influence of pressure and temperature and bond with the inner cores.

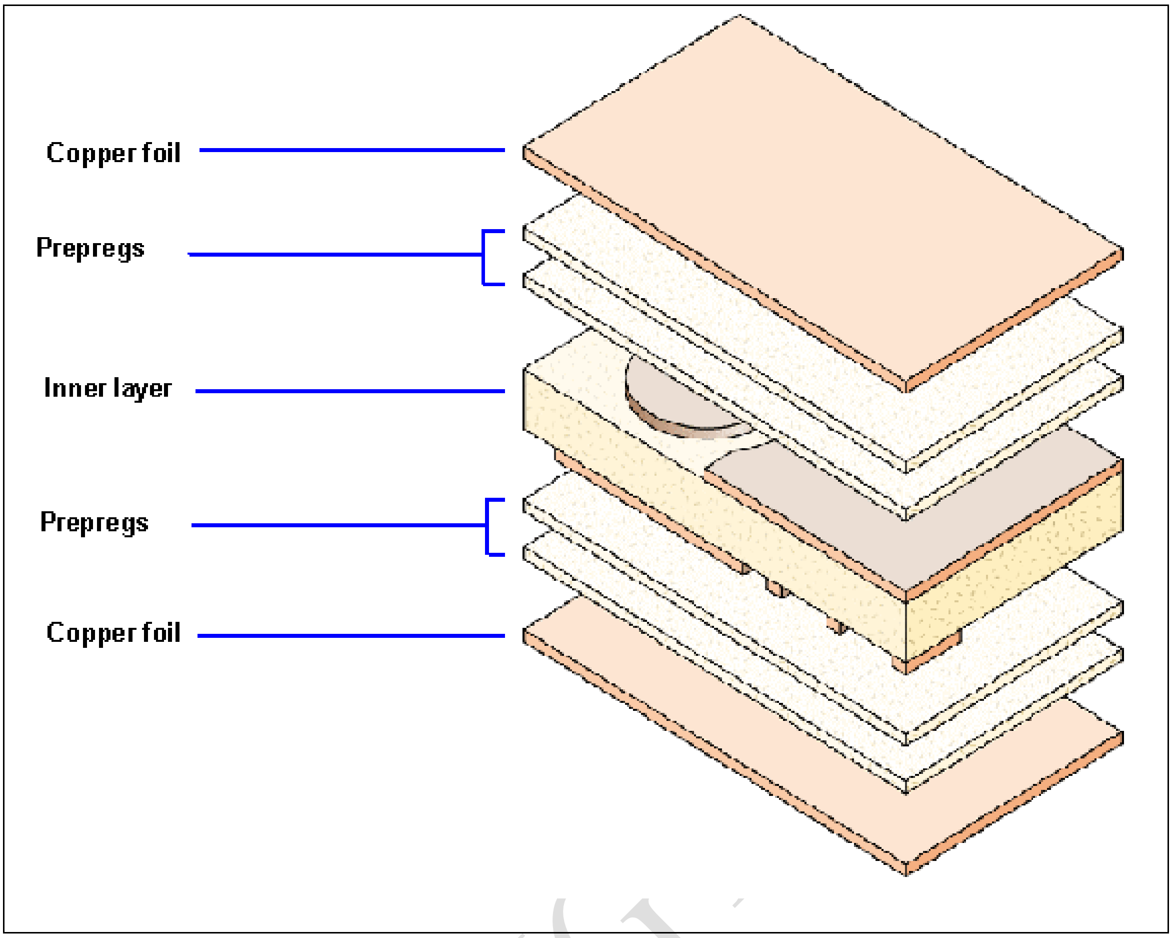


Figure 2-35: Schematic of a multilayer board

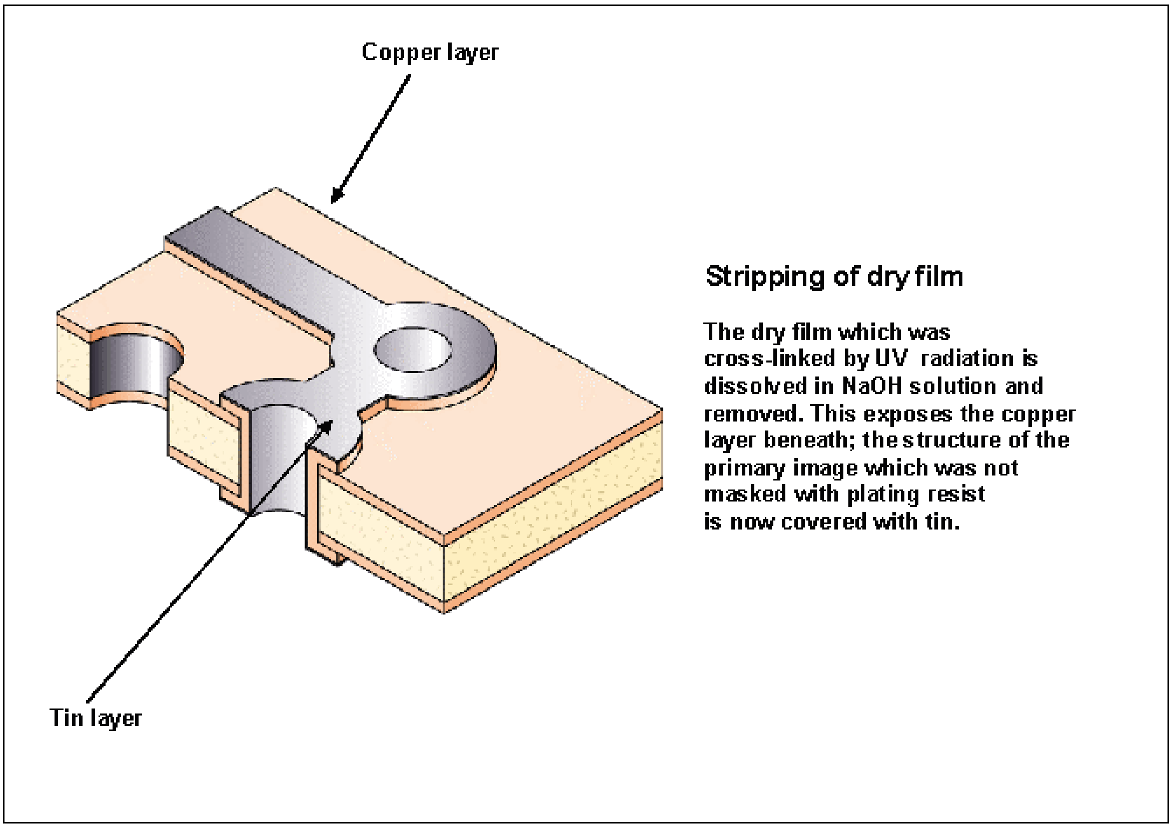
The principal working steps for the lamination process are:

- lay up (registration) in the lay-up station;
- lamination in a vacuum press;
- destacking of the lamination tool;
- trimming of the flash on the rim of the MLB.

Environmental considerations
Offcuts from laminating and trimming can be recycled to recover the metals via specialist companies.

2.6.2.8 Resist stripping

After electroplating, the photoresist film has served its purpose of defining the circuit image and is, therefore, completely removed from the board surfaces (Figure 2.36).



Stripping of dry film

The dry film which was cross-linked by UV radiation is dissolved in NaOH solution and removed. This exposes the copper layer beneath; the structure of the primary image which was not masked with plating resist is now covered with tin.

Figure 2-36: Stripping of dry film

Resist strippers are designed to strip fully both aqueous dry film and liquid photoresists. The resist strippers have been formulated in order to remove the resist rapidly without attacking the copper or the tin/tin-lead. Controlled swell characteristics minimise lock in between fine tracks.

• typical operating temperature	30 °C [159, TWG, 2004];
• dwell time approximately	60-120 seconds;
• solution	dilute alkali (NaOH or KOH 10- 20 g/l) with organic additives such as butyl glycol or butyl diglycol, although in Germany systems are often run without organic additives [159, TWG, 2004].

Environmental considerations
Copper emissions, and COD from the soluble organic additives.

The stripper breaks down the film into large particles, which are easily removed from the effluent by filtration. The effluent may be concentrated using filtration and evaporation, with distillate being sent to waste water treatment (for COD) and concentrate being managed as a hazardous waste.

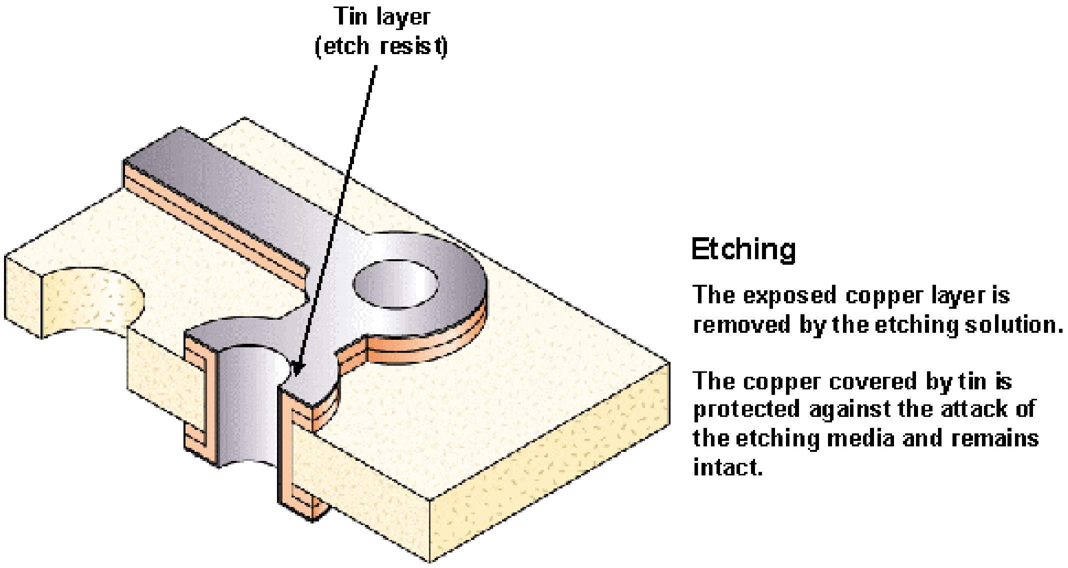
To prevent deterioration of the workplace atmosphere, process tanks may be equipped with fume extraction to remove generated aerosols.

Waste waters may require treatment in a treatment plant. These treatments include filtering, neutralisation and settlement.

2.6.2.9 Etching

Etching is undertaken to completely remove the base copper thus leaving only the circuit pattern which is protected by the tin/tin-lead deposit (etch resist), see Figure 2.37. Typically, modern etchants will remove copper at 5 to 50 microns per minute at 50 °C.

The type of etchant used, the equipment in which it is used and the rate of etch is of great importance, as they all influence the amount of undercut that occurs. The undercut is where copper is dissolved from beneath the metal etch resist, producing an overhang of the metal resist.



Etching

The exposed copper layer is removed by the etching solution.

The copper covered by tin is protected against the attack of the etching media and remains intact.

Figure 2-37: Etching

The following etchants are in use:

- A~~a~~mmoniacal etchants: ammonium salts (chloride, sulphate, carbonate): PCBs that have been made resistant by deposited metals, i.e. tin (metal-resist technology) are almost exclusively used in this process, and it is frequently used. Atmospheric oxygen acts as an oxidising agent.
- A~~a~~cidic etchants: copper(II) chloride solution used as a starter solution (approximately 30 g/l Cu), attacks metallic copper in the presence of HCl and forms copper (I) chloride (CuCl). In the presence of hydrochloric acid (200 – 240 mg/l) and hydrogen peroxide, the inactive copper (I) is oxidised to copper (II). It is used for inner layer etching, single-sided, double-sided and multilayer non-pth boards.
- H~~h~~ydrogen peroxide/sulphuric acid are used for micro-etching and as a replacement for persulphate sulphuric acid.
- A~~a~~cidic, ferric chloride ($FeCl_3$) is now rarely used.

Etching is performed predominantly in horizontal in-line installations. Those PCBs that have been made resistant by deposited metals, i.e. tin (metal-resist technology), subsequently are almost exclusively processed in ammoniacal etchants. The bases are ammonia compounds like ammonium chloride, ammonium sulphate and ammo-nium carbonate. Aerial oxygen serves as oxidation agent. The etching solution has the following parameters [159, TWG, 2004]:

- pH:	8.0- 9.5;
- temperature:	20- 45 °C;
- copper:	145- 170 g/l;
- halide:	235- 265 g/l; content of chloride 4 – 4.5 mol/l;
- redox potential:	about 600 mV.

Ventilation is likely to be required to remove ammonia and achieve a comfortable work environment, as well as meeting health and safety requirements. A controlled balance is necessary. Excessive ventilation will reduce pH and ammonia levels; insufficient ventilation will allow excessive fumes and an increase in pH and ammonia. Ideally, the ventilation should be dedicated to the etch line only.

Environmental considerations
Processes are available to recover significant amounts of copper and minimise etchant top up as well as storage and transport of hazardous solutions.

Where ammonia etchant is used, process tanks may be equipped with fume extraction to remove generated aerosols and fumes to maintain the workplace atmosphere within health and safety levels. Fume extraction may require scrubbing, which will increase ammonia levels in the effluent.

Effluents may require separate treatment prior to a typical waste water treatment plant, depending on etchant chemistry.

Etching solutions are generally returned to suppliers or external companies for processing. This involves exchanging used bath solutions for new ones, with handling and storage. Internal reprocessing may be possible with additional recycling modules.

Acidic etching solutions: generated concentrates in the acidic etching process (hydrochloric acid, copper chloride and hydrogen peroxide) are recycled by external suppliers or contractors. By optimum management of all parameters and by enriching the copper, these wastes can be sold. The regenerated hydrochloric acid can be re-used in the process. Other methods of recycling have not proven to be successful.

Ammonia etching solutions: processes are available to recover significant amounts of copper and minimise etchant top-up as well as storage and transport of hazardous solutions, see Section 4.15.7.

2.6.2.10 Tin stripping

This process is now typically undertaken in a horizontal mode as a two-stage tin lead stripping technique. The first stage strips to the intermetallic layer, then the second stage strips the intermetallic layer thus leaving a blemish-free copper surface. Hydrogen tetrafluoroborate, tin fluoroborate or nitric acid solutions are used:

- stage 1: temperature and immersion time 25 – 35 °C for 20 – 60 seconds;
- stage 2: temperature and immersion time 25 – 35 °C for 10 – 30 seconds.

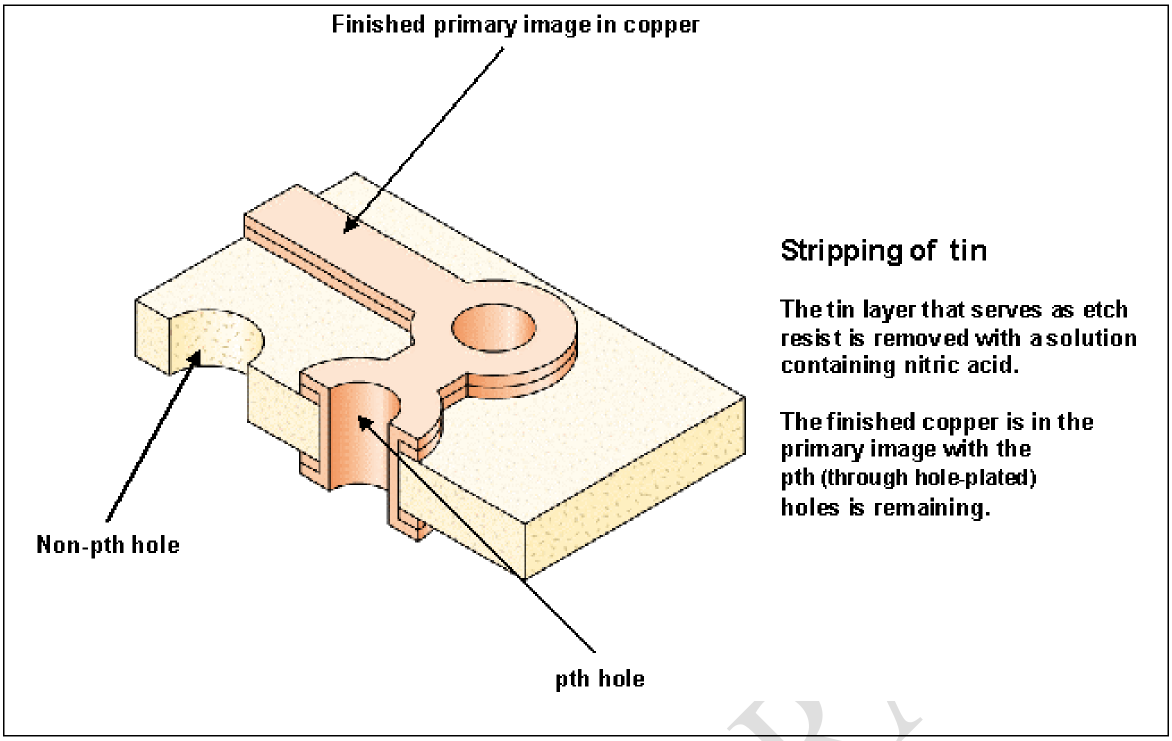


Figure 2-38: Stripping of tin resist

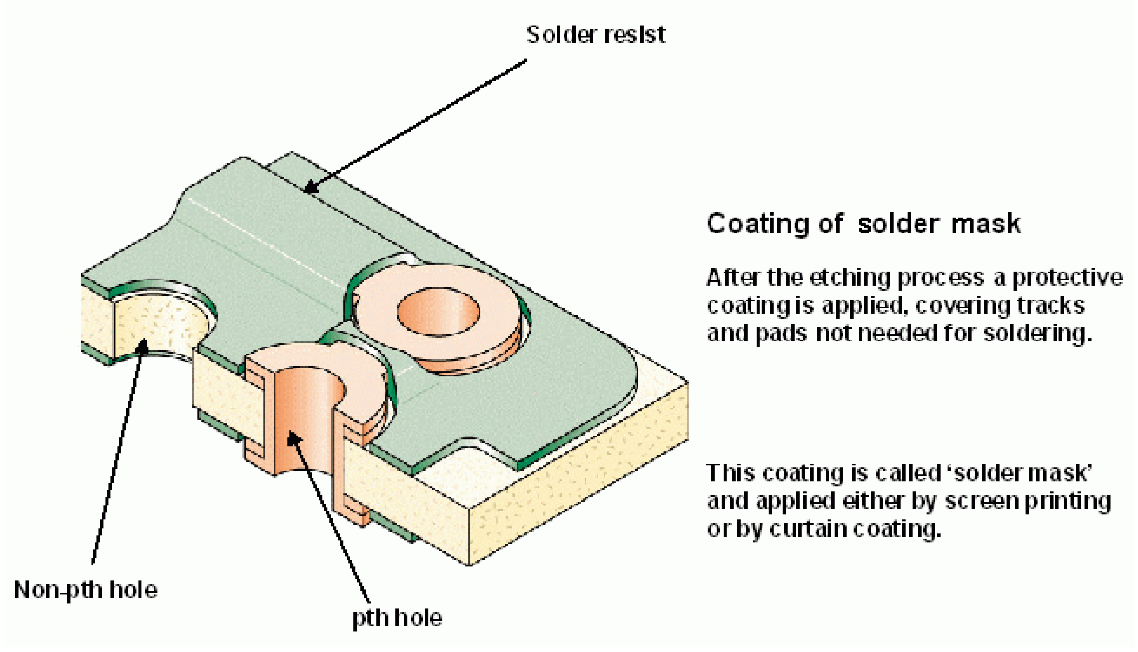
Environmental considerations
To prevent deterioration of the workplace atmosphere, process tanks may be equipped with fume extraction to remove generated aerosols.

Waste waters may require treatment in a treatment plant. These treatments include filtering, neutralisation and settlement. Internal reprocessing has not proven effective for the quantity of metal recovered.

2.6.2.11 Application of solder mask

After the stripping of the etch resist, the unprotected copper surfaces on the PCBs needs protection from corrosion, and from solder bridging (solder making unwanted connections between tracks) during the soldering process when components are added to the board. All copper portions which are not required in the assembly process are covered with an insulating resin matrix (see Figure 2.39 and Figure 2.40). Several methods are available, the most important ones being screen printing and curtain coating.

Screen printing is described in Section 2.11.1.3. The difference here is that a solder mask is applied. However, this technique is not normally used for high volume production.



Coating of solder mask

After the etching process a protective coating is applied, covering tracks and pads not needed for soldering.

This coating is called 'solder mask' and applied either by screen printing or by curtain coating.

Figure 2-39: Coating with solder mask

Curtain coating is more efficient and used for high production volumes. The panels are passed on a horizontal belt (at approximately 20 m/min) through a curtain of solder mask. After it is tack cured it is exposed through a photo stencil (similarly to etch resist, see Section 2.11.2.5). As in developing etch resist, the non-exposed surfaces are selectively stripped in a developer solution of sodium carbonate or ethyl glycol: aqueous alkaline masks are increasingly used. The panels are then rinsed, dried and cured in line, see Figure 2.39.

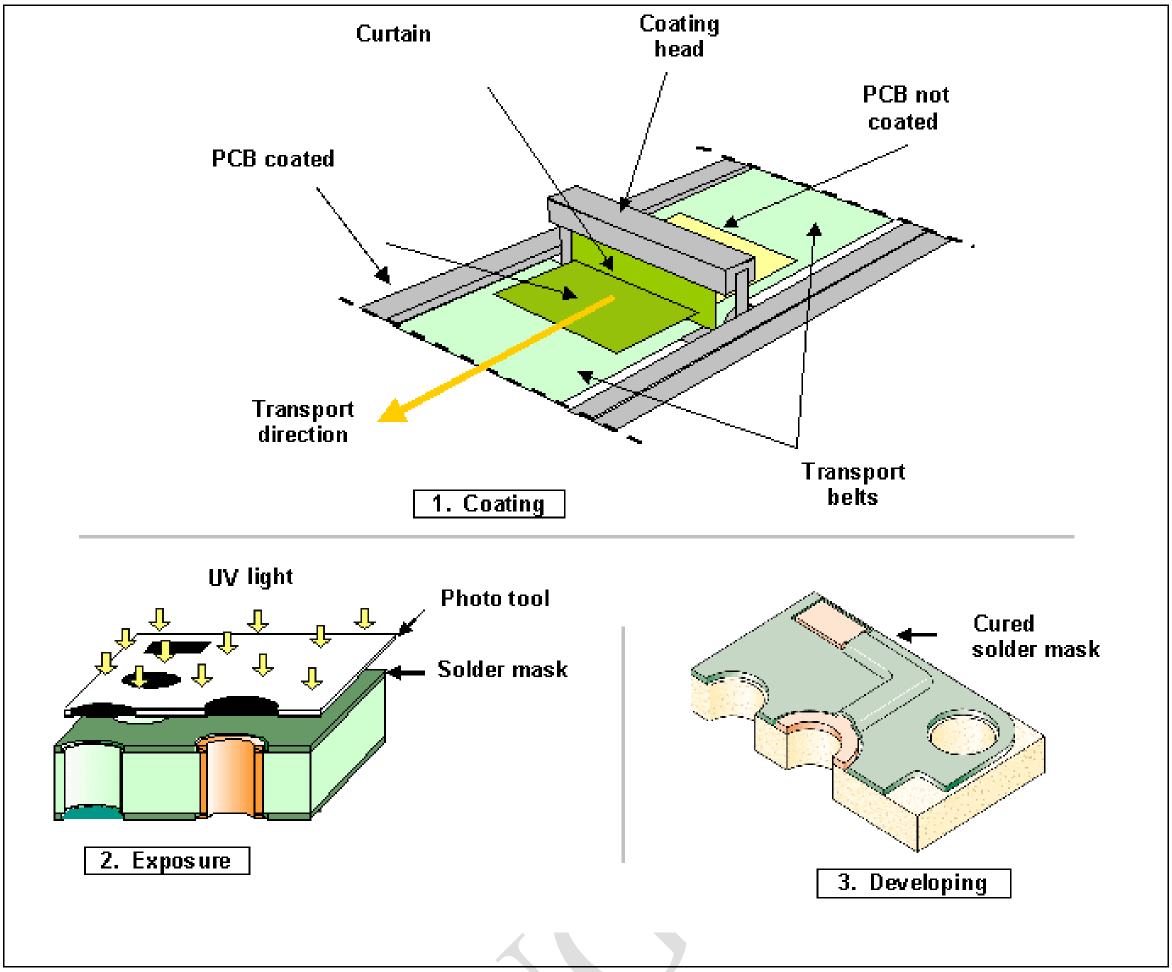


Figure 2-40: Curtain application by and curing of solder mask

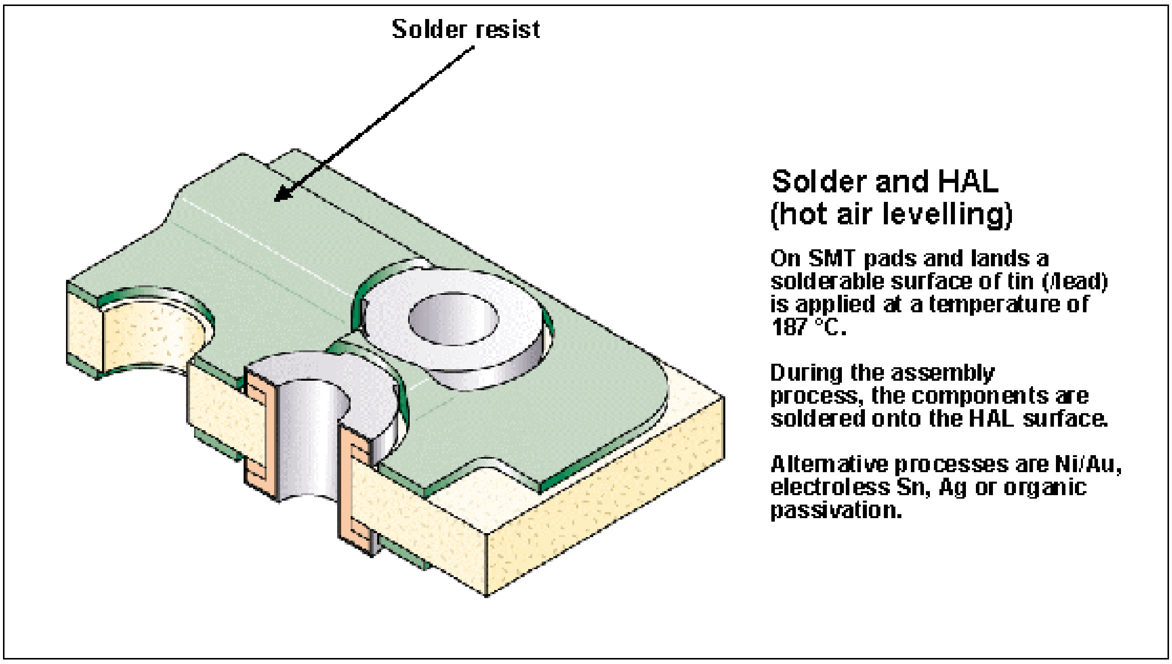
Environmental considerations

Residues originating from developing photosensitive inks and masks are disposed of. The containers in which lacquers have been supplied may still have residues of their contents after emptying. These containers may be collected for recycling.

2.6.3 Additional surface finishing activities

There are several surface finishes: Hot Air Solder Level (HASL), Organic Solderability Preservative (OSP), Electroless Nickel Immersion Gold (ENIG), Immersion Silver (ImmAg), Immersion Tin (ImmSn), Reflowed Tin/Lead, Electrolytic Nickel Gold, and Electroless Palladium. Some of these are described below and in Sections 2.2.1.8 and 2.2.2.2. The selection of which steps are applied depends on specifications and subsequent process requirements.. As this industry develops rapidly, further information can be found on industry websites. [159, TWG, 2004].

The application of a solder mask leaves areas (called pads and lands) for the surface mounting of components. These surfaces need protecting, usually by Ni/Au, if the soldering of components is not carried out immediately.



Solder and HAL
(hot air levelling)

On SMT pads and lands a solderable surface of tin (/lead) is applied at a temperature of 187 °C.

During the assembly process, the components are soldered onto the HAL surface.

Alternative processes are Ni/Au, electroless Sn, Ag or organic passivation.

Figure 2-41: Hot air levelling

2.6.3.1 Solder application

This is also called Hot Air Leveling (HAL) or Hot Air Solder Leveling (HASL). After pre-cleaning (degreasing, deoxidation and drying), the boards are immersed in a flux (rosin) bath, followed by dipping in a eutectic tin-lead bath at approximately 240 °C. The molten tin-lead is blown out of the holes under high pressure. This hot air knife levels the tin-lead deposit, with a thickness of about 1 – 25 µm., as in Figure 2.41. The boards are rinsed and dried.

Environmental considerations
Rinsing produces effluents containing thermally cracked fluxes and therefore has a chemical oxygen demand.

Fume extraction may be required.

The replacement of tin-lead solder used in the HAL process will be finalised by 1 July 2006 to meet the requirements of the ELV Directive [99, EC, 2000] and the ROHS Directive [98, EC, 2003]. Alternatives are either lead-free solders or electroless plating of tin, nickel/gold or organic substances, which protect the metallic copper of tracks and holes from dirt and oxidation and maintain their solderability.

The resulting dross and solder has a commercial value and is returned to the suppliers for external processing.

2.6.3.2 Nickel gold and/or tin

After surface preparation, a layer of electroless nickel is applied (see Section 2.5.8), followed by an immersion gold coating (see Section 2.5.9) [159, TWG, 2004].

Environmental considerations
Precious metals can be recovered.

2.6.3.3 Organic passivation

Organic passivations are increasingly used on horizontal moving lines. A protective layer of 0.2 – 0.3 µm is deposited out of a solution of acetic acid, imidazole derivates and ammonium compounds. This layer is removed by a flux immediately prior to the soldering process.

Environmental considerations
Rinsing waters and concentrates can be treated in a waste water treatment plant. Prior separation and/or treatment may be required to prevent complexes being formed with metals.

2.6.3.4 Other activities – Stripping (de-metallising) racks and plating baskets

The plating racks and plating baskets must be regularly stripped of metal build-up (see Section 2.3.9). Carriers used in electroless copper plating are usually stripped in sodium persulphate solutions. Metal carriers which have been electroplated with copper and tin are stripped chemically, very often with nitric acid or in an anodic process.

2.7 Semiconductors manufacturing

2.7.1 Wafer manufacturing

Wafer manufacturing is a foundational process in semiconductor fabrication, involving the production of thin, flat discs of silicon known as wafers. These wafers serve as the substrate upon which semiconductor devices are built. The manufacturing process begins with the extraction and purification of silicon, which is then melted and solidified into cylindrical ingots. These ingots are sliced into thin wafers using precision saws, and the resulting wafers undergo rigorous cleaning and polishing to achieve a smooth and defect-free surface. Following surface preparation, the wafers are subjected to various processing steps such as doping, lithography, etching and deposition to create intricate patterns and structures that form the basis of semiconductor devices. Wafer manufacturing requires precision and consistency to produce high-quality wafers with uniform properties, ensuring the reliability and performance of semiconductor devices in diverse electronic applications. (ESIA contribution to [170, TWG, 2023])

2.7.2 Front-end operations

2.7.2.1 Deposition

Depositing materials plays a crucial role in the fabrication of semiconductor devices. When adding new layers, they can align epitaxially with the exposed crystalline surface. This process relies on precise control of the absorption and desorption rates of the depositing atoms in order to selectively grow the layers in desired regions. Conversely, non-epitaxial deposition can yield polycrystalline and amorphous layers, conformally covering the entire exposed surface.

PVD
Physical vapour deposition (PVD), also known as sputter deposition, involves a physical mechanism wherein material from a target is ejected onto a nearby wafer in a vacuum. The deposited material can be of very high purity and does not require a chemical reaction for the deposition to take place. Usually, a metal cathode, electrically grounded, serves as the target within a vacuum chamber. Argon gas is introduced into the chamber, becoming positively ionised and propelled toward the cathode target. Upon ion impact, metal atoms are dislodged from the target, ultimately depositing onto the surface of a nearby wafer.

CVD
Chemical vapour deposition (CVD) involves the delivery of atoms through gases passing over the wafer surface within a heated chamber in a rarified gas medium. Upon contact with the wafer, these transport gases trigger chemical reactions, leading to the deposition of new material. The gas composition can determine the deposition of thin semiconductor layers, such as silicon with controlled dopant amounts, or insulators like SiO_2. CVD operates as a heterogeneous reaction comprising three primary steps: transport of the species (kinetic and diffusive), surface reaction, and removal of by-products. The rate of deposition is controlled by the rate of arrival of reactants, the surface reaction rate, and the rate of removal of by-products.

ALD
Atomic layer deposition (ALD) is a thin-film deposition technique capable of creating conformal layers ranging from angstroms to nanometers in thickness. Unlike CVD, ALD relies on a series of alternating self-limiting chemical reactions occurring on the wafer's surface. During each step, the wafer is exposed to gas precursors until the surface reaction for a single atomic layer is fully completed. Subsequently, a second set of self-limiting precursors is introduced to the newly formed surface to facilitate the buildup of another atomic layer atop the first.

Molecular beam epitaxy (MBE) is an atomic deposition process performed in an ultra-high vacuum.
(ESIA contribution to [170, TWG, 2023])

2.7.2.2 Coating application (photoresist)

The purpose of photoresist application is the establishment of a thin, uniform, defect-free film of photoresist on the wafer surface. This requires sophisticated equipment and stringent controls. The usual methods of applying thin layers of liquids to surfaces are brushing, rolling and dipping. None of these methods are adequate to achieve the resist film quality necessary for photomasking. The method used is spinning and the processes are designed to prevent or minimise the build-up of a bead of resist around the outer edge of the wafer. (ESIA contribution to [170, TWG, 2023])

2.7.2.3 Photoresist exposure (lithography)

Photolithography is a pattern transfer process similar to photography and stencilling. First, the pattern on the reticle or mask is transferred into a layer of photoresist. Then, the image is encoded in the photoresist layer from an exposing light or other radiation source. Exposure to light causes changes in the structure and properties of the photoresist. (ESIA contribution to [170, TWG, 2023])

Photoresist development
After the wafer completes the alignment and exposure step, the device pattern is coded in the photoresist as regions of exposed and unexposed resist. The pattern is developed in the resist by the chemical dissolution of the unpolymerised resist regions. Development techniques are designed to leave on the resist layer an exact copy of the pattern that was on the mask or reticle. (ESIA contribution to [170, TWG, 2023])

2.7.2.4 Etching

(ESIA contribution to [170, TWG, 2023])

Etching is the process of removing the top layer(s) from the wafer surface through the openings in the resist pattern. Etching processes fall into two main categories: wet and dry. The primary goal of each is an exact transfer of the image from the mask/reticle onto the wafer surface.

2.7.2.4.1 Wet etching

(ESIA contribution to [170, TWG, 2023])

Wet chemical etching operates through three fundamental stages: initial diffusion of reactants to the reacting surface, ensuing chemical reactions at the surface, and subsequent removal of by-products via diffusion and evacuation. The etch rate, representing the quantity of film removed through etching per unit of time, is impacted by factors including the concentration of the etchant in the solution, liquid agitation, and the temperature of the etchant solution. Wafers are immersed in a tank of an etchant for a specific time, transferred to a rinse station for acid removal, and transferred to a station for the final rinse and spin dry step.

2.7.2.4.2 Dry etchning

Dry etching refers to the use of gases as an etch medium so that wafers are etched without wet chemicals or rinsing. The wafers enter and exit the system in a dry state. There are three dry etching techniques: plasma, ion beam milling, and reactive ion etch (RIE). Dry etching techniques encompass a variety of methods such as plasma etching, reactive-ion etching (RIE), sputter etching, magnetically enhanced RIE (MERIE), reactive-ion-beam etching, and high-density plasma (HDP) etching. These methods have been engineered to ensure precise replication of mask patterns by inducing highly anisotropic etch rates, with minimal lateral etching compared to vertical etching. Achieving this involves applying directional bias to the etchants, frequently by generating plasma within a low-pressure gas environment. (ESIA contribution to [170, TWG, 2023])

2.7.2.5 Photoresist stripping

After etching, the pattern is a permanent part of the top layer of the wafer. The resist layer that has acted as an etch barrier is no longer needed and is removed (or stripped) from the surface. (ESIA contribution to [170, TWG, 2023])

2.7.2.6 Doping – Diffusion

Thermal diffusion is a chemical process in which the wafer is heated to around 1 000 °C and is exposed to vapours of the proper dopant (impurities). Dopant atoms in the vapour move into the exposed wafer surface through the chemical process of diffusion to form a thin layer in the wafer surface. (ESIA contribution to [170, TWG, 2023])

2.7.2.7 Doping – Ion implantation

Ion implantation is a physical process. Wafers are loaded in one end of an implanter and dopant sources, usually in gas form, in the other end. At the source end, the dopant atoms are ionised, accelerated to a high speed, and swept across the wafer surface. The momentum of the atoms carries them into the wafer surface. (ESIA contribution to [170, TWG, 2023])

2.7.2.8 Layering – Epitaxial growth

Epitaxial growth is a crucial process in semiconductor manufacturing that involves the deposition of a single-crystal semiconductor layer onto a crystalline substrate. This technique allows for the controlled growth of semiconductor materials with specific properties, such as composition, thickness and crystal structure, essential for the fabrication of advanced semiconductor devices. During epitaxial growth, vapour-phase precursors are introduced onto the substrate surface under controlled conditions, promoting the nucleation and growth of semiconductor crystals in a precise and uniform manner. Epitaxial layers can be grown using various techniques, including chemical vapour deposition (CVD) and molecular beam epitaxy (MBE), each offering distinct advantages in terms of material quality, scalability, and compatibility with different semiconductor materials and device structures. Epitaxial growth plays a critical role in the development of high-performance semiconductor devices, including integrated circuits, optoelectronic devices, and power electronics, by enabling the engineering of material properties tailored to specific device requirements. (ESIA contribution to [170, TWG, 2023])

2.7.2.9 Layering – Sputtering

Sputtering is a physical process that takes place in a vacuum and is referred to as physical vapour deposition (PVD). Inside the vacuum is a solid slab, called the target, of the desired film material. The target is electrically grounded. Argon gas is introduced into the chamber and is ionised to a positive charge. The positively charged argon atoms are attracted to the grounded target and accelerate to it. During the acceleration they gain momentum, which is force, and strike the target. At the target a phenomenon called momentum transfer takes place and the argon ions strike the slab of film material, causing its atoms to scatter. The argon atoms 'knock off' atoms and molecules from the target into the chamber. This is the sputtering activity. The sputtered atoms or molecules scatter in the chamber with some coming to rest on the wafer. A principal feature of a sputtering process is that the target material is deposited on the wafer without chemical or compositional change. (ESIA contribution to [170, TWG, 2023])

2.7.2.10 Layering – Chemical vapour deposition

Chemical vapour deposition (CVD) is a fundamental process in semiconductor manufacturing used to deposit thin films of materials onto substrates with precise control over composition, thickness and uniformity. In CVD, precursor gases containing the desired elements react at the substrate surface, forming a solid film through chemical reactions and deposition. The process occurs within a vacuum or controlled atmosphere at elevated temperatures, facilitating the decomposition and deposition of the precursor molecules onto the substrate surface. CVD is widely employed in semiconductor fabrication for depositing various materials, including silicon dioxide (SiO_2), silicon nitride (Si_3N_4), metals, and semiconductor compounds such as silicon (Si), gallium arsenide (GaAs), and indium phosphide (InP). Different variations of CVD, such as plasma-enhanced CVD (PECVD) and low-pressure CVD (LPCVD), offer enhanced control over film properties and deposition rates, making CVD a versatile and essential technique for manufacturing advanced semiconductor devices and integrated circuits. (ESIA contribution to [170, TWG, 2023])

2.7.2.11 Chemical mechanical polishing

In contrast to other etching methods, chemical mechanical polishing (CMP) combines both chemical and abrasive actions to eliminate material. A slurry is employed, containing particles acting as abrasives along with chemicals like dilute HF. This slurry is applied onto a pad made of a porous material, fixed onto a rotating plate. The wafer, in turn, is affixed to a chuck that can also rotate, coming into contact with the slurry and/or pad. Since its inception, CMP has found widespread adoption in both front-end and particularly back-end processes. The efficiency of the process largely depends on the characteristics of the slurry and pad, with these consumable elements often representing a substantial cost in the manufacturing process. CMP offers precise control at the angstrom level.

A wafer is mounted on a rotating platform. A rotating polishing pad is pressured against the wafer surface. A slurry carrying small abrasive particles is directed onto the platform. The particles attack and remove small pieces of wafer surface, which are carried away by the movement of the slurry across the surface. The combined actions of the two rotations and the abrasive slurry polish the wafer surface. High plateaus on the wafer are polished first and faster than the lower areas, thus achieving planarisation. These are the mechanical polishing actions. However, mechanical polishing alone is unsuitable for semiconductor processing due to excessive mechanical damage to the surface. Damage is reduced and/or managed by selecting a slurry chemistry that dissolves or etches the surface materials. Chemical removal generally requires the corrosion of the surface, usually through an oxidation mechanism. (ESIA contribution to [170, TWG, 2023])

2.7.2.12 Solvent stations

In semiconductor manufacturing, solvent stations play a crucial role in the cleaning and preparation of semiconductor substrates and components before and after various processing steps. These stations typically use solvents, such as isopropyl alcohol (IPA) or acetone, to remove contaminants, residues and organic materials from semiconductor surfaces, ensuring the integrity and quality of subsequent manufacturing processes. Solvent stations are strategically placed within the fabrication facility to provide convenient access for cleaning critical components, including wafers, masks and equipment parts. By effectively removing contaminants and residues, solvent stations help minimise defects, improve yield and enhance the reliability and performance of semiconductor devices. Additionally, solvent stations contribute to maintaining clean room conditions and meeting stringent cleanliness standards required for semiconductor fabrication. (ESIA contribution to [170, TWG, 2023])

2.7.2.13 Wet chemical stations

Wet chemical stations are integral components in semiconductor manufacturing facilities, serving as key units for chemical processing and surface treatment of semiconductor wafers and components. These stations are equipped with various chemical baths and solutions tailored to specific processes, such as cleaning, etching and deposition, to achieve the desired material properties and device structures. Wet chemical stations play a crucial role in removing contaminants, oxide layers, and residues from semiconductor surfaces, preparing them for subsequent processing steps like lithography and deposition. Additionally, these stations enable selective etching or patterning of semiconductor materials to create intricate device structures and features essential for semiconductor device fabrication. By providing precise control over chemical processes and parameters, wet chemical stations contribute to the production of high-quality semiconductor devices with optimal performance and reliability. (ESIA contribution to [170, TWG, 2023])

2.7.2.14 Tool/Fab wipe cleaning

Tool wipe cleaning plays a critical role in maintaining the cleanliness and performance of semiconductor processing equipment. This process involves the manual or automated wiping of tool surfaces, such as chambers, wafers and parts, using specialised cleaning wipes or materials saturated with solvents or cleaning solutions. Tool wipe cleaning helps remove contaminants, residues and particles that accumulate during processing, preventing cross-contamination between different process runs and ensuring consistent performance and yield. By regularly cleaning equipment surfaces, tool wipe cleaning contributes to the prevention of defects, improves process stability, and extends the lifespan of semiconductor processing tools. Additionally, it plays a vital role in maintaining clean room conditions and meeting strict cleanliness standards required for semiconductor fabrication. (ESIA contribution to [170, TWG, 2023])

2.7.3 Back-end operations

2.7.3.1 Back grinding

Back grinding is a critical process in semiconductor manufacturing used to thin down the silicon wafer after the front-end processes have been completed, enabling the production of ultra-thin semiconductor devices. During back grinding, the backside of the wafer, as opposed to the side with the active semiconductor devices, is ground down to achieve the desired thickness while maintaining precision and uniformity. This process involves using grinding wheels with fine abrasives to remove material gradually from the wafer's backside, followed by polishing to achieve a smooth and flat surface. Back grinding is essential for reducing the thickness of the wafer to improve electrical performance, reduce thermal resistance, and facilitate the packaging and integration of semiconductor devices into electronic products. Additionally, back grinding enables the production of advanced semiconductor technologies such as stacked-die packages and three-dimensional integrated circuits (3DICs), where ultra-thin wafers are required to achieve high device density and performance. (ESIA contribution to [170, TWG, 2023])

2.7.3.2 Wafer mounting

Wafer mounting is a critical step in semiconductor manufacturing where processed silicon wafers are securely attached to a support substrate or carrier for subsequent processing steps. This process ensures the stability and integrity of the wafer during handling, processing and transportation within the semiconductor fabrication facility. Wafer mounting typically involves bonding the backside of the processed wafer to a rigid or flexible carrier using adhesives or tapes specifically designed for semiconductor applications. The mounted wafers are then ready for further processing steps such as back grinding, thinning, lithography, deposition and etching. Proper wafer mounting is essential to prevent damage to delicate semiconductor structures, maintain alignment accuracy, and ensure consistency and repeatability in subsequent manufacturing processes, ultimately contributing to the production of high-quality semiconductor devices. (ESIA contribution to [170, TWG, 2023])

2.7.3.3 Wafer sawing

The wafer is sawed into the individual dies. First, a diamond saw is passed over the scribble lines. Either the wafers are separated by a complete saw through, or the saw only creates a trench about one third through the wafer and then the separation is completed by the stress and roller technique. (ESIA contribution to [170, TWG, 2023])

2.7.3.4 Die attach

Die attachment has several goals: (1) creating a strong physical bond between the die and the package, (2) providing either an electrical conducting or insulating contact between the die and the package, and (3) serving as a medium to transfer heat from the chip to the package. (ESIA contribution to [170, TWG, 2023])

2.7.3.5 Wire bonding

In wire bonding, up to hundreds of wires must be perfectly bonded from the bonding pads to the package inner leads. A thin wire is first bonded to the chip bonding pad and spanned to the inner lead of the package lead frame. Then, the wire is bonded to the inner lead. Last, the wire is clipped and the entire process is repeated at the next bonding pad. (ESIA contribution to [170, TWG, 2023])

2.7.3.6 Moulding

Moulding, or encapsulation, in semiconductor manufacturing involves the process of protecting delicate semiconductor chips or devices by encapsulating them within a protective casing or package. This casing is typically made of a durable and insulating material such as plastic or epoxy resin, which shields the semiconductor components from mechanical stress, moisture, contaminants and environmental factors. The moulding process begins with placing the semiconductor device, such as an integrated circuit or sensor, onto a lead frame or substrate within a mould cavity. The mould cavity is then filled with liquid encapsulant material, which solidifies and forms a protective shell around the semiconductor device upon curing. Once encapsulated, the semiconductor devices are trimmed, lead wires are attached, and the packages are tested for functionality and reliability. Moulding is a crucial step in semiconductor manufacturing, ensuring the longevity, reliability and performance of semiconductor devices in various electronic applications. (ESIA contribution to [170, TWG, 2023])

2.7.3.7 Ball attach

The bonding wire is fed out of a thin tube called a capillary. An instantaneous electrical spark or small hydrogen flame melts the tip of the wire into a ball and positions the wire over the first bonding pad. The effect of the heat and the downward pressure forms a strong alloy bond between the two materials. (ESIA contribution to [170, TWG, 2023])

2.7.3.8 Post-mould cure

In semiconductor manufacturing, post-mould cure refers to the curing process that follows the encapsulation or moulding of semiconductor devices. After the encapsulant material has been injected into the mould cavity and formed around the semiconductor device, the package undergoes a curing or hardening process to ensure proper adhesion, strength and the stability of the encapsulant. This curing process typically involves exposing the moulded packages to elevated temperatures for a specific duration, allowing the encapsulant material to cross-link and polymerise, thereby forming a robust and durable protective casing around the semiconductor device. Post-mould cure is essential for optimising the mechanical and electrical properties of the encapsulant, enhancing its resistance to thermal and environmental stresses, and ensuring the long-term reliability of semiconductor devices in various electronic applications. (ESIA contribution to [170, TWG, 2023])

2.7.3.9 Laser marking and dejunk, dambar cut

In semiconductor manufacturing, the dambar cut is a critical process used to separate individual semiconductor devices or chips from a wafer during the packaging stage. This process involves cutting the dambar, which is a small section of material that connects adjacent devices on the wafer, using specialised sawing equipment such as dicing saws. The dambar cut is performed with precision to ensure clean and accurate separation of semiconductor devices while minimising damage to the surrounding structures. After the dambar cut, the individual semiconductor devices are picked up and packaged into their respective housings or packages for further testing and assembly into electronic products. The dambar cut plays a crucial role in semiconductor manufacturing, enabling the high-volume production of discrete semiconductor components with consistent quality and performance. (ESIA contribution to [170, TWG, 2023])

2.7.3.10 Package saw

In semiconductor manufacturing, the package saw, also known as a dicing saw, is a specialised piece of equipment used to single out semiconductor devices from a wafer after the back-end processing steps have been completed. This process involves cutting the wafer into individual chips or dice, each containing a single semiconductor device, using a high-precision cutting blade. The package saw operates with utmost precision to ensure accurate positioning and cutting of the wafer, minimising the risk of damage to the semiconductor devices. After separation the individual chips are collected and packaged into their final housings or packages for testing and integration into electronic products. The package saw is a critical tool in semiconductor manufacturing, enabling the mass production of discrete semiconductor components with consistent quality and performance. (ESIA contribution to [170, TWG, 2023])

2.7.3.11 Plating

Plating serves several important functions. First, the additional metal finish improves the lead solderability, resulting in a more reliable electrical connection of the package and the printed circuit. Second, the finish protects the leads from oxidation or corrosion during periods of storage prior to mounting on the circuit board. Third, the plating protects the leads from corrosive agents in the packaging and printed circuit board mounting processes. (ESIA contribution to [170, TWG, 2023])

2.7.3.12 Trim and form

In semiconductor manufacturing, the trimming and forming process step involves the manipulation and preparation of lead frames or substrates before semiconductor devices are attached and encapsulated. During this process, lead frames or substrates are precisely trimmed to the desired dimensions and shape using specialised cutting or stamping equipment. Additionally, the leads or terminals on the lead frames are formed into specific configurations, such as gull-wing or J-lead shapes, to facilitate the attachment of semiconductor devices and ensure proper electrical connections. The trimming and forming process is critical for achieving uniformity and consistency in semiconductor packaging, enabling efficient assembly of semiconductor devices and reliable electrical performance in electronic applications. (ESIA contribution to [170, TWG, 2023])

2.7.3.13 Testing and finishing

At the conclusion of the packaging process, the completed package is put through a series of environmental, electrical and reliability tests. These tests vary in type and specifications, depending on the customer and use of the packaged devices. (ESIA contribution to [170, TWG, 2023])

2.8 Porcelain (vitreous) enamelling of metals

[169, Russo et al. 2021]

2.8.1 Substrates for enamelling

The quality and the chemical composition of the metal substrate have an important influence on the parameters of the enamelling process. In addition, the properties of the metal determine the use of one or another deposition technique. Therefore, knowledge of the properties and main characteristics of the metal substrates used is crucial.

The most common substrates for enamelling are cast iron, low-carbon steel and aluminium alloys. Stainless steel is also suitable for enamelling, while copper, silver and gold are only enamelled for artistic purposes. Enamel coatings can also be applied on glass substrates and on high-temperature alloys.

Cast iron for enamelling
The most commonly used cast iron for enamelling is gray cast iron, with a perlitic matrix and a graphitic structure. The typical chemical elements present in a cast iron suitable for enamelling are carbon, silicon, phosphorus, manganese and sulphur. The metallographic structure of a cast iron is commonly constituted by graphite, ferrite, cementite, perlite, manganese sulphide and steatite (iron phosphide). The combined and uncombined carbon percentages play an important role in determining the suitability of cast iron substrates for enamelling.

Steel for enamelling
Conventional enamelling on cold-rolled steel was developed in the 1960s after the invention of open coil decarburised steel. Enamelling on hot-rolled substrates was developed in parallel, but it was mainly used for enamelling of water heaters. The use of hot-rolled steel tends to cause the formation of blisters on the enamelled surface caused by oversaturation of hydrogen at the metal-enamel interface. For this reason, hot-rolled steels are only used for special applications where given strength requirements need to be addressed effectively, but the porcelain enamelling process is usually limited to one side of the sheet to promote the removal of hydrogen from the unenamelled side. As regards cold-rolled steels, the EN 10209:2013 standard constitutes an important guide for the choice of the right steel quality for enamelling.

Aluminium alloys for enamelling
Aluminium requires the use of low-melting enamels. Aluminium alloys can be mainly divided into two groups: the heat-treatable alloys and the non-heat-treatable alloys, but another important classification is based on the alligant elements (alloy elements that are added to the steel substrate to enhance the bonding between the steel and the enamel coating). The most suitable aluminium alloys for enamelling are the 3003 and 4006 series alloys, but, in general, a low content of Mg is required to avoid adherence problems between the substrate and the enamel layer.

2.8.2 Surface pretreatment

Surface pretreatment ensures the perfect cleaning of the surface from rolling oils and other surface contaminants and it gives the surface an adequate roughness, thus facilitating the adherence between the metal and the enamel coating. The surface pretreatment could involve only or both chemical and mechanical methods. Among the mechanical methods, grit blasting and sand blasting are the most common. Grit blasting is used in the pretreatment of heavy gauge pieces made of steel or cast iron, such as hot water tanks and chemical vessels. Blasting is not common for the pretreatment of sheet iron or aluminium alloy-based substrates, as it could deform the material itself. Chemical pretreatments are commonly used on steel and aluminium substrates.

Cast iron substrate pretreatment

The preparation of cast iron surfaces is mainly carried out by blasting to completely clean the surface of the cast objects of production contaminants. Blasting forms a homogeneous surface in terms of roughness and surface defects in order to ease the adhesion of the enamel layer to the substrate. The blasting process is sometimes followed by an annealing treatment at 800-850 °C. This thermal treatment is also commonly used to obtain good results on cast iron types with a high cementite content.

Steel substrate pretreatment

The first step is the chemical cleaning of the surface, also called degreasing. During chemical cleaning, the substrate is cleaned with aqueous solutions of alkaline detergents in order to remove oils and greases. Cleaning can be done by immersion or by spraying. In both cases, the operating temperature ranges from 40 °C to 70 °C, for 5-10 minutes. Typical components of industrial cleaner solutions (pH 10-13) are mainly constituted by sodium silicates, sodium carbonate and hydroxides (as a source of alkalinity), although other components can be added in limited concentrations. Nowadays, the chemical cleaning is sometimes replaced by electrolytic cleaning. This procedure uses the flow of current through the bath, while the ware to be cleaned is made the cathode. The alkali content of the bath is about 40 g/l, and the pH of the bath is kept around 13. The cleaning procedure is very fast, especially if automatic equipment is used. The cleaning procedure is always followed by a rinsing step carried out in running water.

The next step, pickling, consists of the elimination of metal oxides from the substrate surface by using an acid solution. The most common pickling solution has a sulphuric acid concentration of 5–10 wt% and is commonly used at 65–75 °C. Pickling can be done either by spraying or by immersion; in the case of immersion, the typical time is 8 minutes, whereas in immersion it can take up to 30 minutes. There are also acid pickling solutions based on phosphoric acid. These solutions have important advantages if used for the treatment of products that must undergo direct enamelling, as the phosphoric acid attacks the metal product in a controlled manner, leaving a very homogeneous surface at the end of the treatment. The pickling step must be followed by a deep rinsing in water and by immersion in a neutralising bath. The neutralising bath, a hot solution of Na_2O in water, is used to completely remove all traces of acid. The last step of the pretreatment process is the drying of the substrate.

Aluminium substrate pretreatment

The aluminium substrate is cleaned of greases and oils, then it is degreased in an alkaline solution (20-40 g/l at 50 °C), leached in an alkaline bath (10 wt% NaOH at 70 °C for up to 5 minutes) to remove the natural oxide film, desmudged in acid water (25 wt% nitric acid solution) to remove adherent hydroxides, rinsed several times, and in some cases pre-fired at about 400 °C to reform a uniform oxide layer.

2.8.3 Enamelling process

The enamelling process could be divided into the following three main steps: the preparation of the frit (a mixture of silica, alumina, borax and other minerals), the milling and the application of enamel on the substrate.

2.8.3.1 Frit making

The frit is produced by the combined melting of oxides and salts at temperatures between 1 000 °C and 1 500 °C to form a mixture that is then cooled to obtain glassy granules or flakes, whose composition is specifically modified according to the substrate and final application.

The raw materials used in frit making can be divided into four main groups: refractories, fluxes, opacifiers and colours. Refractories are acidic oxides that give body to the glassy enamel matrix; fluxes are alkaline oxides, which are mainly used to react with refractories to form the glass and to lower the melting temperature of the glass itself. Opacifiers, such as tin oxide and antimony compounds, are used to give the enamel their typical opaque appearance. Other important components of frits are adherence oxides.

The raw materials for frit production are stored in silos from where they are automatically taken and weighed. After that, these oxides are mixed and inserted into the furnace for the melting process. On leaving the furnace, the frit can be cooled to obtain glassy flakes using rollers or small frit granules by rapid cooling. After cooling, the frit is appropriately dried before use.

2.8.3.2 Milling

Before the formulation of enamel, the frit must be suitably grounded in ball or drum mills. There are two main different types of milling: the dry and wet methods. In the first case, the grinding takes place in the absence of water, and the charge is usually composed only of the frit, any pigments, and additives for special applications. The main control carried out on the dry ground frit is exclusively a quick granulometric check. In the case of ‘wet’ milling, the frit is mixed with water to create an aqueous suspension called ‘torbida’ or ‘slip’. The components that are added to the mill must ensure the perfect suspension of the frit particles in the liquid component. It is essential to add floating agents and electrolytes, usually in a percentage that never exceeds 15% of the weight of the frit. The most common floating agent is clay, although bentonite, colloidal silica, and gums are used in some cases. Electrolytes are important components of the slip as well, as they are soluble compounds (sodium aluminate, potassium carbonate) that are able to control the properties of the slip, such as its consistency.

2.8.3.3 Enamel application on the substrate

The choice of the appropriate application method is very important to achieve the desired product characteristics. Enamel application techniques can be mainly divided into ‘dry’ and ‘wet’ methods, based on the type of milling previously performed. In addition, it is also important to distinguish between the application of ground and cover coat enamels. Ground enamels are formulated with the addition of cobalt oxides to promote adhesion with the substrate, whereas cover coat enamels are formulated to guarantee optimal aesthetical properties. Nowadays, the most common application sequence is known as ‘2C/2F’ (two-coat, two-firing), but it is also possible to use a ‘2C/1F’ application. The ‘2C/1F’ application can be realised wet on wet, powder on powder, or powder on a wet dried layer. It is also possible to directly enamel the pieces to be covered, but it is necessary to effectively pretreat the decarburised steel substrate and use coloured enamels (with a percentage of adherence oxides).

2.8.3.3.1 Enamelling of steel

Steel is currently the most widely used material in enamelling, as it allows the widest choice of application methods. The table below summarises the possible application methods for steel enamelling. Wet enamelling can be carried out by immersion or by spraying. The immersion method is commonly used to apply ground enamels on big products, such as chimney pipes, washing machine baskets, and boilers, whereas the spraying method is used to apply cover coat layers as it guarantees good aesthetical features of the finished product. The dipping method consists of immersing the product in a tank containing the enamel slip and extracting it at a controlled speed to freely drain away the enamel excess. The flow coating method uses a similar principle, but, in this case, the enamel is poured from above onto the piece to be covered. This method is commonly used for the enamelling of hollow tubular elements.

Table 2-5: Application techniques for enamelling of steel

Application	Application method	Description
Wet	Dip coating	Immersion of the piece in the slip

	Flow coating	Pouring of the slip on the piece
	Spray coating	The slip is air-atomised
	Electrostatic wet spray coating	The atomised slip is charged
	Electrophoretic coating	Migration of the slip to the substrate
Dry	Electrostatic dry powder coating	The enamel powder is charged
Source: [169, Russo et al. 2021]		

The evolution of the traditional spraying technique is the electrostatic spraying method. The slurry particles are electrically charged by passing through a strong electric field and they are sprayed onto the substrate, which is grounded. In this way, the slip particles are able, following the electric field lines, to cover the whole substrate surface in a homogeneous way, avoiding huge over-spraying. This application method, although very efficient, is influenced by many operating parameters, such as the spray distance and the application speed.

The operating principle of the electrostatic dry powder method is similar to that of electrostatic wet spraying, but, in this case, enamel particles are encapsulated in organic compounds so that they can acquire an electric charge and be ‘sprayed’ on the metal object. As a following step, the powder is deposited on the metal, and its electrical charge is passed to the metal. The most important parameters to be controlled are the humidity in the application chamber, which influences the adhesion of the powder onto the substrate (it modifies the resistivity of the enamel particles), and the granulometry of the enamel powder. This method is the most widespread worldwide, but it implies important investments and thus large-scale production to pay back costs.

Similar to wet electrostatic deposition and electrostatic powder deposition, the electrophoretic deposition technique method uses an electric field. The negatively charged enamel particles migrate toward the positively charged substrate to be coated. This migration occurs in the slip when it is subjected to an electric field. This system is still not very widespread nowdays, but it has some interesting advantages over other wet applications, such as controlled thicknesses, compact and automated production systems, and good edge coverage.

2.8.3.3.2 Enamelling of cast iron and aluminium

Cast iron is usually enamelled by wet spraying, but, with respect to steel, the thickness of the enamel layer could be up to 400 microns to counteract the negative effect of the substrate roughness. Aluminium alloys are usually covered by wet application methods, in particular wet spraying and flow coating.

2.8.3.4 Drying and firing

In the case of wet application of enamel, the coating must be dried before the subsequent firing phase to remove the application carrier material (usually water). The formation of a dried enamel layer, called ‘biscuit’, is of extreme importance; otherwise, trapped water could suddenly evaporate during the firing process, causing bubbling and enamel detachment and cracking.

The firing process is the last step involved in the production of enamelled objects. All the furnaces are commonly powered by electricity or gaseous fuels; in the first case, operating costs are higher, but there is a quick response to temperature adjustments and less contamination of the enamelled pieces. Regardless of the power supply, almost all industrial ovens are equipped with a conveyor. The firing temperature mainly depends on the substrate type. The firing temperature of a steel product can vary between 750 °C and 890 °C, for durations varying between 2 and 8 minutes, depending on the thickness of the sheet. Cast iron pieces are usually fired at temperatures of about 730-770 °C for over 40 minutes. On the other hand, aluminium is always fired at temperatures below 600 °C, due to the low melting temperature of the substrate;

this last operating condition represents a challenge in the development of low-melting glazes with high chemical and abrasion resistance.

3 CURRENT CONSUMPTION AND EMISSION LEVELS FOR THE SURFACE TREATMENT OF METALS AND PLASTICS

The following sections present the emission and consumption data reported by the surface treatment of metals and plastics plants/installations across the European Union (EU) that took part in the STM BREF review data collection.

[Note to the TWG: Most of the information contained in this section of the old BREF has been removed and replaced with up-to-date information obtained from the data collection. Please note that figures and graphs will be fully updated at a later stage]

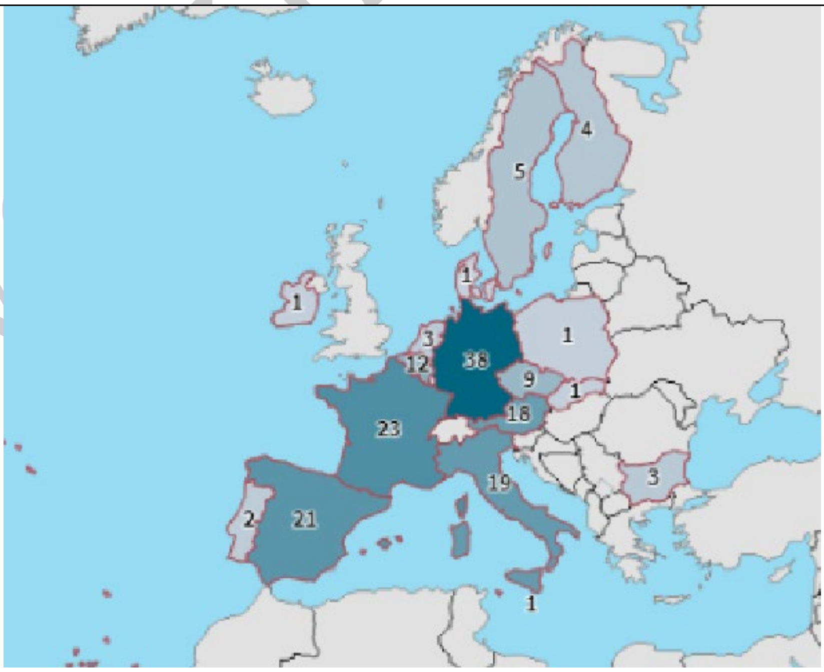
~~3.1~~ Introduction

~~Introduction - utilities and input materials~~

The data for emission and consumption levels presented in this chapter were collected from 162 plants/installations across the EU. The participating plants are located in 17 Member States (AT, BE, BG, CZ, DK, FI, FR, DE, ES, EI, IT, MT, NL, PL, PT, SE and SK).

The geographical distribution of plants/installations is shown in Figure 3-1. The data refer to the most recent and representative 3 reference years covering the period from 2012 to 2022. The list of plants that participated in the data collection is given in Annex 8.5. These plants are from the following sectors:

- electrolytic or chemical plating;
- continuous steel coil coating;
- aluminium coil, sheet conversion coating and anodising;
- porcelain (vitreous) enamelling of metals;
- printed circuit board (PCB) manufacturing;
- semiconductor manufacturing.



Source: [168, TWG 2023]

Figure 3-1: Georgraphical distribution of plants that participated in the data collection

The most significant environment factors for surface treatment installations are energy and water consumption, the efficient use of raw materials including hazardous chemicals, the emission of pollutants in waters, and the production of hazardous wastes. The emission of pollutants into the air is usually of less consequence.

Many factors determine the consumption of raw materials as well as the emission of pollutants at these installations. ~~There is some difficulty in producing comparable statistics for both consumptions and emissions because of the large variation between installations: it is likely that no two of the 18000 installations operated in the 15 EU Member States (EU-15) are similar enough in design and customers to be directly comparable with one another on a like-for-like throughput basis.~~ For general plating activities t~~T~~he variations in the options for plant design are due to the large number of the operating parameters, see Section 1.2. and the general introduction to Chapter 2. The most important are: [104, UBA, 2003]:

- the input substrates (e.g. steel, non-ferrous metals, plastics, etc.);
- the form of the workpieces (e.g. small components, wires, sheet metals, small and large coils, pipes, complex assemblies);
- the transport technology of the treatment (jig, barrel, continuous coil);
- the cleaning technology (aqueous, alkaline, acid, electrochemical, etc.);
- the technology for the manufacture of a metallic bright surface (pickling with hydrochloric acid, sulphuric acid, acid mixtures, etc.);
- the coating programme (e.g. copper, nickel, chromium, zinc, tin, alloys, combinations of individual layers such as plating followed by electropainting);
- the selection of individual coatings (chemical, electrolytic and process chemistry);
- the post treatment systems (chromating type, other systems);
- the rinsing technology;
- the waste water and waste gas purification technology.

~~The best starting point for determining consumptions and emissions for comparisons would be on a throughput measure such as 'unit used per square metre treated'. This would enable both interplant comparisons and individual plants to monitor their performance when considering and managing changes within the same plant. For surface treatments, the preferred basis would be surface area treated. However, the differing sizes, shapes and complexity of the workpieces and/or substrates make the accurate calculation of surface area difficult in all but the most straightforward cases.~~

The data collection for the STM BREF review focused on information gathering using a standardised questionnaire for the following topics:

- identification and description of the plant/installation;
- processes and emission sources;
- channelled and diffuse emissions to air;
- channelled emissions to water;
- energy consumption;
- waste and residue generation;
- water consumption and discharge;
- material and chemical consumption;
- circular economy, industrial symbiosis and decarbonisation.

To ensure accurate comparisons and performance monitoring, the relevant benchmark for determining consumption and emissions is a throughput measure based on 'unit used per square metre treated'. This approach enables both interplant comparisons and intra-plant assessments, as well as the evaluation of changes and management decisions within individual facilities. For surface treatment activities, the surface area treated may be considered; precise calculations in the simplest of cases, and alternative methods, e.g. based on estimates or order of magnitude where the inherent complexities and variability in workpiece and substrate sizes and shapes are needed, may be necessary to achieve reliable results.

~~On the emission side, the situation appears simpler, as emission standards and measurements exist. However, these are largely for end-of-pipe discharges. Relating discharge quantities to throughput factors for accurate comparison would be best, but are again very difficult.~~

~~However, none of these problems should prevent benchmarks being set.~~ Consumption data such as energy usage can always be used in-house to monitor the individual installations' ongoing performance [112, Assogalvanica, 2003]. Other benchmarks can be derived that may be used on an interplant basis. Material efficiency benchmarks are less complex to apply than surface-related ones and are closely related to the economic efficiency of the process~~, for example see Table 3.7 and examples in Annex 8.5~~. They can be derived by subtracting the amount of material emitted in wastes and waste water from the total amount of metal input [127, Oekopol, 2003, ÜBA, 2004 #123]. However, care must still be taken to ensure a like for like basis: there may be other sources of the material within the installation, for example dissolution of substrate such as zinc from zinc die castings in processing vats.
~~Some basic data are provided in this section. A set of studies on consumption and emission of metals for ten reference plants in Germany are included in Annex 8.5~~

~~Data on the key environmental considerations, such as substances of concern emitted, are given with process descriptions in Chapter 2.~~

~~Annex 8.3.1 provides examples of regulatory limits for various processes and countries.~~

Handling of Confidential Business Information (CBI)
During the data collection, the following data were considered CBI for the continuous steel coil coating activities:

- operating hours and operational data;
- specific energy consumption;
- specific amount of hazardous chemicals consumed.

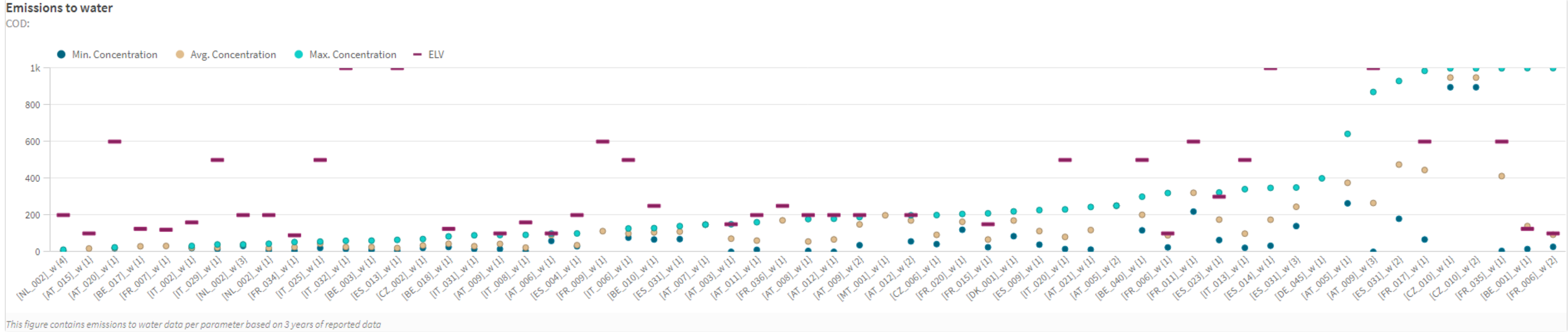
In order to maintain data confidentiality, plant names are not directly mentioned in the graphs or figures. The plant names are replaced with anonymised and randomly attributed plant CBI codes. In addition, no contextual information (e.g. process parameters or techniques applied) is included as this could reveal the identity of the plant.

3.2 Electrolytic or chemical plating

3.2.1 Emissions to water

3.2.1.1 COD

The reported data for COD emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-1.



This figure contains emissions to water data per parameter based on 3 years of reported data

Source: [168, TWG 2023]

Figure 3-2: COD emissions to water in electrolytic or chemical plating plants

Table 3-1: Reported data and contextual information for COD emissions to water in electrolytic or chemical plating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[NL_002]_w {4}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	5	6.88	11.7	200	-
[AT_015]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	18.00	-	100	-
[AT_020]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon-Sedimentation	19	21.10	24.3	600	-
[BE_017]_w {1}	Coagulation and flocculation	-	30.00	-	125	-
[FR_007]_w {1}	Coagulation and flocculation-Nitrification/denitrification	-	31.67	-	120	-
[IT_002]_w {1}	Equalisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Biological treatment- Activated sludge process-Nitrification/denitrification	20	22.33	32	160	-
[IT_029]_w {1}	Absorption-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Precipitation-Sedimentation-Evaporation (e.g. vacuum evaporation)	15	22.50	40	500	-
[NL_002]_w {3}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	32	38.92	40	200	-
[NL_002]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Adsorption techniques – activated carbon	7	20.00	44	200	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	5	25.07	53	90	1296
[IT_025]_w {1}	-	21	44.00	56	500	12.22
[IT_032]_w {1}	Coagulation and flocculation-Ion exchange resins	15	26.17	60	1000	-
[BE_003]_w {1}	Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Neutralisation-Reverse osmosis-Use of buffer tanks to reduce waste water and emission load peaks	9.4	25.89	61	-	-
[ES_013]_w {1}	Adsorption techniques – activated carbon-Neutralisation-Coagulation and flocculation-Crystalisation-Flotation-Ion exchange resins-	6	20.53	65	1000	-
[CZ_002]_w {1}	Neutralisation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Adsorption techniques – activated carbon-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)	21	34.07	69.6	-	-
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g.	26	43.53	84	125	-

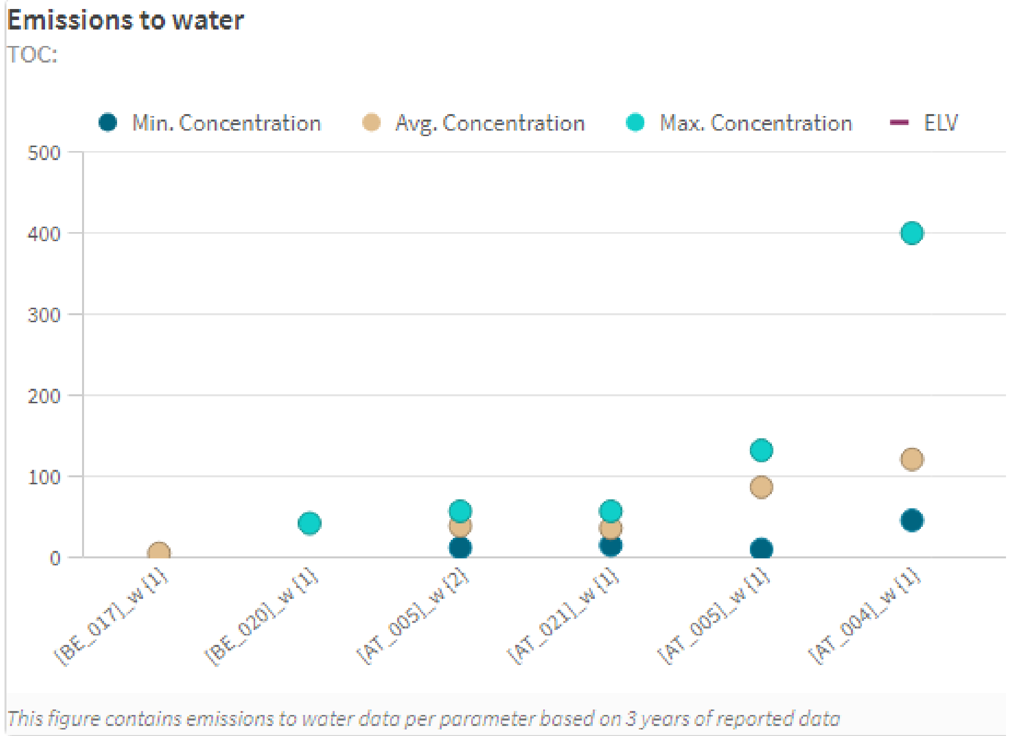
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
	gravel filter, sand filter)-Ion exchange resinsNitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks					
[IT_031]_w {1}	Coagulation and flocculation	15	30.50	90	-	-
[AT_009]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	15	42.79	91	100	-
[IT_008]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation	5	22.83	92	160	-
[AT_006]_w {1}	Coagulation and flocculation-Precipitation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	59.1	90.67	99.4	100	-
[ES_004]_w {1}	Neutralisation-Other-Coagulation and flocculation-Sedimentation	30	35.87	100	200	-
[FR_009]_w {1}	Coagulation and flocculation-Neutralisation	-	112.63	-	600	-
[IT_006]_w {1}	Coagulation and flocculation-Chemical reduction-Precipitation	77	99.50	127	500	-
[BE_010]_w {1}	Coagulation and flocculation	67	106.00	129	250	-
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	69	109.67	140	-	-
[AT_007]_w {1}	Adsorption techniques – activated carbon-Ion exchange resins-Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation	148	148.00	148	-	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0	71.60	150	150	-
[AT_011]_w {1}	Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	11	61.00	161	200	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	171.10	-	250	-
[AT_008]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	5	56.17	178	200	-
[AT_012]_w {1}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	0	67.33	180	200	-
[AT_009]_w {2}	Ion exchange resins-Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Evaporation (e.g. vacuum evaporation)	35.8	149.40	189	200	-

Emission Point	**Abatement technique(s)**	**Min.**	**Avg.**	**Max.**	**ELV**	**Load (g/day)**
[AT_012]_w {2}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	56.7	170.33	199	200	-
[CZ_006]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	41.8	92.34	200	-	-
[FR_020]_w {1}	Other-	120	163.25	206	-	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	24.8	66.93	209.6	150	-
[DK_001]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	85	170.20	220	-	-
[ES_009]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	39	113.00	227	-	-
[IT_020]_w {1}	Coagulation and flocculation	15	81.22	231	500	819.6
[AT_021]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	12.1	118.50	244	-	-
[AT_005]_w {2}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	251	251.00	251	-	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	117	201.33	300	500	-
[FR_006]_w {1}	Precipitation-Coagulation and flocculation	24	89.56	320	100	26.89
[FR_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	219	321.33	-	600	-
[ES_023]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	64	175.33	323	300	-
[IT_013]_w {1}	Chemical reduction	22	99.00	341	500	159.5
[ES_014]_w {1}	Coagulation and flocculation-Membrane micro/ultra/nano filtration-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Other	33	174.67	348	1000	-
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	140	245.00	350	-	-
[DE_045]_w {1}	Other	-	-	400	-	-
[AT_005]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	264	375.67	642	-	-
[AT_009]_w {3}	Evaporation (e.g. vacuum evaporation)	0	265.56	870	1000	-
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	180	475.00	930	-	-
[FR_017]_w {1}	Chemical reduction	67	445.20	985	600	-
[CZ_010]_w {1}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	896	948.67	999	-	1000
[CZ_010]_w {2}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation	896	948.67	999	-	1000

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	5	412.19	999	600	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	15	140.00	1000	125	-
[FR_006]_w {2}	Precipitation-Coagulation and flocculation-Biological treatment- Activated sludge process	27	92.92	1000	100	9.49

3.2.1.2 TOC

The reported data for TOC emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-2.



Source: [168, TWG 2023]

Figure 3-3: TOC emissions to water in electrolytic or chemical plating plants

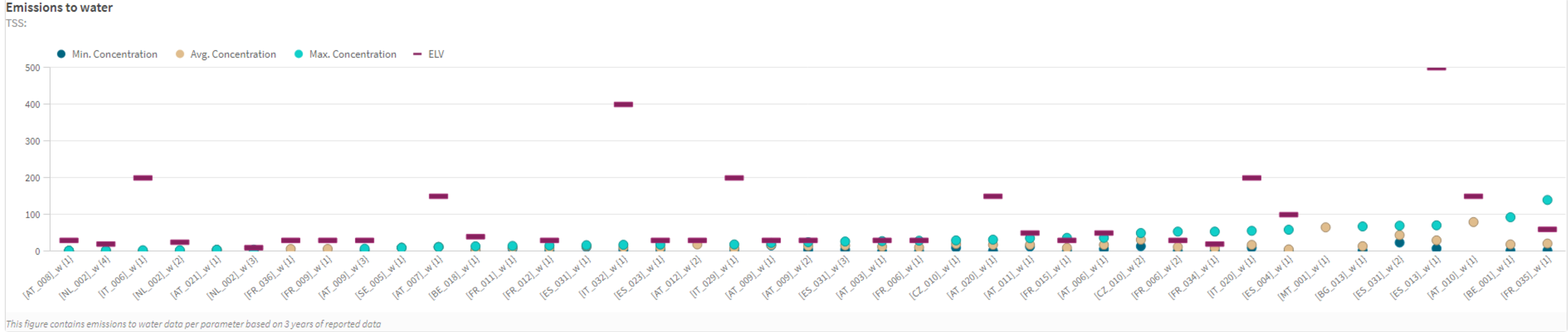
Table 3-2: Reported data and contextual information for TOC emissions to water in electrolytic or chemical plating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[BE_017]_w {1}	Coagulation and flocculation	-	6.2	-	-	-
[BE_020]_w {1}	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other	-	-	43	-	-
[AT_005]_	Neutralisation-Precipitation-Filtration (e.g. gravel filter,	13	39.7	58	-	-

w {2}	sand filter)-Ion exchange resins-Coagulation and flocculation					
[AT_021]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	16	37	58	-	-
[AT_005]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	11	87.67	133	-	-
[AT_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation-Chemical reduction-Sedimentation-Neutralisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	46.7	122	401	-	-

3.2.1.3 TSS

The reported data for TSS emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-3.



Source: [168, TWG 2023]

Figure 3-4: TSS emissions to water in electrolytic or chemical plating plants

Table 3-3: Reported data and contextual information for TSS emissions to water in electrolytic or chemical plating plants

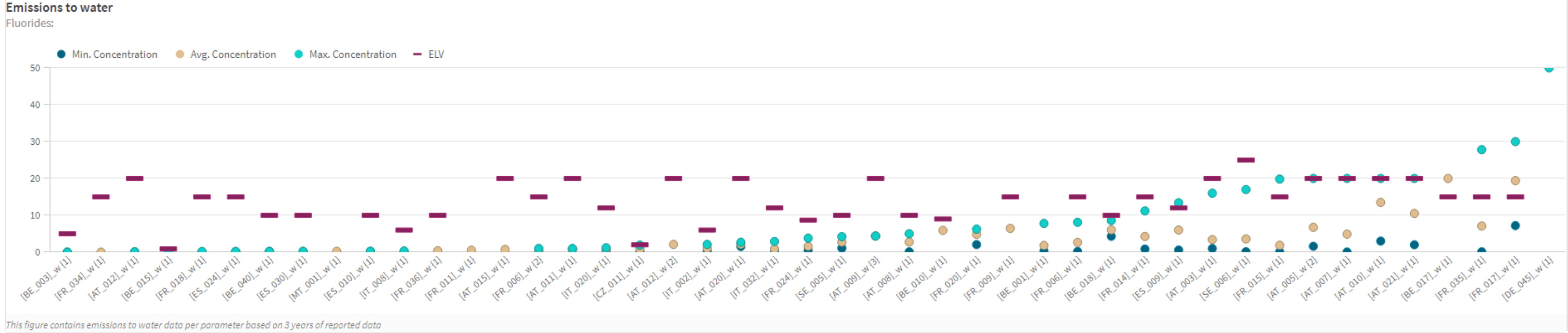
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load ELV
[AT_008]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	2	2.00	2	30	-
[NL_002]_w {4}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.7	2.25	3	20	-
[IT_006]_w {1}	Coagulation and flocculation-Chemical reduction-Precipitation	0.5	1.15	3.2	200	-
[NL_002]_w {2}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	1.33	2.25	3.3	25	-
[AT_021]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	4.5	4.50	4.5	-	-
[NL_002]_w {3}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	1.7	2.42	5	10	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	6.62	-	30	-
[FR_009]_w {1}	Coagulation and flocculation-Neutralisation	-	6.71	-	30	-
[AT_009]_w {3}	Evaporation (e.g. vacuum evaporation)	2.8	-	7.4	30	-
[SE_005]_w {1}	Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Adsorption techniques – activated carbon-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Reverse osmosis-Sedimentation-Neutralisation	10	10	10	-	-
[AT_007]_w {1}	Adsorption techniques – activated carbon-Ion exchange resins-Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation	12	12.00	12	150	-
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	2	4.40	14	40	-
[FR_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	8	10.64	15	-	-
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	2.4	9.10	16	30	-
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	12	14.67	17	-	-
[IT_032]_w {1}	Coagulation and flocculation-Ion exchange resins	4	10.83	18	400	-
[ES_023]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	5	9.50	18.6	30	-

[AT_012]_w {2}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	-	19.00	-	30	-
[IT_029]_w {1}	Absorption-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Precipitation-Sedimentation-Evaporation (e.g. vacuum evaporation)	5	8.50	19	200	-
[AT_009]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	16	17.60	23	30	-
[AT_009]_w {2}	Ion exchange resins-Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Evaporation (e.g. vacuum evaporation)	4.2	14.55	25.2	30	-
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	5	16.00	27	-	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0	13.00	28	30	-
[FR_006]_w {1}	Precipitation-Coagulation and flocculation	1	10.81	29.2	30	30.00
[CZ_010]_w {1}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	10	20.00	30	-	-
[AT_020]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon-Sedimentation	1.47	17.82	32	150	-
[AT_011]_w {1}	Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	13	18.00	36	50	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	2	9.68	36.9	30	0.46
[AT_006]_w {1}	Coagulation and flocculation-Precipitation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	6.6	17.87	37	50	-
[CZ_010]_w {2}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation	14	31.67	50	-	-
[FR_006]_w {2}	Precipitation-Coagulation and flocculation-Biological treatment- Activated sludge process	1	12.08	54	30	30.00
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	2	8.93	54	20	0.08
[IT_020]_w {1}	Coagulation and flocculation	10	17.67	56	200	0.60
[ES_004]_w {1}	Neutralisation-Other-Coagulation and flocculation-Sedimentation	2	5.49	59	100	-
[BG_013]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	2	14.18	68	-	-
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	24	44.33	70	-	-
[ES_013]_w {1}	Adsorption techniques – activated carbon-Neutralisation-Coagulation and flocculation-Crystalisation-Flotation-Ion	8	30.05	71	500	-

	exchange resins					
[AT_010]_w {1}	Precipitation-Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Evaporation (e.g. vacuum evaporation)-Electrolysis-Evaporation (e.g. vacuum evaporation)-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange resins	-	79.90	-	150	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	2	19.00	93	-	-
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	2	21.32	140	60	0.13

3.2.1.4 Fluorides

The reported data for fluorides emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-4.



This figure contains emissions to water data per parameter based on 3 years of reported data

Source: [168, TWG 2023]

Figure 3-5: Fluorides emissions to water in electrolytic or chemical plating plants

Table 3-4: Reported data and contextual information for fluorides emissions to water in electrolytic or chemical plating plants

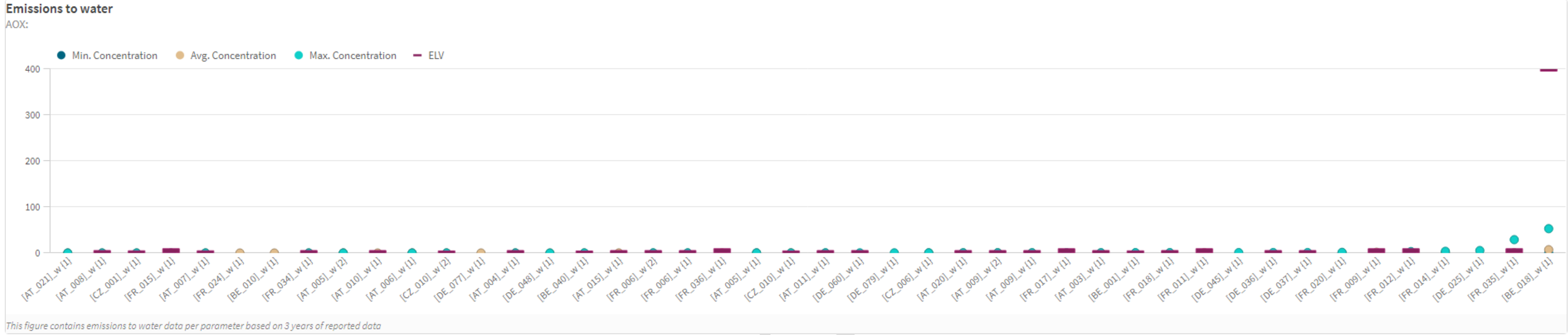
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[BE_003]_w {1}	Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Neutralisation-Reverse osmosis-Use of buffer tanks to reduce waste water and emission load peaks	0.00	0.00	0.00	5.00	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	-	0.01	-	15.00	-
[AT_012]_w {1}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	0.05	0.08	0.10	20.00	-
[BE_015]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Chemical reduction-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Biological treatment- Activated sludge process-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.12	0.12	0.12	0.90	-
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.10	0.12	0.19	15.00	-
[ES_024]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Other	0.09	0.17	0.20	15.00	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0.20	0.20	0.20	10	-
[ES_030]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Precipitation	0.20	0.20	0.20	10	-
[ES_010]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Precipitation	0.20	0.20	0.24	10	-
[IT_008]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation	0.10	0.12	0.33	6.00	26.96
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	0.39	-	10	-
[FR_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	-	0.53	-	-	-
[AT_015]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.74	-	20.00	-
[FR_006]_w {2}	Precipitation-Coagulation and flocculation-Biological treatment- Activated sludge process-	0.23	0.46	1.00	15.00	51.20
[AT_011]_w {1}	Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Ion exchange	0.75	0.85	1.00	20.00	-

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
	resins					
[IT_020]_ w {1}	Coagulation and flocculation	0.29	0.83	1.20	12.00	12.96
[CZ_011]_ w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid	0.14	0.87	1.91	2.00	-
[AT_012]_ w {2}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	-	2.10	-	20.00	-
[IT_002]_ w {1}	Equalisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Neutralisation-Coagulation and flocclation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Biological treatment- Activated sludge process-Nitrification/denitrification	0.20	1.06	2.10	6.00	32.00
[AT_020]_ w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon-Sedimentation	1.52	2.12	2.69	20.00	188.00
[IT_032]_ w {1}	Coagulation and flocculation-Ion exchange resins	0.50	0.90	2.90	12.00	-
[FR_024]_ w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation	0.55	1.59	3.79	8.70	-
[SE_005]_ w {1}	Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Adsorption techniques – activated carbon-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Reverse osmosis-Sedimentation-Neutralisation	1.10	2.71	4.20	10	-
[AT_009]_ w {3}	Evaporation (e.g. vacuum evaporation)	4.38	4.38	4.38	20.00	-
[AT_008]_ w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.10	2.75	5.00	10	-
[BE_010]_ w {1}	Coagulation and flocculation	-	5.91	-	9.00	-
[FR_020]_ w {1}	Other	2.06	4.85	6.24	-	-
[FR_009]_ w {1}	Coagulation and flocculation-Neutralisation	-	6.44	-	15.00	-
[BE_001]_ w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.33	1.83	7.80	-	-
[FR_006]_ w {1}	Precipitation-Coagulation and flocculation	0.20	2.64	8.10	15.00	873.28
[BE_018]_ w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	4.30	6.05	8.60	10	-
[FR_014]_ w {1}	Chemical reduction-Chemical reduction-Chemical reduction	0.85	4.26	11.20	15.00	-

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[ES_009]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.58	6.01	13.41	12.00	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	1.00	3.41	16.00	20.00	-
[SE_006]_w {1}	Chemical reduction-Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.13	3.60	17.00	25.00	39.00
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.10	1.87	19.82	15.00	-
[AT_005]_w {2}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	1.59	6.73	20.00	20.00	363.50
[AT_007]_w {1}	Adsorption techniques – activated carbon-Ion exchange resins-Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation	0.04	4.89	20.00	20.00	-
[AT_010]_w {1}	Precipitation-Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Evaporation (e.g. vacuum evaporation)-Electrolysis-Evaporation (e.g. vacuum evaporation)-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange resins	3.00	13.50	20.00	20.00	-
[AT_021]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	2.00	10.50	20.00	20.00	280.46
[BE_017]_w {1}	Coagulation and flocculation	-	20.00	-	15.00	-
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0.10	7.08	27.80	15.00	202.79
[FR_017]_w {1}	Chemical reduction	7.20	19.41	30.00	15.00	-
[DE_045]_w {1}	Other	-	-	50.00	-	-

3.2.1.5 AOX

The reported data for AOX emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-5.



Source: [168, TWG 2023]

Figure 3-6: AOX emissions to water in electrolytic or chemical plating plants

Table 3-5: Reported data and contextual information for AOX emissions to water in electrolytic or chemical plating plants

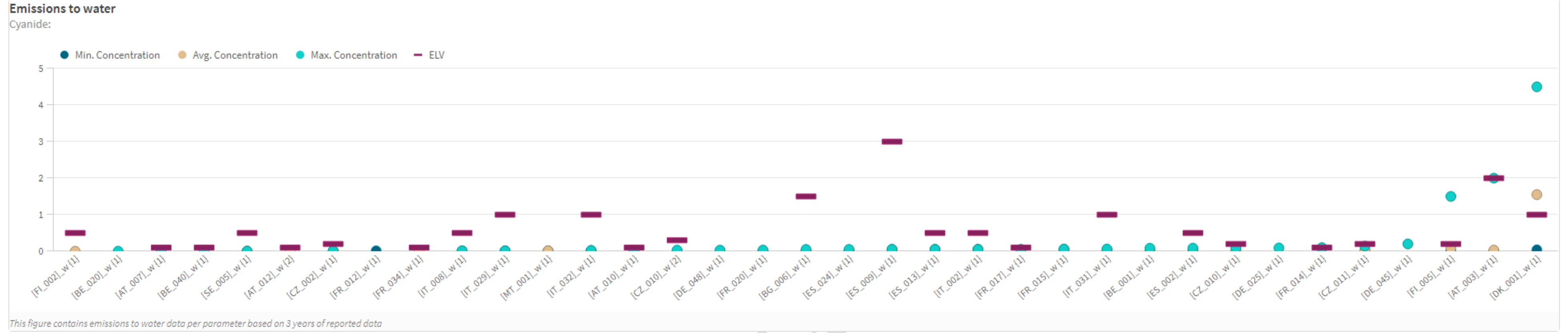
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[AT_021]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0.02	0.02	0.02	-	-
[AT_008]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.02	0.02	0.03	1.00	-
[CZ_001]_w {1}	Neutralisation-Sedimentation	0.00	0.00	0.04	0.50	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.05	5.00	-
[AT_007]_w {1}	Adsorption techniques – activated carbon-Ion exchange resins-Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation	0.05	0.05	0.05	0.50	-
[FR_024]_w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation	-	0.05	-	-	-
[BE_010]_w {1}	Coagulation and flocculation	-	0.06	-	-	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	0.00	0.05	0.10	1.00	2.65
[AT_005]_w {2}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0.05	0.07	0.10	-	-
[AT_010]_w {1}	Precipitation-Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Evaporation (e.g. vacuum evaporation)-Electrolysis-Evaporation (e.g. vacuum evaporation)-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange resins	-	0.11	-	1.00	-
[AT_006]_w {1}	Coagulation and flocculation-Precipitation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-	0.03	0.06	0.12	-	-
[CZ_010]_w {2}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation	0.01	0.05	0.12	0.20	4.42
[DE_077]_w {1}	-	-	0.12	-	-	-
[AT_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation-Chemical reduction-Sedimentation-Neutralisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	0.06	0.07	0.15	1.00	-
[DE_048]_w {1}	-	-	0.06	0.15	-	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0.00	0.05	0.17	0.10	-
[AT_015]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.24	-	1.00	-
[FR_006]_w {2}	Precipitation-Coagulation and flocculation-Biological treatment- Activated sludge process	0.07	0.14	0.26	1.00	18.53
[FR_006]_w {1}	Precipitation-Coagulation and flocculation	0.03	0.07	0.28	1.00	15.63

[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	0.28	-	5.00	-
[AT_005]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.10	0.17	0.30	-	-
[CZ_010]_w {1}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.05	0.35	0.20	0.30	8.57
[AT_011]_w {1}	Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.11	0.12	0.36	1.00	-
[DE_060]_w {1}	Adsorption techniques – activated carbon-Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks-Sedimentation-Precipitation	-	-	0.41	1.00	-
[DE_079]_w {1}	Neutralisation-Precipitation-Flotation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	-	0.43	-	-
[CZ_006]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.03	0.17	0.50	-	-
[AT_020]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon-Sedimentation-	0.15	0.28	0.54	1.00	10.50
[AT_009]_w {2}	Ion exchange resins-Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Evaporation (e.g. vacuum evaporation)	0.38	0.47	0.58	1.00	-
[AT_009]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.22	0.29	0.59	1.00	-
[FR_017]_w {1}	Chemical reduction	0.12	0.22	0.59	5.00	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.10	0.28	0.68	1.00	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.02	0.15	0.73	0.40	-
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.13	0.41	0.85	1.00	-

[FR_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	-	0.97	-	5.00	-
[DE_045]_w {1}	Other-	-	-	1.00	-	-
[DE_036]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Electrolysis-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Other-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon	-	-	1.10	1.00	-
[DE_037]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks	-	-	1.10	1.00	-
[FR_020]_w {1}	Other	0.26	0.63	1.50	-	-
[FR_009]_w {1}	Coagulation and flocculation-Neutralisation	-	1.71	-	5.00	-
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.82	1.71	3.20	5.00	-
[FR_014]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction	0.46	1.52	3.81	-	-
[DE_025]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Adsorption techniques – activated carbon-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	-	-	5.50	-	-
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0.02	0.89	29.14	5.00	-
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	0.02	7.28	53.00		-

3.2.1.6 Cyanides

The reported data for cyanide emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-6.



Source: [168, TWG 2023]

Figure 3-7: Cyanide emissions to water in electrolytic or chemical plating plants

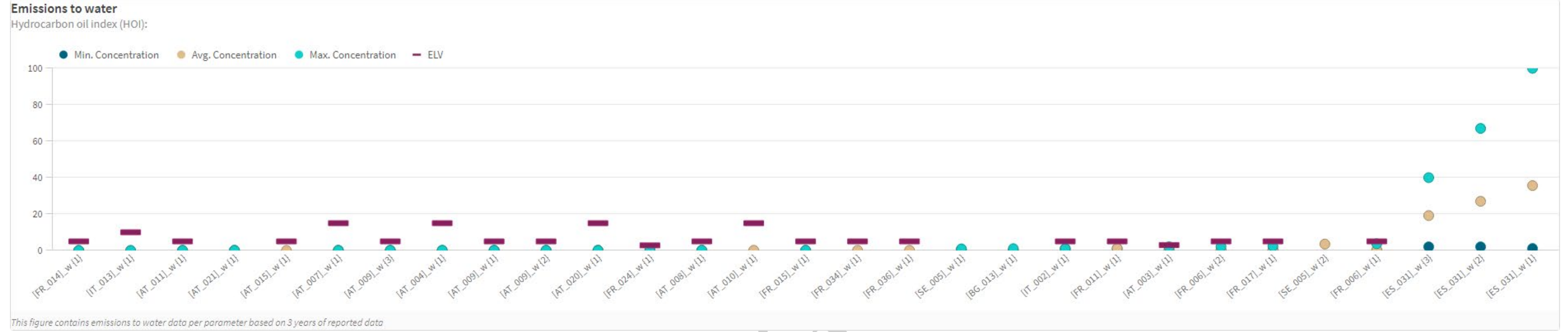
Table 3-6: Reported data and contextual information for cyanide emissions to water in electrolytic or chemical plating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[FI_002]_w {1}	Precipitation-Flotation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)	-	0.00	-	0.50	-
[BE_020]_w {1}	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other	-	-	0.00	-	-
[AT_007]_w {1}	Adsorption techniques – activated carbon-Ion exchange resins-Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation	0.00	0.00	0.00	0.10	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0.00	0.00	0.00	0.10	-
[SE_005]_w {1}	Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Adsorption techniques – activated carbon-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Reverse osmosis-Sedimentation-Neutralisation	0.00	0.00	0.00	0.50	-
[AT_012]_w {2}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	-	0.01	-	0.10	-
[CZ_002]_w {1}	Neutralisation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Adsorption techniques – activated carbon-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)	0.01	0.01	0.01	0.20	-
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.01	-	-	-	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	-	0.01	-	0.10	-
[IT_008]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation	0.01	0.01	0.01	0.50	1.87
[IT_029]_w {1}	Absorption-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Precipitation-Sedimentation-Evaporation (e.g. vacuum evaporation)	0.01	0.01	0.01	1.00	5.38
[IT_032]_w {1}	Coagulation and flocculation-Ion exchange resins	0.02	0.02	0.02	1.00	-
[AT_010]_w {1}	Precipitation-Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Evaporation (e.g. vacuum evaporation)-Electrolysis-Evaporation (e.g. vacuum evaporation)-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange resins	0.01	0.01	0.03	0.10	-
[CZ_010]_w {2}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation	0.00	0.00	0.03	0.30	0.57
[DE_048]_w {1}	-	-	0.01	0.03	-	-
[FR_020]_w {1}	Other	0.01	0.02	0.03	-	-
[BG_006]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Adsorption techniques – activated carbon-Physical separation (e.g. screens, sieves, grit	0.00	0.01	0.05	1.50	-

	separators, grease separators, oil-water separation)-Use of buffer tanks to reduce waste water and emission load peaks					
[ES_024]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Other	0.01	0.03	0.05	-	-
[ES_009]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.05	0.05	0.05	3.00	-
[ES_013]_w {1}	Adsorption techniques – activated carbon-Neutralisation-Coagulation and flocculation-Crystalisation-Flotation-Ion exchange resins	0.05	0.05	0.05	0.50	-
[IT_002]_w {1}	Equalisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Biological treatment- Activated sludge process-Nitrification/denitrification	0.05	0.05	0.05	0.50	16.00
[FR_017]_w {1}	Chemical reduction	0.01	0.03	0.05	0.10	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.05	0.05	0.06	-	-
[IT_031]_w {1}	Coagulation and flocculation	0.02	0.03	0.06	1.00	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.08	-	-
[ES_002]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.03	0.04	0.08	0.50	-
[CZ_010]_w {1}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.00	0.01	0.09	0.20	0.45
[DE_025]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Adsorption techniques – activated carbon-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	-	-	0.09	-	-
[FR_014]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction	0.09	0.09	0.10	0.10	-
[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid-	0.00	0.04	0.14	0.20	-
[DE_045]_w {1}	Other	-	-	0.20	-	-
[FI_005]_w {1}	-	0.00	0.07	1.50	0.20	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.00	0.03	2.00	2.00	-
[DK_001]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.04	1.55	4.50	1.00	

3.2.1.7 HOI

The reported data for HOI emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-7.



This figure contains emissions to water data per parameter based on 3 years of reported data

Source: [168, TWG 2023]

Figure 3-8: HOI emissions to water in electrolytic or chemical plating plants

Table 3-7: Reported data and contextual information for HOI emissions to water in electrolytic or chemical plating plants

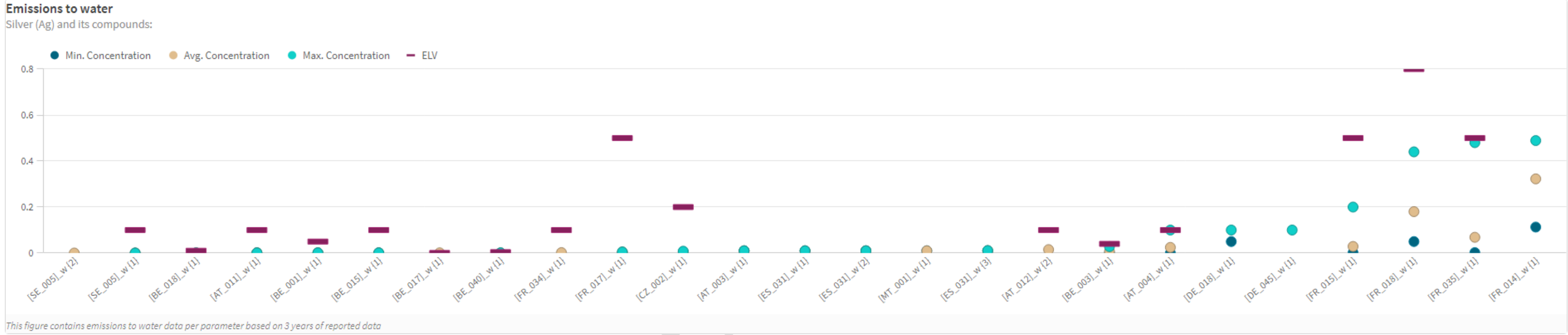
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[FR_014]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction	0.00	0.00	0.00	5.00	-
[IT_013]_w {1}	Chemical reduction	-	0.00	0.00	10	0
[AT_011]_w {1}	Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.05	0.05	0.05	5	-
[AT_021]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0.05	0.05	0.05	-	-
[AT_015]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.05	-	5	-
[AT_007]_w {1}	Adsorption techniques – activated carbon-Ion exchange resins-Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation	0.06	0.06	0.06	15	-
[AT_009]_w {3}	Evaporation (e.g. vacuum evaporation)	0.06	0.06	0.06	5	-
[AT_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation-Chemical reduction-Sedimentation-Neutralisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	0.02	0.04	0.08	15	-
[AT_009]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.08	0.08	0.08	5	-
[AT_009]_w {2}	Ion exchange resins-Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Evaporation (e.g. vacuum evaporation)	0.06	0.07	0.08	5	-
[AT_020]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon-Sedimentation	0.08	0.08	0.08	15	-
[FR_024]_w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation	0.05	0.05	0.08	2.80	-
[AT_008]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.10	0.10	0.10	5	-
[AT_010]_w {1}	Precipitation-Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Evaporation (e.g. vacuum evaporation)-Electrolysis-Evaporation (e.g. vacuum evaporation)-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange resins	-	0.10	-	15	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.03	0.10	0.10	5	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration	-	0.10	-	5	-

	(e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks					
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	0.10	-	5	-
[SE_005]_w {1}	Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Adsorption techniques – activated carbon-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Reverse osmosis-Sedimentation-Neutralisation	0.50	0.56	0.88	-	-
[BG_013]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.06	0.39	1	-	-
[IT_002]_w {1}	Equalisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Biological treatment- Activated sludge process-Nitrification/denitrification	1	1	1	5	
[FR_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	1.02	1.16	-	5	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0	0.64	2	3	-
[FR_006]_w {2}	Precipitation-Coagulation and flocculation-Biological treatment- Activated sludge process	0.02	0.30	2.10	5	99.60
[FR_017]_w {1}	Chemical reduction	0.20	0.62	2.40	5	-
[SE_005]_w {2}	Evaporation (e.g. vacuum evaporation)	-	3.50	-	-	-
[FR_006]_w {1}	Precipitation-Coagulation and flocculation	0.05	0.46	3.70	5	
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	2	19.15	40	-	-
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	2	27	67	-	-
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	1.10	35.63		-	-

3.2.1.8 Metals

3.2.1.8.1 Ag

The reported data for Ag emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-8.



Source: [168, TWG 2023]

Figure 3-9: Ag emissions to water in electrolytic or chemical plating plants

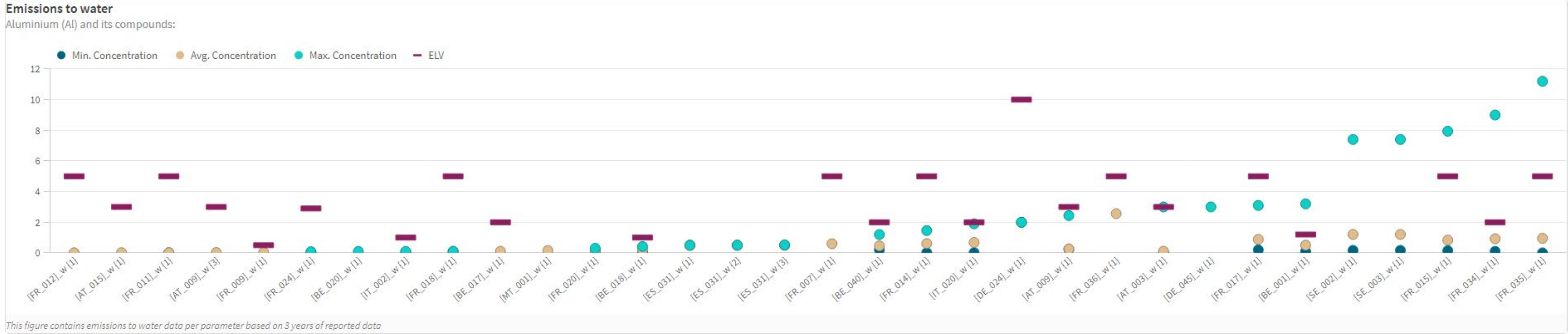
Table 3-8: Reported data and contextual information for Ag emissions to water in electrolytic or chemical plating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[BE_020]_w {1}	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other	-	-	0	-	-
[SE_005]_w {2}	Evaporation (e.g. vacuum evaporation)	-	0	-	-	-
[SE_005]_w {1}	Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Adsorption techniques – activated carbon-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Reverse osmosis-Sedimentation-Neutralisation	0	0	0	0.10	-
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	0	0	0	0.01	-
[AT_011]_w {1}	Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0	0	0	0.10	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0	0	0	0.05	-
[BE_015]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Chemical reduction-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Biological treatment-Activated sludge process-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0	0	0	0.10	-
[BE_017]_w {1}	Coagulation and flocculation	-	0	-	0	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0	0	0	0	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks-	-	0	-	0.10	-
[FR_017]_w {1}	Chemical reduction-	0	0	0.01	0.50	-
[CZ_002]_w {1}	Neutralisation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Adsorption techniques – activated carbon-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)	0.01	0.01	0.01	0.20	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange	0.01	0.01	0.01	-	-

	resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process					
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.01	0.01	0.01	-	-
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.01	0.01	0.01	-	-
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.01	0.01	0.01	-	-
[AT_012]_w {2}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	-	0.02	-	0.10	-
[BE_003]_w {1}	Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Neutralisation-Reverse osmosis-Use of buffer tanks to reduce waste water and emission load peaks	0	0.01	0.03	0.04	-
[AT_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation-Chemical reduction-Sedimentation-Neutralisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	0	0.02	0.10	0.10	-
[DE_018]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation	0.05	-	0.10	-	-
[DE_045]_w {1}	Other	-	-	0.10	-	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0	0.03	0.20	0.50	-
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.05	0.18	0.44	0.80	-
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0	0.07	0.48	0.50	-
[FR_014]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction	0.11	0.32	0.49	-	-

3.2.1.8.2 Al

The reported data for Al emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-9.



Source: [168, TWG 2023]

Figure 3-10: Al emissions to water in electrolytic or chemical plating plants

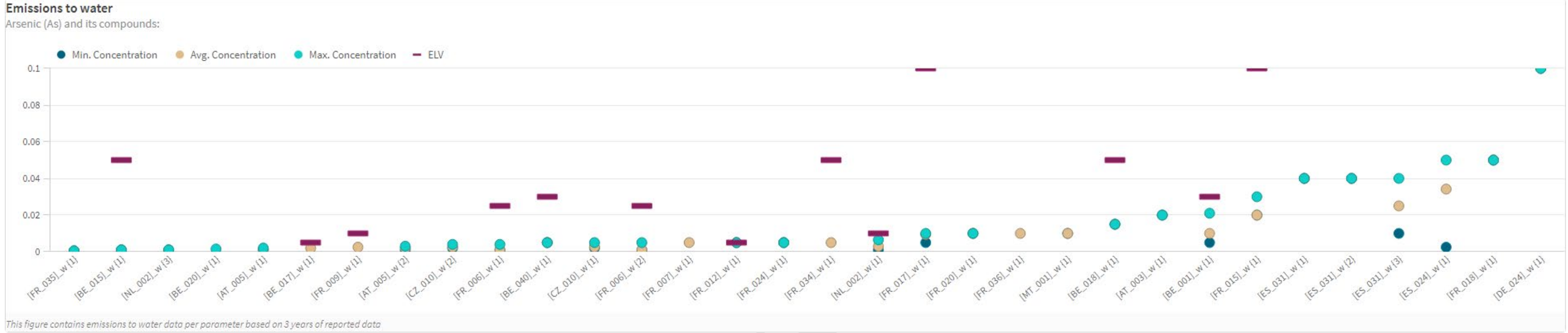
Table 3-9: Reported data and contextual information for Al emissions to water in electrolytic or chemical plating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	-	0.01	-	5	-
[AT_015]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.01	-	3	-
[FR_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.01	0.02	-	5	-
[AT_009]_w {3}	Evaporation (e.g. vacuum evaporation)	-	0.03	-	3	-
[FR_009]_w {1}	Coagulation and flocculation-Neutralisation	-	0.03	-	0.50	-
[FR_024]_w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation	0.01	0.03	0.08	2.90	-
[BE_020]_w {1}	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other	-	-	0.10	-	-
[IT_002]_w {1}	Equalisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Biological treatment- Activated sludge process-Nitrification/denitrification	0.01	0.07	0.10	1	18
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.10	0.10	0.10	5	-
[BE_017]_w {1}	Coagulation and flocculation	-	0.11	-	2	-
[FR_020]_w {1}	Other	0.11	0.18	0.30	-	-
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	0.08	0.21	0.42	1	-
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.50	0.50	0.50	-	-
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.50	0.50	0.50	-	-
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.50	0.51	0.52	-	-
[FR_007]_w {1}	Coagulation and flocculation-Nitrification/denitrification	-	0.60	-	5	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0.20	0.46	1.20	2	-
[FR_014]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction	0.02	0.61	1.46	5	0.28

[IT_020]_w {1}	Coagulation and flocculation	0.02	0.68	1.90	2	19.92
[DE_024]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Sedimentation	2	2	2	10	-
[AT_009]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.23	0.26	2.44	3	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical searation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation-	-	2.56	-	5	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0	0.11	3	3	-
[DE_045]_w {1}	Other	-	-	3	-	-
[FR_017]_w {1}	Chemical reduction	0.20	0.88	3.10	5	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.10	0.50	3.20	1.20	-
[SE_002]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.17	1.21	7.40	-	-
[SE_003]_w {1}	Neutralisation	0.17	1.21	7.40	-	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.15	0.83	7.94	5	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	0.10	0.92	9	2	49.41
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0.01	0.95	11.20	5	24.33

3.2.1.8.3 As

The reported data for As emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-10.



Source: [168, TWG 2023]

Figure 3-11: As emissions to water in electrolytic or chemical plating plants

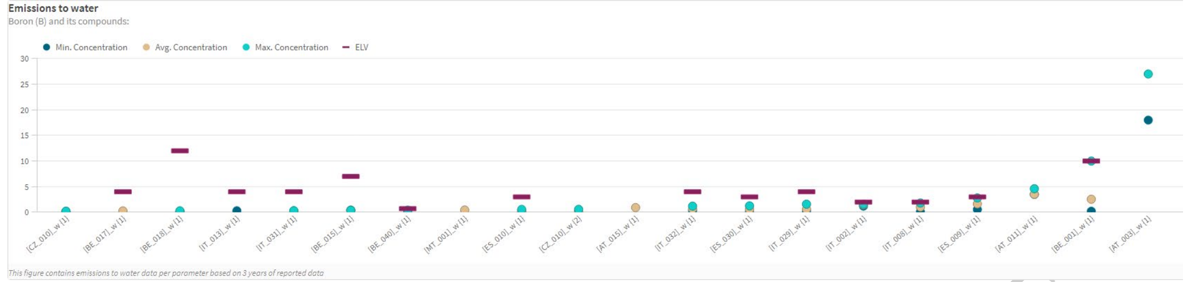
Table 3-10: Reported data and contextual information for As emissions to water in electrolytic or chemical plating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[AT_021]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0	0	0	-	-
[BE_003]_w {1}	Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Neutralisation-Reverse osmosis-Use of buffer tanks to reduce waste water and emission load peaks	0	0	0	-	-
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0	0	0	-	-
[BE_015]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Chemical reduction-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Biological treatment-Activated sludge process-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0	0	0	0.05	-
[NL_002]_w {3}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0	0	0	-	-
[BE_020]_w {1}	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other	-	-	0	-	-
[AT_005]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0	0	0	-	-
[BE_017]_w {1}	Coagulation and flocculation	-	0	-	0.01	-
[FR_009]_w {1}	Coagulation and flocculation-Neutralisation	-	0	-	0.01	-
[AT_005]_w {2}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0	0	0	-	-
[CZ_010]_w {2}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation	0	0	0	-	0.12
[FR_006]_w {1}	Precipitation-Coagulation and flocculation	0	0	0	0.03	0.17
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.01	0.03	-
[CZ_010]_w {1}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0	0	0.01	-	0.18
[FR_006]_w {2}	Precipitation-Coagulation and flocculation-Biological treatment- Activated sludge process-	0	0	0.01	0.03	0.08
[FR_007]_w {1}	Coagulation and flocculation-Nitrification/denitrification	-	0.01	-	-	-
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.01	0.01	-
[FR_024]_w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation	0.01	0.01	0.01	-	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	-	0.01	-	0.05	-

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[NL_002]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Adsorption techniques – activated carbon	0	0	0.01	0.01	-
[FR_017]_w {1}	Chemical reduction	0.01	0.01	0.01	0.10	-
[FR_020]_w {1}	Other	0.01	0.01	0.01	-	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	0.01	-	-	-
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks-	0.02	0.02	0.02	0.05	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.02	0.02	0.02	-	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.02	0.03	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.02	0.02	0.03	0.10	-
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.04	0.04	0.04	-	-
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.04	0.04	0.04	-	-
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.01	0.03	0.04	-	-
[ES_024]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Other	0	0.03	0.05	-	-
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.05	0.05	0.05	-	-
[DE_024]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Sedimentation	0.10	0.10	0.10	-	-

3.2.1.8.4 B

The reported data for boron (B) emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-11.



Source: [168, TWG 2023]

Figure 3-12: B emissions to water in electrolytic or chemical plating plants

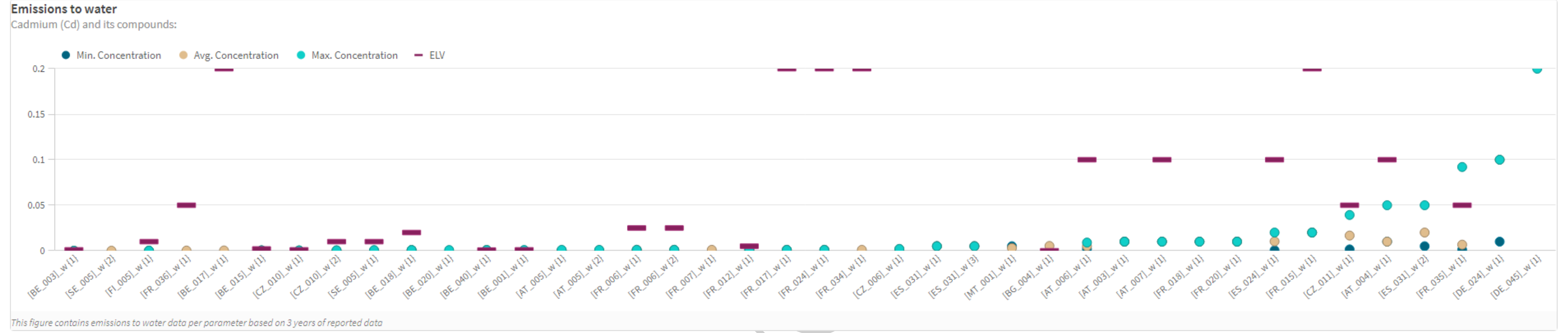
Table 3-11: Reported data and contextual information for B emissions to water in electrolytic or chemical plating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[CZ_010]_w {1}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.11	0.17	0.21	-	17.21
[BE_017]_w {1}	Coagulation and flocculation	-	0.27	-	4	-
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	0.13	0.16	0.29	12	-
[IT_013]_w {1}	Chemical reduction	0.30	-	-	4	0.20
[IT_031]_w {1}	Coagulation and flocculation	0.21	0.26	0.32	4	-
[BE_015]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Chemical reduction-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Biological treatment-Activated sludge process-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.40	0.40	0.40	7	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0.21	0.28	0.42	0.70	-
[ES_010]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Precipitation	0.01	0.29	0.56	3	-
[CZ_010]_w {2}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation-	0.05	0.20	0.57	-	13.96
[AT_015]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.92	-	-	-
[IT_032]_w {1}	Coagulation and flocculation-Ion exchange resins	0.30	0.67	1.20	4	-

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[ES_030]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Precipitation	0.07	0.54	1.25	3	-
[IT_029]_w {1}	Absorption-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Precipitation-Sedimentation-Evaporation (e.g. vacuum evaporation)	0.26	0.61	1.58	4	
[IT_002]_w {1}	Equalisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Biological treatment- Activated sludge process-Nitrification/denitrification	1.20	1.47	1.60	2	
[IT_008]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation	0.07	1.02	1.80	2	
[ES_009]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.55	1.63	2.80	3	-
[AT_011]_w {1}	Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	3.50	3.50	4.60	-	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.21	2.55	10	10	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	18	-	27	-	-

3.2.1.8.5 Cd

The reported data for Cd emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-12.



Source: [168, TWG 2023]

Figure 3-13: Cd emissions to water in electrolytic or chemical plating plants

Table 3-12: Reported data and contextual information for Cd emissions to water in electrolytic or chemical plating plants

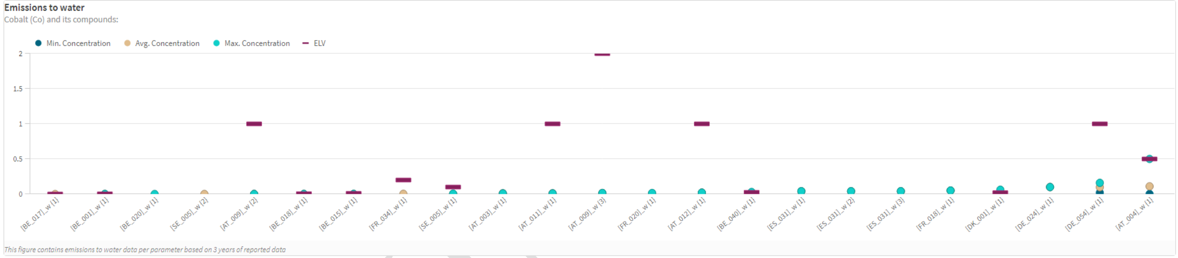
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[CZ_007]_w {1}	Absorption-Sedimentation-Coagulation and flocculation-Electrodialysis-Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	-	-	-	-
[BE_003]_w {1}	Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Neutralisation-Reverse osmosis-Use of buffer tanks to reduce waste water and emission load peaks	0	0	0	0	-
[AT_021]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0	0	0	-	-
[SE_005]_w {2}	Evaporation (e.g. vacuum evaporation)	-	0	-	-	-
[FI_005]_w {1}	-	0	0	0	0.01	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	0	-	0.05	-
[BE_017]_w {1}	Coagulation and flocculation	-	0	-	0.20	-
[BE_015]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Chemical reduction-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Biological treatment-Activated sludge process-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0	0	0	0	-
[CZ_010]_w {1}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0	0	0	0	0.10
[CZ_010]_w {2}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation	0	0	0	0.01	0.01
[SE_005]_w {1}	Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Adsorption techniques – activated carbon-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Reverse osmosis-Sedimentation-Neutralisation	0	0	0	0.01	-
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/ denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	0	0	0	0.02	-
[BE_020]_w {1}	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other	-	-	0	-	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of	0	0	0	0	-

	buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)					
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0	0	0	0	-
[AT_005]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0	0	0	-	-
[AT_005]_w {2}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0	0	0	-	-
[FR_006]_w {1}	Precipitation-Coagulation and flocculation	0	0	0	0.03	0.16
[FR_006]_w {2}	Precipitation-Coagulation and flocculation-Biological treatment- Activated sludge process	0	0	0	0.03	0.06
[FR_007]_w {1}	Coagulation and flocculation-Nitrification/denitrification	-	0	-	-	-
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0	0	0	0.01	-
[FR_017]_w {1}	Chemical reduction	0	0	0	0.20	-
[FR_024]_w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation	0	0	0	0.20	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	-	0	-	0.20	-
[CZ_006]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0	0	0	-	-
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.01	0.01	0.01	-	-
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.01	0.01	0.01	-	-
[BG_004]_w {1}	Neutralisation	-	0.01	-	0	-
[AT_006]_w {1}	Coagulation and flocculation-Precipitation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0	0.01	0.01	0.10	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.01	0.01	0.01	-	-
[AT_007]_w {1}	Adsorption techniques – activated carbon-Ion exchange resins-Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation	0.01	0.01	0.01	0.10	-
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.01	0.01	0.01	-	-
[FR_020]_w {1}	Other	0.01	0.01	0.01	-	-
[ES_024]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Other	0	0.01	0.02	0.10	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.02	0.02	0.02	0.20	-
[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated	0	0.02	0.04	0.05	-

	carbon-Ion exchange liquid- liquid					
[AT_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation-Chemical reduction-Sedimentation-Neutralisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	0.01	0.01	0.05	0.10	-
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.01	0.02	0.05	-	-
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0	0.01	0.09	0.05	0.06
[DE_024]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Sedimentation	0.01	0.10	0.10	-	-
[DE_045]_w {1}	Other	-	-	0.20	-	-

3.2.1.8.6 Co

The reported data for cobalt (Co) emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-13.



Source: [168, TWG 2023]

Figure 3-14: Co emissions to water in electrolytic or chemical plating plants

Table 3-13: Reported data and contextual information for Co emissions to water in electrolytic or chemical plating plants

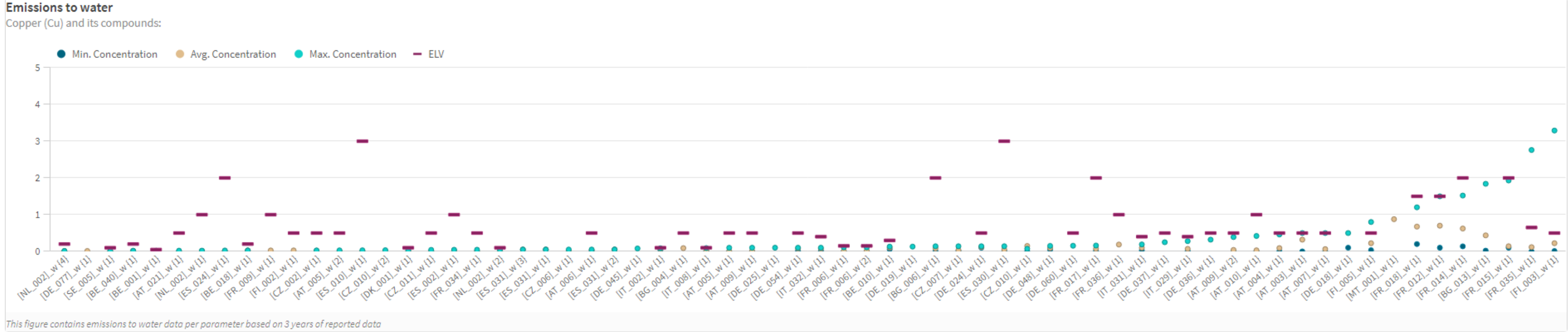
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[BE_017]_w {1}	Coagulation and flocculation	-	0	-	0.00	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0	0	0	0	-
[BE_020]_w {1}	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other	-	-	0	-	-
[SE_005]_w {2}	Evaporation (e.g. vacuum evaporation)	-	0	-	-	-
[AT_009]_w {2}	Ion exchange resins-Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Evaporation (e.g. vacuum evaporation)	0	0	0	1	-

[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	0	0	0	0.01	-
[BE_015]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Chemical reduction-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Biological treatment-Activated sludge process-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0	0	0	0.01	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	-	0	-	0.20	-
[SE_005]_w {1}	Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Adsorption techniques – activated carbon-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Reverse osmosis-Sedimentation-Neutralisation	0	0	0.01	0.10	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.01	0.01	0.01	-	-
[AT_011]_w {1}	Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.01	0.01	0.01	1	-
[AT_009]_w {3}	Evaporation (e.g. vacuum evaporation)	0.02	0.02	0.02	2	-
[FR_020]_w {1}	Other	0.01	0.01	0.02	-	-
[AT_012]_w {1}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	0.02	0.02	0.02	1	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0	0	0.03	0.03	-
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.04	0.04	0.04	-	-
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.04	0.04	0.04	-	-
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.04	0.04	0.04	-	-
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.05	0.05	0.05	-	-
[DK_001]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0	0.01	0.06	0.02	0.79
[DE_024]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-	0.10	0.10	0.10	-	-

	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Sedimentation					
[DE_054]_w {1}	Coagulation and flocculation	0.02	0.10	0.16	1	-
[AT_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation-Chemical reduction-Sedimentation-Neutralisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	0	0.11	0.50	0.50	-

3.2.1.8.7 Cu

The reported data for Cu emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-14.



Source: [168, TWG 2023]

Figure 3-15: Cu emissions to water in electrolytic or chemical plating plants

Table 3-14: Reported data and contextual information for Cu emissions to water in electrolytic or chemical plating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[BE_003]_w {1}	Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Neutralisation-Reverse osmosis-Use of buffer tanks to reduce waste water and emission load peaks	0	0	0	0.50	-
[BE_020]_w {1}	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other	-	-	0	-	-
[AT_015]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0	-	0.50	-
[AT_020]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon-Sedimentation	0	0	0	0.50	-
[SE_005]_w {2}	Evaporation (e.g. vacuum evaporation)	-	0	-	-	-
[BE_015]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Chemical reduction-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Biological treatment-Activated sludge process-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0	0	0	0.50	-
[FR_007]_w {1}	Coagulation and flocculation-Nitrification/denitrification	-	0.01	-	5	-
[AT_011]_w {1}	Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.01	0.01	0.01	0.50	-
[BE_017]_w {1}	Coagulation and flocculation	-	0.01	-	0.05	-
[FR_024]_w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation	0.01	0.01	0.01	1.20	-
[NL_002]_w {3}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0	0.01	0.01	1	-
[NL_002]_w {4}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.01	0.20	-
[DE_077]_w {1}	-	-	0.01	-	-	-
[SE_005]_w {1}	Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Adsorption techniques – activated carbon-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Reverse osmosis-Sedimentation-Neutralisation	0	0.01	0.01	0.10	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand	0.02	0.02	0.02	0.20	-

	filter)					
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0	0	0.02	0.05	-
[AT_021]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0	0	0.02	0.50	0.02
[NL_002]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Adsorption techniques – activated carbon	0.01	0.01	0.02	1	-
[ES_024]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Other	0	0.02	0.03	2	-
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	0.03	0.03	0.03	0.20	-
[FR_009]_w {1}	Coagulation and flocculation-Neutralisation	-	0.03	-	1	-
[FI_002]_w {1}	Precipitation-Flotation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)	-	0.03	-	0.50	-
[CZ_002]_w {1}	Neutralisation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Adsorption techniques – activated carbon-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)	0	0.02	0.03	0.50	-
[AT_005]_w {2}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0	0	0.03	0.50	0.06
[ES_010]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Precipitation	0.01	0.01	0.03	3	-
[CZ_010]_w {2}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation	0	0.02	0.03	-	0.31
[DK_001]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0	0.01	0.04	0.10	1.39
[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid	0.01	0.01	0.04	0.50	-
[ES_002]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.02	0.02	0.05	1	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	0.01	0.01	0.05	0.50	0
[NL_002]_w {2}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.05	0.10	-
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.05	0.05	0.05	-	-
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.05	0.05	0.05	-	-
[CZ_006]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0	0.01	0.05	-	-
[AT_006]_w {1}	Coagulation and flocculation-Precipitation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.02	0.04	0.05	0.50	-
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves,	0.05	0.05	0.05	-	-

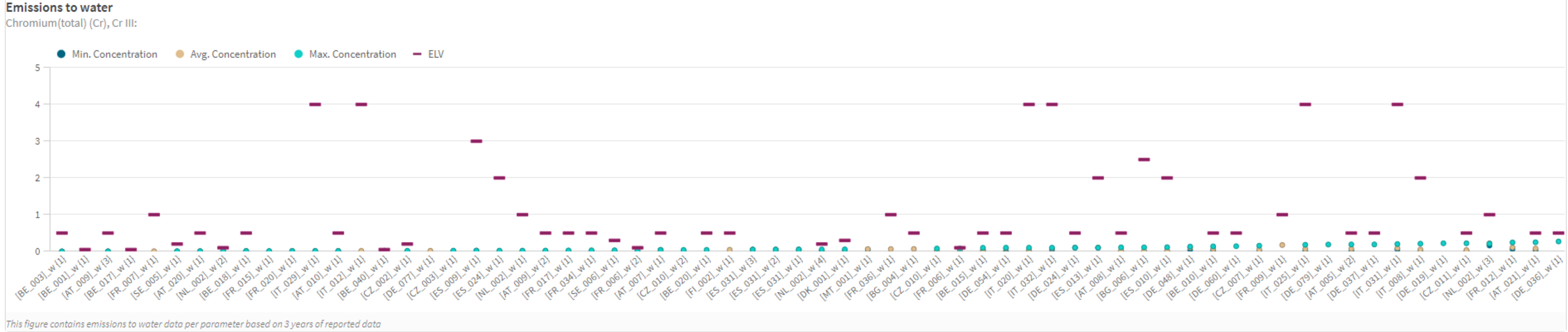
	grit separators, grease separators, oil-water separation)					
[DE_045]_w {1}	Other	-	-	0.08	-	-
[IT_002]_w {1}	Equalisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Biological treatment- Activated sludge process-Nitrification/denitrification	0.04	0.07	0.09	0.10	14
[BG_004]_w {1}	Neutralisation	-	0.09	-	0.50	-
[IT_008]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation	0.01	0.03	0.09	0.10	5.30
[AT_005]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.00	0	0.10	0.50	0.06
[AT_009]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0	0.01	0.10	0.50	-
[DE_025]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Adsorption techniques – activated carbon-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	-	-	0.10	-	-
[DE_054]_w {1}	Coagulation and flocculation	0.01	0.08	0.10	0.50	-
[IT_032]_w {1}	Coagulation and flocculation-Ion exchange resins	0.02	0.07	0.10	0.40	-
[FR_006]_w {1}	Precipitation-Coagulation and flocculation	0.01	0.01	0.11	0.15	7.64
[FR_006]_w {2}	Precipitation-Coagulation and flocculation-Biological treatment- Activated sludge process	0.01	0.02	0.11	0.15	4.80
[BE_010]_w {1}	Coagulation and flocculation	0.06	0.10	0.13	0.30	-
[DE_019]_w {1}	Chemical reduction	-	-	0.13	-	-
[BG_006]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Adsorption techniques – activated carbon-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Use of buffer tanks to reduce waste water and emission load peaks	0	0.08	0.14	2	-
[CZ_007]_w {1}	Absorption-Sedimentation-Coagulation and flocculation-Electrodialysis-Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.02	0.03	0.14	-	-
[DE_024]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Sedimentation	0.10	0.12	0.14	0.50	-
[ES_030]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Precipitation	0.01	0.05	0.14	3	-
[CZ_010]_w {1}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0	0.15	0.07	-	0.27
[DE_048]_w {1}	-	0.05	0.09	0.15	-	-
[DE_060]_w {1}	Adsorption techniques – activated carbon-Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Use of buffer	-	-	0.15	0.50	-

	tanks to reduce waste water and emission load peaks-Sedimentation-Precipitation					
[FR_017]_w {1}	Chemical reduction	0.01	0.07	0.16	2	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	0.19	-	1	-
[IT_031]_w {1}	Coagulation and flocculation	0.03	0.10	0.19	0.40	-
[DE_037]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks	-	-	0.25	0.50	-
[IT_029]_w {1}	Absorption-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Precipitation-Sedimentation-Evaporation (e.g. vacuum evaporation)	0.01	0.07	0.28	0.40	14.20
[DE_036]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Electrolysis-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Other-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon	-	-	0.32	0.50	-
[AT_009]_w {2}	Ion exchange resins-Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Evaporation (e.g. vacuum evaporation)	0	0.04	0.39	0.50	-
[AT_010]_w {1}	Precipitation-Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Evaporation (e.g. vacuum evaporation)-Electrolysis-Evaporation (e.g. vacuum evaporation)-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange resins	0	0.03	0.42	1	-
[AT_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation-Chemical reduction-Sedimentation-Neutralisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	0	0.09	0.46	0.50	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0	0.32	0.50	0.50	-
[AT_007]_w {1}	Adsorption techniques – activated carbon-Ion exchange resins-Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-	0	0.06	0.50	0.50	-

[DE_018]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation	0.10	-	0.50	-	-
[FI_005]_w {1}	-	0.03	0.22	0.80	0.50	-
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.20	0.67	1.20	1.50	-
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.10	0.70	1.50	1.50	-
[FR_014]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction	0.14	0.62	1.52	2	-
[BG_013]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.02	0.44	1.84	-	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.10	0.14	1.93	2	-
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0	0.12	2.76	0.65	0.99
[FI_003]_w {1}	-	0.01	0.22	3.29	0.50	-

3.2.1.8.8 Cr

The reported data for Cr emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-15.



Source: [168, TWG 2023]

Figure 3-16: Cr emissions to water in electrolytic or chemical plating plants

Table 3-15: Reported data and contextual information for Cr emissions to water in electrolytic or chemical plating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[BE_003]_w {1}	Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Neutralisation-Reverse osmosis-Use of buffer tanks to reduce waste water and emission load peaks	0	0	0	0.50	-
[DE_023]_w {1}	Evaporation (e.g. vacuum evaporation)-Evaporation (e.g. vacuum evaporation)-Chemical reduction-Neutralisation	0	0	0	-	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0	0	0	0.05	-
[AT_009]_w {3}	Evaporation (e.g. vacuum evaporation)	0	0	0	0.50	-
[BE_017]_w {1}	Coagulation and flocculation	-	0.01	-	0.05	-
[FR_007]_w {1}	Coagulation and flocculation-Nitrification/denitrification	-	0.01	-	1	-
[SE_005]_w {1}	Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Adsorption techniques – activated carbon-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Reverse osmosis-Sedimentation-Neutralisation	0	0	0.01	0.20	-
[AT_020]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon-Sedimentation	0	0.01	0.01	0.50	-
[NL_002]_w {2}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.01	0.10	-
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	0.01	0.01	0.01	0.50	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0	0	0.01	-	-
[FR_020]_w {1}	Other	0.01	0.01	0.01	-	-
[IT_029]_w {1}	Absorption-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Precipitation-Sedimentation-Evaporation (e.g. vacuum evaporation)	0.01	0.01	0.01	4	4.64
[AT_010]_w {1}	Precipitation-Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Evaporation (e.g. vacuum evaporation)-Electrolysis-Evaporation (e.g. vacuum evaporation)-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange resins	0.01	0.01	0.01	0.50	-

[IT_012]_w {1}	No technique applied	-	0.01	-	4	0.15
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0.02	0.02	0.02	0.05	-
[CZ_002]_w {1}	Neutralisation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Adsorption techniques – activated carbon-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)	0	0	0.02	0.20	-
[DE_077]_w {1}	-	-	0.02	-	-	-
[CZ_003]_w {1}	Neutralisation	0	0.01	0.02	-	-
[ES_009]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.02	0.02	0.02	3	-
[ES_024]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Other-	0.01	0.01	0.02	2	-
[NL_002]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Adsorption techniques – activated carbon	0.01	0.01	0.02	1	-
[AT_009]_w {2}	Ion exchange resins-Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Evaporation (e.g. vacuum evaporation)	0.01	0.02	0.02	0.50	-
[FR_017]_w {1}	Chemical reduction	0	0.01	0.03	0.50	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	0.01	0.01	0.03	0.50	0.27
[SE_006]_w {1}	Chemical reduction-Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0	0.02	0.03	0.30	0.20
[FR_006]_w {2}	Precipitation-Coagulation and flocculation-Biological treatment- Activated sludge process	0.01	0.01	0.04	0.10	0.99
[AT_007]_w {1}	Adsorption techniques – activated carbon-Ion exchange resins-Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation	0.04	0.04	0.04	0.50	-
[CZ_010]_w {2}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation	0	0	0.04	-	1.83
[BE_020]_w {1}	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other-	-	-	0.04	0.50	-
[FI_002]_w {1}	Precipitation-Flotation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-	-	0.04	-	0.50	-
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.05	0.05	0.05	-	-
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.05	0.05	0.05	-	-
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.05	0.05	0.05	-	-
[NL_002]_w {4}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.02	0.05	0.20	-
[DK_001]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0	0.01	0.06	0.30	1.50
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the	-	0.06	-	1	-

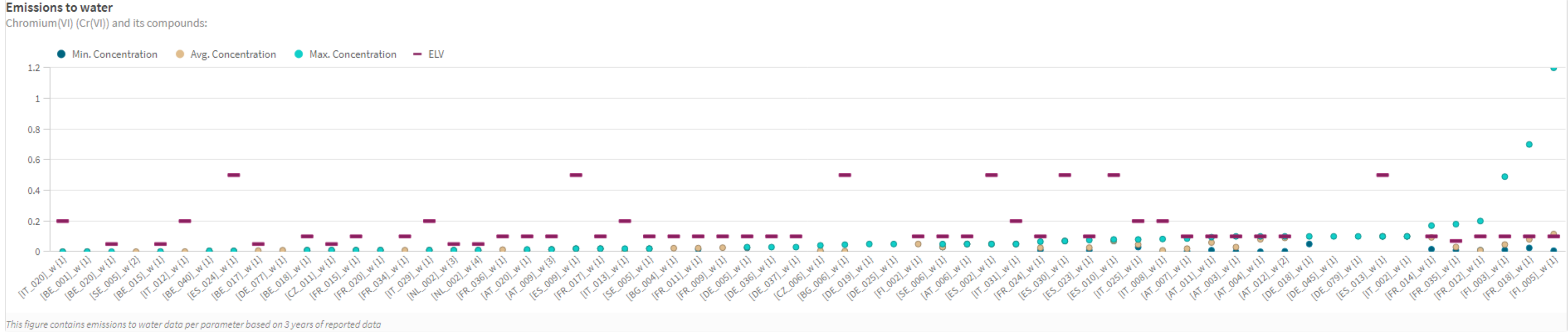
	individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation					
[BG_004]_w {1}	Neutralisation	-	0.07	-	0.50	-
[CZ_010]_w {1}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0	0	0.08	-	1.83
[FR_006]_w {1}	Precipitation-Coagulation and flocculation	0.01	0.01	0.08	0.10	0.95
[BE_015]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Chemical reduction-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Biological treatment-Activated sludge process-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.02	0.05	0.10	0.50	-
[DE_054]_w {1}	Coagulation and flocculation	0.01	0.08	0.10	0.50	-
[IT_020]_w {1}	Coagulation and flocculation	0.02	0.04	0.10	4	1.68
[IT_032]_w {1}	Coagulation and flocculation-Ion exchange resins	0.05	0.08	0.10	4	-
[DE_024]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Sedimentation	0.10	0.10	0.10	0.50	-
[ES_013]_w {1}	Adsorption techniques – activated carbon-Neutralisation-Coagulation and flocculation-Crystalisation-Flotation-Ion exchange resins	0.10	0.10	0.10	2	-
[AT_008]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.01	0.03	0.11	0.50	-
[BG_006]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Adsorption techniques – activated carbon-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Use of buffer tanks to reduce waste water and emission load peaks	0	0.01	0.11	2.50	0
[ES_010]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Precipitation	0	0.03	0.12	2	-
[DE_048]_w {1}	-	0.04	0.10	0.13	-	-
[BE_010]_w {1}	Coagulation and flocculation	0.03	0.07	0.14	0.50	-
[DE_060]_w {1}	Adsorption techniques – activated carbon-Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks-Sedimentation-Precipitation	-	-	0.14	0.50	-
[CZ_007]_w {1}	Absorption-Sedimentation-Coagulation and flocculation-Electrodialysis-Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.01	0.05	0.16	-	-

[FR_009]_w {1}	Coagulation and flocculation-Neutralisation	-	0.17	-	1	-
[IT_025]_w {1}	-	0.01	0.07	0.18	4	0.05
[DE_079]_w {1}	Neutralisation-Precipitation-Flotation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-	-	-	0.19	-	-
[AT_005]_w {2}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0.02	0.07	0.19	0.50	4.41
[DE_037]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks	-	-	0.19	0.50	-
[IT_031]_w {1}	Coagulation and flocculation	0.05	0.09	0.20	4	-
[IT_008]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation	0.01	0.05	0.21	2	12.32
[DE_019]_w {1}	Chemical reduction	-	-	0.22	-	-
[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid-	0.01	0.04	0.22	0.50	-
[NL_002]_w {3}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.16	0.22	0.21	1	-
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-	0.06	0.11	0.24	-	-
[AT_021]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0.03	0.08	0.25	0.50	2.08
[DE_036]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Electrolysis-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Other-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon	-	-	0.27	0.50	-
[IT_002]_w {1}	Equalisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Biological treatment- Activated sludge process-Nitrification/denitrification	0.09	0.16	0.30	2	44
[AT_005]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.01	0.08	0.31	0.50	2.41
[ES_023]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.06	0.15	0.34	0.50	-
[CZ_006]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0	0.11	0.46	-	-
[AT_011]_w {1}	Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.02	0.21	0.46	0.50	-

[AT_006]_w {1}	Coagulation and flocculation-Precipitation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.03	0.08	0.47	0.50	-
[AT_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation-Chemical reduction-Sedimentation-Neutralisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	0	0.20	0.48	0.50	-
[AT_012]_w {2}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	0	0.28	0.49	0.50	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0	0.22	0.50	0.50	-
[DE_018]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation	0.10	-	0.50	-	-
[DE_025]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Adsorption techniques – activated carbon-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	-	-	0.50	-	-
[DE_045]_w {1}	Other	-	-	0.50	-	-
[IT_013]_w {1}	Chemical reduction	0	0.13	0.60	4	0
[FR_024]_w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation	0.04	0.11	0.83	1.20	-
[ES_002]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.05	0.28	0.88	2.50	-
[ES_030]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Precipitation	0.02	0.25	0.90	2	-
[IT_006]_w {1}	Coagulation and flocculation-Chemical reduction-Precipitation	0.70	0.81	0.96	4	13.09
[FR_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.13	0.23	1	-	-
[FI_003]_w {1}	-	0.01	0.07	1.75	0.50	-
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0	0.23	2.42	1	7.28
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.32	0.83	4	1.50	-
[FR_014]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction	0.02	1.12	4.25	2	-

3.2.1.8.9 Cr(VI)

The reported data for Cr(VI) emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-16.



Source: [168, TWG 2023]

Figure 3-17: Cr(VI) emissions to water in electrolytic or chemical plating plants

Table 3-16: Reported data and contextual information for Cr(VI) emissions to water in electrolytic or chemical plating plants

Emission Point	**Abatement technique(s)**	**Min**	**Avg**	**Max**	**ELV conc**	**Load (g/day)**
[IT_020]_w {1}	Coagulation and flocculation	0	0	0	0.20	0
[DE_023]_w {1}	Evaporation (e.g. vacuum evaporation)-Evaporation (e.g. vacuum evaporation)-Chemical reduction-Neutralisation	0	0	0	-	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0	0	0	-	-
[BE_020]_w {1}	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other	-	-	0	0.05	-
[SE_005]_w {2}	Evaporation (e.g. vacuum evaporation)	-	0	-	-	-
[BE_015]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Chemical reduction-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Biological treatment-Activated sludge process-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0	0	0	0.05	-
[IT_012]_w {1}	No technique applied	-	0	-	0.20	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.01	-	-
[ES_024]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Other	0.01	0.01	0.01	0.50	-
[BE_017]_w {1}	Coagulation and flocculation	-	0.01	-	0.05	-
[DE_077]_w {1}	-	-	0.01	-	-	-
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	0.01	0.01	0.01	0.10	-
[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid	0.01	0.01	0.01	0.05	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.01	0.10	-
[FR_020]_w {1}	Other	0.01	0.01	0.01	-	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	-	0.01	-	0.10	-
[IT_029]_w {1}	Absorption-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical	0.01	0.01	0.01	0.20	5.17

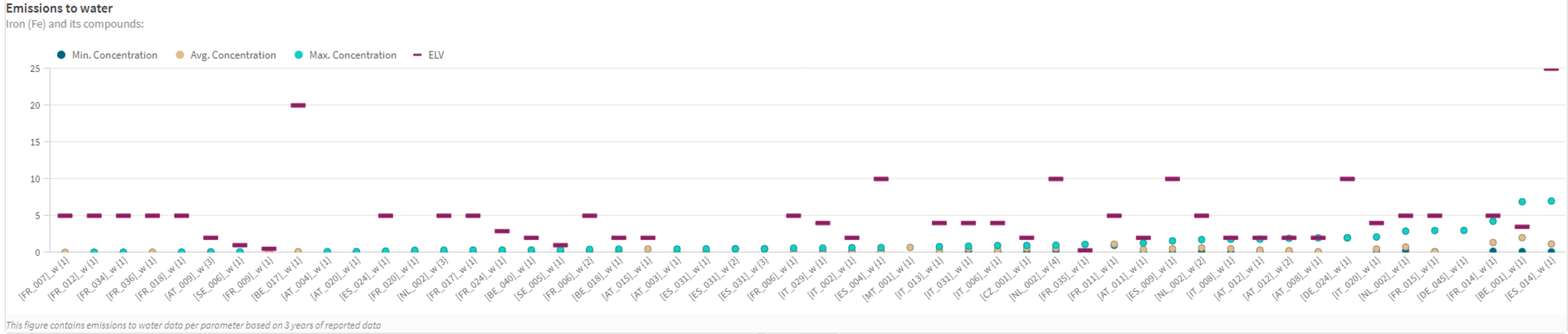
	reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Precipitation-Sedimentation-Evaporation (e.g. vacuum evaporation)					
[NL_002]_w {3}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.01	0.05	-
[NL_002]_w {4}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.01	0.05	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	0.01	-	0.10	-
[AT_020]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon-Sedimentation	0.01	0.01	0.02	0.10	-
[AT_009]_w {3}	Evaporation (e.g. vacuum evaporation)-	0.02	0.02	0.02	0.10	-
[ES_009]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.02	0.02	0.02	0.50	-
[FR_017]_w {1}	Chemical reduction	0.02	0.02	0.02	0.10	-
[IT_013]_w {1}	Chemical reduction	0	0	0.02	0.20	0
[SE_005]_w {1}	Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Adsorption techniques – activated carbon-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Reverse osmosis-Sedimentation-Neutralisation-	0.02	0.02	0.02	0.10	-
[BG_004]_w {1}	Neutralisation-	-	0.02	-	0.10	-
[FR_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-	0.02	0.02	-	0.10	-
[FR_009]_w {1}	Coagulation and flocculation-Neutralisation	-	0.03	-	0.10	-
[DE_005]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Precipitation-Membrane micro/ultra/nano filtration-Filtration (e.g. gravel filter, sand filter)-Other	0.03	0.03	0.03	0.10	-
[DE_036]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Electrolysis-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Other-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon	-	-	0.03	0.10	-
[DE_037]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g.	-	-	0.03	0.10	-

	gravel filter, sand filter)-Ion exchange resins-Neutralisation-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks					
[CZ_006]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0	0.01	0.04	-	-
[BG_006]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Adsorption techniques – activated carbon-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Use of buffer tanks to reduce waste water and emission load peaks	0	0	0.05	0.50	0
[DE_019]_w {1}	Chemical reduction	-	-	0.05	-	-
[DE_025]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Adsorption techniques – activated carbon-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	-	-	0.05	-	-
[FI_002]_w {1}	Precipitation-Flotation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)	-	0.05	-	0.10	-
[SE_006]_w {1}	Chemical reduction-Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.03	0.03	0.05	0.10	0.32
[AT_006]_w {1}	Coagulation and flocculation-Precipitation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.05	0.05	0.05	0.10	-
[ES_002]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.05	0.05	0.05	0.50	-
[IT_031]_w {1}	Coagulation and flocculation	0.05	0.05	0.05	0.20	-
[FR_024]_w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation	0.01	0.03	0.07	0.10	-
[ES_030]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Precipitation	0.07	0.07	0.07	0.50	-
[ES_023]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.01	0.03	0.08	0.10	-
[ES_010]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Precipitation	0.07	0.07	0.08	0.50	-
[IT_025]_w {1}	-	0.03	0.05	0.08	0.20	0.05
[IT_008]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-	0	0.01	0.08	0.20	2.49
[AT_007]_w {1}	Adsorption techniques – activated carbon-Ion exchange resins-Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-	0	0.02	0.09	0.10	-
[AT_011]_w {1}	Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.01	0.06	0.10	0.10	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0	0.03	0.10	0.10	-
[AT_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation-Chemical reduction-Sedimentation-Neutralisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-	0	0.08	0.10	0.10	-

	Precipitation					
[AT_012]_w {2}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	0	0.09	0.10	0.10	-
[DE_018]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation	0.05	-	0.10	-	-
[DE_045]_w {1}	Other	-	-	0.10	-	-
[DE_079]_w {1}	Neutralisation-Precipitation-Flotation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	-	0.10	-	-
[ES_013]_w {1}	Adsorption techniques – activated carbon-Neutralisation-Coagulation and flocculation-Crystalisation-Flotation-Ion exchange resins	0.10	0.10	0.10	0.50	-
[IT_002]_w {1}	Equalisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Biological treatment- Activated sludge process-Nitrification/denitrification	0.10	0.10	0.10	-	32
[FR_014]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction	0.02	0.09	0.17	0.10	0.01
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0.01	0.03	0.18	0.07	0.83
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.20	0.10	-
[FI_003]_w {1}	-	0.01	0.05	0.49	0.10	-
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.03	0.08	0.70	0.10	-
[FI_005]_w {1}	-	0.01	0.12	1.20	0.10	-

3.2.1.8.10 Fe

The reported data for Fe emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-17.



Source: [168, TWG 2023]

Figure 3-18: Fe emissions to water in electrolytic or chemical plating plants

Table 3-17: Reported data and contextual information for Fe emissions to water in electrolytic or chemical plating plants

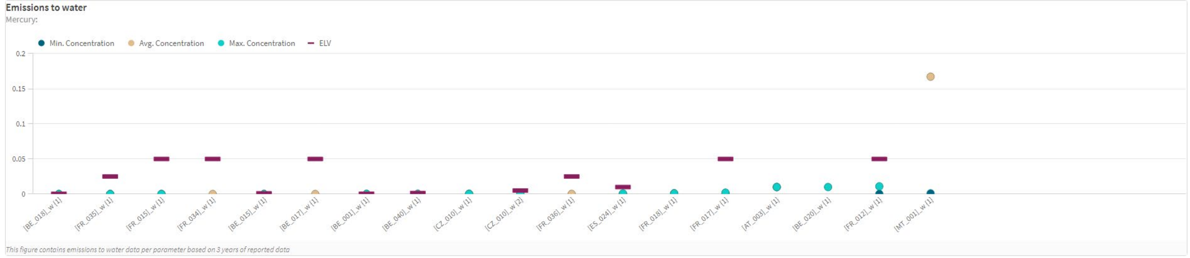
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[FR_007]_w {1}	Coagulation and flocculation-Nitrification/denitrification	-	0.02	-	5	-
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.03	5	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	0.01	0.02	0.04	5	0.84
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	0.05	-	5	-
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.02	0.05	0.05	5	-
[AT_009]_w {3}	Evaporation (e.g. vacuum evaporation)	0.07	0.07	0.07	2	-
[SE_006]_w {1}	Chemical reduction-Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.05	0.05	0.08	1	0.55
[FR_009]_w {1}	Coagulation and flocculation-Neutralisation	-	0.10	-	0.50	-
[BE_017]_w {1}	Coagulation and flocculation	-	0.11	-	20	-
[AT_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation-Chemical reduction-Sedimentation-Neutralisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	0	0.06	0.12	-	-
[AT_020]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon-Sedimentation	0.01	0.10	0.12	-	-
[ES_024]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Other	0.03	0.07	0.19	5	-
[FR_020]_w {1}	Other	0.11	0.18	0.30	-	-
[NL_002]_w {3}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.02	0.15	0.32	5	-
[FR_017]_w {1}	Chemical reduction	0.02	0.06	0.33	5	-
[FR_024]_w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation	0.02	0.09	0.35	2.90	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0.10	0.12	0.35	2	-

[SE_005]_w {1}	Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Adsorption techniques – activated carbon-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Reverse osmosis-Sedimentation-Neutralisation	0.08	0.21	0.42	1	-
[FR_006]_w {2}	Precipitation-Coagulation and flocculation-Biological treatment- Activated sludge process	0.07	0.18	0.43	5	23.41
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	0.03	0.13	0.46	2	-
[AT_015]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.47	-	2	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0	0.06	0.47	-	-
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.05	0.20	0.50	-	-
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.50	0.50	0.50	-	-
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.50	0.50	0.50	-	-
[FR_006]_w {1}	Precipitation-Coagulation and flocculation	0.04	0.12	0.60	5	35.13
[IT_029]_w {1}	Absorption-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Precipitation-Sedimentation-Evaporation (e.g. vacuum evaporation)	0.05	0.26	0.61	4	65.94
[IT_002]_w {1}	Equalisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Biological treatment- Activated sludge process-Nitrification/denitrification	0.12	0.29	0.66	2	87
[ES_004]_w {1}	Neutralisation-Other-Coagulation and flocculation-Sedimentation	0.20	0.24	0.67	10	-
[IT_013]_w {1}	Chemical reduction	0	0.35	0.80	4	0.08
[IT_031]_w {1}	Coagulation and flocculation	0.21	0.50	0.86	4	-
[IT_006]_w {1}	Coagulation and flocculation-Chemical reduction-Precipitation	0.09	0.36	0.95	4	10.12
[CZ_001]_w {1}	Neutralisation-Sedimentation	0.05	0.55	0.96	2	-
[NL_002]_w {4}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.30	0.57	0.99	10	-
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0.01	0.06	1.10	0.30	1.15
[FR_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel	0.98	1.13	-	5	-

	filter, sand filter)-Ion exchange resins					
[AT_011]_w {1}	Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.10	0.41	1.30	2	-
[ES_009]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.01	0.50	1.58	10	-
[NL_002]_w {2}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.21	0.62	1.75	5	-
[IT_008]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation	0.07	0.51	1.80	2	92.90
[AT_012]_w {1}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	0.02	0.32	1.81	2	-
[AT_012]_w {2}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	0.02	0.25	1.93	2	-
[AT_008]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.02	0.10	2	2	-
[DE_024]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Sedimentation	2	2	2	10	-
[IT_020]_w {1}	Coagulation and flocculation	0.02	0.47	2.11	4	25.68
[NL_002]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Adsorption techniques – activated carbon	0.30	0.75	2.90	5	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.10	0.10	2.98	5	-
[DE_045]_w {1}	Other	-	-	3	-	-
[FR_014]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction	0.17	1.36	4.25	5	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.13	2.01	6.90	3.50	-
[ES_014]_w {1}	Coagulation and flocculation-Membrane micro/ultra/nano filtration-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Other	0.09	1.16	7	25	62.56

3.2.1.8.11 Hg

The reported data for Hg emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-18.



Source: [168, TWG 2023]

Figure 3-19: Hg emissions to water in electrolytic or chemical plating plants

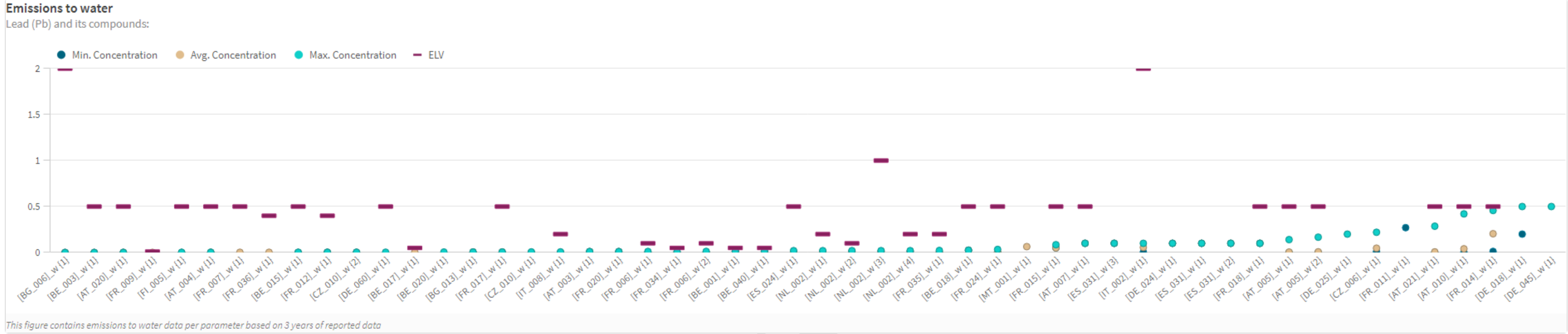
Table 3-18: Reported data and contextual information for Hg emissions to water in electrolytic or chemical plating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	0	0	0	0	-
[BE_003]_w {1}	Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Neutralisation-Reverse osmosis-Use of buffer tanks to reduce waste water and emission load peaks	0	0	0	-	-
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0	0	0	0.03	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0	0	0	0.05	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	-	0	-	0.05	-
[BE_015]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Chemical reduction-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Biological treatment-Activated sludge process-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0	0	0	0	-
[BE_017]_w {1}	Coagulation and flocculation	-	0	-	0.05	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0	0	0	0	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0	0	0	0	-
[CZ_010]_w {1}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0	0	0	-	0.02

[CZ_010]_w {2}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation	0	0	0	0.01	0.01
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	0	-	0.03	-
[ES_024]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Other	0	0	0	0.01	-
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0	0	0	-	-
[FR_017]_w {1}	Chemical reduction	0	0	0	0.05	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.01	0.01	0.01	-	-
[BE_020]_w {1}	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other	-	-	0.01	-	-
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0	-	0.01	0.05	-

3.2.1.8.12 Pb

The reported data for Pb emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-19.



Source: [168, TWG 2023]

Figure 3-20: Pb emissions to water in electrolytic or chemical plating plants

Table 3-19: Reported data and contextual information for Pb emissions to water in electrolytic or chemical plating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[BG_006]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Adsorption techniques – activated carbon-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Use of buffer tanks to reduce waste water and emission load peaks	0	0	0	2	0
[BE_003]_w {1}	Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Neutralisation-Reverse osmosis-Use of buffer tanks to reduce waste water and emission load peaks	0	0.00	0.00	0.50	-
[AT_020]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon-Sedimentation	0.00	0.00	0.00	0.50	-
[FR_009]_w {1}	Coagulation and flocculation-Neutralisation	-	0.00	-	0.01	-
[FI_005]_w {1}	-	0.00	0.00	0.00	0.50	-
[AT_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation-Chemical reduction-Sedimentation-Neutralisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	0.00	0.00	0.00	0.50	-
[FR_007]_w {1}	Coagulation and flocculation-Nitrification/denitrification	-	0.00	-	0.50	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	0.00	-	0.40	-
[BE_015]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Chemical reduction-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Biological treatment-Activated sludge process-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.00	0.00	0.00	0.50	-
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.00	0.00	0.00	0.40	-
[CZ_010]_w {2}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation	0.00	0.00	0.00	-	0.06
[DE_060]_w {1}	Adsorption techniques – activated carbon-Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks-	-	-	0.00	0.50	-

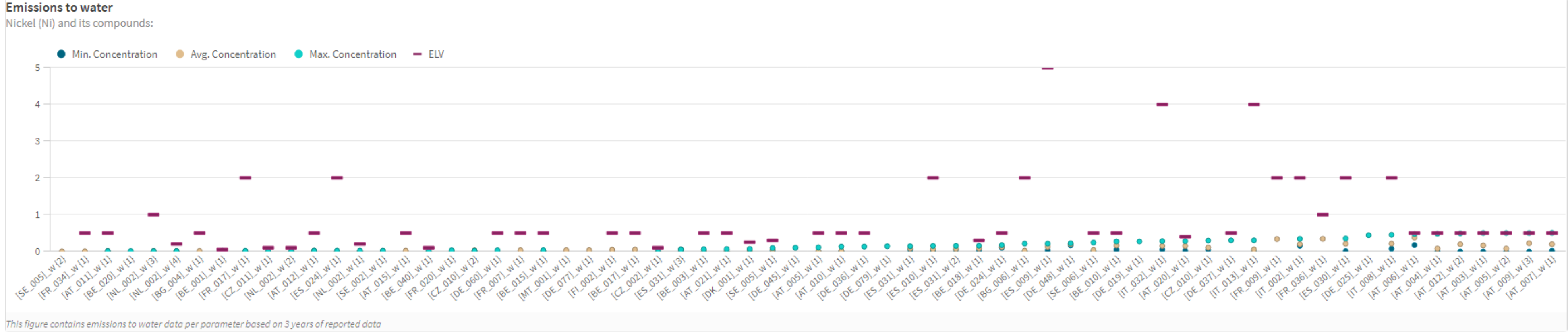
	Sedimentation-Precipitation					
[BE_017]_w {1}	Coagulation and flocculation	-	0.01	-	0.05	-
[BE_020]_w {1}	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other	-	-	0.01	-	-
[BG_013]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.01	0.01	0.01	-	-
[FR_017]_w {1}	Chemical reduction	0.01	0.01	0.01	0.50	-
[CZ_010]_w {1}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.00	0.00	0.01	-	0.09
[IT_008]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation	0.00	0.00	0.01	0.20	0.17
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.01	0.01	0.01	-	-
[FR_020]_w {1}	Other	0.01	0.01	0.01	-	-
[FR_006]_w {1}	Precipitation-Coagulation and flocculation	0.00	0.00	0.01	0.10	0.47
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	0.00	0.00	0.01	0.05	-
[FR_006]_w {2}	Precipitation-Coagulation and flocculation-Biological treatment- Activated sludge process	0.00	0.00	0.01	0.10	0.42
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.02	0.02	0.02	0.05	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.02	0.05	-
[ES_024]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Other	0.00	0.01	0.02	0.50	-
[NL_002]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Adsorption techniques – activated carbon	0.01	0.01	0.02	0.20	-
[NL_002]_w {2}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.02	0.02	0.10	-
[NL_002]_w {3}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.02	0.02	1.00	-
[NL_002]_w {4}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.02	0.02	0.20	-
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0.00	0.01	0.02	0.20	0.07
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use	0.03	0.03	0.03	0.50	-

	of buffer tanks to reduce waste water and emission load peaks					
[FR_024]_w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation	0.00	0.01	0.03	0.50	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.05	0.05	0.09	0.50	-
[AT_007]_w {1}	Adsorption techniques – activated carbon-Ion exchange resins-Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation	0.10	0.10	0.10	0.50	-
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.10	0.10	0.10	-	-
[IT_002]_w {1}	Equalisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Biological treatment- Activated sludge process-Nitrification/denitrification	0.00	0.06	0.10	2.00	18.00
[DE_024]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Sedimentation	0.10	0.10	0.10	-	-
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.10	0.10	0.10	-	-
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.10	0.10	0.10	-	-
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.10	0.10	0.10	0.50	-
[AT_005]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.00	0.00	0.14	0.50	0.14
[AT_005]_w {2}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0.00	0.01	0.17	0.50	0.12
[DE_025]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Adsorption techniques – activated carbon-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	-	-	0.20	-	-
[CZ_006]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.01	0.05	0.22	-	-
[FR_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.27	-	-	-	-
[AT_021]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0.00	0.01	0.29	0.50	0.18
[AT_010]_w {1}	Precipitation-Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Evaporation (e.g. vacuum evaporation)-Electrolysis-Evaporation (e.g. vacuum evaporation)-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange resins	0.01	0.04	0.42	0.50	-
[FR_014]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction	0.01	0.20	0.46	0.50	-

[DE_018]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-	0.20	-	0.50	-	-
[DE_045]_w {1}	Other-	-	-	0.50	-	-

3.2.1.8.13 Ni

The reported data for Ni emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-20.



This figure contains emissions to water data per parameter based on 3 years of reported data

Source: [168, TWG 2023]

Figure 3-21: Ni emissions to water in electrolytic or chemical plating plants

Table 3-20: Reported data and contextual information for Ni emissions to water in electrolytic or chemical plating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[DE_023]_w {1}	Evaporation (e.g. vacuum evaporation)-Evaporation (e.g. vacuum evaporation)-Chemical reduction-Neutralisation	0.00	0.00	0.00	-	-
[SE_005]_w {2}	Evaporation (e.g. vacuum evaporation)	-	0.00	-	-	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	-	0.01	-	0.50	-
[AT_011]_w {1}	Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.01	0.01	0.01	0.50	-
[BE_020]_w {1}	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other	-	-	0.01	-	-
[NL_002]_w {3}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.01	1.00	-
[NL_002]_w {4}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.01	0.20	-
[BG_004]_w {1}	Neutralisation	-	0.01	-	0.50	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.02	0.05	-
[FR_017]_w {1}	Chemical reduction	0.00	0.01	0.02	2.00	-
[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid	0.01	0.01	0.02	0.10	-
[NL_002]_w {2}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.02	0.10	-
[AT_012]_w {1}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	0.02	0.02	0.02	0.50	-
[ES_024]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Other	0.01	0.01	0.02	2.00	-
[NL_002]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Adsorption techniques – activated carbon	0.01	0.01	0.02	0.20	-
[SE_002]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.00	0.02	0.02	-	-
[AT_015]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.02	-	0.50	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.02	0.10	-

[FR_020]_w {1}	Other	0.01	0.02	0.03	-	-
[CZ_010]_w {2}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation	0.00	0.03	0.02	-	0.45
[DE_060]_w {1}	Adsorption techniques – activated carbon-Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks-Sedimentation-Precipitation	-	-	0.03	0.50	-
[FR_007]_w {1}	Coagulation and flocculation-Nitrification/denitrification	-	0.03	-	0.50	-
[BE_015]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Chemical reduction-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Biological treatment-Activated sludge process-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.00	0.02	0.03	0.50	-
[DE_077]_w {1}	-	-	0.03	-	-	-
[FI_002]_w {1}	Precipitation-Flotation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)	-	0.04	-	0.50	-
[BE_017]_w {1}	Coagulation and flocculation	-	0.05	-	0.50	-
[CZ_002]_w {1}	Neutralisation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Adsorption techniques – activated carbon-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)	0.01	0.01	0.05	0.10	-
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.05	0.05	0.05	-	-
[BE_003]_w {1}	Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Neutralisation-Reverse osmosis-Use of buffer tanks to reduce waste water and emission load peaks	0.00	0.01	0.06	0.50	-
[AT_021]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0.00	0.01	0.06	0.50	0.32
[DK_001]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.00	0.02	0.07	0.25	4.68
[SE_005]_w {1}	Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Adsorption techniques – activated carbon-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Reverse osmosis-Sedimentation-Neutralisation	0.03	0.05	0.09	0.30	-
[DE_045]_w {1}	Other	-	-	0.10	-	-
[AT_005]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.00	0.01	0.11	0.50	0.28
[AT_010]_w {1}	Precipitation-Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Evaporation (e.g. vacuum evaporation)-Electrolysis-Evaporation (e.g. vacuum evaporation)-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange resins	0.01	0.02	0.13	0.50	-
[DE_036]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Electrolysis-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange	-	-	0.13	0.50	-

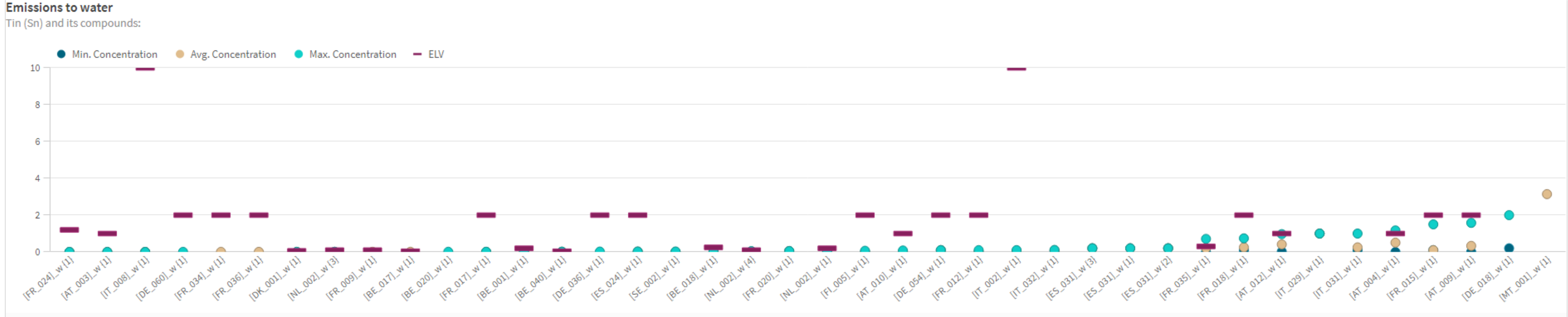
	resins-Neutralisation-Other-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon					
[DE_079]_w {1}	Neutralisation-Precipitation-Flotation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	-	0.14	-	-
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.05	0.08	0.14	-	-
[ES_010]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Precipitation	0.01	0.06	0.15	2.00	-
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.05	0.07	0.15	-	-
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	0.03	0.08	0.15	0.30	-
[DE_024]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Sedimentation	0.10	0.12	0.17	0.50	-
[BG_006]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Adsorption techniques – activated carbon-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Use of buffer tanks to reduce waste water and emission load peaks	0.00	0.02	0.21	2.00	-
[ES_009]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.03	0.13	0.21	5.00	-
[DE_048]_w {1}	-	0.16	0.19	0.22	-	-
[SE_006]_w {1}	Chemical reduction-Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.04	0.24	0.50	0.31
[BE_010]_w {1}	Coagulation and flocculation	0.04	0.16	0.27	0.50	-
[DE_019]_w {1}	Chemical reduction	-	-	0.27	-	-
[IT_032]_w {1}	Coagulation and flocculation-Ion exchange resins	0.05	0.15	0.28	4.00	-
[AT_020]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon-Sedimentation	0.02	0.15	0.28	0.40	0.14
[CZ_010]_w {1}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.05	0.11	0.29	-	11.57
[DE_037]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Sedimentation-Use of buffer tanks to reduce waste water and emission load	-	-	0.30	0.50	-

	peaks					
[IT_013]_w {1}	Chemical reduction	0.00	0.05	0.30	4.00	0.00
[FR_009]_w {1}	Coagulation and flocculation-Neutralisation	-	0.33	-	2.00	-
[IT_002]_w {1}	Equalisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Biological treatment- Activated sludge process-Nitrification/denitrification	0.15	0.19	0.34	2.00	54.00
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	0.34	-	1.00	-
[ES_030]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Precipitation	0.01	0.21	0.35	2.00	-
[DE_025]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Adsorption techniques – activated carbon-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	-	-	0.44	-	-
[IT_008]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation	0.07	0.21	0.45	2.00	40.18
[AT_006]_w {1}	Coagulation and flocculation-Precipitation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.17	0.38	0.47	0.50	-
[AT_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation-Chemical reduction-Sedimentation-Neutralisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	0.00	0.08	0.48	0.50	-
[AT_012]_w {2}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	0.00	0.19	0.49	0.50	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.00	0.16	0.50	0.50	-
[AT_005]_w {2}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0.00	0.08	0.50	0.50	6.13
[AT_009]_w {3}	Evaporation (e.g. vacuum evaporation)	0.00	0.22	0.50	0.50	-
[AT_007]_w {1}	Adsorption techniques – activated carbon-Ion exchange resins-Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation	0.02	0.19	0.50	0.50	-
[IT_029]_w {1}	Absorption-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Precipitation-Sedimentation-Evaporation (e.g. vacuum evaporation)	0.08	0.17	0.52	4.00	25.67
[FR_006]_w {2}	Precipitation-Coagulation and flocculation-Biological	0.02	0.20	0.71	0.20	16.70

	treatment- Activated sludge process					
[FI_005]_w {1}	-	0.02	0.27	0.72	0.50	-
[ES_002]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.06	0.26	0.76	5.00	-
[FR_006]_w {1}	Precipitation-Coagulation and flocculation	0.01	0.12	0.81	0.20	38.29
[FR_024]_w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation	0.05	0.20	0.81	1.20	-
[DE_054]_w {1}	Coagulation and flocculation	0.10	0.35	0.86	0.50	-
[DE_018]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation	0.10	-	1.00	-	-
[IT_031]_w {1}	Coagulation and flocculation	0.10	0.35	1.10	4.00	-
[FI_003]_w {1}	-	0.01	0.08	1.16	1.00	-
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.05	0.64	1.30	2.00	-
[CZ_007]_w {1}	Absorption-Sedimentation-Coagulation and flocculation-Electrodialysis-Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.12	0.49	1.34	-	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.10	0.10	1.54	5.00	-
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0.00	0.29	1.96	0.50	7.52
[FR_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.30	1.08	2.00	2.00	-
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.10	0.70	2.00	2.00	-
[FR_014]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction	0.14	1.17	2.00	2.00	-
[IT_020]_w {1}	Coagulation and flocculation	0.02	0.67	3.34	4.00	3.36

3.2.1.8.14 Sn

The reported data for Sn emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-21.



This figure contains emissions to water data per parameter based on 3 years of reported data

Source: [168, TWG 2023]

Figure 3-22: Sn emissions to water in electrolytic or chemical plating plants

Table 3-21: Reported data and contextual information for Sn emissions to water in electrolytic or chemical plating plants

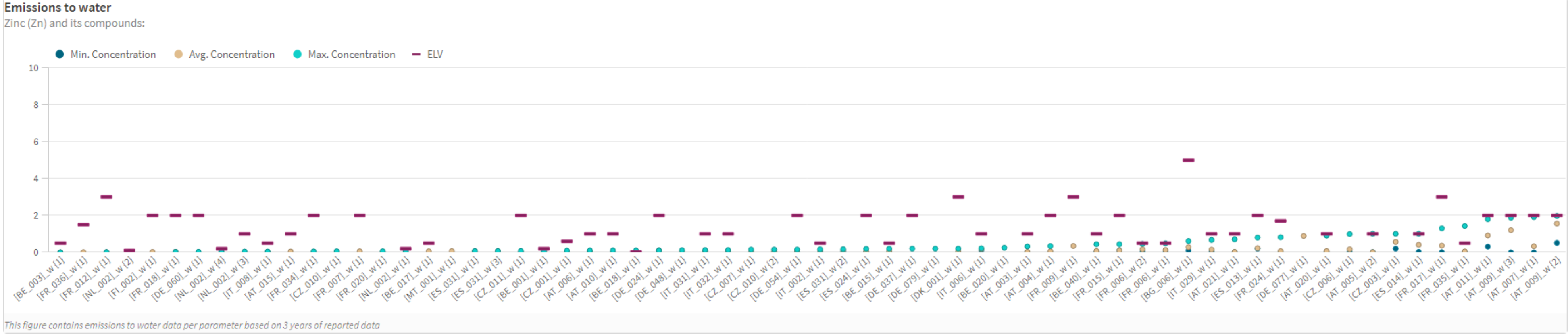
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[FR_024]_w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation	0.00	0.00	0.00	1.20	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.00	0.00	0.00	1.00	-
[IT_008]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation	0.00	0.00	0.00	10.00	0.15
[DE_060]_w {1}	Adsorption techniques – activated carbon-Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks-Sedimentation-Precipitation	-	-	0.01	2.00	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	-	0.01	-	2.00	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	0.01	-	2.00	-
[DK_001]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.00	0.00	0.01	0.06	0.22
[NL_002]_w {3}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.01	0.10	-
[FR_009]_w {1}	Coagulation and flocculation-Neutralisation	-	0.01	-	0.10	-
[BE_017]_w {1}	Coagulation and flocculation	-	0.01	-	0.04	-
[BE_020]_w {1}	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other	-	-	0.01	-	-
[FR_017]_w {1}	Chemical reduction	0.00	0.00	0.01	2.00	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.01	0.20	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.01	0.04	-
[DE_036]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation	-	-	0.02	2.00	-

	assisted)-Chemical reduction-Coagulation and flocculation-Electrolysis-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Other-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon					
[ES_024]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Other	0.01	0.02	0.03	2.00	-
[SE_002]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.00	0.01	0.03	-	-
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	0.04	0.04	0.04	0.25	-
[NL_002]_w {4}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.03	0.05	0.10	-
[FR_020]_w {1}	Other	0.05	0.05	0.05	-	-
[NL_002]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Adsorption techniques – activated carbon	0.01	0.02	0.05	0.20	-
[FI_005]_w {1}	-	0.00	0.02	0.06	2.00	-
[AT_010]_w {1}	Precipitation-Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Evaporation (e.g. vacuum evaporation)-Electrolysis-Evaporation (e.g. vacuum evaporation)-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange resins	0.01	0.02	0.08	1.00	-
[DE_054]_w {1}	Coagulation and flocculation	0.10	0.10	0.10	2.00	-
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.00	0.02	0.10	2.00	-
[IT_002]_w {1}	Equalisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Biological treatment- Activated sludge process-Nitrification/denitrification	0.00	0.05	0.10	10.00	16.00
[IT_032]_w {1}	Coagulation and flocculation-Ion exchange resins	0.05	0.10	0.11	-	-
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.20	0.20	0.20	-	-
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.20	0.20	0.20	-	-
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.20	0.20	0.20	-	-
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0.00	0.21	0.71	0.30	3.23
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.10	0.25	0.74	2.00	-
[AT_012]_w {1}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	0.02	0.41	0.97	1.00	-

[IT_029]_w {1}	Absorption-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Precipitation-Sedimentation-Evaporation (e.g. vacuum evaporation)	1.00	1.00	1.00	-	
[IT_031]_w {1}	Coagulation and flocculation	0.10	0.25	1.00	-	-
[AT_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation-Chemical reduction-Sedimentation-Neutralisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	0.00	0.51	1.17	1.00	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.10	0.10	1.50	2.00	-
[AT_009]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.00	0.33	1.58	2.00	-
[DE_018]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation	0.20	-	2.00	-	-

3.2.1.8.15 Zn

The reported data for Zn emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-22.



Source: [168, TWG 2023]

Figure 3-23: Zn emissions to water in electrolytic or chemical plating plants

Table 3-22: Reported data and contextual information for Zn emissions to water in electrolytic or chemical plating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[BE_003]_w {1}	Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Neutralisation-Reverse osmosis-Use of buffer tanks to reduce waste water and emission load peaks	0.00	0.00	0.00	0.50	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	0.01	-	1.50	-
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.01	3.00	-
[NL_002]_w {2}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.00	0.01	0.02	0.10	-
[FI_002]_w {1}	Precipitation-Flotation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)	-	0.02	-	2.00	-
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.02	0.02	0.02	2.00	-
[DE_060]_w {1}	Adsorption techniques – activated carbon-Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks-Sedimentation-Precipitation	-	-	0.03	2.00	-
[NL_002]_w {4}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.03	0.03	0.03	0.20	-
[NL_002]_w {3}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.00	0.00	0.04	1.00	-
[IT_008]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation	0.01	0.02	0.04	0.50	6.31
[AT_015]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.04	-	1.00	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	0.01	0.01	0.05	2.00	1.08
[CZ_010]_w {1}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.03	0.06	-	1.58
[FR_007]_w {1}	Coagulation and flocculation-Nitrification/denitrification	-	0.06	-	2.00	-
[FR_020]_w {1}	Other	0.02	0.03	0.06	-	-
[NL_002]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-	0.03	0.03	0.06	0.20	-

	Adsorption techniques – activated carbon					
[BE_017]_w {1}	Coagulation and flocculation	-	0.06	-	0.50	-
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.05	0.06	0.07	-	-
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.05	0.06	0.07	-	-
[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid	0.01	0.01	0.07	2.00	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.06	0.06	0.08	0.20	-
[CZ_001]_w {1}	Neutralisation-Sedimentation	0.01	0.02	0.09	0.60	-
[AT_006]_w {1}	Coagulation and flocculation-Precipitation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.02	0.05	0.10	1.00	-
[AT_010]_w {1}	Precipitation-Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Electrolysis-Evaporation (e.g. vacuum evaporation)-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange resins	0.01	0.01	0.10	1.00	-
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	0.01	0.01	0.10	0.03	-
[DE_024]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Sedimentation	0.10	0.10	0.10	2.00	-
[DE_048]_w {1}	-	-	0.06	0.11	-	-
[IT_031]_w {1}	Coagulation and flocculation	0.05	0.09	0.12	1.00	-
[IT_032]_w {1}	Coagulation and flocculation-Ion exchange resins	0.05	0.09	0.12	1.00	-
[CZ_007]_w {1}	Absorption-Sedimentation-Coagulation and flocculation-Electrodialysis-Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.00	0.04	0.15	-	-
[CZ_010]_w {2}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation	0.01	0.05	0.15	-	3.92
[DE_054]_w {1}	Coagulation and flocculation	0.03	0.09	0.15	2.00	-
[IT_002]_w {1}	Equalisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Biological treatment- Activated sludge process-Nitrification/denitrification	0.05	0.11	0.16	0.50	24.00
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.05	0.11	0.17	-	-

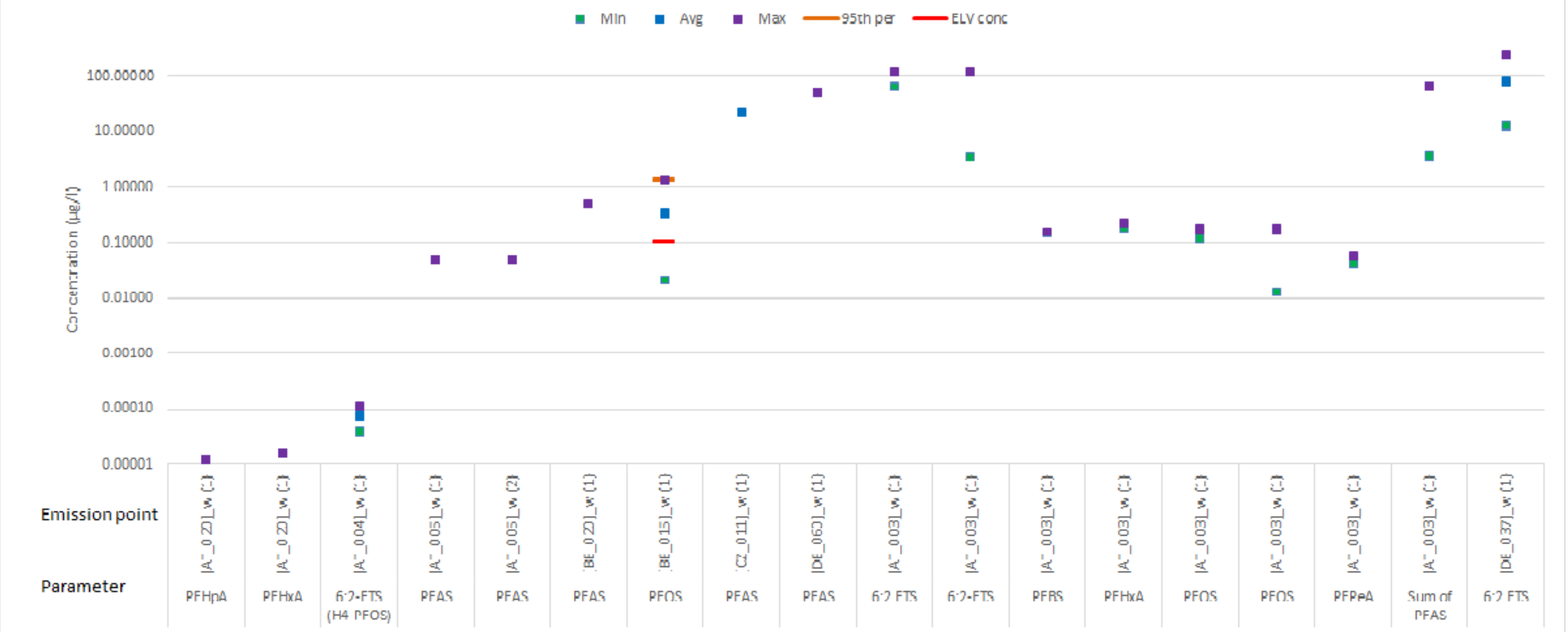
[ES_024]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Other	0.02	0.05	0.19	2.00	-
[BE_015]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Chemical reduction-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Biological treatment-Activated sludge process-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.06	0.20	0.50	-
[DE_037]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks	-	-	0.20	2.00	-
[DE_079]_w {1}	Neutralisation-Precipitation-Flotation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	-	0.20	-	-
[DK_001]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.01	0.03	0.20	3.00	3.93
[IT_006]_w {1}	Coagulation and flocculation-Chemical reduction-Precipitation	0.12	0.18	0.22	1.00	3.49
[BE_020]_w {1}	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other	-	-	0.25	-	-
[BE_031]_w {1}	Acid (resin) sorption or retardation	0.23	0.25	0.27		-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.00	0.03	0.32	1.00	-
[AT_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation-Chemical reduction-Sedimentation-Neutralisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	0.00	0.05	0.34	2.00	-
[FR_009]_w {1}	Coagulation and flocculation-Neutralisation	-	0.35	-	3.00	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and emission load peaks-Filtration (e.g. gravel filter, sand filter)	0.02	0.07	0.44	1.00	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.10	0.10	0.44	2.00	-
[FR_006]_w {2}	Precipitation-Coagulation and flocculation-Biological treatment- Activated sludge process	0.03	0.16	0.46	0.50	22.13
[FR_006]_w {1}	Precipitation-Coagulation and flocculation	0.01	0.12	0.49	0.50	38.70
[BG_006]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Adsorption techniques – activated carbon-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Use	0.10	0.28	0.61	5.00	-

	of buffer tanks to reduce waste water and emission load peaks					
[IT_029]_w {1}	Absorption-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Precipitation-Sedimentation-Evaporation (e.g. vacuum evaporation)	0.02	0.14	0.67	1.00	29.06
[AT_021]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0.01	0.02	0.71	1.00	0.67
[ES_013]_w {1}	Adsorption techniques – activated carbon-Neutralisation-Coagulation and flocculation-Crystalisation-Flotation-Ion exchange resins	0.20	0.23	0.80	2.00	-
[FR_024]_w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation	0.01	0.07	0.81	1.70	-
[DE_077]_w {1}	-	-	0.89	-	-	-
[AT_020]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon-Sedimentation	0.00	0.07	0.90	1.00	0.07
[CZ_006]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.00	0.16	0.99	-	-
[AT_005]_w {2}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0.01	0.01	1.00	1.00	1.16
[CZ_003]_w {1}	Neutralisation	0.20	0.57	1.00	-	-
[ES_014]_w {1}	Coagulation and flocculation-Membrane micro/ultra/nano filtration-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Othe	0.03	0.41	1.00	1.00	1.70
[FR_017]_w {1}	Chemical reduction-	0.01	0.36	1.30	3.00	-
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0.01	0.05	1.43	0.50	2.19
[AT_011]_w {1}	Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.31	0.91	1.80	2.00	-
[AT_009]_w {3}	Evaporation (e.g. vacuum evaporation)	0.00	1.20	1.88	2.00	-
[AT_007]_w {1}	Adsorption techniques – activated carbon-Ion exchange resins-Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation	0.00	0.33	1.91	2.00	-
[AT_009]_w {2}	Ion exchange resins-Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Evaporation (e.g. vacuum evaporation)	0.51	1.56	1.97	2.00	-
[AT_005]_w {1}	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.01	0.13	2.00	2.00	5.54
[AT_008]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.10	0.60	2.00	2.00	-
[AT_012]_w {2}	Filtration (e.g. gravel filter, sand filter)-Neutralisation-Precipitation-Ion exchange resins-Coagulation and flocculation-Sedimentation	0.02	0.75	2.00	2.00	-
[DE_018]_w {1}	Chemical reduction-Coagulation and flocculation-	0.10	-	2.00	-	-

	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation					
[DE_025]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Adsorption techniques – activated carbon-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	-	-	2.00	-	-
[DE_045]_w {1}	Other	-	-	2.00	-	-
[ES_009]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.05	0.54	2.50	10.00	-
[FR_014]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction	0.01	2.09	2.91	3.00	-
[FR_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.35	1.33	3.00	3.00	-
[CZ_002]_w {1}	Neutralisation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Adsorption techniques – activated carbon-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)	0.15	1.18	3.32	4.00	-
[BG_013]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.12	1.05	4.60	-	-
[ES_002]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.76	2.55	4.95	5.00	-
[FI_005]_w {1}	-	0.09	0.88	7.10	2.00	-

3.2.1.9 Perfluoroalkyl and polyfluoroalkyl substances (PFAS)

The reported data for PFAS emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-23.



NB: Concentration axis in logarithmic scale.

Source: [168, TWG 2023]

Figure 3-24: PFAS emissions to water in electrolytic or chemical plating plants

Table 3-23: Reported data and contextual information for PFAS emissions to water in electrolytic or chemical plating plants

Emission Point	Parameter	Abatement technique(s)	Min.	Avg.	Max.	ELV	95th perc.	Removal efficiency	Monitoring standard	LoQ	Purpose of monitoring	Additional information
[AT_020]_w {1}	PFHpA	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon-Sedimentation	0.000012	0.000012	0.000012				-	0.00001	-	Reference year 2024
[AT_020]_w {1}	PFHxA	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon-Sedimentation	0.000016	0.000016	0.000016				DIN 38407-42	0.00001	-	Reference year 2024
[AT_004]_w {1}	6:2-FTS (H4-PFOS)	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation-Chemical reduction-Sedimentation-Neutralisation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Precipitation	0.000039	0.000075	0.000110				DIN 38407-42	-	-	Reference year 2024
[AT_005]_w {1}	PFAS	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.05	0.05	0.05				DIN 38407-42 : 2011-03	0.05	-	<
[AT_005]_w {2}	PFAS	Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Coagulation and flocculation	0.05	0.05	0.05				DIN 38407-42 : 2011-03	0.05	-	<
[BE_020]_w {1}	PFAS	Chemical reduction-Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Other-Other			0.51				External lab	-	Other	One time PFAS level check of chrome passivation bath relevant for external waste processor.

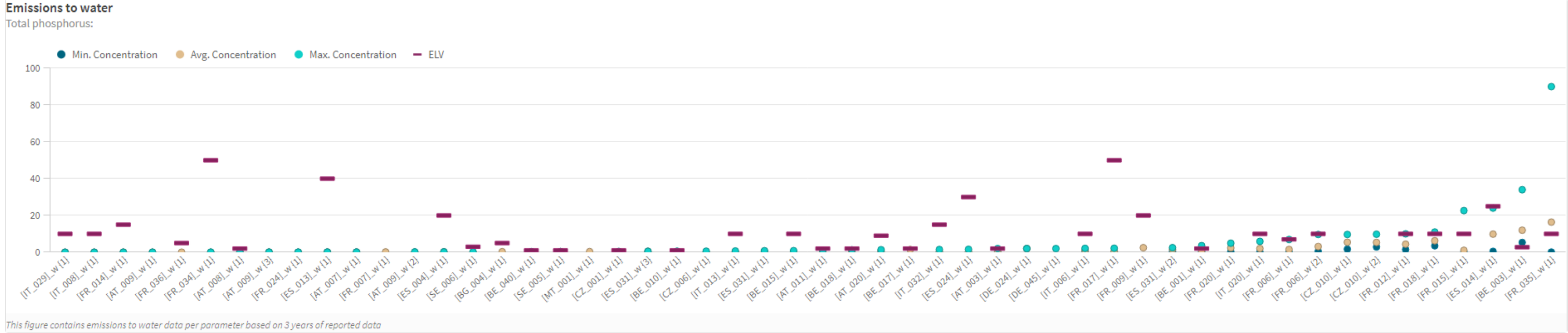
[BE_015]_w {1}	PFOS	Use of buffer tanks to reduce waste water and emission load peaks-Chemical reduction-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Biological treatment-Activated sludge process-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.021	0.345	1.32	1.263	0.0001	99	-	-	Compliance monitoring	Results for discharged PFOS in effluent from site waste water treatment incl. treated water from plating, in 2022. PFOS still in effluent due to diffuse sources, but minority from outlet active carbon treatment for waste water from plating baths due to removal efficiency of 99 % of the active carbon treatment. Note no intentional dosage/usage of PFOS since 2014, but still relevant concentration of PFOS in the plating baths. Specified ELV needs to be respected all time and will become according permit more stringent in Sept 2024 (20 ng/l).
[CZ_011]_w {1}	PFAS	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid		22.7					-	0.5	-	Sum PFAS; PFOS 18,6; leaching resulting from historical use
[DE_060]_w {1}	PFAS	Adsorption techniques – activated carbon-Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks-Sedimentation-Precipitation			53				DIN 38407-42	-	Operator self-monitoring	Orientating measurement, sum parameter (PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNoA, PFDeA, PFUnA, PFDoA, PFOSA, PFBS, PFPeS, PFHxS, PFHpS, PFOS, PFDeS, FTS 4:2, FTS 6:2, FTS 8:2)
[AT_003]_w {1}	6:2 FTS	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	65		120				-	-	-	6:2 FTS: 3 times, 65- 120 µg/l (in use)

[AT_003] _w {1}	6:2-FTS	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	3.4		120				DIN 38407 -42	-	-	6:2 FTS: 3 times, 65- 120 µg/l (in use)
[AT_003] _w {1}	PFBS	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.15		0.16				-	-	-	PFBS: 3 times; 0,15- 0,16 µg/l (small use until last month)
[AT_003] _w {1}	PFHxA	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.18		0.23				-	-	-	PFHxA; 3 times, 0,18- 0,23 µg/l
[AT_003] _w {1}	PFOS	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.12		0.17				-	-	-	PFOS, 3 times: 0,12- 0,17 µg/l (no more in use since 2012)
[AT_003] _w {1}	PFOS	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.013		0.17				DIN 38407 -42	-	-	PFOS, 3 times: 0,12- 0,17 µg/l (no more in use since 2012)
[AT_003] _w {1}	PFPeA	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.042		0.057				-	-	-	PFPeA: 3 times: 0,042- 0,057 µg/l
[AT_003] _w {1}	Sum of PFAS	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	3.6	66	66				DIN 38407 -42	-	-	Sum of 25 PFASPFBA, PFBS, PFPeA, PFPeS, PFHxA, PFHxS, PFHpA, 7H-PFHpA, PFHpS, PFO, PFOS, PFOSA, PFNA, PFNS, PFDA, PFDS, PFUnDA, PFuNDS, PFDoDA, PFDoDS, PFTrDA, PFTrDS, PFTeDA, 6:2-FTS (1H, 1H, 2H, 2H-PFOS), 2H,2H,3H,3H-PFUnDA

[DE_037]_w {1}	6:2 FTS	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks	13	80.7	250				-	-	-	Chrome-containing rinse water is circulated > 95 %. The remaining rinse water is treated in a batch and the treated waste water is then purified via a special H4PFOS ion exchanger. The purified rinse water no longer contains H4PFOS concentrations. Through this partial flow treatment, the H4PFOS content in the total waste water can be significantly reduced. 5 measurements per year.

3.2.1.10 Total phosphorus

The reported data for total phosphorus emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-24.



Source: [168, TWG 2023]

Figure 3-25: Total phosphorus emissions to water in electrolytic or chemical plating plants

Table 3-24: Reported data and contextual information for total phosphorus emissions to water in electrolytic or chemical plating plants

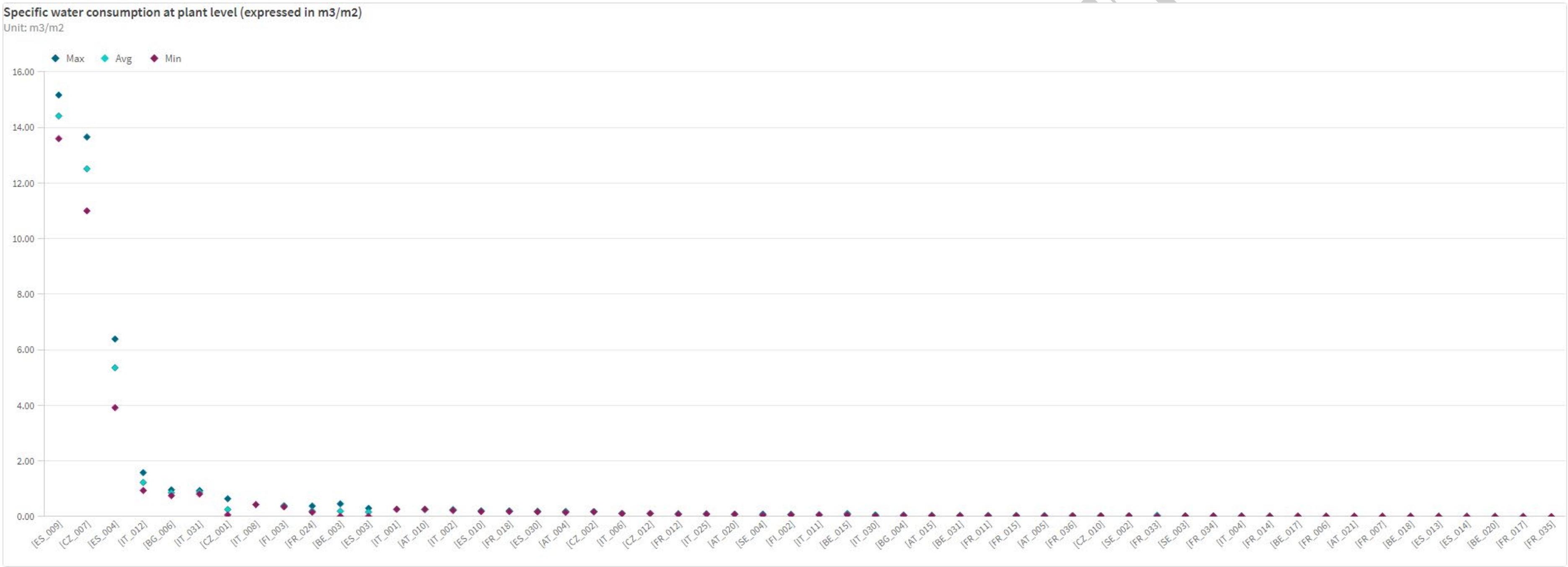
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[IT_029]_w {1}	Absorption-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Precipitation-Sedimentation-Evaporation (e.g. vacuum evaporation)	0.01	0.01	0.01	10.00	41.96
[IT_008]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-	0.01	0.01	0.03	10.00	2.15
[FR_014]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction	0.02	0.05	0.05	15.00	-
[AT_009]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.01	0.03	0.05	-	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	0.06	-	5.00	-
[FR_034]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Use of buffer tanks to reduce waste water and emission load peaks	0.01	0.05	0.06	50.00	2.54
[AT_008]_w {1}	Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins	0.08	0.08	0.08	2.00	-
[AT_009]_w {3}	Evaporation (e.g. vacuum evaporation)	0.08	0.08	0.08	-	-
[FR_024]_w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation-Sedimentation	0.05	0.05	0.08	-	-
[ES_013]_w {1}	Adsorption techniques – activated carbon-Neutralisation-Coagulation and flocculation-Crystalisation-Flotation-Ion exchange resins	0.10	0.10	0.10	40.00	-
[AT_007]_w {1}	Adsorption techniques – activated carbon-Ion exchange resins-Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation	0.11	0.11	0.11	-	-
[FR_007]_w {1}	Coagulation and flocculation-Nitrification/denitrification	-	0.18	-	-	-
[AT_009]_w {2}	Ion exchange resins-Precipitation-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Evaporation (e.g. vacuum evaporation)	0.07	0.10	0.19	-	-
[ES_004]_w {1}	Neutralisation-Other-Coagulation and flocculation-Sedimentation	0.20	0.20	0.20	20.00	-
[SE_006]_w {1}	Chemical reduction-Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.03	0.06	0.26	3.00	0.55
[BG_004]_w {1}	Neutralisation	-	0.29	-	5.00	-
[BE_040]_w {1}	Neutralisation-Coagulation and flocculation-Use of buffer tanks to reduce waste water and emission load peaks-Use of buffer tanks to reduce waste water and	0.20	0.22	0.30	1.00	-

	emission load peaks-Filtration (e.g. gravel filter, sand filter)					
[SE_005]_w {1}	Coagulation and flocculation-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Adsorption techniques – activated carbon-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Membrane micro/ultra/nano filtration-Reverse osmosis-Sedimentation-Neutralisation	0.30	0.30	0.30	1.00	-
[CZ_001]_w {1}	Neutralisation-Sedimentation	0.00	0.14	0.45	1.00	-
[ES_031]_w {3}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.50	0.50	0.50	-	-
[BE_010]_w {1}	Coagulation and flocculation	0.23	0.38	0.59	1.00	-
[CZ_006]_w {1}	Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	0.05	0.14	0.59	-	-
[IT_013]_w {1}	Chemical reduction	0.00	0.33	0.70	10.00	0.39
[ES_031]_w {1}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.50	0.62	0.85	-	-
[BE_015]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Chemical reduction-Specific abatement of PFOS, 6:2 FTS or other PFAS by adsorption on activated carbon, ion exchange resins or other adsorbents-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Biological treatment-Activated sludge process- Filtration (e.g. gravel filter, sand filter)	0.11	0.27	0.87	10.00	-
[AT_011]_w {1}	Chemical reduction-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)	0.16	0.37	1.12	2.00	-
[BE_018]_w {1}	Coagulation and flocculation-Neutralisation-Biological treatment- Activated sludge process-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Nitrification/denitrification-Reverse osmosis-Precipitation-Membrane micro/ultra/nano filtration-Use of buffer tanks to reduce waste water and emission load peaks	0.15	0.44	1.32	2.00	-
[AT_020]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Adsorption techniques – activated carbon-Sedimentation	0.33	0.80	1.39	9.00	23.10
[BE_017]_w {1}	Coagulation and flocculation	-	1.50	-	2.00	-
[IT_032]_w {1}	Coagulation and flocculation-Ion exchange resins	0.10	0.48	1.50	15.00	-
[ES_024]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Other	0.05	0.35	1.60	30.00	-
[AT_003]_w {1}	Chemical reduction-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Sedimentation-Ion exchange resins-Filtration (e.g. gravel filter, sand filter)-Biological treatment- Activated sludge process	0.00	0.55	2.00	2.00	-
[DE_024]_w {1}	Chemical reduction-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Sedimentation	2.00	2.00	2.00	-	-
[DE_045]_w {1}	Other	-	-	2.00	-	-
[IT_006]_w {1}	Coagulation and flocculation-Chemical reduction-	0.76	1.17	2.12	10.00	25.48

	Precipitation					
[FR_017]_w {1}	Chemical reduction	0.09	0.63	2.20	50.00	-
[FR_009]_w {1}	Coagulation and flocculation-Neutralisation	-	2.49	-	20.00	-
[ES_031]_w {2}	Neutralisation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	0.50	1.57	2.50	-	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.30	0.96	3.60	2.00	-
[FR_020]_w {1}	Other	0.33	2.33	4.94	-	-
[IT_020]_w {1}	Coagulation and flocculation	0.10	2.03	5.91	10.00	9.03
[FR_006]_w {1}	Precipitation-Coagulation and flocculation	0.09	1.52	6.94	7.00	
[FR_006]_w {2}	Precipitation-Coagulation and flocculation-Biological treatment- Activated sludge process	0.50	3.12	9.65	10.00	
[CZ_010]_w {1}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	1.69	5.45	9.66	-	
[CZ_010]_w {2}	Neutralisation-Coagulation and flocculation-Flotation-Sedimentation	2.89	5.35	9.80	-	
[FR_012]_w {1}	Chemical reduction-Chemical reduction-Chemical reduction-Neutralisation-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)	1.50	4.39	10.00	10.00	-
[FR_018]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	3.50	6.25	11.00	10.00	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.15	1.07	22.67	10.00	-
[ES_014]_w {1}	Coagulation and flocculation-Membrane micro/ultra/nano filtration-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Other	0.50	9.84	24.00	25.00	
[BE_003]_w {1}	Evaporation (e.g. vacuum evaporation)-Filtration (e.g. gravel filter, sand filter)-Ion exchange liquid- liquid-Neutralisation-Reverse osmosis-Use of buffer tanks to reduce waste water and emission load peaks	5.33	11.98	34.00	2.75	-
[FR_035]_w {1}	Chemical reduction-Evaporation (e.g. vacuum evaporation)-Coagulation and flocculation-Ion exchange resins-Neutralisation-Ion exchange resins	0.10	16.38	90.00	10.00	

3.2.2 Water consumption and waste water discharge

The reported data for specific water consumption are presented in Figure 3-26. Emission data and contextual information are also presented in Table 3-25.



Source: [168, TWG 2023]

Figure 3-26: Specific water consumption expressed in m^3 per m^2 of surface treated in electrolytic or chemical plating plants

Table 3-25: Reported data (expressed in m^3 per m^2 of surface treated) and contextual information for specific water consumption in electrolytic or chemical plating plants

Plant name	Max.	Avg.	Min.	Associated process	Monitoring method	Technique	Year of impleme-ntation	Add_info
[AT_004]	0.18	0.17	0.15	Other-Rinsing-	-	Use of closed cooling systems-Other	all cool/heating	-----

							baths-use of cascades-	
[AT_005]	0.03	0.03	0.02	Degreasing-Pickling-Lacquering-Rinsing-	Measured	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Reuse of water by using multiple rinsing steps	-	Galvanik: 1980; KTL: 2012
[AT_010]	0.26	0.26	0.26	-	Estimated	Reuse of water by using multiple rinsing steps-Recirculating rinsing water from etching and surface treatment to surface treatment baths	-	
[AT_015]	0.04	0.04	0.03	Rinsing-	Measured	Reuse of water by using multiple rinsing steps	-	
[AT_020]	0.09	0.09	0.08	Pickling-Degreasing-Plating-	Measured	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Use of closed cooling systems	2010-2010-1974-	--Zn plating---
[AT_021]	0.01	0.01	0.01	Degreasing-	Measured	Recirculating rinsing water from etching and surface treatment to surface treatment baths	2021-	-----
[BE_003]	0.46	0.19	0.01	Etching-Rinsing-Degreasing	Measured	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Reuse of purified water from evaporation (e.g. from waste water)-Use of closed cooling systems-Reuse of water by using multiple rinsing steps-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	-	-----
[BE_015]	0.11	0.08	0.06	Rinsing-Plating-Plating-	Estimated	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Reuse of water by using multiple rinsing steps-Use of closed cooling systems	2012	Year of implementation < 2012. Note: etching = separated from plating.-Cascade rinsing baths-Year of implementation < 2012.---
[BE_017]	0.02	0.02	0.02	Lacquering	Measured	Reuse of water by using multiple rinsing steps-Other	2000-	cascade system on the e-coating baths-UF-filter with closed re-usingsystem
[BE_018]	0.01	0.01	0.01	Rinsing-Degreasing-	Measured	Reuse of water by using multiple rinsing steps-Other	-	Recuperation via small ion exchanger (Bath 22) on diphose installation-Bath 8/10, Bath 16/18 on diphose installation-RO installation Demulsifing degreaser on bath 2, 4, 6 on diphose installation--
[BE_020]	0.01	0.01	0.01	Rinsing-	Measured	Other-	1997-	Fresh water is only added to first 2 rinse baths when max limit conductivity is reached.-The last 2 rinsing baths are in closed loop with ion exchanger, no fresh water needed except for regeneration ion exchanger.----
[BE_031]	0.04	0.04	0.03	Degreasing-Phosphating-	Estimated	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	2003-	-----

[BG_004]	0.06	0.05	0.04	Plating-	Measured	Reuse of purified water from evaporation (e.g. from waste water)	2006-	-----
[BG_006]	0.96	0.86	0.75	Other-Rinsing-	Calculated	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Use of closed cooling systems-Reuse of water by using multiple rinsing steps-Recirculating rinsing water from etching and surface treatment to surface treatment baths	-	Purified waste water atfer WWT Plants passes through the ion exchange columns and returns to the vats---Plate area Asmega 1 - rinsing water after chrome vats has ion exchange columns for water purification and return of circulating water (100% recycled)--
[CZ_001]	0.64	0.26	0.06	Other-Pickling-Degreasing-	Measured	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Recirculating rinsing water from etching and surface treatment to surface treatment baths	2003-2007-2009-	Water for water cooling systems is recycled-----
[CZ_002]	0.18	0.18	0.17	Other-	Measured	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	2020-	hand cleaning of floors and technologies-----
[CZ_007]	13.66	12.51	11.00	Rinsing-Anodising-Other-	Calculated	Reuse of purified water from evaporation (e.g. from waste water)-Reuse of water by using multiple rinsing steps-Use of closed cooling systems-Other	2019-2000-2016-2022-	only for rinsing after degreasing or pickling-our lines are developed with mupltiple steps of rinsing (doublle or tripple rinse)-cooling system means circuit for cooling active bath (e.g. Alkaline Zn or alkaline ZnNi)-working with informations wich were gained by official water audit (by rules of ministry of industry and market, TITOMPO941)--
[CZ_010]	0.03	0.03	0.03	-	Measured	-	-	-----
[CZ_012]	0.11	0.11	0.11	-	Measured	No technique applied	-	-----
[ES_003]	0.30	0.16	0.01	-	Measured	No technique applied	-	-----
[ES_004]	6.39	5.36	3.92	Cleaning-	Calculated	Reuse of water by using multiple rinsing steps	-	-----
[ES_009]	15.17	14.41	13.60	Other-	Estimated	Other	2022-	We use digitized flow meters in both DI and mains water. We control the flow in each plating line
[ES_010]	0.21	0.19	0.18	Plating-	-	Use of closed cooling systems	2015-	-----
[ES_013]	0.01	0.01	0.01	Rinsing-Rinsing-	Estimated	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Reuse of water by using multiple rinsing steps	1999-1999-	-----
[ES_014]	0.01	0.01	0.01	Plating-	-	Use of closed cooling systems	2008-	-----

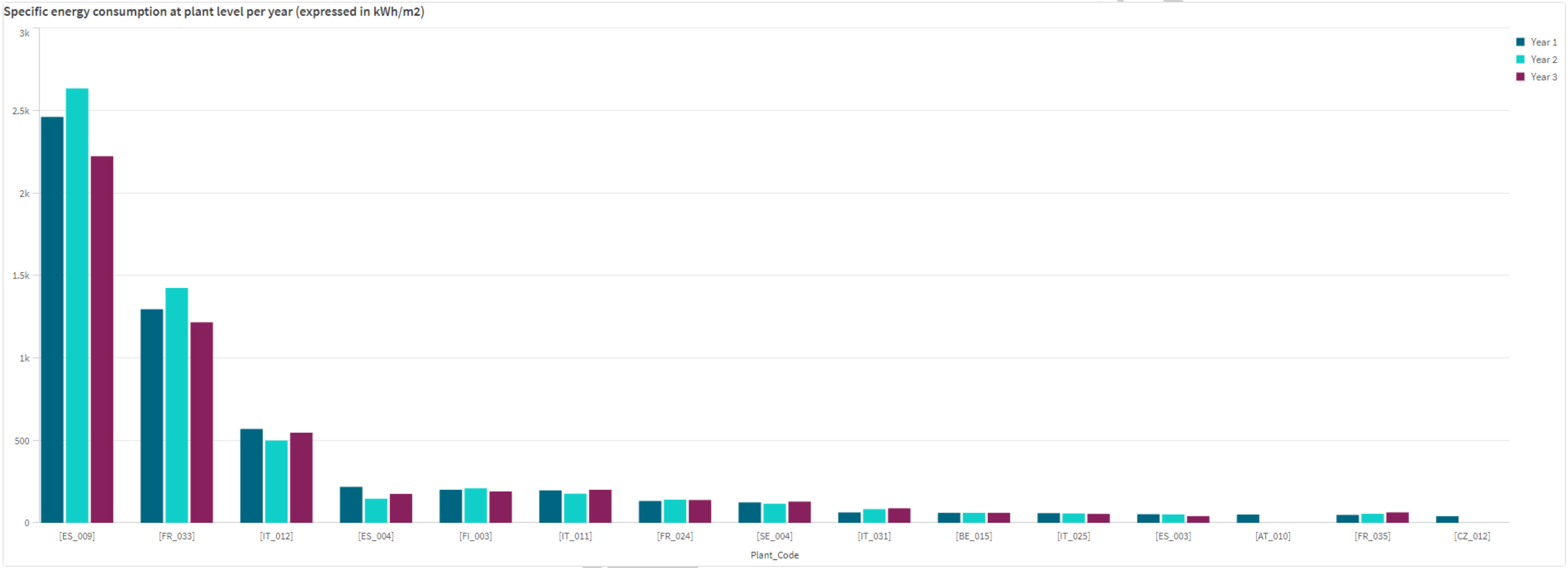
[ES_030]	0.19	0.18	0.17	Plating-Cleaning-	Calculated	Reuse of water by using multiple rinsing steps-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	-	-----
[FI_002]	0.08	0.07	0.06	-Rinsing-Etching-	Measured	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Reuse of water by using multiple rinsing steps-Recirculating rinsing water from etching and surface treatment to surface treatment baths	-	-----
[FI_003]	0.39	0.37	0.35	Rinsing-Other-	Calculated	Reuse of water by using multiple rinsing steps-Recirculating rinsing water from etching and surface treatment to surface treatment baths-Use of closed cooling systems	-1993-~1981-	Tous les rinçages : dégraissage, décapage, revêtement, passivation-Sur deuxième rinçages chromique (chromage et passivation)-Refroidissement des circuits secondaires sur Tours aéro-réfrigérantes---
[FR_006]	0.01	0.01	0.01	Degreasing-Phosphating-	Measured	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Reuse of water by using multiple rinsing steps-Reuse of water by using multiple rinsing steps	1994-	Use overflow of degreasing rinse bath (stage 5) to maintain the level of hot degreasing baths (stages 1-4) - See attached document : FR_Renault_Batilly_Schemas process TTS_F1-2 degreasing counterflow rinse (stages 5/6) - See attached document : FR_Renault_Batilly_Schemas process TTS_F1-3 phosphating counterflow rinse (stages 9/10/11) - See attached document : FR_Renault_Batilly_Schemas process TTS_F1---
[FR_007]	0.01	0.01	0.01	Degreasing-Phosphating-Other-	Measured	Reuse of water by using multiple rinsing steps	1992-	--passivation---
[FR_011]	0.04	0.03	0.03	Plating-Cleaning- Other-Plating	Measured	Reuse of water by using multiple rinsing steps- Other-Recirculating rinsing water from etching and surface treatment to surface treatment baths	1992-2021-2023	all lines--spray rinsing-control of solenoid flow valves lines 4 & 5-use of flowmeters lines 2, 5 & 6-line 8 : zero discharge workshop
[FR_012]	0.10	0.09	0.08	-Rinsing-	Measured	No technique applied-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	-	-----
[FR_014]	0.02	0.01	0.01	-	Measured	Other	-	-----
[FR_015]	0.04	0.03	0.03	Plating-	Measured	Reuse of water by using multiple rinsing steps-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Other	2000-1990-2020-2016-	Using the output water from the cooling system to re-new water in the next rinsing vats instead of the normal adding of water-Depending on the treatment vats, replacing "simple" rinsing by

								double or tripple cascades rinsing vats-Using treated water from WWTP for pre-treatment rinsing + water cooling système --> Dropout in 2022 because of salinity (clogging of pipes + inlet temperature to high for the cooling system)-Automation of lines (electrovalves + conductivity sensor to re-new rinsing bath)--
[FR_017]	0.00	0.00	0.00	Rinsing-Degreasing-	Estimated	Reuse of water by using multiple rinsing steps-Recirculating rinsing water from etching and surface treatment to surface treatment baths	2010-	-----
[FR_018]	0.21	0.20	0.18	Rinsing-Plating-	Measured	Reuse of water by using multiple rinsing steps-Recirculating rinsing water from etching and surface treatment to surface treatment baths	before 2006-	Waterfall rinses-Reuse of dead nickel rinse to level the nickel bath----
[FR_024]	0.38	0.20	0.16	Rinsing-Degreasing-	Measured	Reuse of water by using multiple rinsing steps-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	-	Cascade-DG5 and FT1 : A part of water from rinsing is reused to complete degreasing vats----
[FR_033]	0.04	0.02	0.00	Plating-	Measured	Use of closed cooling systems	2004-	Cooling Tower-----
[FR_034]	0.02	0.02	0.02	Plating-Rinsing-	Measured	Other-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	2021-<2020-	Reused of rinsing water after physico chemical treatment to cool vats.-Reused of rinsing water after physico chemical treatment for main rinsing vats.----
[FR_035]	0.00	0.00	0.00	Degreasing-Pickling-Anodising-Other-	Measured	Reuse of water by using multiple rinsing steps-Other	2016-2022-2009-2011-	2 cascade rinsingh baths-new rinsing bath in 2022 = 1 dead rinsing + 3 cascade rinsing baths (2 cascade rinsing baths before 2022)-2 cascade rinsing baths instead of one rinsing bath-Neutralisation after pickling : new neutralisation product without rinsing step--
[FR_036]	0.03	0.03	0.03	Etching-Degreasing-Plating-Other-	Estimated	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Reuse of purified water from evaporation (e.g. from waste water)-Reuse of water by using multiple rinsing steps	2008-1995-	--Degreasing, cleaning etching. This technique will be deployed to all the plating workshop in the first trimester 2025.-Plating with cadmium there is a process of rinsing with multiple rinsing and purified water from evaporation--
[IT_001]	0.27	0.26	0.26	Plating-	Measured	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Reuse of water by using multiple rinsing steps	before 2000-1995-	-----

[IT_002]	0.25	0.23	0.22	Plating-	Measured	Recirculating rinsing water from etching and surface treatment to surface treatment baths	2007-	closed cycle purification system that reuses the washing water.-----
[IT_004]	0.02	0.02	0.02	Rinsing-Plating-	Measured	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Recirculating rinsing water from etching and surface treatment to surface treatment baths	2002-2004-	Recover the water used in the cooling process to the rinsing circuit-Recover the first rinsing step water in to the plating process, where it is permitted----
[IT_006]	0.12	0.11	0.11	Rinsing-	Measured	Reuse of purified water from evaporation (e.g. from waste water)	2010-	First evaporating system was implemented in 2010 and the second one in 2018-----
[IT_008]	0.43	0.43	0.43	-	Measured	No technique applied	-	-----
[IT_011]	0.07	0.06	0.06	Rinsing-	Measured	Reuse of water by using multiple rinsing steps	2005-	-----
[IT_012]	1.58	1.23	0.94	Plating-Degreasing-Pickling-	Measured	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Reuse of purified water from evaporation (e.g. from waste water)-Reuse of water by using multiple rinsing steps-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	2011-2011-	--Used also for pickling and plating-Used also for plating--
[IT_025]	0.10	0.09	0.09	Plating-Cleaning-	Measured	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	1992	-----
[IT_030]	0.06	0.04	0.02	Rinsing-Plating-	Measured	Reuse of water by using multiple rinsing steps-Other	2011-	Extractor solution condensate recovery
[IT_031]	0.94	0.88	0.81	Cleaning-Plating-	Estimated	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	2004-	All the process water used for washing the products being processed is treated by ion exchange systems and/or activated carbon and completely recirculated.-The recovery solutions placed downstream of the nickel and silver plating are reused to restore the levels in the respective process solutions.----
[SE_002]	0.03	0.03	0.03	Anodising-	Measured	Reuse of water by using multiple rinsing steps-Use of closed cooling systems-Other	1990-1965-	Reuse of concentrate from osmosis.
[SE_003]	0.03	0.03	0.03	Anodising-	Measured	Reuse of water by using multiple rinsing steps-Use of closed cooling systems	2006	-----
[SE_004]	0.09	0.07	0.05	Plating-Rinsing-	Measured	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Use of closed cooling systems-Reuse of water by using multiple rinsing steps	1995-1982-1995-	Implementation year estimated---

3.2.3 Energy efficiency

The reported data for specific energy consumption are presented in Figure 3-27. Emission data and contextual information are also presented in Table 3-26.



Source: [168, TWG 2023]

Figure 3-27: Specific energy consumption expressed in kWh per m^2 of surface treated in electrolytic or chemical plating plants

Table 3-26: Reported data and contextual information for specific energy consumption expressed in kWh per m^2 of surface treated emissions to water in electrolytic or chemical plating plants

Plant code	Net Energy (kWh/m^2)	Net Electricity (kWh/m^2)	Net Heat (kWh/m^2)	How the energy consumption is monitored	Proportion of energy recovered (%)	How the recovered energy is monitored	Total volume of workspace heated (m^3)	Additional information
[AT_003]	-	-	-	Measured	-	-	-	-
[AT_004]	22.37	10.87	11.50	-	-	-	-	-
[AT_005]	-	2.74	-	Measured	-	-	-	Line 1: 3,40kWh/m², Line 2: 2,29kWh/m²
[AT_006]	-	-	-	Measured	-	-	-	Total energy consumption is measured. Not possible to calculate specific net energy consumption due to different reference units (pipes in m, small parts in t or containers, etc.)
[AT_007]	-	-	-	-	-	-	4630.3	not possible to calculate specific values due to different reference units (depending on plated product)
[AT_008]	-	-	-	Calculated	-	-	21	Energy consumption for entire installation (also including casting plant). Total energy consumption of entire plant devided by t surface treated material.
[AT_009]	-	-	-	-	-	-	145	-
[AT_010]	50.7	-	-	Measured	-	-	-	-
[AT_011]	-	-	-	Measured	-	-	-	-
[AT_012]	-	-	-	-	-	-	-	Due to the big variety of electroplated products (regarding size, shape, quality requirements, etc.) representative specific consumption parameters cannot be derived.
[AT_015]	-	-	-	-	-	-	-	-
[AT_016]	-	-	-	-	-	-	20.8	there is only the record of the total electricity consumption of the establishmentconsumption values are calculated per jig, loading of jigs differs significantly, no representative spezific values per m² or per t possible (reslut of environmental audit)
[AT_020]	-	-	-	Calculated	-	-	24500	Alle Verbräuche aus Netzbezug ohne Eigenproduktion
[AT_021]	-	1.10	-	Measured	-	-	-	-
[BE_001]	-	-	-	Measured	-	-	-	value is in PJ (not per ton), is the total energy consumption for the entire plant (also non-STM activities)
[BE_003]	0.060	-	-	-	-	-	0.1	total consumption 5187 MWh

Plant code	Net Energy (kWh/m²)	Net Electricity (kWh/m²)	Net Heat (kWh/m²)	How the energy consum-ption is monitored	Proportion of energy recovered (%)	How the recovered energy is monitored	Total volume of workspace heated (m³)	Additional information
[BE_010]	-	-	-	Other	-	-	22000	elec 669990 KWh; gas 756620 KWH (E-consumption per year) (only total E-consumption available)
[BE_015]	60.8	33.00	27.80	Calculated	-	Not monitored	7400	-
[BE_017]	-	-	-	-	-	-	1045.64	electricity (plant-site)
[BE_018]	1.40	0.55	0.85	Calculated	36.767	Calculated	-	Datagap from 18/11/2022-31/12/2022, the consumption during this gap was estimated
[BE_020]	5.49	2.47	3.01	Measured	13	Measured	168	gas and electricity combined, total m² going through our paint shop is estimated at 290000 m²/year.
[BE_031]	3.89	4.58	0.00	Measured	0	Calculated	1250	0,0004% it was in Nov/Dec
[BE_040]	-	-	-	-	-	-	121640	we only have data for the complete plant, not for the STM related installations only
[BG_004]	-	-	-	-	-	-	135.06	We have separately electricity metering for a workshop Line 1
[BG_006]	-	33.00	72.00	Calculated	-	-	-	-
[BG_013]	-	-	-	Measured	-	-	-	-
[CZ_001]	4.8596	0.65	1.42	Measured	-	Not monitored	-	-
[CZ_002]	37.60	18.56	19.05	-	-	-	-	-
[CZ_003]	-	-	-	Measured	-	-	2917	-
[CZ_006]	-	8.93	-	Measured	-	-	14.04	-
[CZ_007]	-	-	-	Measured	-	-	-	-
[CZ_010]	18.01	5.27	-	Measured	-	-	-	-
[CZ_011]	-	904.55	-	Measured	-	Not monitored	1570.1	We have only consumption MWh, main unit for work is landing gear per year, we cannot more details about consumption.
[CZ_012]	40.395	-	-	Measured	8	Calculated	54500	-
[CZ_014]	-	-	-	Measured	-	Not monitored	16	-
[DE_005]	-	-	-	Measured	-	-	-	The specific consumptions cannot be determined because the total surface treated cannot be determined.
[DE_018]	-	-	-	-	-	-	-	3363160 kWh/a

Plant code	Net Energy (kWh/m^2)	Net Electricity (kWh/m^2)	Net Heat (kWh/m^2)	How the energy consum-ption is monitored	Proportion of energy recovered (%)	How the recovered energy is monitored	Total volume of workspace heated (m^3)	Additional information
[DE_019]	-	-	-	-	-	-	-	-
[DE_023]	-	-	-	-	-	-	-	-
[DE_024]	-	-	-	-	-	-	-	-
[DE_025]	-	-	-	-	-	-	-	-
[DE_033]	-	-	-	-	-	-	-	-
[DE_036]	-	-	-	Measured	-	-	-	Only absolute figures available
[DE_037]	-	-	-	Measured	-	-	-	Only absolute figures available
[DE_038]	-	-	-	-	-	-	-	-
[DE_041]	-	-	-	-	-	-	-	-
[DE_045]	-	-	-	-	-	-	-	-
[DE_048]	-	-	-	-	-	-	-	-
[DE_054]	-	-	-	Measured	-	-	23000	-
[DE_059]	-	-	-	-	-	-	-	-
[DE_060]	-	-	-	-	-	-	-	-
[DE_062]	-	-	-	-	-	-	-	-
[DE_077]	-	-	-	Measured	-	-	-	-
[DE_079]	-	-	-	-	-	-	-	-
[DK_001]	-	-	-	Measured	-	-	27900	Electricity consumption is for all plant in general
[ES_002]	-	-	-	Calculated	0	-	-	It is taken 2022 production as a refernce. 11981 Tn
[ES_003]	48.13	32.11	-	Measured	0	-	35000	-
[ES_004]	180.41	43.69	136.72	Calculated	-	Not monitored	-	-
[ES_009]	2440.39	2,440.40	-	Estimated	-	-	-	-
[ES_010]	-	17.00	-	Measured	-	-	423.88	2152763 kWh/t natural gas consumption and 11,20 specific net gas consumption kWh/m2. 5121364 kWh total net energy consumption and 28,2 kWh/m2 total net energy consumption.
[ES_013]	12.806	6.26	6.55	Measured	-	-	-	-

Plant code	Net Energy (kWh/m^2)	Net Electricity (kWh/m^2)	Net Heat (kWh/m^2)	How the energy consumption is monitored	Proportion of energy recovered (%)	How the recovered energy is monitored	Total volume of workspace heated (m^3)	Additional information
[ES_023]	-	-	-	Estimated	0	Not monitored	-	Estimated 3,5% of total energy consumation in the plant
[ES_024]	-	-	-	-	-	-	-	Diesel consumption is not counted as it is not associated with the process itself but with the movement of the forklift
[ES_030]	-	20.45	-	Measured	-	-	297.24	Natural gas consumption: 1515137 kWh/year. Specific net gas consumption 10,10 kWh/m2. 4583682 kWh total net energy consumption and 30,55 kWh/m2 total net energy consumption.
[ES_031]	-	-	-	-	1	Calculated	931929	The heat from the compressors is reused for domestic hot water.The energy consumption is associated to the total production activities, not only for the surface treatment activities.
[FI_002]	-	38.88	-	Calculated	-	-	16000	Calculated from total energy consumption (including lights, laboratory)
[FI_003]	199.92	151.20	-	-	-	-	-	The figure is estimated by dividing the total plant electricity consumption by the estimated total area of chromated objects.
[FI_005]	-	-	-	Measured	5	Estimated	56000	Energy consumption is only measured for the whole site (incl. offices etc.). It is not possible to estimate specific net energy consumption due to variety (shape, size, thickness) of coated items.
[FR_006]	9.81	3.12	-	Measured	0	Not monitored	-	See attached document : FR_Renault_Batilly_Energie site & TTS 2020-22_Version 2_F8
[FR_007]	0.21	0.16	0.05	Measured	0	Not monitored	-	-
[FR_009]	19.6	-	-	-	-	-	-	-
[FR_011]	3.64	-	-	Measured	0	Measured	37566	overall consumption for all site activities, details available on request for lines 1,2,3,4
[FR_012]	-	-	-	-	-	-	-	-
[FR_014]	1.5	1.50	0.03	Estimated	0	Not monitored	-	-
[FR_015]	1.57	1.06	0.51	Measured	-	Not monitored	16300	Heating buildings thanks to hot water from the methanisation plant next to ours. Not monitored yet
[FR_016]	-	8.00	-	Calculated	-	-	9374	No data yet for the gas consumption. We are not able to separate our specific net heat consumption.
[FR_017]	0.678	0.09	0.59	Calculated	0	-	11760	Hot water and not steam in KWh PCS
[FR_018]	29.985	15.00	14.35	Measured	-	-	-	ratio by ton or m² is not representative. Consumption electricity global plant : 14385896 KWh. Consumption wood heating district pipe global plant :

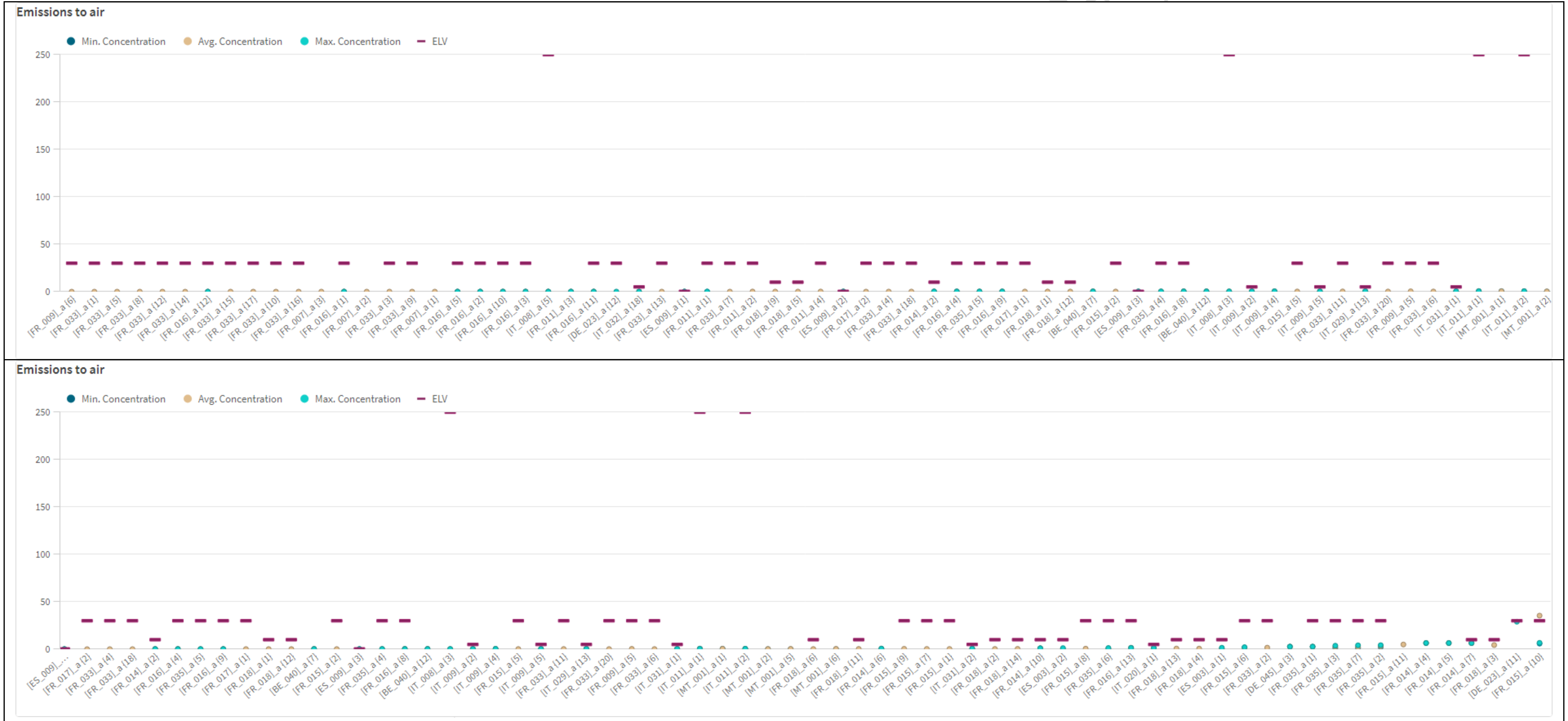
Plant code	Net Energy (kWh/m^2)	Net Electricity (kWh/m^2)	Net Heat (kWh/m^2)	How the energy consumption is monitored	Proportion of energy recovered (%)	How the recovered energy is monitored	Total volume of workspace heated (m^3)	Additional information
								5446000 KWh
[FR_020]	-	-	-	Not monitored	0	Not monitored	-	see global information in additional information in line 96
[FR_024]	137.37	-	-	Measured	0	-	6000	-
[FR_033]	1312.06	398.44	913.63	Estimated	0	-	22420	Surf. : 21990m² Conso gaz : 17912MWh Conso Elec : 8829MWh
[FR_034]	3.68	3.69	-	Measured	0	-	1650	-
[FR_035]	55.48	40.04	15.44	Calculated	0	Not monitored	17028.2	-
[FR_036]	23.8	-	-	Measured	-	-	-	-
[IT_001]	35.4	31.23	4.07	Measured	-	-	6903	-
[IT_002]	23.33	9.67	13.67	Measured	-	-	45000	-
[IT_004]	19.673	11.61	8.06	Calculated	-	-	8000	-
[IT_006]	23.004	10.02	12.98	Measured	0	-	5850	Total electricity consumption for industrial use in 2021: 419125 kWh kWh; Total thermal energy consumption in 2021: 540016 kWh, thermal energy consumption is derived by estimation, converting methane consumption into energy equivalents. We process mainly sheet metal, which has a high surface area in relation to weight.
[IT_008]	21.20	6.49	14.72	Estimated	0	Not monitored	10000	-
[IT_009]	-	-	-	Measured	-	-	-	As a subcontractor company it is not possible to determine the measurements and weight of the items treated
[IT_011]	191.43	10.89	180.54	Measured	-	-	-	Measured for electricity, calculated for heat
[IT_012]	538.10	-	-	Measured	0	Calculated	-	We perform special Hard-chrome plating processes, and in most cases the permanence in galvanic baths is very long (even up to 70 hours in some cases).
[IT_013]	-	-	-	Estimated	0	-	35100	Total energy consumption of galvanics processes is 1094602.00 kWh/year
[IT_020]	-	-	-	Other	-	-	-	Annual consumption: 52655 kWh (electric); 1318109.09 kWh (thermal from methane). Conversion factor applied to MC of Methane equal to 10.55. Electricity consumption reported for Production lines only.
[IT_025]	56.703	50.43	6.27	Measured	0	Calculated	51725	-

Plant code	Net Energy (kWh/m^2)	Net Electricity (kWh/m^2)	Net Heat (kWh/m^2)	How the energy consum-ption is monitored	Proportion of energy recovered (%)	How the recovered energy is monitored	Total volume of workspace heated (m^3)	Additional information
[IT_029]	-	-	-	Measured	0	Other	11500	These specific consumptions are obtained by dividing the total consumption by the total material processed in the company. Therefore these data do not concerned only the galvanic processes because there is not a dedicated meter. In addition, the treated pieces have a high surface-to-weight ratio.
[IT_030]	26.16	3.63	22.56	Estimated	-	-	24.4	The specific amount is estimated on the basis of a single factor (average m2 per jig) the mesuring unit requested isn't rapresentative due to the great vaiability of the prcessed article
[IT_031]	78.267	21.73	58.01	Estimated	-	-	88.5	the consumption data used to estimate the specific consumption are those of the entire factory, but have been referred to the galvanic process only. The specific amount is estimated on the basis of a single factor (average m2 per jig) the mesuring unit requested isn't rapresentative due to the great vaiability of the prcessed article
[IT_032]	-	-	-	Measured	-	-	38.6	The total energy consumption is 1213798 kWh/year incuded 318104 kwh/year of eletric energy, it's impossible to use the defined unit of measure because the hig variabiliy of the item processed, but the specific consumption is calculated for eletric energy in Kwh/rack treated and is 132
[IT_033]	-	-	-	-	-	-	-	-
[NL_001]	-	-	-	Measured	0	-	12.5	-
[NL_002]	-	-	-	-	-	-	-	-
[PT_002]	-	-	-	Measured	-	-	34.6	LPG is consumed in Ton
[SE_002]	9.3	-	-	-	-	-	-	Electricity and district heating
[SE_003]	-	-	-	-	-	-	-	Electricity and district heating.
[SE_004]	123	106.67	16.33	Measured	-	Not monitored	54000	Main heating is done by heat recovery from process, % unknown
[SE_005]	-	-	-	-	-	-	-	No statistic regarding tonnes or m2 in surface treatment
[SE_006]	-	-	-	Measured	0	-	24174	Total energy consumption 1559 MWh, and 2020 was 385 ton of steel surface treated.

3.2.4 Emissions to air

3.2.4.1 NH_3

The reported data for NH_3 emissions to air are presented in Figure 3-28. Emission data and contextual information are also presented in Table 3-27.



Source: [168, TWG 2023]

Figure 3-28: NH_3 emissions to air in electrolytic or chemical plating plants

Table 3-27: Reported data and contextual information for NH_3 emissions to air in electrolytic or chemical plating plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[BE_040]_a {7}	Etching and descaling of aluminium-Other-	No technique applied	0.27	0.27	0.27	-	-
[BE_040]_a {12}	Anodising-	No technique applied	0.30	0.30	0.30	-	-
[DE_023]_a {11}	Pickling (not electrically), descaling and desmutting-Plating-	-	29.00	-	-	30.00	0.01
		-	26.00	-	-	30.00	0.01
[DE_023]_a {12}	Plating	-	0.10	-	-	30.00	0.00
[DE_045]_a {3}	Other-	Scrubber-absorption (acid/alkaline)	2.70	2.70	2.70	-	-
[ES_003]_a {1}	Plating	Scrubber-absorption (acid/alkaline)	1.54	1.04	0.69	10.00	-
			1.21	1.13	1.09	10.00	-
			0.12	0.07	0.01	10.00	-
[ES_003]_a {2}	Plating	Scrubber-absorption (acid/alkaline)	1.18	0.69	0.92	10.00	-
			0.71	0.24	0.01	10.00	-
[ES_009]_a {1}	Alkaline degreasing-Other-Electrocoating (e-coating)-	Scrubber-absorption (acid/alkaline)	0.12	0.12	0.12	0.30	< 9,64E-6
			0.09	0.09	0.09	0.30	< 3,45E-3
			0.07	0.07	0.07	0.30	<2,96E-3
[ES_009]_a {2}	Alkaline degreasing-Other-Electrocoating (e-coating)-	Scrubber-absorption (acid/alkaline)	0.17	0.17	0.17	0.30	0.01
			0.11	0.11	0.11	0.30	<4,32E-3
			0.09	0.09	0.09	0.30	< 9,64E-6
[ES_009]_a {3}	Alkaline degreasing-Other-	Scrubber-absorption (acid/alkaline)	0.30	0.30	0.30	0.30	< 9,64E-6
			0.08	0.08	0.08	0.30	<2,93E-3
			0.06	0.06	0.06	0.30	<2,34E-3
[FR_007]_a {1}	Alkaline degreasing	-	-	0.07	-	-	-
		-	-	0.02	-	-	-
[FR_007]_a {2}	Alkaline degreasing	-	-	0.03	-	-	-
[FR_007]_a {3}	Plating	-	-	0.05	-	-	-
		-	-	0.02	-	-	0.00
[FR_009]_a {5}	Plating-Pickling (not electrically), descaling and desmutting-	-	-	0.44	-	30.00	0.01
		-	-	0.28	-	30.00	0.01
[FR_009]_a {6}	Plating-	-	-	0.00	-	30.00	0.00
[FR_011]_a {1}	Alkaline degreasing-Other	No technique applied	0.12	-	0.10	30.00	-
[FR_011]_a {2}	Other	No technique applied	-	0.13	-	30.00	-
[FR_011]_a {3}	Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-	No technique applied	0.10	0.10	0.10	-	-
[FR_011]_a {4}		-	-	0.14	-	30.00	-
[FR_014]_a {2}	Other	Other	0.20	0.20	0.20	10.00	-

[FR_014]_a {4}	-	Absorption	6.50	6.50	6.50	-	-
[FR_014]_a {5}	-	Absorption	6.50	6.50	6.50	-	-
[FR_014]_a {6}		-	0.60	0.60	0.60	-	-
[FR_014]_a {7}	-	Absorption	6.50	6.50	6.50	10.00	-
[FR_014]_a {10}	-	Absorption	1.00	1.00	1.00	10.00	-
[FR_015]_a {1}	Electrolytically assisted pickling, activation and degreasing-Plating-	No technique applied	-	0.27	-	30.00	-
[FR_015]_a {2}	Electrolytically assisted pickling, activation and degreasing-Plating-	-	-	0.14	-	30.00	-
		No technique applied	-	0.14	-	30.00	-
[FR_015]_a {5}	Electrolytically assisted pickling, activation and degreasing-Plating-	No technique applied	-	0.19	-	30.00	-
[FR_015]_a {6}	Electrolytically assisted pickling, activation and degreasing- Plating-Other-	No technique applied	2.10	2.00	1.80	30.00	-
			-	0.65	-	30.00	-
[FR_015]_a {7}	Electrolytically assisted pickling, activation and degreasing-Plating- Other-	No technique applied	-	0.66	-	30.00	-
			-	0.29	-	30.00	-
			-	0.01	-	30.00	-
[FR_015]_a {8}	Electrolytically assisted pickling, activation and degreasing-Other-	Other	-	1.20	-	30.00	-
			-	0.29	-	30.00	-
			-	0.27	-	30.00	-
[FR_015]_a {9}	Anodising-Electrolytically assisted pickling, activation and degreasing-Plating-	No technique applied	-	0.60	-	30.00	-
			-	0.27	-	30.00	-
[FR_015]_a {10}	Electrolytically assisted pickling, activation and degreasing-Plating-	No technique applied	6.70	5.80	5.90	30.00	-
			-	65.00	-	30.00	-
[FR_015]_a {11}	Use of fuel-fired burners (combustion)	Fabric filter	-	6.10	-	-	-
			-	5.60	-	-	-
			-	3.10	-	-	-
[FR_016]_a {1}	Other	No technique applied	0.06	0.06	0.06	30.00	0.00
[FR_016]_a {2}	Metal stripping	No technique applied	0.08	0.08	0.08	30.00	0.00
[FR_016]_a {3}	Anodising	No technique applied	0.09	0.09	0.09	30.00	0.00
[FR_016]_a {4}	Other	No technique applied	0.20	0.20	0.20	30.00	0.00
[FR_016]_a {5}	Etching or pickling of plastics	No technique applied	0.07	0.07	0.07	30.00	0.00
[FR_016]_a {8}	Plating	No technique applied	0.30	0.30	0.30	30.00	0.00
[FR_016]_a {9}	Plating	No technique applied	0.20	0.20	0.20	30.00	0.00
[FR_016]_a {10}	Plating	No technique applied	0.08	0.08	0.08	30.00	0.00
[FR_016]_a {11}	Plating	No technique applied	0.10	0.10	0.10	30.00	0.00
[FR_016]_a {12}	Plating	-	0.02	0.02	0.02	30.00	0.00
[FR_016]_a {13}	Plating	-	1.40	1.40	1.40	30.00	0.01
[FR_017]_a {1}	Alkaline degreasing--Rinsing	-	-	0.21	-	30.00	0.01
			-	0.00	-	30.00	0.00
[FR_017]_a {2}	Plating-Rinsing-	-	-	0.17	-	30.00	0.00
		-	-	0.02	-	30.00	0.00
		-	-	0.00	-	30.00	0.00
[FR_018]_a {1}	Other-	Scrubber-absorption (acid/alkaline)	-	0.23	-	10.00	0.00
			-	0.10	-	10.00	0.00
			-	0.01	-	10.00	0.00

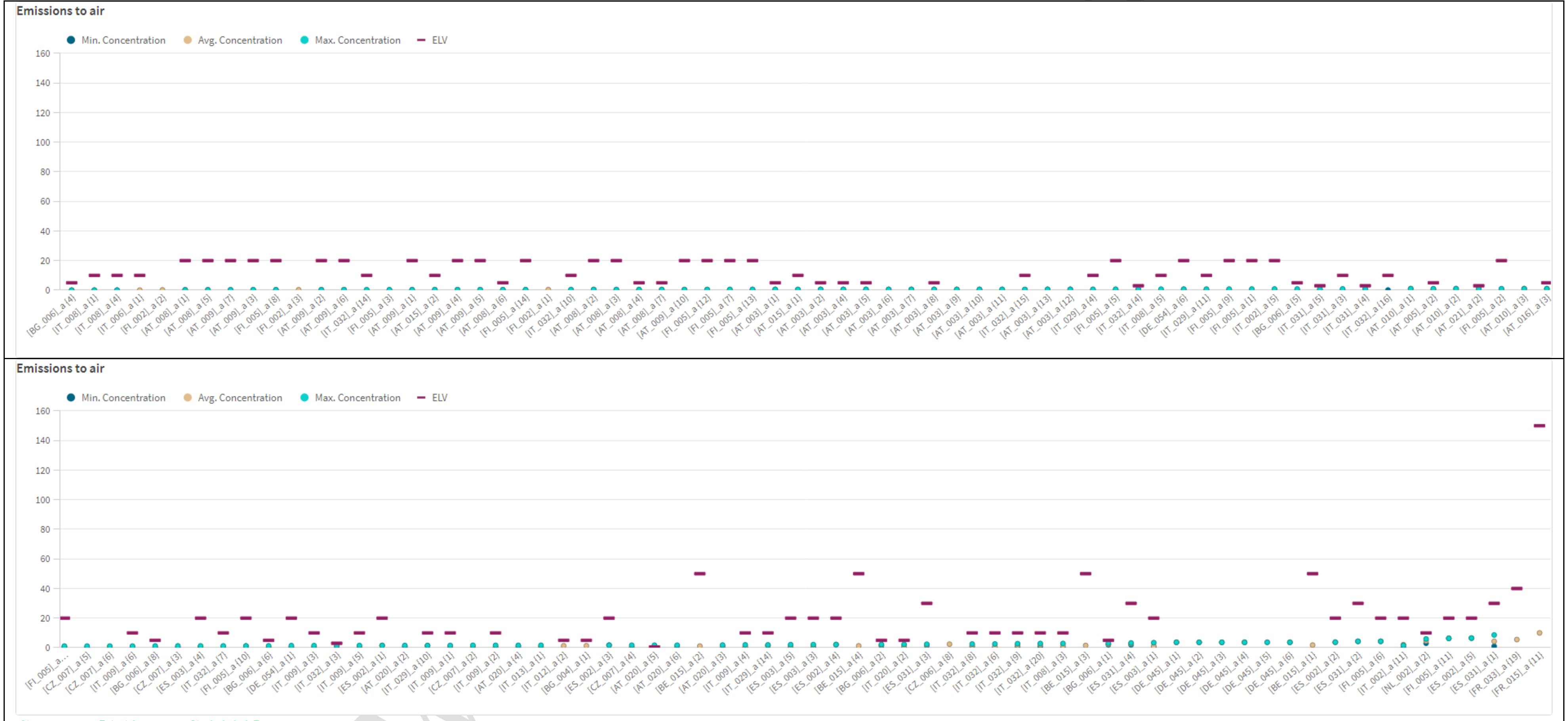
[FR_018]_a {2}	Metal stripping-Conditioning of plastics	Scrubber-absorption (acid/alkaline)	-	0.80	-	10.00	0.08
			-	0.07	-	10.00	0.00
			-	0.01	-	10.00	0.00
[FR_018]_a {3}	Metal stripping-Conditioning of plastics-Etching or pickling of plastics--Other-Plating	Scrubber-absorption (acid/alkaline)	-	7.50	-	10.00	0.19
			-	5.59	-	10.00	0.12
			-	0.01	-	10.00	0.00
[FR_018]_a {4}	Plating-	Scrubber-absorption (acid/alkaline)	-	1.52	-	10.00	0.02
			-	0.40	-	10.00	0.00
			-	0.02	-	10.00	0.00
[FR_018]_a {5}	Aqueous cleaning- Plating- Other-	Scrubber-absorption (acid/alkaline)	-	0.14	-	10.00	0.00
			-	0.10	-	10.00	0.00
			-	0.02	-	10.00	0.00
[FR_018]_a {6}	Metal stripping	Scrubber-absorption (acid/alkaline)	-	0.50	-	10.00	0.00
			-	0.13	-	10.00	0.00
			-	0.01	-	10.00	0.00
[FR_018]_a {9}	Other	Scrubber-absorption (acid/alkaline)	-	0.13	-	10.00	0.00
			-	0.10	-	10.00	0.00
			-	0.01	-	10.00	0.00
[FR_018]_a {11}	Conditioning of plastics-Etching or pickling of plastics- Rinsing- Other	Scrubber-absorption (acid/alkaline)	-	0.50	-	10.00	0.02
			-	0.40	-	10.00	0.01
			-	0.01	-	10.00	0.00
[FR_018]_a {12}	Plating	Scrubber-absorption (acid/alkaline)	-	0.25	-	10.00	0.00
			-	0.10	-	10.00	0.00
			-	0.01	-	10.00	0.00
[FR_018]_a {13}	Plating-Other-	Scrubber-absorption (acid/alkaline)	-	1.50	-	10.00	0.02
			-	0.55	-	10.00	0.01
			-	0.01	-	10.00	0.00
[FR_018]_a {14}	Metal stripping--	Scrubber-absorption (acid/alkaline)	-	0.80	-	10.00	0.03
			-	0.29	-	10.00	0.00
			-	0.01	-	10.00	0.00
[FR_033]_a {1}	Plating-Metal stripping-Electrolytically assisted pickling, activation and degreasing- Rinsing-Other	No technique applied	-	0.01	-	30.00	0.00
			-	0.01	-	30.00	0.00
[FR_033]_a {2}	Plating--Metal stripping- Rinsing-	No technique applied	-	2.70	-	30.00	0.11
			-	1.40	-	30.00	0.06
			-	0.78	-	30.00	0.03
[FR_033]_a {3}	Rinsing-Other-	No technique applied	-	0.06	-	30.00	0.00
			-	0.03	-	30.00	0.00
[FR_033]_a {4}	Plating	Mist filter (demister)	-	0.17	-	30.00	0.00
			-	0.01	-	30.00	0.00
[FR_033]_a {5}	Plating	Mist filter (demister)	-	0.01	-	30.00	0.00
			-	0.01	-	30.00	0.00
[FR_033]_a {6}	Plating	Mist filter (demister)	-	0.47	-	30.00	0.00
			-	0.04	-	30.00	0.00
			-	0.01	-	30.00	0.00
[FR_033]_a {7}	Plating	No technique applied	-	0.12	-	30.00	0.00
			-	0.01	-	30.00	0.00
			-	0.01	-	30.00	0.00
[FR_033]_a {8}	Plating	Mist filter (demister)	-	0.01	-	30.00	0.00
			-	0.01	-	30.00	0.00
[FR_033]_a {9}	Aqueous cleaning-- Oiling-Alkaline degreasing- Rinsing-	No technique applied	-	0.06	-	30.00	0.00
			-	0.04	-	30.00	0.00
			-	0.01	-	30.00	0.00
[FR_033]_a {10}	Pickling (not electrically), descaling and	No technique	-	0.03	-	30.00	0.00

	desmutting-Other-Rinsing-	applied	-	0.01	-	30.00	0.00
[FR_033]_a {11}	Metal stripping-Alkaline degreasing-plating	No technique applied	-	0.38	-	30.00	0.00
			-	0.09	-	30.00	0.00
[FR_033]_a {12}	Other-Etching and descaling of aluminium-	No technique applied	-	0.01	-	30.00	0.00
			-	0.01	-	30.00	0.00
[FR_033]_a {13}	Metal stripping-Metal stripping-	No technique applied	-	0.11	-	30.00	0.00
			-	0.02	-	30.00	0.00
			-	0.01	-	30.00	0.00
[FR_033]_a {14}	Other-Pickling (not electrically), descaling and desmutting	No technique applied	-	0.01	-	30.00	0.00
			-	0.01	-	30.00	0.00
[FR_033]_a {15}	-Rinsing-Etching and descaling of aluminium-Rinsing	No technique applied	-	0.03	-	30.00	0.00
			-	0.01	-	30.00	0.00
[FR_033]_a {16}	Pickling (not electrically), descaling and desmutting-Other-	No technique applied	-	0.04	-	30.00	0.00
			-	0.01	-	30.00	0.00
			-	0.01	-	30.00	0.00
[FR_033]_a {17}	Alkaline degreasing- Rinsing-	No technique applied	-	0.03	-	30.00	0.00
			-	0.01	-	30.00	0.00
[FR_033]_a {18}	Pickling (not electrically), descaling and desmutting-Other-	Mist filter (demister)	-	0.19	-	30.00	0.00
			-	0.01	-	30.00	0.00
[FR_033]_a {20}	-Rinsing-Other-Pickling (not electrically), descaling and desmutting	No technique applied	-	0.40	-	30.00	0.00
			-	0.04	-	30.00	0.00
			-	0.01	-	30.00	0.00
[FR_035]_a {1}	Plating- Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)- Alkaline degreasing- Chemical polishing-Other- Etching and descaling of aluminium-Etching	Scrubber-absorption (acid/alkaline)	2.71	2.71	2.71	30.00	0.08
			2.70	2.70	2.70	30.00	0.06
			2.66	2.66	2.66	30.00	0.05
[FR_035]_a {2}	Plating-Other-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)- Alkaline degreasing- Other-Chemical polishing- Etching and descaling of aluminium-Etching – Alkaline etching of aluminium-	Scrubber-absorption (acid/alkaline)	4.24	4.24	4.24	30.00	0.03
			2.80	2.80	2.80	30.00	0.05
			2.15	2.15	2.15	30.00	0.05
[FR_035]_a {3}	Etching or pickling of plastics-Conditioning of plastics--Plating-Electrocoating (e-coating)- Rinsing-Degreasing-Metal stripping-Other-	Scrubber-absorption (acid/alkaline)	3.70	3.70	3.70	30.00	0.08
			2.50	2.50	2.50	30.00	0.06
			1.19	1.19	1.19	30.00	0.03
[FR_035]_a {4}	Pickling (not electrically), descaling and desmutting-Metal stripping-Degreasing-Electrolytically assisted pickling, activation and degreasing-Other-	Scrubber-absorption (acid/alkaline)	0.30	0.30	0.30	30.00	0.01
			0.20	0.20	0.20	30.00	-
			0.10	0.10	0.10	30.00	0.00
[FR_035]_a {5}	Plating-Other-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)- Other-Alkaline degreasing-Etching and descaling of aluminium-Etching – Alkaline etching of aluminium	Scrubber-absorption (acid/alkaline)	0.20	0.20	0.20	30.00	0.00
			0.10	0.10	0.10	30.00	-
			0.09	0.09	0.09	30.00	-
[FR_035]_a {6}	Electrocoating (e-coating)-Other-Electrolytically assisted pickling, activation and degreasing--Rinsing-Degreasing-	Scrubber-absorption (acid/alkaline)	1.25	1.25	1.25	30.00	0.01
			0.90	0.90	0.90	30.00	0.01
			0.45	0.45	0.45	30.00	0.00
[FR_035]_a {7}	Electrocoating (e-coating)- Other-	Scrubber-absorption (acid/alkaline)	4.10	4.10	4.10	30.00	0.02
			1.42	1.42	1.42	30.00	0.01
			1.27	1.27	1.27	30.00	0.01
[IT_008]_a {3}	Alkaline degreasing-Rinsing-	-	0.32	0.32	0.32	250.00	39.15

	Electrolytically assisted pickling, activation and degreasing- Other- Electrocoating (e-coating)-Rinsing-	-	0.05	0.05	0.05	250.00	6.79
[IT_008]_a {5}	Drying	-	0.09	0.09	0.09	250.00	0.64
		-	0.07	0.07	0.07	250.00	0.54
[IT_009]_a {2}	Plating-Rinsing--Drying-	Scrubber-absorption (acid/alkaline)	0.35	0.30	0.28	5.00	-
[IT_009]_a {4}	Plating-	Scrubber-absorption (acid/alkaline)	0.36	0.36	0.36	-	-
			0.35	0.35	0.35	-	-
			0.35	0.35	0.35	-	-
[IT_009]_a {5}	Rinsing-Plating-	Scrubber-absorption (acid/alkaline)	0.36	0.36	0.36	5.00	-
			0.36	0.36	0.36	5.00	-
			0.28	0.28	0.28	5.00	-
[IT_011]_a {1}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber-absorption (acid/alkaline)	0.50	0.50	0.50	250.00	0.00
[IT_011]_a {2}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber-absorption (acid/alkaline)	0.50	0.50	0.50	250.00	0.00
[IT_020]_a {1}	Anodising-Electrocoating (e-coating)--	Scrubber-absorption (acid/alkaline)	1.50	1.40	1.30	5.00	0.05
			0.80	0.70	0.60	5.00	0.03
			0.40	0.35	0.30	5.00	0.01
[IT_029]_a {13}	Other	No technique applied	0.40	0.40	0.40	5.00	-
[IT_031]_a {1}	Plating-Rinsing- Electrolytically assisted pickling, activation and degreasing-Degreasing-Pickling (not electrically), descaling and desmutting- Other-	Scrubber-absorption (acid/alkaline)	0.49	0.49	0.49	5.00	0.01
			0.25	0.25	0.25	5.00	0.01
			0.20	0.20	0.20	5.00	0.00
[IT_031]_a {2}	Metal stripping-Degreasing--Rinsing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Other-	Scrubber-absorption (acid/alkaline)	0.79	0.79	0.79	5.00	0.02
			0.73	0.73	0.73	5.00	0.01
			0.25	0.25	0.25	5.00	0.01
[IT_032]_a {18}	Plating-Other-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Plating-	No technique applied	0.10	0.10	0.10	5.00	0.00
			0.07	0.07	0.07	5.00	0.00

3.2.4.2 Dust

The reported data for dust emissions to air are presented in Figure 3-29. Emission data and contextual information are also presented in Table 3-28.



Source: [168, TWG 2023]

Figure 3-29: Dust emissions to air in electrolytic or chemical plating plants

Table 3-28: Reported data and contextual information for dust emissions to air in electrolytic or chemical plating plants

EP	Associated processes	Applied techniques	Max.	Avg..	Min	ELV	Load
[AT_003]_a {1}	Pickling (not electrically), descaling and desmutting-Other-Metal stripping-Plating	Aerosol/droplet separator-Other-Scrubber- absorption (acid/alkaline)	0.50	0.50	0.50	5.00	-
[AT_003]_a {2}	Degreasing-Plating-	Scrubber- absorption (acid/alkaline)-Other-Aerosol/droplet separator	0.50	0.50	0.50	5.00	-
[AT_003]_a {4}	Pickling (not electrically), descaling and desmutting-Anodising-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.50	0.50	0.50	5.00	-
[AT_003]_a {5}	Alkaline degreasing-Etching – Alkaline etching of aluminium-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.50	0.50	0.50	5.00	-
[AT_003]_a {6}	Pickling (not electrically), descaling and desmutting-Plating-	-Other-Mist filter (demister)	0.50	0.50	0.50	-	-
[AT_003]_a {7}	Alkaline degreasing-Plating-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.50	0.50	0.50	-	-
[AT_003]_a {8}	Pickling (not electrically), descaling and desmutting-Plating-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.50	0.50	0.50	5.00	-
[AT_003]_a {9}	Alkaline degreasing-Plating-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.50	0.50	0.50	-	-
[AT_003]_a {10}	Pickling (not electrically), descaling and desmutting-Plating-	Mist filter (demister)-Other	0.50	0.50	0.50	-	-
[AT_003]_a {11}	Alkaline degreasing-Plating-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.50	0.50	0.50	-	-
[AT_003]_a {12}	Pickling (not electrically), descaling and desmutting-Plating- Other-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.55	0.55	0.55	-	-
[AT_003]_a {13}	Alkaline degreasing-Plating- Other	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.54	0.54	0.54	-	-
[AT_005]_a {2}	Heat treatment	Straight thermal oxidation	1.00	1.00	1.00	5.00	-
			0.50	0.50	0.50	5.00	-
[AT_008]_a {1}	Other-Plating--Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	0.20	0.20	0.20	20.00	-
[AT_008]_a {2}	Pickling (not electrically), descaling and desmutting--Plating-Deburring and/or tumbling-Rinsing	Scrubber- absorption (acid/alkaline)	0.40	0.40	0.40	20.00	-
[AT_008]_a {3}	Pickling (not electrically), descaling and desmutting-Rinsing-Drying- Other-Degreasing-Electrolytically assisted pickling, activation and degreasing-Deburring and/or tumbling-Plating	Scrubber- absorption (acid/alkaline)	0.40	0.40	0.40	20.00	-
[AT_008]_a {4}	Drying	Scrubber- absorption (acid/alkaline)	0.40	0.40	0.40	5.00	-

[AT_008]_a {5}	Drying		0.20	0.20	0.20	20.00	-
[AT_008]_a {6}	Degreasing- Plating-Rinsing-Electrocoating (e-coating)-	Scrubber- absorption (acid/alkaline)	0.30	0.30	0.30	5.00	-
[AT_008]_a {7}	Degreasing-Rinsing-Plating-Electrocoating (e-coating)-	Scrubber- absorption (acid/alkaline)	0.40	0.40	0.40	5.00	-
[AT_009]_a {1}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating	Aerosol/droplet separator	0.30	0.30	0.30	20.00	-
[AT_009]_a {2}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating	Aerosol/droplet separator	0.27	0.27	0.27	20.00	-
[AT_009]_a {3}	Plating-	Aerosol/droplet separator	0.23	0.23	0.23	20.00	-
[AT_009]_a {4}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator	0.30	0.30	0.30	20.00	-
[AT_009]_a {5}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator	0.30	0.30	0.30	20.00	-
[AT_009]_a {6}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing- Plating-Other-	Aerosol/droplet separator	0.27	0.27	0.27	20.00	-
[AT_009]_a {7}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing- Plating-Other-	Aerosol/droplet separator	0.20	0.20	0.20	20.00	-
[AT_009]_a {10}	Degreasing-Pickling (not electrically), descaling and desmutting-Other-Anodising	Aerosol/droplet separator	0.40	0.30	0.30	20.00	-
[AT_010]_a {1}	Alkaline degreasing-Aqueous cleaning-Drying-Electrolytically assisted pickling, activation and degreasing-Etching – Alkaline etching of aluminium-Hand wiping-Heat treatment-Mechanical polishing/linishing-Pickling (not electrically), descaling and desmutting-Plating-	Scrubber- absorption (acid/alkaline)	1.00	1.00	1.00	-	-
[AT_010]_a {2}	Other-Plating-	Scrubber- absorption (acid/alkaline)	1.00	1.00	1.00	-	-

[AT_010]_a {3}	Plating-	Scrubber- absorption (acid/alkaline)	1.00	1.00	1.00	-	-
[AT_010]_a {4}	Pickling (not electrically), descaling and desmutting	Scrubber- absorption (acid/alkaline)	1.00	1.00	1.00	-	-
[AT_015]_a {1}	Degreasing- Pickling (not electrically), descaling and desmutting-Rinsing-Other-	Scrubber- absorption (acid/alkaline)	0.50	0.50	0.50	10.00	0.02
			0.30	0.30	0.30	10.00	0.01
[AT_015]_a {2}	Other-	Scrubber- absorption (acid/alkaline)	0.30	0.30	0.30	10.00	0.04
[AT_016]_a {3}	Abrasive blasting	Fabric filter	1.00	1.00	1.00	5.00	-
[AT_020]_a {1}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Plating-	Aerosol/droplet separator	1.10	1.10	1.10	-	-
			0.50	0.50	0.50	-	-
[AT_020]_a {2}	Electropolishing	-	1.50	1.50	1.50	-	-
		-	0.50	0.50	0.50	-	-
[AT_020]_a {3}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Chemical polishing-Electrolytically assisted pickling, activation and degreasing-	-	1.80	1.80	1.80	-	-
		-	0.50	0.50	0.50	-	-
[AT_020]_a {4}	Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Plating-Alkaline degreasing-	-	1.60	1.60	1.60	-	-
		-	0.50	0.50	0.50	-	-
[AT_020]_a {5}	Plating-	Aerosol/droplet separator	1.70	1.70	1.70	-	-
			0.50	0.50	0.50	0.50	-
[AT_020]_a {6}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-	Aerosol/droplet separator	1.70	1.70	1.70	-	-
			0.50	0.50	0.50	-	-
[AT_021]_a {2}	Heat treatment	No technique applied	1.00	1.00	1.00	3.00	-
[BE_015]_a {1}	Other-Plating-	Other	-	3.70	-	50.00	-
			-	0.80	-	50.00	-
			-	0.80	-	50.00	-
[BE_015]_a {2}	Plating	Other	-	1.80	-	50.00	-
			-	1.00	-	50.00	-
			-	0.50	-	50.00	-
[BE_015]_a {3}	Other-Plating-	Other	-	3.00	-	50.00	-
			-	1.00	-	50.00	-
			-	0.50	-	50.00	-
[BE_015]_a {4}	Plating	Other	-	2.20	-	50.00	-
			-	1.00	-	50.00	-
			-	0.50	-	50.00	-
[BG_004]_a {1}	Solvent degreasing-Etching or pickling of plastics-Other-Chromium conversion coatings-Soak clean-Hand wipping-pretreatment step	Scrubber- absorption (acid/alkaline)	-	1.68	-	5.00	0.04
			-	1.29	-	5.00	0.03
			-	1.06	-	5.00	0.03
[BG_006]_a {1}	Plating	Scrubber- absorption (acid/alkaline)	3.13	3.13	3.13	5.00	0.06
			2.41	2.41	2.41	5.00	0.05
			1.93	1.93	1.93	5.00	0.04

[BG_006]_a {2}	Electrocoating (e-coating)	Scrubber- absorption (acid/alkaline)	2.21	2.21	2.21	5.00	0.03
			1.70	1.70	1.70	5.00	0.02
			1.22	1.22	1.22	5.00	0.01
[BG_006]_a {4}	Electrocoating (e-coating)	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	5.00	0.00
[BG_006]_a {5}	Electrocoating (e-coating)	Scrubber- absorption (acid/alkaline)	0.81	0.81	0.81	5.00	0.01
			0.00	0.00	0.00	5.00	0.00
[BG_006]_a {6}	Electrocoating (e-coating)	Scrubber- absorption (acid/alkaline)	1.26	1.26	1.26	5.00	0.01
			0.00	0.00	0.00	5.00	0.00
[BG_006]_a {8}	Metal stripping	No technique applied	1.18	1.18	1.18	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
[CZ_006]_a {8}		-	-	2.40	-	-	-
[CZ_007]_a {1}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	Aerosol/droplet separator-Cyclone-	1.10	0.60	0.10	-	-
			0.90	0.60	0.30	-	-
			0.90	0.50	0.10	-	-
[CZ_007]_a {2}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	Aerosol/droplet separator-Cyclone-	1.60	1.20	0.80	-	-
			1.10	0.80	0.50	-	-
			0.70	0.40	0.10	-	-
[CZ_007]_a {3}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	1.20	0.70	0.10	-	-
		-	0.90	0.60	0.30	-	-
		-	0.80	0.50	0.20	-	-
[CZ_007]_a {4}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	1.70	1.30	0.90	-	-
		-	1.20	0.80	0.40	-	-
		-	0.70	0.40	0.10	-	-
[CZ_007]_a {5}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	1.10	0.70	0.30	-	-
		-	0.80	0.50	0.20	-	-
		-	0.70	0.40	0.10	-	-
[CZ_007]_a {6}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	1.10	0.70	0.30	-	-
		-	0.80	0.50	0.20	-	-
		-	0.60	0.30	0.00	-	-
[DE_025]_a {4}		No technique applied	1.00	0.37	0.00	-	-
[DE_045]_a {1}	Etching or pickling of plastics-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	3.65	3.65	3.65	-	-

	Conditioning of plastics						
[DE_045]_a {2}	Other-	Scrubber- absorption (acid/alkaline)	3.65	3.65	3.65	-	-
[DE_045]_a {3}	Other-	Scrubber- absorption (acid/alkaline)	3.65	3.65	3.65	-	-
[DE_045]_a {4}	Other-	Scrubber- absorption (acid/alkaline)	3.65	3.65	3.65	-	-
[DE_045]_a {5}	Electrocoating (e-coating)	Scrubber- absorption (acid/alkaline)	3.65	3.65	-	-	-
[DE_045]_a {6}	Electrocoating (e-coating)-Other-	Scrubber- absorption (acid/alkaline)	3.65	3.65	3.65	-	-
[DE_054]_a {1}	Alkaline degreasing-Other	Scrubber- absorption (acid/alkaline)	1.40	0.60	0.30	20.00	0.00
[DE_054]_a {6}	Other	Scrubber- absorption (acid/alkaline)	0.70	0.60	0.40	20.00	0.00
[ES_002]_a {1}	Pickling (not electrically), descaling and desmutting-Plating-Other-	No technique applied	1.50	1.50	1.50	20.00	0.02
[ES_002]_a {2}	Pickling (not electrically), descaling and desmutting-Plating-Other	No technique applied	3.73	3.73	3.73	20.00	0.07
[ES_002]_a {3}	Pickling (not electrically), descaling and desmutting-Alkaline degreasing-Plating-Other-	No technique applied	1.70	1.70	1.70	20.00	0.01
[ES_002]_a {4}	Pickling (not electrically), descaling and desmutting-Alkaline degreasing-Other-Plating-	No technique applied	2.10	2.10	2.10	20.00	0.02
[ES_002]_a {5}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Other-	No technique applied	6.47	6.47	6.47	20.00	0.04
[ES_003]_a {1}	Plating	Scrubber- absorption (acid/alkaline)	3.41	2.08	1.42	20.00	-
			0.69	0.66	0.64	20.00	-
			0.51	0.50	0.48	20.00	-
[ES_003]_a {2}	Plating	Scrubber- absorption (acid/alkaline)	1.09	1.05	1.01	20.00	-
			0.76	0.54	0.42	20.00	-
			0.51	0.51	0.51	20.00	-
[ES_003]_a {3}	Plating	Scrubber- absorption (acid/alkaline)	2.08	2.02	1.96	20.00	-
			1.04	1.01	0.97	20.00	-
			0.53	0.51	0.49	20.00	-
[ES_003]_a {4}	Plating	Scrubber- absorption (acid/alkaline)	1.20	0.86	0.49	20.00	-
			0.63	0.48	0.53	20.00	-
[ES_003]_a {5}	Plating	Scrubber- absorption (acid/alkaline)	2.06	2.00	1.96	20.00	-
			1.25	1.10	0.99	20.00	-
			0.52	0.51	0.49	20.00	-
[ES_031]_a {1}	Alkaline degreasing	Scrubber- absorption (acid/alkaline)	8.60	8.60	8.60	30.00	0.04
			3.30	2.15	1.00	30.00	0.01
[ES_031]_a {2}	Pickling (not electrically), descaling and desmutting-Degreasing-	Scrubber- absorption (acid/alkaline)	4.30	4.30	4.30	30.00	0.04
[ES_031]_a {3}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-	Scrubber- absorption (acid/alkaline)	2.37	2.37	2.37	30.00	0.01
			1.60	1.60	1.60	30.00	0.00
			1.40	1.40	1.40	30.00	0.00
[ES_031]_a {4}	Degreasing-	Scrubber- absorption	3.20	3.20	3.20	30.00	0.01

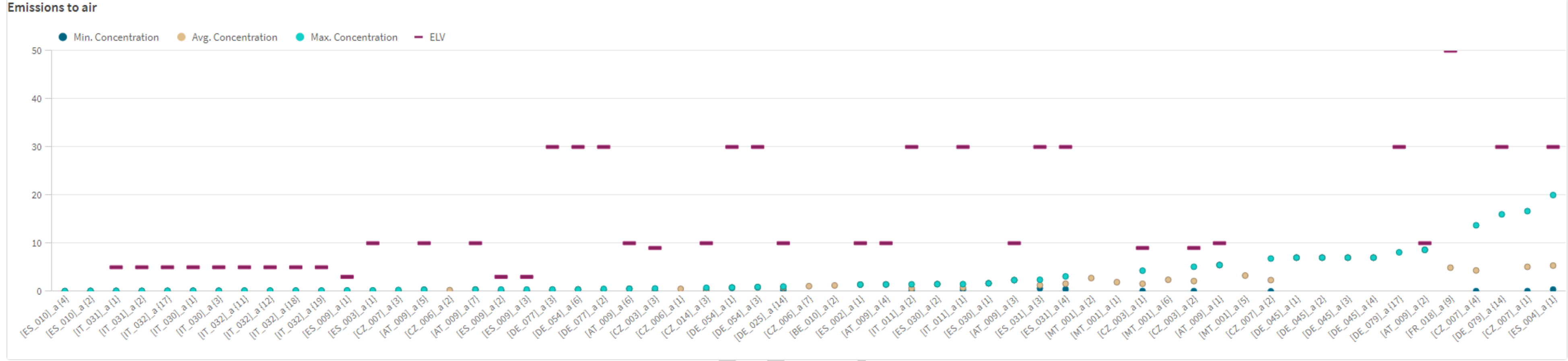
		(acid/alkaline)	2.90	2.90	2.90	30.00	0.01
			1.92	1.92	1.92	30.00	0.01
[FI_002]_a {1}	Aqueous cleaning-Platingg	Scrubber- absorption (acid/alkaline)	-	0.36	-	-	-
[FI_002]_a {2}	Alkaline degreasing-Plating	Scrubber- absorption (acid/alkaline)	-	0.19	-	-	-
[FI_002]_a {3}	Plating	Scrubber- absorption (acid/alkaline)	-	0.26	-	-	-
[FI_005]_a {1}		-	0.76	0.57	0.38	20.00	0.01
		-	0.22	0.17	0.11	20.00	0.00
[FI_005]_a {2}		-	1.00	0.90	0.79	20.00	0.01
		-	0.51	0.46	0.41	20.00	0.01
[FI_005]_a {3}		-	0.28	0.20	0.13	-	0.00
[FI_005]_a {4}		-	1.10	0.86	0.62	20.00	0.01
		-	0.66	0.65	0.64	20.00	0.01
[FI_005]_a {5}		-	0.65	0.59	0.53	20.00	0.01
		-	0.25	0.22	0.20	20.00	0.00
[FI_005]_a {6}		-	4.30	4.30	4.30	20.00	0.03
[FI_005]_a {7}		-	0.44	0.43	0.41	20.00	0.01
[FI_005]_a {8}		-	0.25	0.23	0.22	20.00	0.00
[FI_005]_a {9}		-	0.73	0.50	0.26	20.00	0.00
[FI_005]_a {10}		-	1.20	1.10	1.10	20.00	0.00
[FI_005]_a {11}		-	6.30	6.30	6.30	20.00	0.02
[FI_005]_a {12}		-	0.41	0.39	0.37	20.00	0.00
[FI_005]_a {13}		-	0.49	0.46	0.44	20.00	0.00
[FI_005]_a {14}		-	0.33	0.29	0.26	20.00	0.00
[FR_015]_a {11}	Use of fuel-fired burners (combustion)	Fabric filter	-	14.00	-		-
			-	8.00	-		-
[FR_033]_a {19}	Abrasive blasting	Fabric filter	-	9.80	-	40.00	0.03
			-	6.00	-	40.00	0.03
			-	0.70	-	40.00	0.00
[IT_002]_a {5}	Mechanical polishing/linishing	Cyclone	0.80	0.80	0.80	20.00	2.65
			0.70	0.70	0.70	20.00	2.61
			0.10	0.10	0.10	20.00	0.41
[IT_002]_a {11}	Abrasive blasting	Cyclone	1.60	4.60	0.10	20.00	0.00
			1.30	0.80	0.60	20.00	0.00
			0.70	0.70	0.70	20.00	0.00
[IT_006]_a {1}	Descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Alkaline degreasing-Plating-Other-	Scrubber- absorption (acid/alkaline)	-	0.03	-	10.00	0.02
			-	0.06	-	10.00	-
[IT_008]_a {1}	Alkaline degreasing-Rinsing-Electrolytically assisted pickling, activation and degreasing-Plating-	-	0.01	0.01	0.01	10.00	0.47
		-	0.01	0.01	0.01	10.00	0.49
[IT_008]_a {3}	Rinsing-Electrolytically assisted pickling, activation and degreasing- Alkaline degreasing-Plating-Rinsing-Other--Electrocoating (e-coating)-	-	2.85	2.69	2.43	10.00	
		-	0.01	0.01	0.01	10.00	1.36
[IT_008]_a {4}	Alkaline degreasing-	-	0.01	0.01	0.01	10.00	0.56

	Rinsing-Electrolytically assisted pickling, activation and degreasing--Other-Plating-Drying-	-	0.01	0.01	0.01	10.00	0.70
[IT_008]_a {5}	Drying	-	0.70	0.65	0.60	10.00	4.99
		-	0.01	0.01	0.01	10.00	0.07
[IT_009]_a {1}	Degreasing-Alkaline-Electrolytically assisted pickling, activation and degreasing-Plating-Rinsing-	Scrubber- absorption (acid/alkaline)	1.51	0.85	0.33	10.00	-
[IT_009]_a {2}	Plating-Rinsing-Drying-	Scrubber- absorption (acid/alkaline)	1.60	0.69	0.20	10.00	-
[IT_009]_a {3}	Rinsing-Other-Degreasing-Alkaline degreasing-Metal stripping-Plating-	Scrubber- absorption (acid/alkaline)	1.40	0.61	0.22	10.00	-
[IT_009]_a {4}	Plating-	Scrubber- absorption (acid/alkaline)	1.90	0.78	0.20	10.00	-
[IT_009]_a {5}	Rinsing-Plating-	Scrubber- absorption (acid/alkaline)	1.47	0.64	0.22	10.00	-
[IT_009]_a {6}	Degreasing-Pickling (not electrically), descaling and desmutting-Alkaline degreasing-Plating	Scrubber- absorption (acid/alkaline)	1.10	0.53	0.23	10.00	-
[IT_012]_a {2}	Mechanical polishing/linishing	Fabric filter	-	1.65	-	5.00	0.00
			-	1.48	-	5.00	0.00
			-	0.80	-	5.00	0.00
[IT_013]_a {1}	Mechanical polishing/linishing	Other	1.63	0.86	0.20	-	-
[IT_020]_a {2}	Mechanical polishing/linishing	Fabric filter	2.24	2.24	2.24	5.00	0.00
			0.69	0.69	0.69	2.50	0.00
			0.45	0.45	0.45	5.00	0.00
[IT_029]_a {4}	Other	No technique applied	0.60	0.57	0.50	10.00	0.00
			0.40	0.37	0.30	10.00	0.00
			0.30	0.23	0.20	10.00	0.00
[IT_029]_a {10}	Other	Other	1.50	1.43	1.40	10.00	0.00
			1.50	1.43	1.40	10.00	0.00
			1.30	1.23	1.20	10.00	0.00
[IT_029]_a {11}	Other	Other	0.70	0.63	0.60	10.00	0.00
			0.50	0.43	0.40	10.00	0.00
			0.40	0.37	0.30	10.00	0.00
[IT_029]_a {14}	Other	Fabric filter	1.90	1.83	1.80	10.00	0.00
			1.60	1.57	1.50	10.00	0.00
			1.40	1.33	1.30	10.00	0.00
[IT_031]_a {3}	Mechanical polishing/linishing	Fabric filter	0.86	0.86	0.86	10.00	0.01
			0.75	0.75	0.75	10.00	0.01
			0.18	0.18	0.18	10.00	0.00
[IT_031]_a {4}	Other	Fabric filter	0.94	0.94	0.94	3.00	0.01
			0.93	0.93	0.93	3.00	0.01
			0.52	0.52	0.52	3.00	0.00
[IT_031]_a {5}	Other	Fabric filter	0.83	0.83	0.83	3.00	0.01
			0.34	0.34	0.34	3.00	0.00
[IT_032]_a {3}	Other	Other	1.44	1.44	1.44	3.00	0.02
			0.97	0.97	0.97	3.00	0.01

			0.23	0.23	0.23	3.00	0.00
[IT_032]_a {4}	Other	Fabric filter	0.68	0.68	0.68	3.00	0.00
			0.52	0.52	0.52	3.00	0.00
			0.51	0.51	0.51	3.00	0.00
[IT_032]_a {6}	Mechanical polishing/linishing	Fabric filter	2.54	2.54	2.54	10.00	0.00
			0.25	0.25	0.25	10.00	0.00
			0.07	0.07	0.07	10.00	0.01
[IT_032]_a {7}	Abrasive blasting	Fabric filter	1.20	1.20	1.20	10.00	0.00
			0.28	0.28	0.28	10.00	0.00
			0.23	0.23	0.23	10.00	0.00
[IT_032]_a {8}	Other	No technique applied	2.49	2.49	2.49	10.00	0.01
			0.97	0.97	0.97	10.00	0.00
			0.72	0.72	0.72	10.00	0.00
[IT_032]_a {9}	Other	No technique applied	2.72	2.72	2.72	10.00	0.00
			1.21	1.21	1.21	10.00	0.00
			0.90	0.90	0.90	10.00	0.00
[IT_032]_a {10}	Abrasive blasting	No technique applied	0.39	0.39	0.39	10.00	0.00
			0.26	0.26	0.26	10.00	0.00
			0.05	0.05	0.05	10.00	0.00
[IT_032]_a {14}	Abrasive blasting	Fabric filter	0.27	0.27	0.27	10.00	0.00
			0.16	0.15	0.14	10.00	0.00
[IT_032]_a {15}	Other	Fabric filter	0.50	0.50	0.50	10.00	0.00
			0.37	0.30	0.22	10.00	0.00
[IT_032]_a {16}	Abrasive blasting	No technique applied	-	-	0.99	10.00	0.00
			-	-	0.78	10.00	0.00
			-	-	0.13	10.00	0.00
[IT_032]_a {20}	Other	Regenerative thermal oxidation	2.84	2.84	2.84	10.00	0.00
			2.15	2.15	2.15	10.00	0.00
			0.78	0.78	0.78	10.00	0.00
[NL_002]_a {2}	Electrocoating (e-coating)	-	5.90	4.60	3.00	10.00	-

3.2.4.3 Gaseous chlorides

The reported data for gaseous chlorides emissions to air are presented in Figure 3-30. Emission data and contextual information are also presented in Table 3-36.



Source: [168, TWG 2023]

Figure 3-30: Gaseous chlorides emissions to air in electrolytic or chemical plating plants

Table 3-29: Reported data and contextual information for gaseous chlorides emissions to air in electrolytic or chemical plating plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[AT_009]_a {1}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating	Aerosol/droplet separator	5.46	5.46	5.46	10	-
[AT_009]_a {2}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating	Aerosol/droplet separator	8.62	8.62	8.62	10.00	-
[AT_009]_a {3}	Plating-	Aerosol/droplet separator	2.33	2.33	2.33	10.00	-
[AT_009]_a {4}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator	1.43	1.43	1.43	10.00	-
[AT_009]_a {5}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator	0.33	0.33	0.33	10.00	-
[AT_009]_a {6}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating-Other	Aerosol/droplet separator	0.53	0.53	0.53	10.00	-
[AT_009]_a {7}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating-Other	Aerosol/droplet separator	0.36	0.36	0.36	10.00	-
[BE_010]_a {2}	Pickling (not electrically), descaling and desmutting	No technique applied	-	1.22	-	-	-
[CZ_003]_a {1}	Pickling (not electrically), descaling and desmutting-	No technique applied-	4.29	1.48	0.08	9.00	0.01
			2.10	2.00	1.90	9.00	0.01
			1.40	1.20	0.90	9.00	0.01
[CZ_003]_a {2}	Pickling (not electrically), descaling and desmutting-	No technique applied-	5.10	4.50	4.10	9.00	0.02
			1.67	0.88	0.06	9.00	0.00
			1.10	1.00	0.90	9.00	0.00
[CZ_003]_a {3}	Pickling (not electrically), descaling and desmutting-	No technique applied-	0.60	0.50	0.40	9.00	0.00
			0.30	0.30	0.30	9.00	0.00
			0.27	0.13	0.06	9.00	0.00
[CZ_006]_a {1}	Pickling (not electrically), descaling and desmutting	-	-	0.51	-	-	-
[CZ_006]_a {2}		-	-	0.24	-	-	-
[CZ_006]_a {7}		-	-	1.07	-	-	-
[CZ_007]_a {1}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	Aerosol/droplet separator-Cyclone	16.66	14.79	12.92	-	-
			0.50	0.36	0.21	-	-
			0.15	0.11	0.06	-	-
[CZ_007]_a {2}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	Aerosol/droplet separator-Cyclone	6.81	2.54	2.27	-	-
			5.40	4.35	3.29	-	-
			0.11	0.11	0.00	-	-
[CZ_007]_a {3}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-	-	0.29	0.19	0.06	-	-
		-	0.06	0.06	0.00	-	-
		-	0.05	0.05	0.00	-	-

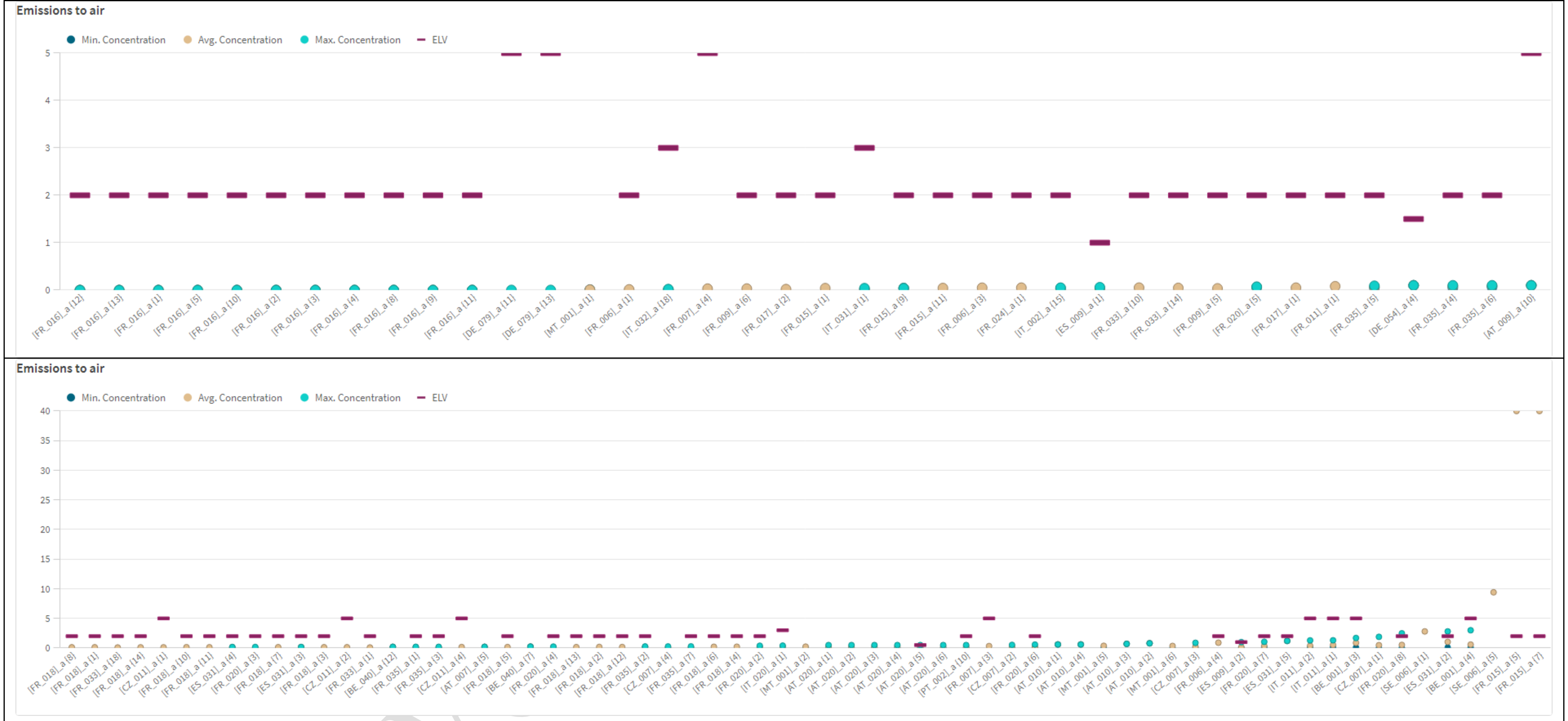
	Rinsing-						
[CZ_007]_a {4}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	13.72	12.39	11.06	-	-
		-	0.74	0.49	0.25	-	-
		-	0.21	0.13	0.05	-	-
[CZ_014]_a {3}	Pickling (not electrically), descaling and desmutting-	Absorption	0.74	0.69	0.59	10.00	0.02
			0.38	0.34	0.29	10.00	0.01
			0.22	0.21	0.21	10.00	0.01
[DE_025]_a {14}	Other	Scrubber- absorption (acid/alkaline)	1.00	0.77	0.30	10.00	-
[DE_045]_a {1}	Etching or pickling of plastics-Electrolytically assisted pickling, activation and degreasing-Conditioning of plastics	Scrubber- absorption (acid/alkaline)	7.00	7.00	7.00	-	-
[DE_045]_a {2}	Other-	Scrubber- absorption (acid/alkaline)	7.00	7.00	7.00	-	-
[DE_045]_a {3}	Other	Scrubber- absorption (acid/alkaline)	7.00	7.00	7.00	-	-
[DE_045]_a {4}	Other-	Scrubber- absorption (acid/alkaline)	7.00	7.00	7.00	-	-
[DE_054]_a {1}	Alkaline degreasing-Other	Scrubber- absorption (acid/alkaline)	0.80	0.80	0.70	30.00	0.00
[DE_054]_a {3}	Plating-Other-	Aerosol/droplet separator	0.90	0.90	0.80	30.00	0.08
[DE_054]_a {6}	Other	Scrubber- absorption (acid/alkaline)	0.40	0.40	0.40	30.00	0.00
[DE_077]_a {2}	Degreasing-Pickling (not electrically), descaling and desmutting- Electrolytically assisted pickling, activation and degreasing-Other-Electrocoating (e-coating)-	Scrubber- absorption (acid/alkaline)-Aerosol/droplet separator	0.50	0.37	0.30	30.00	-
[DE_077]_a {3}	Degreasing-Pickling (not electrically), descaling and desmutting- Electrolytically assisted pickling, activation and degreasing- Electrocoating (e-coating)-Other-	Scrubber- absorption (acid/alkaline)	0.40	0.31	0.22	30.00	-
[DE_079]_a {14}	Other	No technique applied	16.00	-	-	30.00	-
[DE_079]_a {17}	Pickling (not electrically), descaling and desmutting	No technique applied	8.10	-	-	30.00	-
[ES_002]_a {1}	Pickling (not electrically), descaling and desmutting-Plating-Other-	No technique applied	1.40	1.40	1.40	10.00	-
[ES_003]_a {1}	Plating	Scrubber- absorption (acid/alkaline)	0.21	0.17	0.13	10.00	-
			0.14	0.11	0.10	10.00	-
[ES_004]_a {1}	Pickling (not electrically), descaling and desmutting-Aqueous cleaning-Degreasing-	Scrubber- absorption (acid/alkaline)	20.00	14.70	9.00	30.00	0.20
			0.52	0.45	0.37	30.00	0.01
			0.90	0.90	0.90	30.00	0.10
[ES_009]_a {1}	Alkaline degreasing-Other-Electrocoating (e-coating)-Other	Scrubber- absorption (acid/alkaline)	0.20	0.15	0.11	3.00	6,196 E-3
			0.18	0.13	0.09	3.00	< 5,22 E-3

			0.14	0.13	0.13	3.00	<1,31 E-3
[ES_009]_a {2}	Alkaline degreasing-Other-Electrocoating (e-coating)-Other-	Scrubber- absorption (acid/alkaline)	0.37	0.23	0.13	3.00	6,196 E-3
			0.20	0.19	0.18	3.00	< 7,71 E-3
			0.13	0.12	0.12	3.00	< 4,65 E-3
[ES_009]_a {3}	Alkaline degreasing-Other-Electrocoating (e-coating)-	Scrubber- absorption (acid/alkaline)	0.37	0.23	0.17	3.00	6,196 E-3
			0.15	0.15	0.14	3.00	< 5,19 E-3
			0.15	0.14	0.13	3.00	<5,23E-3
[ES_010]_a {2}	Plating-	Scrubber- absorption (acid/alkaline)	0.09	0.09	0.09	-	-
[ES_010]_a {4}	Etching or pickling of plastics-Plating-	Scrubber- absorption (acid/alkaline)	0.05	0.05	0.05	-	-
[ES_030]_a {1}	Plating-	Scrubber- absorption (acid/alkaline)	1.66	1.66	1.66	-	-
[ES_030]_a {2}	Etching or pickling of plastics-Plating-	Scrubber- absorption (acid/alkaline)	1.49	1.49	1.49	-	-
[ES_031]_a {3}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting	Scrubber- absorption (acid/alkaline)	2.40	2.40	2.40	30.00	0.01
			0.79	0.79	0.79	30.00	0.00
			0.61	0.61	0.61	30.00	0.00
[ES_031]_a {4}	Degreasing-	Scrubber- absorption (acid/alkaline)	3.10	3.10	3.10	30.00	0.01
			1.20	1.20	1.20	30.00	0.00
			0.43	0.43	0.43	30.00	0.00
[FR_018]_a {9}	Other	Scrubber- absorption (acid/alkaline)	-	9.49	-	500	0.00
			-	0.34	-	50.00	0.00
[IT_011]_a {1}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	1.50	0.83	0.34	30.00	0.03
			0.79	0.60	0.41	30.00	0.04
[IT_011]_a {2}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	1.46	0.82	0.17	30.00	0.02
			0.90	0.51	0.12	30.00	0.01
			0.75	0.53	0.31	30.00	0.01
[IT_030]_a {1}	Plating-	-	0.13	0.12	0.12	5.00	0.00
[IT_030]_a {3}	Plating-	-	0.13	0.12	0.11	5.00	0.00
[IT_031]_a {1}	Plating-Rinsing- Other- Electrolytically assisted pickling, activation and degreasing-Degreasing-Pickling (not electrically), descaling and desmutting	Scrubber- absorption (acid/alkaline)	0.10	0.10	0.10	5.00	0.00
			0.10	0.10	0.10	5.00	0.00
			0.10	0.10	0.10	5.00	0.00
[IT_031]_a {2}	Metal stripping-Degreasing-Rinsing-	Scrubber- absorption	0.10	0.10	0.10	5.00	2.00

	Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Other	(acid/alkaline)	0.10	0.10	0.10	5.00	2.10
			0.09	0.09	0.09	5.00	1.80
[IT_032]_a {11}	Plating-	No technique applied	0.17	0.17	0.17	5.00	0.00
			0.10	0.10	0.10	5.00	0.00
[IT_032]_a {12}	Plating	No technique applied	0.17	0.17	0.17	5.00	0.00
			0.10	0.10	0.10	5.00	0.00
[IT_032]_a {17}	Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-	No technique applied	0.12	0.12	0.12	5.00	0.00
			0.11	0.11	0.11	5.00	0.00
			0.10	0.10	0.10	5.00	0.00
[IT_032]_a {18}	Other-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Plating-	No technique applied	0.17	0.17	0.17	5.00	0.00
			0.10	0.10	0.10	5.00	0.00
[IT_032]_a {19}	Electrolytically assisted pickling, activation and degreasing-Other- Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Plating-	No technique applied	0.17	0.17	0.17	5.00	0.00
			0.13	0.13	0.13	5.00	0.00
			0.10	0.10	0.10	5.00	0.00

3.2.4.4 Gaseous fluorides

The reported data for gaseous fluorides emissions to air are presented in Figure 3-31. Emission data and contextual information are also presented in Table 3-36.



Source: [168, TWG 2023]

Figure 3-31: Gaseous fluorides emissions to air in electrolytic or chemical plating plants

Table 3-30: Reported data and contextual information for gaseous fluorides emissions to air in electrolytic or chemical plating plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[AT_007]_a {5}	Other	Scrubber- absorption (acid/alkaline)	0.20	0.20	0.20	-	-
[AT_009]_a {10}	Degreasing-Pickling (not electrically), descaling and desmutting-Other-Anodising-	Aerosol/droplet separator	0.10	0.10	0.10	5.00	-
[AT_010]_a {1}	Alkaline degreasing-Aqueous cleaning-Drying-Electrolytically assisted pickling, activation and degreasing-Etching – Alkaline etching of aluminium-Hand wiping-Heat treatment-Mechanical polishing/linishing-Pickling (not electrically), descaling and desmutting-Plating-	Scrubber- absorption (acid/alkaline)	0.60	0.60	0.60	-	-
[AT_010]_a {2}	Other-Plating-	Scrubber- absorption (acid/alkaline)	0.80	0.80	0.80	-	-
[AT_010]_a {3}	Plating-	Scrubber- absorption (acid/alkaline)	0.70	0.70	0.70	-	-
[AT_010]_a {4}	Pickling (not electrically), descaling and desmutting	Scrubber- absorption (acid/alkaline)	0.60	0.60	0.60	-	-
[AT_020]_a {1}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Plating-	Aerosol/droplet separator	0.50	0.50	0.50	-	-
			0.02	0.02	0.02	-	-
[AT_020]_a {2}	Electropolishing	-	0.50	0.50	0.50	-	-
		-	0.02	0.02	0.02	-	-
[AT_020]_a {3}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Chemical polishing-Electrolytically assisted pickling, activation and degreasing--	-	0.50	0.50	0.50	-	-
		-	0.02	0.02	0.02	-	-
[AT_020]_a {4}	Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Plating-Alkaline degreasing-	-	0.50	0.50	0.50	-	-
		-	0.02	0.02	0.02	-	-
[AT_020]_a {5}	Plating-	Aerosol/droplet separator	0.50	0.50	0.50	0.50	-
			0.02	0.02	0.02	-	-
[AT_020]_a {6}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-	Aerosol/droplet separator	0.50	0.50	0.50	-	-
			0.02	0.02	0.02	-	-
[BE_001]_a {3}	Pickling (not electrically), descaling and desmutting-	Scrubber- absorption (acid/alkaline)	1.69	0.87	0.09	5.00	-
[BE_001]_a {4}	Other-Electrocoating (e-coating)-	Scrubber- absorption (acid/alkaline)	3.00	0.58	0.09	5.00	-
[BE_040]_a {7}	Etching and descaling of aluminium-Other-	No technique applied	0.24	0.24	0.24	-	-
[BE_040]_a {12}	Anodising--	No technique applied	0.20	0.20	0.20	-	-
[CZ_007]_a {1}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	Aerosol/droplet separator-Cyclone	1.88	0.68	0.41	-	-
			0.33	0.28	0.22	-	-
			0.01	-	0.00	-	-
[CZ_007]_a {2}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	Aerosol/droplet separator-Cyclone	0.53	0.42	0.28	-	-
			0.31	0.26	0.21	-	-
			0.05	0.05	0.00	-	-
[CZ_007]_a {3}	Alkaline degreasing-Electrocoating (e-	-	0.88	0.63	0.37	-	-

	coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.07	0.05	0.03	-	-
		-	0.05	0.05	0.00	-	-
[CZ_007]_a {4}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.26	0.17	0.09	-	-
		-	0.09	0.07	0.05	-	-
		-	0.05	0.05	0.00	-	-
[CZ_011]_a {1}	Anodising-Anodising-Metal stripping-Pickling (not electrically), descaling and desmutting	-	-	0.16	-	5.00	0.00
		-	-	0.10	-	5.00	0.00
[CZ_011]_a {2}	Anodising-Pickling (not electrically), descaling and desmutting-Metal stripping-Plating	-	-	0.18	-	5.00	0.00
		-	-	0.11	-	5.00	0.00
[CZ_011]_a {4}	Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-Plating	-	-	0.20	-	5.00	0.00
		-	-	0.14	-	5.00	0.00
		-	-	0.14	-	5.00	0.00
[DE_054]_a {4}	Alkaline degreasing-Other-	Scrubber- absorption (acid/alkaline)	0.10	0.10	0.10	1.50	0.00
[DE_079]_a {11}	Anodising	No technique applied	0.00	-	-	5.00	-
[DE_079]_a {13}	Pickling (not electrically), descaling and desmutting	No technique applied	0.00	-	-	5.00	-
[ES_009]_a {1}	Alkaline degreasing-Electrocoating (e-coating)-Other	Scrubber- absorption (acid/alkaline)	0.06	0.05	0.05	1.00	< 2,24E-3
			0.04	0.03	0.03	1.00	<5,39 E-3
			0.03	0.03	0.03	1.00	< 0,001 13
[ES_009]_a {2}	Alkaline degreasing-Electrocoating (e-coating)-Other	Scrubber- absorption (acid/alkaline)	0.99	0.37	0.03	1.00	<1,2 E-3
			0.04	0.04	0.04	1.00	<1,48 E-3
			0.03	0.03	0.02	1.00	< 0,001 13
[ES_009]_a {3}	Alkaline degreasing-Electrocoating (e-coating)-Other	Scrubber- absorption (acid/alkaline)	0.12	0.07	0.04	1.00	0.00
			0.05	0.05	0.04	1.00	< 1,63E-3
			0.03	0.03	0.03	1.00	< 0,001 13
[ES_031]_a {2}	Pickling (not electrically), descaling and desmutting-Degreasing-Degreasing	Scrubber- absorption (acid/alkaline)	2.80	2.80	2.80	2.00	0.33
			0.20	0.20	0.20	2.00	0.00
			0.09	0.09	0.09	2.00	0.00
[ES_031]_a {3}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-	Scrubber- absorption (acid/alkaline)	0.18	0.18	0.18	2.00	0.00
			0.15	0.15	0.15	2.00	0.00
			0.13	0.13	0.13	2.00	0.00
[ES_031]_a {4}	Degreasing-	Scrubber- absorption (acid/alkaline)	0.17	0.17	0.17	2.00	0.00
			0.15	0.15	0.15	2.00	0.00
			0.11	0.11	0.11	2.00	0.00
[ES_031]_a {5}	Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and Degreasing-	Scrubber- absorption (acid/alkaline)	1.20	1.20	1.20	2.00	0.00
[FR_006]_a {1}	Alkaline degreasing	No technique applied	-	0.01	-	2.00	0.00

[FR_006]_a {3}	Rinsing	No technique applied	-	0.05	-	2.00	0.00
[FR_006]_a {4}	Other	No technique applied	-	0.90	-	2.00	0.00
[FR_007]_a {3}	Plating	-	-	0.51	-	5.00	0.00
		-	-	0.24	-	5.00	-
[FR_007]_a {4}	Other-Rinsing-	-	-	0.03	-	5.00	-
[FR_009]_a {5}	Plating-Pickling (not electrically), descaling and desmutting-	-	-	0.07	-	2.00	0.00
		-	-	0.00	-	2.00	-
[FR_009]_a {6}	Plating	-	-	0.03	-	2.00	0.00
		-	-	0.03	-	2.00	0.00
[FR_011]_a {1}	Alkaline degreasing-Alkaline degreasing-Other	No technique applied	-	0.08	-	2.00	-
[FR_015]_a {1}	Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	0.04	-	2.00	-
[FR_015]_a {5}	Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	40.00	-	2.00	-
[FR_015]_a {7}	Electrolytically assisted pickling, activation and degreasing-Plating-Other-	No technique applied	-	40.00	-	2.00	-
[FR_015]_a {9}	Anodising-Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	0.04	0.04	0.04	2.00	-
			-	0.04	-	2.00	-
[FR_015]_a {11}	Use of fuel-fired burners (combustion)	Fabric filter	-	0.04	-	2.00	-
[FR_016]_a {1}	Other	No technique applied	0.00	0.00	0.00	2.00	0.00
[FR_016]_a {2}	Metal stripping	No technique applied	0.00	0.00	0.00	2.00	0.00
[FR_016]_a {3}	Anodising	No technique applied	0.00	0.00	0.00	2.00	0.00
[FR_016]_a {4}	Other	No technique applied	0.00	0.00	0.00	2.00	0.00
[FR_016]_a {5}	Etching or pickling of plastics	No technique applied	0.00	0.00	0.00	2.00	0.00
[FR_016]_a {8}	Plating	No technique applied	0.00	0.00	0.00	2.00	0.00
[FR_016]_a {9}	Plating	No technique applied	0.00	0.00	0.00	2.00	0.00
[FR_016]_a {10}	Plating	No technique applied	0.00	0.00	0.00	2.00	0.00
[FR_016]_a {11}	Plating	No technique applied	0.00	0.00	0.00	2.00	0.00
[FR_016]_a {12}	Plating	-	0.00	0.00	0.00	2.00	0.00
[FR_016]_a {13}	Plating	-	0.00	0.00	0.00	2.00	0.00
[FR_017]_a {1}	Alkaline degreasing-Alkaline degreasing-Rinsing	-	-	0.07	-	2.00	0.00
		-	-	0.06	-	2.00	0.00
		-	-	0.01	-	2.00	0.00
[FR_017]_a {2}	Rinsing-Plating-Rinsing-	-	-	0.04	-	2.00	0.00
		-	-	0.02	-	2.00	0.00
		-	-	0.01	-	2.00	0.00
[FR_018]_a {1}	Other-	Scrubber- absorption (acid/alkaline)	-	0.14	-	2.00	0.00
			-	0.12	-	2.00	0.00
[FR_018]_a {2}	Metal stripping-Conditioning of plastics-	Scrubber- absorption (acid/alkaline)	-	0.24	-	2.00	0.00
			-	0.12	-	2.00	0.00
[FR_018]_a {3}	Metal stripping-Conditioning of plastics-Etching or pickling of plastics-Other-Plating-	Scrubber- absorption (acid/alkaline)	-	0.18	-	2.00	0.00
			-	0.09	-	2.00	0.00
[FR_018]_a {4}	Plating-	Scrubber- absorption (acid/alkaline)	-	0.33	-	2.00	0.00
			-	0.10	-	2.00	0.00
[FR_018]_a {5}	Aqueous cleaning-Plating-Other-	Scrubber- absorption (acid/alkaline)	-	0.24	-	2.00	0.00
			-	0.08	-	2.00	0.00
[FR_018]_a {6}	Metal stripping	Scrubber- absorption	-	0.31	-	2.00	0.00

		(acid/alkaline)	-	0.10	-	2.00	0.00
[FR_018]_a {7}	Other	Scrubber- absorption (acid/alkaline)	-	0.18	-	2.00	0.00
			-	0.11	-	2.00	0.00
[FR_018]_a {8}	Other	Scrubber- absorption (acid/alkaline)	-	0.13	-	2.00	0.00
			-	0.12	-	2.00	0.00
[FR_018]_a {9}	Other	Scrubber- absorption (acid/alkaline)	-	0.10	-	2.00	0.00
			-	0.09	-	2.00	0.00
[FR_018]_a {10}	Other	Scrubber- absorption (acid/alkaline)	-	0.17	-	2.00	0.00
			-	0.11	-	2.00	0.00
[FR_018]_a {11}	Conditioning of plastics-Conditioning of plastics-Etching or pickling of plastics-Rinsing-Other	Scrubber- absorption (acid/alkaline)	-	0.17	-	2.00	0.00
			-	0.08	-	2.00	0.00
[FR_018]_a {12}	Plating-	Scrubber- absorption (acid/alkaline)	-	0.25	-	2.00	0.00
			-	0.08	-	2.00	0.00
[FR_018]_a {13}	Plating-	Scrubber- absorption (acid/alkaline)	-	0.24	-	2.00	0.00
			-	0.06	-	2.00	0.00
[FR_018]_a {14}	Metal stripping	Scrubber- absorption (acid/alkaline)	-	0.15	-	2.00	0.00
			-	0.08	-	2.00	0.00
[FR_020]_a {2}		Scrubber- absorption (acid/alkaline)	0.38	0.24	0.11	2.00	0.01
			0.36	0.23	0.09	2.00	0.01
			0.10	0.10	0.10	2.00	-
[FR_020]_a {3}	Alkaline degreasing-Rinsing-Chemical milling-Anodising- Other-	Scrubber- absorption (acid/alkaline)	0.18	0.12	0.07	2.00	0.00
			0.08	0.08	0.08	2.00	-
			0.05	0.04	0.03	2.00	0.00
[FR_020]_a {4}	Metal stripping-Rinsing-Other-	Scrubber- absorption (acid/alkaline)	0.24	0.24	0.24	2.00	0.00
			0.08	0.07	0.07	2.00	0.00
			0.08	0.08	0.08	2.00	0.00
[FR_020]_a {5}	Metal stripping-Other-Rinsing-	Scrubber- absorption (acid/alkaline)	0.07	0.07	0.07	2.00	0.00
			0.07	0.07	0.06	2.00	0.00
			0.05	0.05	0.05	2.00	-
[FR_020]_a {6}	Other-Chemical milling-Rinsing-Alkaline degreasing	Scrubber- absorption (acid/alkaline)	0.58	0.32	0.05	2.00	0.01
			0.11	0.10	0.09	2.00	0.00
			0.09	0.09	0.09	2.00	0.00
[FR_020]_a {7}	Alkaline degreasing-Rinsing-Other	Scrubber- absorption (acid/alkaline)	1.05	0.57	0.09	2.00	0.01
			0.51	0.31	0.12	2.00	0.01
			0.19	0.18	0.16	2.00	0.00
[FR_020]_a {8}	Alkaline degreasing-Rinsing-Other-	Scrubber- absorption (acid/alkaline)	2.48	1.27	0.07	2.00	0.05
			0.34	0.21	0.08	2.00	0.01
			0.10	0.08	0.06	2.00	0.00
[FR_024]_a {1}	Alkaline degreasing-Other-Plating	Aerosol/droplet separator	-	0.05	-	2.00	-
[FR_033]_a {1}	Plating-Metal stripping-Electrolytically assisted pickling, activation and degreasing- Rinsing-Other	No technique applied	-	0.19	-	2.00	0.00
			-	0.06	-	2.00	0.00
			-	0.02	-	2.00	0.00
[FR_033]_a {10}	Pickling (not electrically), descaling and desmutting-Other-Rinsing-	No technique applied	-	0.07	-	2.00	0.00
			-	0.06	-	2.00	0.00
			-	0.02	-	2.00	0.00
[FR_033]_a {14}	Other-Pickling (not electrically), descaling and desmutting	No technique applied	-	0.07	-	2.00	0.00
			-	0.05	-	2.00	0.00

			-	0.02	-	2.00	0.00
[FR_033]_a {18}	Pickling (not electrically), descaling and desmutting-Other-	Mist filter (demister)	-	0.15	-	2.00	0.00
			-	0.07	-	2.00	0.00
			-	0.05	-	2.00	0.00
[FR_035]_a {1}	Plating-Other-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)--Alkaline degreasing-Chemical polishing-Etching and descaling of aluminium-Alkaline etching of aluminium-Metal stripping-	Scrubber- absorption (acid/alkaline)	0.20	0.20	0.20	2.00	0.00
			0.17	0.17	0.17	2.00	0.00
			0.11	0.11	0.11	2.00	0.00
[FR_035]_a {2}	Plating-Other-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)--Alkaline degreasing-Chemical polishing-Etching and descaling of aluminium-Alkaline etching of aluminium-Metal stripping-	Scrubber- absorption (acid/alkaline)	0.26	0.26	0.26	2.00	0.00
			0.20	0.20	0.20	2.00	0.00
			0.17	0.17	0.17	2.00	0.00
[FR_035]_a {3}	Etching or pickling of plastics-Conditioning of plastics- Plating-Electrocoating (e-coating)- Rinsing-Degreasing-Metal stripping-Other-	Scrubber- absorption (acid/alkaline)	0.20	0.20	0.20	2.00	0.00
			0.14	0.14	0.14	2.00	0.00
			0.05	0.05	0.05	2.00	0.00
[FR_035]_a {4}	Pickling (not electrically), descaling and desmutting-Metal stripping-Degreasing- Electrolytically assisted pickling, activation and degreasing-Other-	Scrubber- absorption (acid/alkaline)	0.10	0.10	0.10	2.00	0.00
			0.10	0.10	0.10	2.00	0.00
			0.05	0.05	0.05	2.00	0.00
[FR_035]_a {5}	Plating-Other-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)-Alkaline degreasing-Chemical polishing-Etching and descaling of aluminium-Alkaline etching of aluminium	Scrubber- absorption (acid/alkaline)	0.09	0.09	0.09	2.00	0.00
			0.06	0.06	0.06	2.00	-
			0.05	0.05	0.05	2.00	0.00
[FR_035]_a {6}	Other-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing- Rinsing-Degreasing-	Scrubber- absorption (acid/alkaline)	0.10	0.10	0.10	2.00	0.00
			0.10	0.10	0.10	2.00	0.00
			0.06	0.06	0.06	2.00	0.00
[FR_035]_a {7}	Electrocoating (e-coating)-Other	Scrubber- absorption (acid/alkaline)	0.27	0.15	0.10	2.00	0.00
			0.20	0.20	0.20	2.00	0.00
			0.04	0.04	0.04	2.00	-
[IT_002]_a {15}	Etching and descaling of aluminium-Pickling (not electrically), descaling and desmutting-Metal stripping-	Scrubber- absorption (acid/alkaline)	0.05	0.05	0.05	2.00	0.00
			0.04	0.04	0.04	2.00	0.00
			0.03	0.03	0.03	2.00	0.00
[IT_011]_a {1}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	1.30	0.73	0.15	5.00	0.01
			0.80	0.62	0.43	5.00	0.04
			0.18	0.16	0.14	5.00	0.00
[IT_011]_a {2}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	1.29	0.73	0.17	5.00	0.01
			0.36	0.24	0.12	5.00	0.01
			0.16	0.15	0.13	5.00	0.00
[IT_020]_a {1}	Anodising-Electrocoating (e-coating)-	Scrubber- absorption (acid/alkaline)	0.40	0.40	0.40	3.00	0.01
			0.30	0.25	0.20	3.00	0.01
			0.10	0.10	0.00	3.00	0.00
[IT_031]_a {1}	Plating-Rinsing-Other- Electrolytically	Scrubber- absorption	0.04	0.04	0.04	3.00	0.00

	assisted pickling, activation and degreasing- Degreasing-Pickling (not electrically), descaling and desmutting	(acid/alkaline)	0.02	0.02	0.01	3.00	0.00
[IT_032]_a {18}	Plating-Other-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-	No technique applied	0.02	0.02	0.02	3.00	0.00
			0.01	0.01	0.01	3.00	0.00
			0.01	0.01	0.01	3.00	0.00
[PT_002]_a {10}	Other	Scrubber- absorption (acid/alkaline)	0.50	0.50	0.50	-	0.00
			0.04	0.04	0.03	2.00	0.00
[SE_006]_a {1}	Pickling (not electrically), descaling and desmutting-	Scrubber- absorption (acid/alkaline)	-	2.80	-	-	0.00
[SE_006]_a {5}	Pickling (not electrically), descaling and desmutting-Electropolishing-	Scrubber- absorption (acid/alkaline)	-	9.40	-	-	0.05

3.2.4.5 HCN

The reported data for HCN emissions to air are presented in Figure 3-32. Emission data and contextual information are also presented in Table 3-33.

Source: [168, TWG 2023]

Figure 3-32: HCN emissions to air in electrolytic or chemical plating plants

Table 3-31: Reported data and contextual information for HCN emissions to air in electrolytic or chemical plating plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[AT_003]_a {2}	Degreasing-Plating-	Scrubber- absorption (acid/alkaline)-Other-Aerosol/droplet separator	0.25	0.25	0.25	1	
[AT_003]_a {7}	Alkaline degreasing-Plating-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.06	0.06	0.06	1	
[AT_003]_a {9}	Alkaline degreasing-Plating-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister	0.12	0.12	0.12	1	
[AT_003]_a {11}	Alkaline degreasing-Plating-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.12	0.12	0.12	1	
[AT_003]_a {13}	Alkaline degreasing-Plating- Other-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.24	0.24	0.24	1	
[AT_004]_a {8}		Scrubber- absorption (acid/alkaline)	0.15	0.15	0.15	-	
[AT_004]_a {9}		Scrubber- absorption (acid/alkaline)	0.15	0.15	0.15	-	
[AT_010]_a {1}	Alkaline degreasing-Aqueous cleaning-Drying-Electrolytically assisted pickling, activation and degreasing-Etching – Alkaline etching of aluminium-Hand wiping-Heat treatment-Mechanical polishing/linishing-Pickling (not electrically), descaling and desmutting-Plating-	Scrubber- absorption (acid/alkaline)	0.1	0.1	0.1	-	
[AT_010]_a {2}	Other-Plating-	Scrubber- absorption (acid/alkaline)	0.1	0.1	0.1	-	
[AT_010]_a {3}	Plating-	Scrubber- absorption (acid/alkaline)	0.1	0.1	0.1	-	
[AT_010]_a {4}	Pickling (not electrically), descaling and desmutting	Scrubber- absorption (acid/alkaline)	0.1	0.1	0.1	-	
[CZ_002]_a {3}	Plating	Aerosol/droplet separator	2.41	2.21	2.07	5	
			2.17	2.03	1.84	5	
			1.98	1.96	1.936	5	
[CZ_011]_a {3}	Alkaline Degreasing-Plating-	-	-	0.021	0.006	1	
		-	-	0.013	-	1	
		-	-	0.01	0.003	1	
[DE_024]_a {2}	Plating	Aerosol/droplet separator	1.4	0.55	0.08	-	
[DE_048]_a {3}	Plating	-	1.6	1.6	1.6	-	
[DE_060]_a {3}	Plating-Metal stripping-	Other-Mist filter (demister)-	0.13	0.105	0.08	-	
[FR_015]_a {1}	Electrolytically assisted pickling, activation and degreasing-Plating-	No technique applied	-	0.171	-	1	
[FR_015]_a {2}	Electrolytically assisted pickling, activation and degreasing-Plating-Other-	No technique applied	-	0.1	-	1	
[FR_015]_a {5}	Electrolytically assisted pickling, activation and	No technique applied	-	0.245	-	1	

	degreasing-Plating-						
[FR_015]_a {6}	Electrolytically assisted pickling, activation and degreasing-Plating-Other-	No technique applied	-	3.6	-	1	
[FR_015]_a {6}			-	0.9	-	1	
[FR_015]_a {7}	Electrolytically assisted pickling, activation and degreasing-Plating-ther-	No technique applied	-	0.117	-	1	
[FR_015]_a {8}	Electrolytically assisted pickling, activation and degreasing-Other	Other	-	0.49	-	1	
[FR_015]_a {8}			-	0.27	-	1	
[FR_015]_a {8}			-	0.09	-	1	
[FR_015]_a {9}	Anodising-Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	0.36	-	1	
[FR_015]_a {9}		No technique applied	-	0.11	-	1	
[FR_015]_a {10}	Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	16	-	1	
[FR_015]_a {10}			-	3.3	-	1	
[FR_015]_a {11}	Use of fuel-fired burners (combustion)	Fabric filter	-	0.21	-	1	
[FR_016]_a {1}	Other	No technique applied	0.019	0.019	0.019	1	
[FR_016]_a {2}	Metal stripping	No technique applied	0.014	0.014	0.014	1	
[FR_016]_a {3}	Anodising	No technique applied	0.014	0.014	0.014	1	
[FR_016]_a {4}	Other	No technique applied	0.007	0.007	0.007	1	
[FR_016]_a {5}	Etching or pickling of plastics	No technique applied	0.01	0.01	0.01	1	
[FR_016]_a {8}	Plating	No technique applied	6E-04	6E-04	6E-04	1	
[FR_016]_a {9}	Plating	No technique applied	2E-04	2E-04	2E-04	1	
[FR_016]_a {10}	Plating	No technique applied				1	
[FR_016]_a {11}	Plating	No technique applied	0.006	0.006	0.006	1	
[FR_016]_a {12}	Plating	-	0.004	0.004	0.004	1	
[FR_016]_a {13}	Plating	-	0.005	0.005	0.005	1	
[FR_018]_a {1}	Other	Scrubber- absorption (acid/alkaline)	-	0.018	-	1	
			-	0.007	-	1	
[FR_018]_a {2}	Metal stripping-Conditioning of plastics	Scrubber- absorption (acid/alkaline)	-	0.007	-	1	
			-	0.006	-	1	
[FR_018]_a {3}	Metal stripping-Conditioning of plastics-Etching or pickling of plastics-Plating-	Scrubber- absorption (acid/alkaline)	-	0.007	-	1	
			-	0.004	-	1	
[FR_018]_a {4}	Plating	Scrubber- absorption (acid/alkaline)	-	0.009	-	1	
			-	0.003	-	1	
[FR_018]_a {5}	Aqueous cleaning-Plating-Other	Scrubber- absorption (acid/alkaline)	-	0.012	-	1	
			-	0.008	-	1	
[FR_018]_a {6}	Metal stripping	Scrubber- absorption (acid/alkaline)	-	0.05	-	1	
			-	0.015	-	1	
[FR_018]_a {8}	Other	Scrubber- absorption (acid/alkaline)	-	0.013	-	1	
			-	0.011	-	1	
[FR_018]_a {11}	Conditioning of plastics-Etching or pickling of plastics-Rinsing-Other	Scrubber- absorption (acid/alkaline)	-	0.004	-	1	
			-	0.003	-	1	
[FR_018]_a {12}	Plating	Scrubber- absorption (acid/alkaline)	-	0.008	-	1	
			-	0.007	-	1	
[FR_018]_a {13}	Plating-Other	Scrubber- absorption	-	0.066	-	1	

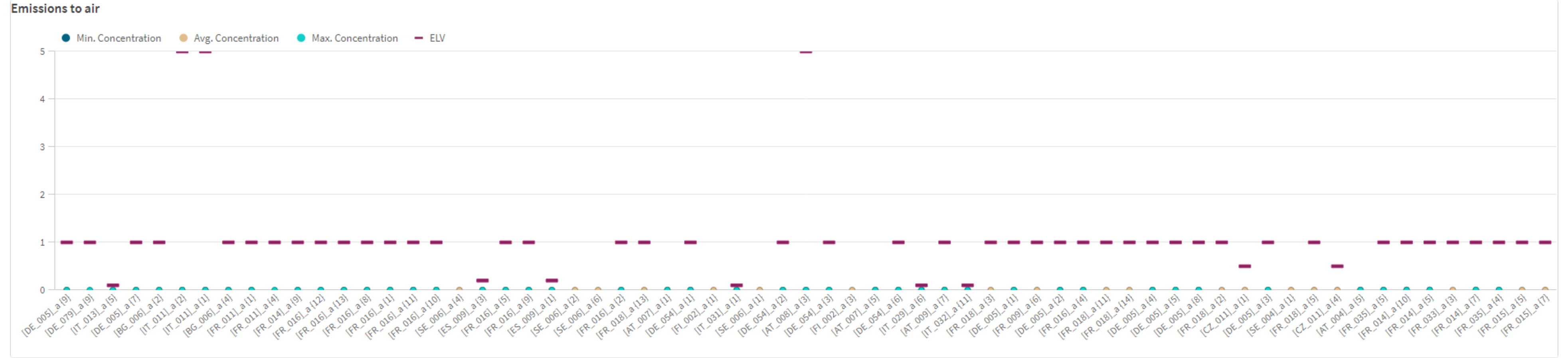
		(acid/alkaline)	-	0.006	-	1	
[FR_018]_a {14}	Metal stripping-Metal stripping	Scrubber- absorption (acid/alkaline)	-	0.008	-	1	
			-	0.004	-	1	
[FR_033]_a {2}	Plating-Metal stripping-Rinsing-	No technique applied	-	0.11	-	1	
			-	0.06	-	1	
			-	0.017	-	1	
[FR_033]_a {11}	Metal stripping-Alkaline degreasing-Plating	No technique applied	-	0.17	-	1	
			-	0.11	-	1	
			-	0.08	-	1	
[FR_035]_a {1}	Plating-Other-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)-Alkaline degreasing-Chemical polishing-Etching and descaling of aluminium- Alkaline etching of aluminiun	Scrubber- absorption (acid/alkaline)	0.026	0.026	0.026	1	
			0.02	0.02	0.02	1	
			0.005	0.005	0.005	1	
[FR_035]_a {2}	Plating-Other-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)-Alkaline degreasing-Chemical polishing-Etching and descaling of aluminium- Alkaline etching of aluminiun	Scrubber- absorption (acid/alkaline)	0.013	0.013	0.013	1	
			0.009	0.009	0.009	1	
			0.004	0.004	0.004	1	
[FR_035]_a {3}	Etching or pickling of plastics-Conditioning of plastics-Plating-Electrocoating (e-coating)-Rinsing-Degreasing-Metal stripping-Other	Scrubber- absorption (acid/alkaline)	0.015	0.015	0.015	1	
			0.009	0.009	0.009	1	
			0.005	0.005	0.005	1	
[FR_035]_a {4}	Other-Pickling (not electrically), descaling and desmutting-Metal stripping-Degreasing-Electrolytically assisted pickling, activation and degreasing-Other	Scrubber- absorption (acid/alkaline)	0.083	0.083	0.083	1	
			0.012	0.012	0.012	1	
[FR_035]_a {5}	Plating-Other-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)-Alkaline degreasing-Chemical polishing-Etching and descaling of aluminium-Etching – Alkaline etching of aluminium-Plating	Scrubber- absorption (acid/alkaline)	0.031	0.031	0.031	1	
			0.021	0.021	0.021	1	
			0.01	0.01	0.01	1	
[FR_035]_a {6}	Other-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Rinsing-Degreasing	Scrubber- absorption (acid/alkaline)	0.374	0.374	0.374	1	
			6E-04	6E-04	6E-04	1	
			4E-04	4E-04	4E-04	1	
[FR_035]_a {7}	Electrocoating (e-coating)-	Scrubber- absorption	1.181	1.181	1.181	1	

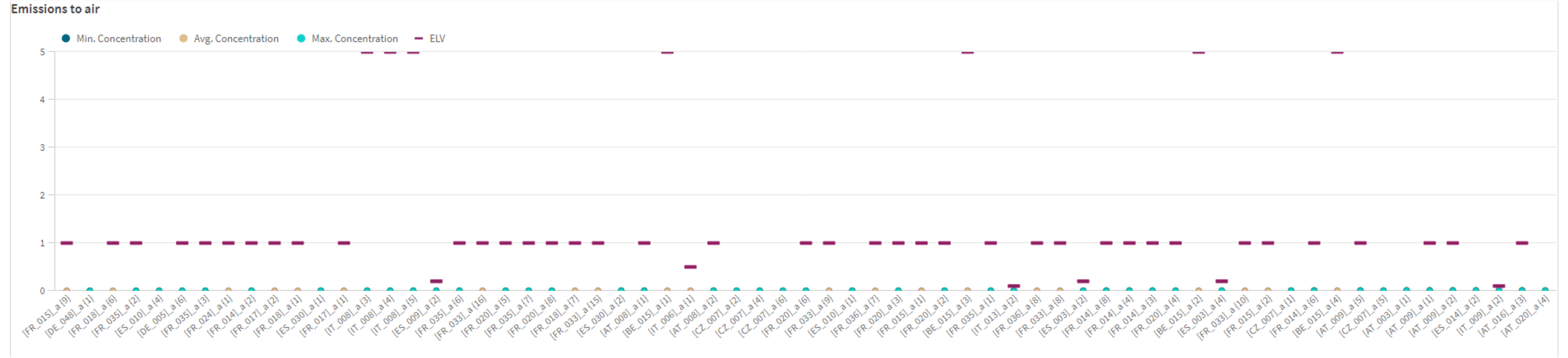
	Other	(acid/alkaline)	0.871	0.871	0.871	1	
			0.213	0.213	0.213	1	
[FR_036]_a {6}	Plating-	Scrubber- absorption (acid/alkaline)	-	0.29	-	1	
[IT_002]_a {2}	Plating	-	0.25	0.25	0.25	5	
			0.25	0.25	0.25	5	
			0.175	0.174	0.172	5	
[IT_002]_a {3}	Plating	-	0.25	0.25	0.25	5	
		-	0.22	0.22	0.22	5	
		-	0.175	0.175	0.175	5	
[IT_002]_a {4}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting	-	0.25	0.25	0.25	5	
		-	0.25	0.25	0.25	5	
		-	0.175	0.175	0.175	5	
[IT_002]_a {7}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating-Lacquering-Drying	-	0.345	0.345	0.345	5	
		-	0.34	0.34	0.34	5	
		-	0.25	0.25	0.25	5	
[IT_002]_a {13}	Etching and descaling of aluminium-Plating	-	0.345	0.345	0.345	5	
		-	0.29	0.29	0.29	5	
		-	0.18	0.18	0.18	5	
[IT_004]_a {2}	Electrolytically assisted pickling, activation and degreasing--Plating	-	0.25	0.22	0.16	0.5	
		-	0.15	0.13	0.1	0.5	
		-	0.05	0.05	0.05	0.5	
[IT_008]_a {2}	Plating-	-	0.182	0.121	0.091	5	
		-	0.01	0.01	0.01	5	
[IT_008]_a {3}	Alkaline degreasing-Rinsing-Electrolytically assisted pickling, activation and degreasing-Other-Plating-Electrocoating (e-coating)	-	0.01	0.01	0.01	5	
		-	0.01	0.01	0.01	5	
[IT_008]_a {5}	Drying	-	0.01	0.01	0.01	5	
		-	0.01	0.01	0.01	5	
[IT_009]_a {3}	Rinsing-Other-Degreasing-Alkaline degreasing-Metal stripping- Plating-	Scrubber- absorption (acid/alkaline)	0.35	0.257	0.1	2	
[IT_009]_a {6}	Degreasing-Pickling (not electrically), descaling and desmutting-Alkaline degreasing-Plating	Scrubber- absorption (acid/alkaline)	0.35	0.257	0.1	2	
[IT_029]_a {12}	Other	Scrubber- absorption (acid/alkaline)	0.05	0.05	0.05	2	
[IT_029]_a {13}	Other	No technique applied	0.05	0.05	0.05	2	
[IT_030]_a {3}	Plating	-	1.59	1.59	1.59	5	
		-	1.25	1.25	1.25	5	
		-	1.09	1.09	1.09	5	
[IT_031]_a {1}	Rinsing-Plating-Other-Electrolytically assisted pickling, activation and degreasing-Degreasing-Pickling (not electrically), descaling and desmutting	Scrubber- absorption (acid/alkaline)	0.18	0.175	0.17	2	
			0.1	0.1	0.1	2	

[IT_031]_a {2}	Metal stripping-Degreasing-Rinsing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	0.1	0.1	0.1	2	
			0.07	0.07	0.07	2	
			0.04	0.04	0.04	2	
[IT_032]_a {18}	Plating-Other-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-	No technique applied	0.05	0.05	0.05	0.1	
			0.03	0.03	0.03	0.1	
			0.02	0.02	0.02	0.1	
[PT_002]_a {10}	Other	Scrubber- absorption (acid/alkaline)	0.02	0.02	0.02	30	

3.2.4.6 Chromium

The reported data for chromium emissions to air are presented in Figure 3-33. Emission data and contextual information are also presented in Table 3-34.





Source: [168, TWG 2023]

Figure 3-33: Chromium emissions to air in electrolytic or chemical plating plants

Table 3-32: Reported data and contextual information for chromium emissions to air in electrolytic or chemical plating plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[AT_003]_a {1}	Pickling (not electrically), descaling and desmutting-Other-Metal stripping-Plating	Aerosol/droplet separator-Other-Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	-	-
[AT_004]_a {5}	Other-Plating-	Aerosol/droplet separator	0.00	0.00	0.00	-	-
[AT_004]_a {9}		Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	-	-
[AT_007]_a {1}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Plating-	Mist filter (demister)-Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-
[AT_007]_a {5}	Other	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-
[AT_008]_a {1}	Other-Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	1.00	-
[AT_008]_a {2}	Pickling (not electrically), descaling and desmutting-Plating-Deburring and/or tumbling-Rinsing	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	1.00	-
[AT_008]_a {3}	Pickling (not electrically), descaling and desmutting-Rinsing-Drying- Other-Degreasing- Electrolytically assisted pickling, activation and degreasing- Deburring and/or tumbling- Plating	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	5.00	-
[AT_009]_a {1}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating	Aerosol/droplet separator	0.01	0.01	0.01	1.00	-
[AT_009]_a {2}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating	Aerosol/droplet separator	0.01	0.01	0.01	1.00	-
[AT_009]_a {3}	Plating-	Aerosol/droplet separator	0.20	0.20	0.20	1.00	-
[AT_009]_a {4}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator	0.09	0.09	0.09	1.00	-
[AT_009]_a {5}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator	0.01	0.01	0.01	1.00	-
[AT_009]_a {6}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing- Plating-Other	Aerosol/droplet separator	0.02	0.01	0.01	1.00	-

[AT_009]_a {7}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing- Plating-Other	Aerosol/droplet separator	0.00	0.00	0.00	1.00	-
[AT_009]_a {9}	Chemical polishing-Plating-Electrolytically assisted pickling, activation and degreasing	Aerosol/droplet separator	0.01	0.01	0.01	1.00	-
[AT_016]_a {3}	Abrasive blasting	Fabric filter	0.01	0.01	0.01	1.00	-
[AT_020]_a {1}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Plating-	Aerosol/droplet separator	0.10	0.10	0.10	-	-
			0.00	0.00	0.00	-	-
[AT_020]_a {2}	Electropolishing	-	0.10	0.10	0.10	-	-
		-	0.00	0.00	0.00	-	-
[AT_020]_a {3}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Chemical polishing-Electrolytically assisted pickling, activation and degreasing-	-	0.10	0.10	0.10	-	-
		-	0.00	0.00	0.00	-	-
[AT_020]_a {4}	Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Plating- Alkaline degreasing-	-	0.01	0.01	0.01	-	-
		-	0.00	0.00	0.00	-	-
[AT_020]_a {5}	Plating-	Aerosol/droplet separator	0.10	0.10	0.10	0.10	-
			0.00	0.00	0.00	-	-
[AT_020]_a {6}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-	Aerosol/droplet separator	0.10	0.10	0.10	-	-
			0.00	0.00	0.00	-	-
[BE_015]_a {1}	Other-Plating-	Other	-	0.01	-	5.00	-
			-	0.00	-	5.00	-
			-	0.00	-	5.00	-
[BE_015]_a {2}	Plating	Other	-	0.01	-	5.00	-
			-	0.00	-	5.00	-
			-	0.00	-	5.00	-
[BE_015]_a {3}	Other-Plating-	Other	-	0.01	-	5.00	-
			-	0.01	-	5.00	-
			-	0.00	-	5.00	-
[BE_015]_a {4}	Plating	Other	-	0.01	-	5.00	-
			-	0.01	-	5.00	-
			-	0.00	-	5.00	-
[BG_006]_a {2}	Electrocoating (e-coating)	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
[BG_006]_a {4}	Electrocoating (e-coating)	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
[CZ_007]_a {1}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	Aerosol/droplet separator-Cyclone-	0.01	0.01	0.00	-	-
			0.01	0.00	0.00	-	-
			0.01	0.00	0.00	-	-
[CZ_007]_a {2}	Alkaline degreasing-	Aerosol/droplet separator-	0.01	0.00	0.00	-	-

	Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	Cyclone	0.01	0.00	0.00	-	-
			0.01	0.00	0.00	-	-
[CZ_007]_a {3}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.01	0.02	0.00	-	-
		-	0.01	0.00	0.00	-	-
		-	0.01	0.00	0.00	-	-
[CZ_007]_a {4}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.01	0.00	0.00	-	-
		-	0.01	0.00	0.00	-	-
		-	0.01	0.00	0.00	-	-
[CZ_007]_a {5}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.01	0.01	0.01	-	-
		-	0.01	0.00	0.00	-	-
		-	0.01	0.00	0.00	-	-
[CZ_007]_a {6}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.01	0.00	0.00	-	-
		-	0.01	0.00	0.00	-	-
		-	0.01	0.00	0.00	-	-
[CZ_011]_a {1}	Anodising-Anodising-Metal stripping-Pickling (not electrically), descaling and desmutting	-	-	0.00	-	0.50	0.00
		-	-	0.00	-	0.50	0.00
		-	-	0.00	-	0.50	0.00
[CZ_011]_a {4}	Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-Plating	-	-	0.00	-	0.50	0.00
		-	-	0.00	-	0.50	0.00
[DE_005]_a {1}		No technique applied	0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	-	0.00
[DE_005]_a {2}		-	0.00	0.00	0.00	1.00	0.00
		-	0.00	0.00	0.00	-	0.00
[DE_005]_a {3}		-	0.00	0.00	0.00	1.00	0.00
		-	0.00	0.00	0.00	-	0.00
[DE_005]_a {4}		-	0.00	0.00	0.00	1.00	0.00
		-	0.00	0.00	0.00	-	0.00
[DE_005]_a {5}		-	0.00	0.00	0.00	1.00	0.00
		-	0.00	0.00	0.00	-	0.00
[DE_005]_a {6}		-	0.00	0.00	0.00	1.00	0.00
		-	0.00	0.00	0.00	-	0.00
[DE_005]_a {7}		-	0.00	0.00	0.00	1.00	0.00
		-	0.00	0.00	0.00	-	0.00
[DE_005]_a {8}		-	0.00	0.00	0.00	1.00	0.00
		-	0.00	0.00	0.00	-	0.00

[DE_005]_a {9}		-	0.00	0.00	0.00	1.00	0.00
		-	0.00	0.00	0.00	-	0.00
[DE_019]_a {1}	Plating-	Aerosol/droplet separator	0.03	0.02	0.02	0.08	-
[DE_019]_a {2}	Plating-	Aerosol/droplet separator	0.03	0.02	0.01	0.08	-
[DE_025]_a {6}	Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-	No technique applied	0.01	0.00	0.00	-	-
[DE_025]_a {13}	Other	No technique applied	0.01	0.01	0.00	0.05	-
[DE_025]_a {15}	Other	Scrubber- absorption (acid/alkaline)	0.03	0.01	0.00	0.05	-
[DE_036]_a {1}	Plating	Scrubber- absorption (acid/alkaline)-Mist filter (demister)-	0.03	0.02	0.01	1.00	-
[DE_037]_a {2}	Plating-	Scrubber- absorption (acid/alkaline)-Mist filter (demister)-	0.08	0.04	0.02	1.00	-
[DE_045]_a {1}	Etching or pickling of plastics-Electrolytically assisted pickling, activation and degreasing-Conditioning of plastics	Scrubber- absorption (acid/alkaline)	0.48	0.48	0.48	-	-
[DE_045]_a {2}	Other-	Scrubber- absorption (acid/alkaline)	0.48	0.48	0.48	-	-
[DE_045]_a {5}	Electrocoating (e-coating)	Scrubber- absorption (acid/alkaline)	0.48	0.48	-	-	-
[DE_045]_a {6}	Electrocoating (e-coating)-Other-	Scrubber- absorption (acid/alkaline)	0.48	0.48	0.48	-	-
[DE_048]_a {1}	Plating	-	0.00	0.00	0.00	-	-
[DE_054]_a {1}	Alkaline degreasing-Other	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
[DE_054]_a {2}	Alkaline degreasing-Other	Aerosol/droplet separator	0.00	0.00	0.00	1.00	0.00
[DE_054]_a {3}	Plating-Other-	Aerosol/droplet separator	0.00	0.00	0.00	1.00	0.00
[DE_054]_a {6}	Other	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
[DE_062]_a {2}	Plating-	Aerosol/droplet separator-Scrubber- absorption (acid/alkaline)	0.03	0.03	0.03	0.05	-
			0.01	0.01	0.01	0.05	-
[DE_079]_a {9}	Other	No technique applied	0.00	-	-	1.00	-
[DE_079]_a {14}	Other	No technique applied	0.01	-	-	1.00	-
			0.00	-	-	1.00	-
[ES_003]_a {2}	Plating	Scrubber- absorption (acid/alkaline)	0.01	0.00	0.00	0.20	-
			0.01	0.00	0.00	0.20	-
			0.00	0.00	0.00	0.20	-
[ES_003]_a {4}	Plating	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.00	0.20	-
			0.00	0.00	0.00	0.20	-
[ES_003]_a {5} [ES_003]_a {5}	Plating	Scrubber- absorption (acid/alkaline)	0.02	0.04	0.01	0.20	-
			0.00	0.00	0.00	0.20	-
			0.00	0.00	0.00	0.20	-
[ES_009]_a {1}	Alkaline degreasing-Other-Electrocoating (e-coating)	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.20	0.00
			0.00	0.00	0.00	0.20	0.00
			0.00	0.00	0.00	0.20	< 9,64 E-6

[ES_009]_a {2}	Alkaline degreasing-Other-Electrocoating (e-coating)	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.20	< 9,64E-6
			0.00	0.00	0.00	0.20	<1,58E-5
			0.00	0.00	0.00	0.20	<1,18E-5
[ES_009]_a {3}	Alkaline degreasing-Other	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.20	< 9,64E-6
			0.00	0.00	0.00	0.20	<1,71E-5
			0.00	0.00	0.00	0.20	<1,14E-5
[ES_010]_a {1}	Metal stripping-Plating-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	-	-
			0.00	0.00	0.00	-	-
[ES_010]_a {3}	Plating-	Scrubber- absorption (acid/alkaline)	0.02	0.02	0.02	-	-
			0.00	0.00	0.00	-	-
[ES_010]_a {4}	Etching or pickling of plastics-Plating-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-
			0.00	0.00	0.00	-	-
[ES_013]_a {1}	Plating	Scrubber- absorption (acid/alkaline)	0.05	0.05	0.05	1.00	0.00
			0.03	0.03	0.03	1.00	0.00
			0.01	0.01	0.01	1.00	0.00
[ES_014]_a {1}	Electrocoating (e-coating)	Other	0.03	0.03	0.03	-	0.00
[ES_014]_a {2}	Electrocoating (e-coating)	Straight thermal oxidation-Other	0.01	0.01	0.01	-	0.00
[ES_023]_a {1}	Plating	Scrubber- absorption (acid/alkaline)-Fabric filter	0.14	0.09	0.01	5.00	0.00
			0.03	0.02	0.01	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
[ES_023]_a {2}	Plating	Scrubber- absorption (acid/alkaline)-Fabric filter	0.23	0.23	0.23	5.00	0.00
			0.11	0.07	0.04	5.00	0.00
			0.03	0.02	0.02	5.00	0.00
[ES_023]_a {3}	Plating	Scrubber- absorption (acid/alkaline)-Fabric filter-Aerosol/droplet separator	0.16	0.16	0.16	5.00	0.00
			0.02	0.02	0.02	5.00	0.00
			0.01	0.01	0.01	5.00	0.00
[ES_023]_a {4}	Plating	Scrubber- absorption (acid/alkaline)-Fabric filter-Aerosol/droplet separator	0.14	0.09	0.01	5.00	0.00
			0.02	0.02	0.02	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
[ES_023]_a {5}	Plating	Scrubber- absorption (acid/alkaline)-Fabric filter	0.17	0.17	0.17	5.00	0.00
			0.09	0.08	0.07	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
[ES_030]_a {1}	Plating-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-
[ES_030]_a {2}	Etching or pickling of plastics-Plating-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-
[FI_002]_a {1}	Aqueous cleaning-Plating	Scrubber- absorption (acid/alkaline)	-	0.00	-	-	-
[FI_002]_a {2}	Alkaline degreasing-Plating	Scrubber- absorption (acid/alkaline)	-	0.00	-	-	-
[FI_002]_a {3}	Plating	Scrubber- absorption (acid/alkaline)	-	0.00	-	-	-
[FI_003]_a {1}		-	0.04	-	-	-	-
[FR_009]_a {6}	Plating	-	-	0.00	-	1.00	0.00
[FR_011]_a {1}	Alkaline degreasing-Other	No technique applied	0.00	0.00	0.00	1.00	-

[FR_011]_a {4}		-	0.00	-	-	1.00	-
[FR_014]_a {2}	Other	Other	0.00	0.00	0.00	1.00	-
[FR_014]_a {3}		Absorption	0.01	0.01	0.01	1.00	-
[FR_014]_a {4}		Absorption	0.01	0.01	0.01	1.00	-
[FR_014]_a {5}		Absorption	0.00	0.00	0.00	1.00	-
[FR_014]_a {6}		-	0.01	0.01	0.01	1.00	-
[FR_014]_a {7}		Absorption	0.00	0.00	0.00	1.00	-
[FR_014]_a {8}		-	0.01	0.01	0.01	1.00	-
[FR_014]_a {9}		Absorption	0.00	0.00	0.00	1.00	-
[FR_014]_a {10}		Absorption	0.00	0.00	0.00	1.00	-
[FR_015]_a {1}	Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	0.01	-	1.00	-
			-	0.00	-	1.00	-
[FR_015]_a {2}	Electrolytically assisted pickling, activation and degreasing-Plating-Other-	No technique applied	-	0.00	-	1.00	-
[FR_015]_a {5}	Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	0.00	-	1.00	-
[FR_015]_a {7}	Electrolytically assisted pickling, activation and degreasing-Plating-Other-	No technique applied	-	0.00	-	1.00	-
[FR_015]_a {9}	Anodising-Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	0.00	-	1.00	-
[FR_016]_a {1}	Other	No technique applied	0.00	0.00	0.00	1.00	0.00
[FR_016]_a {2}	Metal stripping	No technique applied	0.00	0.00	0.00	1.00	0.00
[FR_016]_a {3}	Anodising	No technique applied	0.02	0.02	0.02	1.00	0.00
[FR_016]_a {4}	Other	No technique applied	0.00	0.00	0.00	1.00	0.00
[FR_016]_a {5}	Etching or pickling of plastics	No technique applied	0.00	0.00	0.00	1.00	0.00
[FR_016]_a {8}	Plating	No technique applied	0.00	0.00	0.00	1.00	0.00
[FR_016]_a {9}	Plating	No technique applied	0.00	0.00	0.00	1.00	0.00
[FR_016]_a {10}	Plating	No technique applied	0.00	0.00	0.00	1.00	0.00
[FR_016]_a {11}	Plating	No technique applied	0.00	0.00	0.00	1.00	0.00
[FR_016]_a {12}	Plating	-	0.00	0.00	0.00	1.00	0.00
[FR_016]_a {13}	Plating	-	0.00	0.00	0.00	1.00	0.00
[FR_017]_a {1}	Alkaline degreasing-Alkaline degreasing-Rinsing	-	-	0.00	-	1.00	0.00
		-	-	0.00	-	1.00	0.00
		-	-	0.00	-	1.00	0.00
[FR_017]_a {2}	Rinsing-Plating-Rinsing-	-	-	0.00	-	1.00	0.00
		-	-	0.00	-	1.00	0.00
		-	-	0.00	-	1.00	0.00
[FR_018]_a {1}	Other-	Scrubber- absorption (acid/alkaline)	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {2}	Metal stripping-Conditioning of plastics-	Scrubber- absorption (acid/alkaline)	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {3}	Metal stripping-Conditioning of plastics-Etching or pickling of plastics- Other-Plating-	Scrubber- absorption (acid/alkaline)	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {4}	Plating-	Scrubber- absorption (acid/alkaline)	-	0.02	-	1.00	0.00
			-	0.00	-	1.00	0.00

[FR_018]_a {5}	Aqueous cleaning-Plating-Other-	Scrubber- absorption (acid/alkaline)	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {6}	Metal stripping	Scrubber- absorption (acid/alkaline)	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {7}	Other	Scrubber- absorption (acid/alkaline)	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {11}	Conditioning of plastics-Etching or pickling of plastics-Rinsing- Other	Scrubber- absorption (acid/alkaline)	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {12}	Plating	Scrubber- absorption (acid/alkaline)	0.10	0.05	0.00	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {13}	Plating-Other-	Scrubber- absorption (acid/alkaline)	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {14}	Metal stripping-Metal stripping-	Scrubber- absorption (acid/alkaline)	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_020]_a {2}		Scrubber- absorption (acid/alkaline)	0.01	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[FR_020]_a {3}	Alkaline degreasing-Rinsing-Chemical milling-Other-Rinsing-Anodising-	Scrubber- absorption (acid/alkaline)	0.01	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[FR_020]_a {4}	Metal stripping-Rinsing-Rinsing-Other-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[FR_020]_a {5}	Metal stripping-Other-Rinsing-Other-Metal stripping-Other	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[FR_020]_a {6}	Chemical milling-Other-Rinsing-Alkaline degreasing	Scrubber- absorption (acid/alkaline)	0.01	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[FR_020]_a {7}	Alkaline degreasing- Rinsing-Other	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[FR_020]_a {8}	Alkaline degreasing-Rinsing-Other-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[FR_024]_a {1}	Alkaline degreasing-Other-Plating	Aerosol/droplet separator	-	0.00	-	1.00	-
[FR_033]_a {1}	Plating-Metal stripping-Electrolytically assisted pickling, activation and degreasing- Rinsing-Other	No technique applied	-	0.04	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.01
[FR_033]_a {2}	Plating-Metal stripping-Rinsing-	No technique applied	-	0.04	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_033]_a {3}	Rinsing-Other-	No technique applied	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_033]_a {4}	Plating-	Mist filter (demister)	-	0.07	-	1.00	0.00
			-	0.00	-	1.00	0.00

			-	0.00	-	1.00	0.00
[FR_033]_a {5}	Plating	Mist filter (demister)	-	0.01	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_033]_a {6}	Plating	Mist filter (demister)	-	0.27	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_033]_a {8}	Plating	Mist filter (demister)	-	0.01	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_033]_a {9}	Aqueous cleaning-Oiling-Alkaline degreasing- Rinsing	No technique applied	-	0.01	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_033]_a {10}	Pickling (not electrically), descaling and desmutting-Other-Rinsing-	No technique applied	-	0.01	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_033]_a {12}	Other-Etching and descaling of aluminium-	No technique applied	-	0.03	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_033]_a {13}	Metal stripping-Metal stripping-	No technique applied	-	0.03	-	1.00	0.00
			-	0.02	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_033]_a {14}	Other-Pickling (not electrically), descaling and desmutting	No technique applied	-	0.01	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_033]_a {15}	Etching and descaling of aluminium-Rinsing	No technique applied	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_033]_a {16}	Pickling (not electrically), descaling and desmutting-Other-	No technique applied	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_033]_a {18}	Pickling (not electrically), descaling and desmutting-Other-	Mist filter (demister)	-	0.06	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_033]_a {19}	Abrasive blasting-	Fabric filter	-	0.01	-	-	0.00
			-	0.01	-	-	0.00
			-	0.00	-	-	0.00
[FR_033]_a {20}	-Rinsing-Other-Pickling (not electrically), descaling and desmutting	No technique applied	-	0.02	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_035]_a {1}	Plating-Other-Metal stripping-Electrolytically assisted pickling, activation and degreasing- Alkaline degreasing-Electrocoating (e-coating)-Other- Chemical polishing- Metal stripping- Etching and descaling of aluminium-Etching – Alkaline etching of aluminium	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	1.00	0.00
			0.01	0.01	0.01	1.00	0.00
			0.00	0.00	0.00	1.00	0.00

[FR_035]_a {2}	Plating- Metal stripping- Electrolytically assisted pickling, activation and degreasing- Alkaline degreasing-Electrocoating (e-coating)-Other- Chemical polishing- Etching and descaling of aluminium-Etching – Alkaline etching of aluminium	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	-
			0.00	0.00	0.00	1.00	0.00
[FR_035]_a {3}	Etching or pickling of plastics- Conditioning of plastics-Plating-Electrocoating (e-coating)-Rinsing-Degreasing-Metal stripping-Other-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[FR_035]_a {4}	Other-Pickling (not electrically), descaling and desmutting-Metal stripping-Degreasing- Electrolytically assisted pickling, activation and degreasing- Other-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[FR_035]_a {5}	Plating- Electrolytically assisted pickling, activation and degreasing- Alkaline degreasing-Electrocoating (e-coating)-Other- Chemical polishing- Metal stripping-Etching and descaling of aluminium-Etching – Alkaline etching of aluminium	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[FR_035]_a {6}	Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing- Rinsing-Degreasing- Other	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[FR_035]_a {7}	Electrocoating (e-coating)-Other	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	-
[FR_036]_a {7}	Plating-	Scrubber- absorption (acid/alkaline)	-	0.00	-	1.00	-
[FR_036]_a {8}	Plating-	Scrubber- absorption (acid/alkaline)-Aerosol/droplet separator	-	0.00	-	1.00	-
[IT_001]_a {1}	Electrocoating (e-coating)	Aerosol/droplet separator	0.10	0.05	0.01	0.50	57.00
			0.02	0.02	0.01	0.50	17.00
			0.00	0.00	0.00	0.50	3.42
[IT_001]_a {2}	Electrocoating (e-coating)	Aerosol/droplet separator	0.02	0.02	0.01	0.50	13.50
			0.02	0.02	0.01	0.50	13.50
[IT_001]_a {3}	Electrocoating (e-coating)	Aerosol/droplet separator	0.10	0.05	0.01	0.50	45.11
			0.02	0.02	0.01	0.50	13.54
			0.00	0.00	0.00	0.50	2.71
[IT_001]_a {4}	Electrocoating (e-coating)	Aerosol/droplet separator	0.10	0.05	0.01	0.50	57.09

			0.02	0.02	0.01	0.50	17.13
			0.00	0.00	0.00	0.50	3.43
[IT_001]_a {5}	Electrocoating (e-coating)	Aerosol/droplet separator	0.10	0.05	0.01	0.50	58.49
			0.02	0.02	0.01	0.50	17.55
			0.00	0.00	0.00	0.50	3.51
[IT_001]_a {6}	Electrocoating (e-coating)	Aerosol/droplet separator	0.10	0.05	0.01	0.50	57.09
			0.02	0.02	0.01	0.50	17.13
			0.00	0.00	0.00	0.50	3.43
[IT_004]_a {5}	Electrolytically assisted pickling, activation and degreasing-Plating-Metal stripping-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	0.20	0.00
			0.01	0.01	0.01	0.20	0.00
			0.01	0.01	0.01	0.20	0.00
[IT_006]_a {1}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing- Plating-Other-	Scrubber- absorption (acid/alkaline)	-	0.01	-	0.50	0.00
			-	0.00	-	0.50	-
[IT_008]_a {3}	Alkaline degreasing- Rinsing-Electrolytically assisted pickling, activation and degreasing- Other- Plating-Electrocoating (e-coating)	-	0.00	0.00	0.00	5.00	0.49
		-	0.00	0.00	0.00	5.00	0.54
[IT_008]_a {4}	Alkaline degreasing-Rinsing-Electrolytically assisted pickling, activation and degreasing- Other- Drying-	-	0.00	0.00	0.00	5.00	0.22
		-	0.00	0.00	0.00	5.00	0.28
[IT_008]_a {5}	Drying	-	0.00	0.00	0.00	5.00	0.03
		-	0.00	0.00	0.00	5.00	0.03
[IT_009]_a {2}	Plating-Rinsing-Drying-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.00	0.10	-
[IT_009]_a {4}	Plating-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	0.10	-
[IT_009]_a {5}	Rinsing-Plating-	Scrubber- absorption (acid/alkaline)	0.03	0.01	0.00	0.10	-
[IT_011]_a {1}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	5.00	0.00
[IT_011]_a {2}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
[IT_012]_a {1}	Plating-	Mist filter (demister)	0.05	0.03	0.00	0.50	0.00
			0.05	0.02	0.00	0.50	0.00
			0.01	0.01	0.01	0.50	0.00
[IT_013]_a {2}	Electrocoating (e-coating)	Other Other	0.01	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
[IT_013]_a {3}	Electrocoating (e-coating)		0.01	0.01	0.00	0.10	0.00
[IT_013]_a {5}	Other-	Other	0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
[IT_025]_a {1}	Plating-	Aerosol/droplet separator	0.10	0.14	0.04	0.50	0.00

			0.08	0.04	0.00	0.50	0.00
			0.02	0.02	0.01	0.50	0.00
[IT_025]_a {2}	Other	Aerosol/droplet separator	0.08	0.05	0.02	0.50	0.00
			0.06	0.03	0.00	0.50	0.00
			0.03	0.02	0.01	0.50	0.00
[IT_025]_a {3}	Plating-	Aerosol/droplet separator	0.10	0.05	0.00	0.50	-
			0.08	0.05	0.02	0.50	0.00
			0.02	0.02	0.01	0.50	0.00
[IT_029]_a {6}	Other	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.10	-
[IT_029]_a {8}	Other	No technique applied	0.05	0.05	0.05	0.10	-
[IT_031]_a {1}	Plating-Rinsing- Other-Electrolytically assisted pickling, activation and degreasing- Degreasing-Pickling (not electrically), descaling and desmutting	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.10	0.00
[IT_032]_a {11}	Plating-	No technique applied	0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
[IT_032]_a {20}	Other	Regenerative thermal oxidation	0.07	0.03	0.01	5.00	0.00
[NL_002]_a {1}	Electrocoating (e-coating)	Other	0.15	0.10	0.06	-	-
[NL_002]_a {4}	Other	No technique applied	0.01	0.01	0.01	-	-
[NL_002]_a {5}	Other-	No technique applied	0.05	0.04	0.04	-	-
[NL_002]_a {6}	Other	No technique applied	0.03	0.02	0.01	-	-
[PT_002]_a {10}	Other	Scrubber- absorption (acid/alkaline)	0.03	0.02	0.01	0.20	0.00
[SE_004]_a {1}	Plating	Absorption-Aerosol/droplet separator	-	0.00	-	-	-
[SE_006]_a {1}	Pickling (not electrically), descaling and desmutting-	Scrubber- absorption (acid/alkaline)	-	0.00	-	-	0.00
[SE_006]_a {2}	Electropolishing		-	0.00	-	-	0.00
[SE_006]_a {4}	Electropolishing	-	-	0.00	-	-	0.00
[SE_006]_a {5}	Pickling (not electrically), descaling and desmutting-Electropolishing-	Scrubber- absorption (acid/alkaline)	-	0.03	-	-	0.00
[SE_006]_a {6}	Electropolishing	-	-	0.00	-	-	0.00

3.2.4.7 Cr(VI)

The reported data for Cr(VI) emissions to air are presented in Figure 3-34. Emission data and contextual information are also presented in Table 3-35.

Source: [168, TWG 2023]

Figure 3-34: Cr(VI) emissions to air in electrolytic or chemical plating plants

Table 3-33: Reported data and contextual information for Cr(VI) emissions to air in electrolytic or chemical plating plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[AT_004]_a {5}	Other-Plating-	Aerosol/droplet separator	0.00	0.00	0.00	-	-
[AT_007]_a {1}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Plating-	Mist filter (demister)-Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	-	-
[AT_007]_a {5}	Other	Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	-	-
[AT_009]_a {1}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating	Aerosol/droplet separator	0.01	0.01	0.01	0.05	-
[AT_009]_a {2}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating	Aerosol/droplet separator	0.01	0.01	0.01	0.05	-
[AT_009]_a {3}	Plating-	Aerosol/droplet separator	0.01	0.01	0.01	0.05	-
[AT_009]_a {4}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator	0.05	0.05	0.05	0.05	-
[AT_009]_a {5}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator	0.05	0.05	0.05	0.05	-
[AT_009]_a {6}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing- Plating-Other	Aerosol/droplet separator	0.00	0.00	0.00	0.05	-
[AT_009]_a {7}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing- Plating-Other	Aerosol/droplet separator	0.00	0.00	0.00	0.05	-
[BE_015]_a {1}	Other-Plating	Other	-	0.01	-	0.10	-
			-	0.00	-	0.10	-
			-	0.00	-	0.10	-
[BE_015]_a {2}	Plating	Other	-	0.01	-	0.10	-
			-	0.01	-	0.10	-
			-	0.00	-	0.10	-
[BE_015]_a {3}	Other-Plating	Other	-	0.01	-	0.10	-
			-	0.01	-	0.10	-
			-	0.00	-	0.10	-
[BE_015]_a {4}	Plating	Other	-	0.01	-	0.10	-
			-	0.01	-	0.10	-
			-	0.00	-	0.10	-
[BG_004]_a {1}	Solvent degreasing-Etching or pickling of plastics-Other-Chromium conversion coatings-Soak clean-Hand wipping-Other pretreatment step-	Scrubber-absorption (acid/alkaline)	-	0.01	-	0.05	0.00
			-	0.01	-	0.05	0.00
			-	-	0.00	0.05	-
[CZ_007]_a {1}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and	Aerosol/droplet separator-Cyclone	0.00	0.00	0.00	-	-
			0.00	0.00	0.00	-	-

	desmutting-Rinsing-						
[CZ_007]_a {2}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing	Aerosol/droplet separator-Cyclone	0.01	0.01	0.00	-	-
			0.00	0.00	0.00	-	-
			0.00	0.00	0.00	-	-
[CZ_007]_a {3}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.00	0.00	0.00	-	-
[CZ_007]_a {4}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing	-	0.01	0.01	0.01	-	-
			0.00	0.00	0.00	-	-
			0.00	0.00	0.00	-	-
[DE_019]_a {1}	Plating-	Aerosol/droplet separator	0.03	0.02	0.02	0.03	-
[DE_019]_a {2}	Plating-	Aerosol/droplet separator	0.03	0.03	0.03	-	-
			0.01	0.01	0.01	0.03	-
[DE_023]_a {1}	Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator-Fabric filter	0.00	0.00	0.00	0.05	0.00
[DE_023]_a {2}	Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator-Fabric filter	0.00	0.00	0.00	0.05	0.00
[DE_023]_a {3}	Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator-Fabric filter	0.00	0.00	0.00	0.05	0.00
[DE_023]_a {4}	Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator-Fabric filter	0.00	0.00	0.00	0.05	0.00
[DE_023]_a {5}	Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator-Fabric filter	0.00	0.00	0.00	0.05	0.00
[DE_023]_a {6}	Metal stripping	Aerosol/droplet separator	0.00	0.00	0.00	0.05	0.00
[DE_023]_a {7}	Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator-Fabric filter	0.01	0.01	0.01	0.05	0.00
[DE_023]_a {8}	Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator-Fabric filter	0.00	0.00	0.00	0.05	0.00
[DE_023]_a {9}	Plating-	Aerosol/droplet separator-Fabric filter	0.00	0.00	0.00	0.05	0.02
[DE_036]_a {1}	Plating	Scrubber-absorption (acid/alkaline)-Mist filter (demister)	0.04	0.04	0.04	0.05	-
			0.02	0.02	0.02	0.05	-
[DE_037]_a {2}	Plating-	Scrubber-absorption (acid/alkaline)-Mist filter (demister)	0.04	0.03	0.02	0.05	-
[DE_045]_a {1}	Etching or pickling of plastics-Electrolytically assisted pickling, activation and degreasing-Conditioning of plastics	Scrubber-absorption (acid/alkaline)	0.01	0.01	0.01	-	-
[DE_045]_a {2}	Other-	Scrubber-absorption (acid/alkaline)	0.01	0.01	0.01	-	-

[DE_045]_a {5}	Electrocoating (e-coating)	Scrubber-absorption (acid/alkaline)	0.01	0.01	-	-	-
[DE_062]_a {1}	Plating	Aerosol/droplet separator-Scrubber-absorption (acid/alkaline)	0.07	0.05	0.03	0.05	-
			0.02	0.02	0.02	0.05	-
[DE_062]_a {3}	Plating-	Aerosol/droplet separator-Scrubber-absorption (acid/alkaline)	0.02	0.02	0.02	0.05	-
			0.02	0.02	0.02	0.05	-
[DE_062]_a {4}	Plating	Aerosol/droplet separator-Scrubber-absorption (acid/alkaline)	0.04	0.03	0.02	0.05	-
			0.01	0.01	0.01	0.05	-
[DE_062]_a {5}	Plating	Aerosol/droplet separator-Scrubber-absorption (acid/alkaline)	0.01	0.01	0.01	0.05	-
			0.01	0.01	0.01	0.05	-
			0.01	0.01	0.01	0.05	-
[ES_010]_a {1}	Metal stripping-Plating-	Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	-	-
[ES_010]_a {3}	Plating-	Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	-	-
[ES_010]_a {4}	Etching or pickling of plastics-Plating	Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	-	-
			0.00	0.00	0.00	-	-
[ES_030]_a {1}	Plating-	Scrubber-absorption (acid/alkaline)	0.01	0.01	0.01	-	-
[ES_030]_a {2}	Etching or pickling of plastics-Plating	Scrubber-absorption (acid/alkaline)	0.01	0.01	0.01	-	-
			0.00	0.00	0.00	-	-
[FI_003]_a {1}		-	0.04	-	-	-	-
[FI_005]_a {1}		-	0.00	0.00	0.00	0.01	0.00
		-	0.00	0.00	0.00	0.01	0.00
[FI_005]_a {2}		-	0.00	0.00	0.00	0.01	0.00
		-	0.00	0.00	0.00	0.01	0.00
[FI_005]_a {4}		-	0.00	0.00	0.00	0.01	0.00
		-	0.00	0.00	0.00	0.01	0.00
[FI_005]_a {5}		-	0.00	0.00	0.00	0.01	0.00
[FR_007]_a {1}	Alkaline degreasing	-	-	0.00	-	0.10	-
		-	-	0.00	-	0.10	-
[FR_007]_a {3}	Plating	-	-	0.00	-	0.10	-
[FR_007]_a {4}	Other-Rinsing-	-	-	0.00	-	0.10	-
[FR_009]_a {6}	Plating	-	-	0.01	-	0.10	0.00
[FR_011]_a {1}	Alkaline degreasing-Alkaline degreasing-Other	No technique applied	0.00	-	-	0.10	-
[FR_011]_a {3}	Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-	No technique applied	0.00	0.00	0.00	0.10	-
[FR_015]_a {1}	Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	0.01	-	0.10	-
			-	0.01	-	0.10	-

[FR_015]_a {2}	Electrolytically assisted pickling, activation and degreasing-Plating-Other-	No technique applied	-	0.01	-	0.10	-
			-	0.01	-	0.10	-
[FR_015]_a {5}	Electrolytically assisted pickling, activation and degreasing-Plating-	No technique applied	-	0.01	-	0.10	-
[FR_015]_a {7}	Electrolytically assisted pickling, activation and degreasing-Plating- Other	No technique applied	-	0.01	-	0.10	-
			-	0.01	-	0.10	-
[FR_015]_a {9}	Anodising-Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	0.01	-	0.10	-
[FR_016]_a {1}	Other	No technique applied	0.00	0.00	0.00	0.10	0.00
[FR_016]_a {2}	Metal stripping	No technique applied	0.01	0.01	0.01	0.10	0.00
[FR_016]_a {3}	Anodising	No technique applied	0.01	0.01	0.01	0.10	0.00
[FR_016]_a {4}	Other	No technique applied	0.00	0.00	0.00	0.10	0.02
[FR_016]_a {5}	Etching or pickling of plastics	No technique applied	0.00	0.00	0.00	0.10	0.00
[FR_016]_a {8}	Plating	No technique applied	0.01	0.01	0.01	0.10	0.00
[FR_016]_a {9}	Plating	No technique applied	0.01	0.01	0.01	0.10	0.00
[FR_016]_a {10}	Plating	No technique applied	0.01	0.01	0.01	0.10	0.00
[FR_016]_a {11}	Plating	No technique applied	0.00	0.00	0.00	0.10	0.05
[FR_016]_a {12}	Plating	-	0.00	0.00	0.00	0.10	0.00
[FR_016]_a {13}	Plating	-	0.01	0.01	0.01	0.10	0.00
[FR_017]_a {1}	Alkaline degreasing-Alkaline degreasing-Rinsing	-	-	0.00	-	0.10	0.00
		-	-	0.00	-	0.10	0.00
		-	-	0.00	-	0.10	0.00
[FR_017]_a {2}	Rinsing-Plating-Rinsing	-	-	0.00	-	0.10	0.00
		-	-	0.00	-	0.10	0.00
		-	-	0.00	-	0.10	0.00
[FR_018]_a {1}	Other	Scrubber-absorption (acid/alkaline)	-	0.00	-	0.10	0.00
		Scrubber-absorption (acid/alkaline)	-	0.00	-	0.10	0.00
[FR_018]_a {2}	Metal stripping-Conditioning of plastics	Scrubber-absorption (acid/alkaline)	-	0.00	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_018]_a {3}	Metal stripping-Conditioning of plastics-Etching or pickling of plastics-Other-Other-Other-Plating-	Scrubber-absorption (acid/alkaline)	-	0.00	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_018]_a {4}	Plating-	Scrubber-absorption (acid/alkaline)	-	0.00	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_018]_a {5}	Aqueous cleaning-Plating-Other-	Scrubber-absorption (acid/alkaline)	-	0.00	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_018]_a {6}	Metal stripping	Scrubber-absorption (acid/alkaline)	-	0.00	-	0.10	0.00
			-	0.00	-	0.10	0.00

[FR_018]_a {7}	Other-	Scrubber-absorption (acid/alkaline)	-	0.00	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_018]_a {11}	Conditioning of plastics- Etching or pickling of plastics-Rinsing- Other	Scrubber-absorption (acid/alkaline)	-	0.00	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_018]_a {12}	Plating	Scrubber-absorption (acid/alkaline)	-	0.00	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_018]_a {13}	Plating-Other-	Scrubber-absorption (acid/alkaline)	-	0.00	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_018]_a {14}	Metal stripping-Metal stripping	Scrubber-absorption (acid/alkaline)	-	0.00	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_020]_a {2}		Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
[FR_020]_a {3}	Alkaline degreasing-Rinsing-Chemical milling-Other-Rinsing-Anodising--Alkaline degreasing	Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
[FR_020]_a {4}	Metal stripping-Rinsing- Other-	Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
[FR_020]_a {5}	Metal stripping- RinsingOther	Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
[FR_020]_a {6}	Chemical milling-Other-Rinsing-Alkaline degreasing	Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	-
[FR_020]_a {7}	Alkaline degreasing-Rinsing-Other	Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
[FR_020]_a {8}	Alkaline degreasing-Rinsing-Other	Scrubber-absorption (acid/alkaline)	0.02	0.01	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
[FR_024]_a {1}	Alkaline degreasing-Other-Plating	Aerosol/droplet separator	-	0.00	-	0.10	-
[FR_033]_a {1}	Plating-Metal stripping-Electrolytically assisted pickling, activation and degreasing- Rinsing-Other	No technique applied	-	0.01	-	0.10	-
			-	0.01	-	0.10	0.00
[FR_033]_a {2}	Plating-Metal stripping-Rinsing	No technique applied	-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_033]_a {3}	Rinsing-Other	No technique applied	-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_033]_a {4}	Plating-	Mist filter (demister)	-	0.06	-	0.10	0.00
			-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
[FR_033]_a {5}	Plating-	Mist filter (demister)	-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00

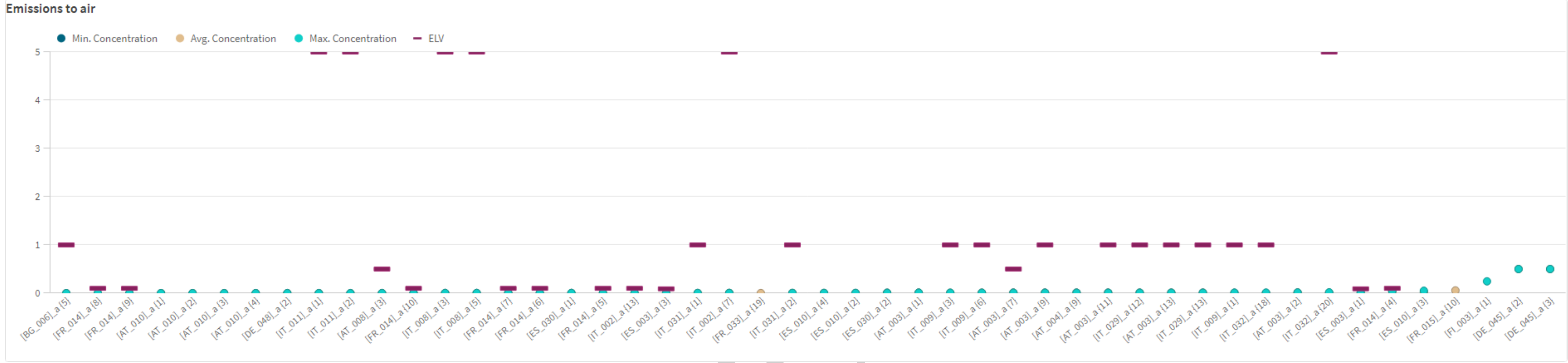
			-	0.01	-	0.10	0.00
[FR_033]_a {6}	Plating	Mist filter (demister)	-	0.02	-	0.10	0.00
			-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
[FR_033]_a {8}	Plating	Mist filter (demister)	-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
[FR_033]_a {9}	Aqueous cleaning- Oiling-Alkaline degreasing- Rinsing	No technique applied	-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_033]_a {10}	Pickling (not electrically), descaling and desmutting-Other-Rinsing	No technique applied	-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
[FR_033]_a {12}	Other-Etching and descaling of aluminium-	No technique applied	-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_033]_a {13}	Metal stripping-Metal stripping-	No technique applied	-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.02
[FR_033]_a {14}	Other-Pickling (not electrically), descaling and desmutting	No technique applied	-	2.20	-	0.10	0.00
			-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
[FR_033]_a {15}	-Rinsing-Etching and descaling of aluminium-Rinsing	No technique applied	-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_033]_a {16}	Pickling (not electrically), descaling and desmutting-Other-	No technique applied	-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_033]_a {18}	Pickling (not electrically), descaling and desmutting-Other-	Mist filter (demister)	-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
[FR_033]_a {20}	-Rinsing-Other-Pickling (not electrically), descaling and desmutting	No technique applied	-	0.01	-	0.10	0.00
			-	0.01	-	0.10	0.00
			-	0.00	-	0.10	0.00
[FR_035]_a {1}	Plating-Other-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)- Etching and descaling of aluminium-Etching – Alkaline etching of aluminium-	Scrubber-absorption (acid/alkaline)	0.01	0.01	0.01	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
[FR_035]_a {2}	Plating-Other-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)-Other-Alkaline degreasing-Chemical polishing- Etching and descaling of aluminium-Etching – Alkaline etching of aluminium-	Scrubber-absorption (acid/alkaline)	0.01	0.01	0.01	0.10	0.00
[FR_035]_a {3}	Etching or pickling of plastics-Conditioning of plastics-Plating-Electrocoating (e-coating)- Rinsing-Degreasing-Metal stripping-Other-	Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	0.10	0.00
[FR_036]_a	Plating-	Scrubber-	-	0.00	-	0.01	-

{8}		absorption (acid/alkaline)-Aerosol/droplet separator					
[IT_002]_a {5}	Mechanical polishing/linishing	Cyclone	0.00	0.00	0.00	1.00	0.01
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.01
[IT_002]_a {6}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Anodising-	-	0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.01
			0.00	0.00	0.00	1.00	0.01
[IT_002]_a {8}	Electrolytically assisted pickling, activation and degreasing-Plating-	Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[IT_002]_a {10}	Metal stripping-Metal stripping-	Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[IT_002]_a {14}	Plating	Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[IT_002]_a {15}	Etching and descaling of aluminium-Pickling (not electrically), descaling and desmutting-Metal stripping-	Scrubber-absorption (acid/alkaline)	0.01	0.01	0.01	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[IT_002]_a {16}	Electrolytically assisted pickling, activation and degreasing-Plating-	Scrubber-absorption (acid/alkaline)	0.04	0.04	0.00	1.00	0.00
			0.02	0.01	0.01	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[IT_008]_a {3}	Alkaline degreasing-Rinsing-Electrolytically assisted pickling, activation and degreasing- Other-Plating- Electrocoating (e-coating)	-	0.00	0.00	0.00	1.00	0.49
		-	0.00	0.00	0.00	1.00	0.54
[IT_008]_a {5}	Drying	-	0.00	0.00	0.00	1.00	0.03
		-	0.00	0.00	0.00	1.00	0.03
[IT_009]_a {2}	Plating-Rinsing-Drying-	Scrubber-absorption (acid/alkaline)	0.01	0.01	0.01	0.10	-
[IT_009]_a {4}	Plating-	Scrubber-absorption (acid/alkaline)	0.01	0.01	0.01	-	-
[IT_009]_a {5}	Rinsing-Plating-	Scrubber-absorption (acid/alkaline)	0.01	0.01	0.00	0.10	-
[IT_011]_a {1}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
[IT_011]_a {2}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber-absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
[IT_012]_a {1}	Plating-	Mist filter (demister)	0.00	0.00	0.00	-	-
[IT_025]_a {1}	Plating-	Aerosol/droplet separator	0.00	0.00	0.00	-	0.00
[IT_025]_a {2}	Other	Aerosol/droplet separator	0.00	0.00	0.00	-	0.00
			0.00	0.00	0.00	-	0.00
[IT_025]_a {3}	Plating	Aerosol/droplet separator	0.00	0.00	0.00	-	0.00
			0.00	0.00	0.00	-	0.00
[IT_029]_a	Other	Scrubber-	0.01	0.01	0.01	0.10	-

{7}		absorption (acid/alkaline)					
[IT_029]_a {12}	Other	Scrubber-absorption (acid/alkaline)	0.01	0.01	0.01	0.10	-
[IT_029]_a {13}	Other	No technique applied	0.01	0.01	0.01	0.10	-
[IT_030]_a {1}	Plating-	-	0.01	0.01	0.00	0.10	0.00
[IT_031]_a {1}	Plating-Rinsing- Electrolytically assisted pickling, activation and degreasing- Degreasing- Pickling (not electrically), descaling and desmutting- Other-	Scrubber-absorption (acid/alkaline)	0.01	0.01	0.01	0.10	0.00
[NL_002]_a {1}	Electrocoating (e-coating)	Other	0.01	0.01	0.01	0.10	-
[NL_002]_a {4}	Other	No technique applied	0.00	0.00	0.00	0.10	-
[NL_002]_a {5}	Other-	No technique applied	0.04	0.02	0.00	0.10	-
[NL_002]_a {6}	Other	No technique applied	0.00	0.00	0.00	0.10	-
[SE_004]_a {1}	Plating	Absorption-Aerosol/droplet separator	-	0.00	-	-	-

3.2.4.8 Copper

The reported data for Cu emissions to air are presented in Figure 3-35. Emission data and contextual information are also presented in Table 3-36.



Source: [168, TWG 2023]

Figure 3-35: Cu emissions to air in electrolytic or chemical plating plants

Table 3-34: Reported data and contextual information for Cu emissions to air in electrolytic or chemical plating plants

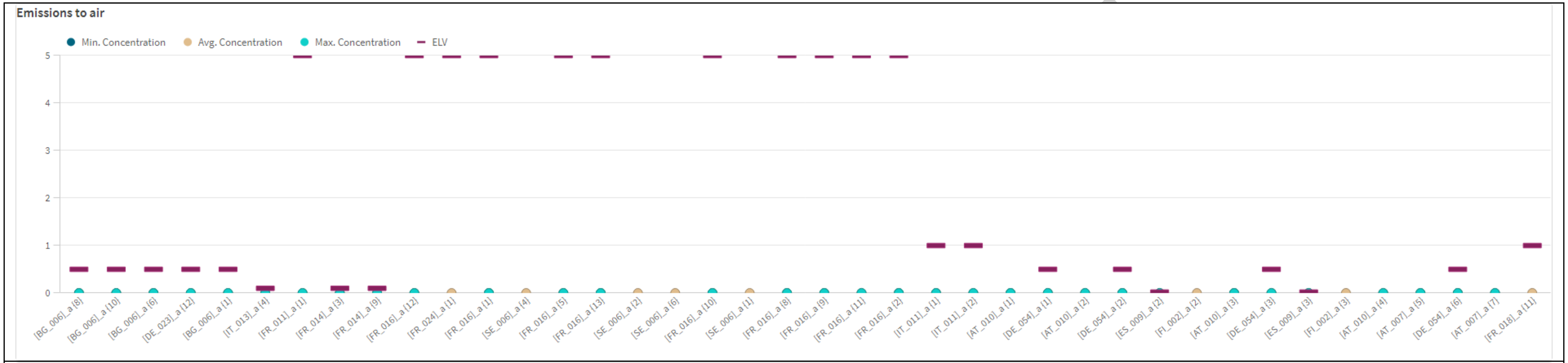
EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	95th perc.	Load
[AT_003]_a {1}	Pickling (not electrically), descaling and desmutting-Other-Metal stripping-Plating	Aerosol/droplet separator-Other-Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	-	-	-
[AT_003]_a {2}	Degreasing-Plating-	Scrubber- absorption (acid/alkaline)-Other-Aerosol/droplet separator	0.02	0.02	0.02	-	-	-
			0.01	0.01	0.01	-	-	-
[AT_003]_a {7}	Alkaline degreasing-Plating-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.01	0.01	0.01	0.50	-	-
[AT_003]_a {9}	Alkaline degreasing-Plating-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.01	0.01	0.01	1.00	-	-
[AT_003]_a {11}	Alkaline degreasing-Plating-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.01	0.01	0.01	1.00	-	-
[AT_003]_a {13}	Alkaline degreasing-Plating-Alkaline degreasing-Plating-Other-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.01	0.01	0.01	1.00	-	-
[AT_004]_a {9}	-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	-	-	-
[AT_008]_a {3}	Pickling (not electrically), descaling and desmutting-Rinsing--Drying-Other-Degreasing- Electrolytically assisted pickling, activation and degreasing- Deburring and/or tumbling- Plating	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.50	-	-
[AT_010]_a {1}	Alkaline degreasing-Aqueous cleaning-Drying-Electrolytically assisted pickling, activation and degreasing-Etching – Alkaline etching of aluminium-Hand wiping-Heat treatment-Mechanical polishing/linishing-Pickling (not electrically), descaling and desmutting-Plating-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-	-
[AT_010]_a {2}	Other-Plating-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-	-
[AT_010]_a {3}	Plating-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-	-
[AT_010]_a {4}	Pickling (not electrically), descaling and desmutting	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-	-
[BG_006]_a {5}	Electrocoating (e-coating)	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	1.00	-	0.00
[DE_045]_a {2}	Other-	Scrubber- absorption (acid/alkaline)	0.50	0.50	0.50	-	-	-
[DE_045]_a {3}	Other	Scrubber- absorption (acid/alkaline)	0.50	0.50	0.50	-	-	-
[DE_048]_a {2}	Plating-	-	0.00	0.00	0.00	-	-	-
[ES_003]_a {1}	Plating	Scrubber- absorption (acid/alkaline)	0.02	0.01	0.00	0.09	0.02	-
			0.00	0.00	0.00	0.09	0.00	-

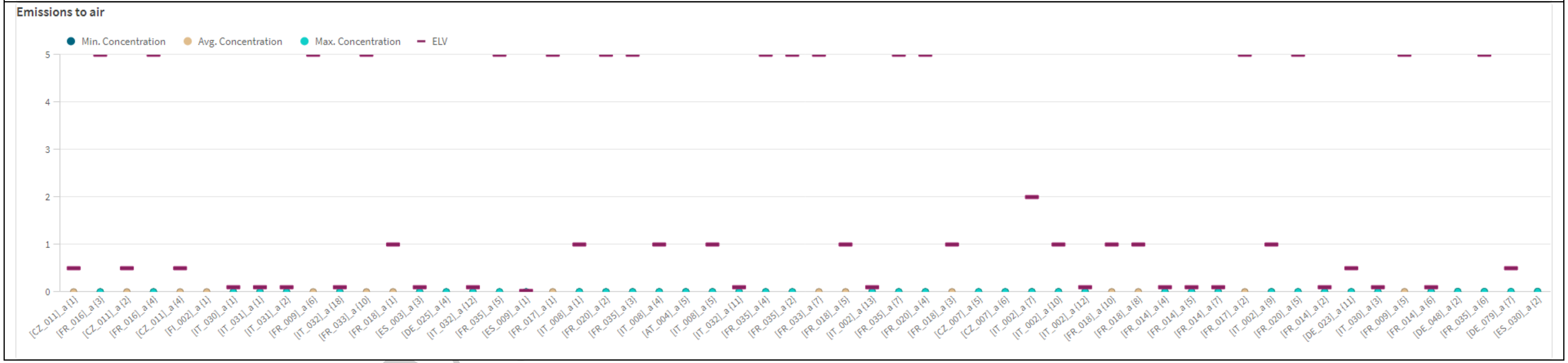
			0.00	0.00	0.00	0.09	-	-
[ES_003]_a {3}	Plating	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.09	0.00	-
			0.00	0.00	0.00	0.09	0.00	-
			0.00	0.00	0.00	0.09	-	-
[ES_010]_a {2}	Plating-	Scrubber- absorption (acid/alkaline)	0.01	0.00	0.00	-	-	-
			0.00	0.00	0.00	-	-	-
[ES_010]_a {3}	Plating-	Scrubber- absorption (acid/alkaline)	0.05	0.05	0.05	-	-	-
			0.01	0.00	0.00	-	-	-
[ES_010]_a {4}	Etching or pickling of plastics-Plating-	Scrubber- absorption (acid/alkaline)	0.01	0.00	0.00	-	-	-
			0.00	0.00	0.00	-	-	-
[ES_030]_a {1}	Plating-Plating-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-	-
[ES_030]_a {2}	Etching or pickling of plastics-Plating-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	-	-	-
[FI_002]_a {1}	Aqueous cleaning-Plating	Scrubber- absorption (acid/alkaline)	-	0.00	-	-	-	-
[FI_002]_a {2}	Alkaline degreasing-Plating-	Scrubber- absorption (acid/alkaline)	-	0.00	-	-	-	-
[FI_002]_a {3}	Plating	Scrubber- absorption (acid/alkaline)	-	0.00	-	-	-	-
[FI_003]_a {1}		-	0.25	-	-	-	-	-
[FR_014]_a {4}		Absorption	0.04	0.04	0.04	0.10	-	-
[FR_014]_a {5}		Absorption	0.00	0.00	0.00	0.10	-	-
[FR_014]_a {6}		-	0.00	0.00	0.00	0.10	-	-
[FR_014]_a {7}		Absorption	0.00	0.00	0.00	0.10	-	-
[FR_014]_a {8}		-	0.00	0.00	0.00	0.10	-	-
[FR_014]_a {9}		Absorption	0.00	0.00	0.00	0.10	-	-
[FR_014]_a {10}		Absorption	0.00	0.00	0.00	0.10	-	-
[FR_015]_a {10}	Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	0.06	-	-	-	-
[FR_033]_a {19}	Abrasive blasting-	Fabric filter	-	0.01	-	-	-	0.00
			-	0.00	-	-	-	0.00
			-	0.00	-	-	-	0.00
[IT_002]_a {7}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating-Lacquering-Drying-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	5.00	-	0.00
			0.01	0.01	0.01	5.00	-	0.00
			0.00	0.00	0.00	5.00	-	0.00
[IT_002]_a {13}	Etching and descaling of aluminium-Plating-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.10	-	0.00
			0.00	0.00	0.00	0.10	-	0.00
			0.00	0.00	0.00	0.10	-	0.00
[IT_008]_a {3}	Alkaline degreasing-Rinsing-Electrolytically assisted pickling, activation and degreasing-Rinsing- Other-Plating--Electrocoating (e-	- -	0.00	0.00	0.00	5.00	-	0.49
			0.00	0.00	0.00	5.00	-	0.54

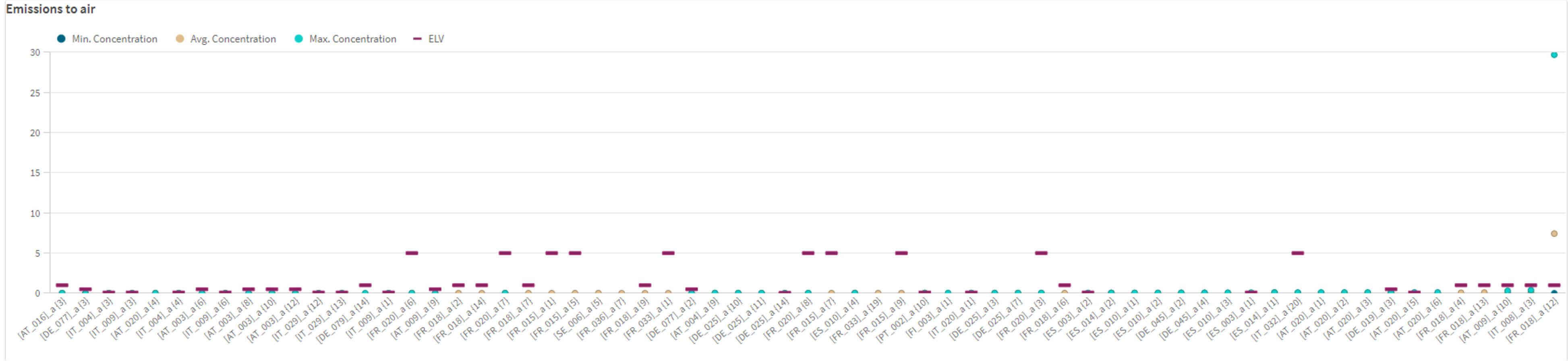
	coating)-							
[IT_008]_ a {5}	Drying	-	0.00	0.00	0.00	5.00	-	0.03
		-	0.00	0.00	0.00	5.00	-	0.03
[IT_009]_ a {1}	Degreasing-Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-Plating-Rinsing-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	1.00	-	-
[IT_009]_ a {3}	Rinsing-Other-Degreasing-Alkaline degreasing-Metal stripping- Plating-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.00	1.00	-	-
[IT_009]_ a {6}	Degreasing-Pickling (not electrically), descaling and desmutting-Alkaline degreasing-Plating	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	1.00	-	-
[IT_011]_ a {1}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	5.00	-	0.00
			0.00	0.00	0.00	5.00	-	0.00
			0.00	0.00	0.00	5.00	-	0.00
[IT_011]_ a {2}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	5.00	-	0.00
			0.00	0.00	0.00	5.00	-	0.00
			0.00	0.00	0.00	5.00	-	0.00
[IT_029]_ a {12}	Other	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	1.00	0.01	-
[IT_029]_ a {13}	Other	No technique applied	0.01	0.01	0.01	1.00	0.01	-
[IT_031]_ a {1}	Plating-Rinsing- Other-Electrolytically assisted pickling, activation and degreasing- Degreasing-Pickling (not electrically), descaling and desmutting	Scrubber- absorption (acid/alkaline)	0.01	0.00	0.00	1.00	-	0.00
			0.00	0.00	0.00	1.00	-	0.00
[IT_031]_ a {2}	Metal stripping-Degreasing-Rinsing- Pickling (not electrically), descaling and desmutting- Electrolytically assisted pickling, activation and degreasing- Other-	Scrubber- absorption (acid/alkaline)	0.01	0.00	0.00	1.00	-	0.00
			0.00	0.00	0.00	1.00	-	0.00
[IT_032]_ a {18}	Plating-Other-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-	No technique applied	0.01	0.01	0.01	1.00	-	0.00
			0.00	0.00	0.00	1.00	-	0.00
[IT_032]_ a {20}	Other	Regenerative thermal oxidation	0.02	0.01	0.00	5.00	-	0.00

3.2.4.9 Nickel

The reported data for Ni emissions to air are presented in Figure 3-36. Emission data and contextual information are also presented in Table 3-37.







Source: [168, TWG 2023]

Figure 3-36: Ni emissions to air in electrolytic or chemical plating plants

Table 3-35: Reported data and contextual information for Ni emissions to air in electrolytic or chemical plating plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[AT_003]_a {1}	Pickling (not electrically), descaling and desmutting-Other-Metal stripping-Plating	Aerosol/droplet separator-Other-Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	-	-
[AT_003]_a {6}	Pickling (not electrically), descaling and desmutting-Plating-	-Other-Mist filter (demister)	0.01	0.01	0.01	0.50	-
[AT_003]_a {8}	Pickling (not electrically), descaling and desmutting-Plating-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.01	0.01	0.01	0.50	-
[AT_003]_a {10}	Pickling (not electrically), descaling and desmutting-Plating-	Mist filter (demister)-Other	0.01	0.01	0.01	0.50	-
[AT_003]_a {12}	Pickling (not electrically), descaling and desmutting, Plating-Other-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.01	0.01	0.01	0.50	-
[AT_004]_a {5}	Other-Plating-	Aerosol/droplet separator	0.00	0.00	0.00	-	-
[AT_004]_a {9}		Scrubber- absorption (acid/alkaline)	0.02	0.02	0.02	-	-
[AT_007]_a {5}	Other	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-
[AT_007]_a {7}	Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-	-	0.00	0.00	0.00	-	-
[AT_009]_a {9}	Chemical polishing-Plating-Electrolytically assisted pickling, activation and degreasing--	Aerosol/droplet separator	0.01	0.01	0.01	0.50	-
[AT_009]_a {10}	Degreasing-Pickling (not electrically), descaling and desmutting--Anodising-Other-	Aerosol/droplet separator	0.30	0.03	0.03	1.00	-
[AT_010]_a {1}	Alkaline degreasing-Aqueous cleaning-Drying-Electrolytically assisted pickling, activation and degreasing-Etching – Alkaline etching of aluminium-Hand wiping-Heat treatment-Mechanical polishing/linishing-Pickling (not electrically), descaling and desmutting-Plating-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-
[AT_010]_a {2}	Other-Plating-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-
[AT_010]_a {3}	Plating-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-
[AT_010]_a {4}	Pickling (not electrically), descaling and desmutting	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-
[AT_016]_a {3}	Abrasive blasting	Fabric filter	0.01	0.01	0.01	1.00	-
[AT_020]_a {1}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Plating-	Aerosol/droplet separator	0.10	0.10	0.10	-	-
			0.00	0.00	0.00	-	-
[AT_020]_a {2}	Electropolishing	-	0.10	0.10	0.10	-	-
		-	0.00	0.00	0.00	-	-
[AT_020]_a {3}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Chemical polishing-Electrolytically assisted pickling, activation and degreasing-	-	0.10	0.10	0.10	-	-
		-	0.00	0.00	0.00	-	-

[AT_020]_a {4}	Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Plating-Alkaline degreasing-	-	0.01	0.01	0.01	-	-
		-	0.00	0.00	0.00	-	-
[AT_020]_a {5}	Plating-	Aerosol/droplet separator	0.10	0.10	0.10	-	-
			0.00	0.00	0.00	0.10	-
[AT_020]_a {6}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-	Aerosol/droplet separator	0.10	0.10	0.10	-	-
			0.00	0.00	0.00	-	-
[BG_006]_a {1}	Plating	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.50	0.00
[BG_006]_a {6}	Electrocoating (e-coating)	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.50	0.00
[BG_006]_a {8}	Metal stripping	No technique applied	0.00	0.00	0.00	0.50	0.00
[BG_006]_a {10}	Metal stripping	No technique applied	0.00	0.00	0.00	0.50	0.00
[CZ_007]_a {5}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.01	0.00	0.00	-	-
[CZ_007]_a {6}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.01	0.00	0.00	-	-
		-	0.01	0.00	0.00	-	-
[CZ_011]_a {1}	Anodising-Anodising-Metal stripping-Pickling (not electrically), descaling and desmutting	-	-	0.00	-	0.50	0.00
		-	-	0.00	-	0.50	0.00
		-	-	0.00	-	0.50	0.00
[CZ_011]_a {2}	Anodising-Pickling (not electrically), descaling and desmutting-Metal stripping-Plating	-	-	0.00	-	0.50	0.00
		-	-	0.00	-	0.50	0.00
		-	-	0.00	-	0.50	0.00
[CZ_011]_a {4}	Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-Plating	-	-	0.00	-	0.50	0.00
		-	-	0.00	-	0.50	0.00
[DE_019]_a {3}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Plating-	Aerosol/droplet separator	0.10	0.10	0.10	0.50	-
[DE_023]_a {11}	Pickling (not electrically), descaling and desmutting-Plating-	-	0.01	0.01	0.01	0.50	0.00
		-	0.00	0.00	0.00	0.50	0.00
[DE_023]_a {12}	Plating-	-	0.00	0.00	0.00	0.50	0.00
[DE_025]_a {3}	Plating-Electrolytically assisted pickling, activation and degreasing-	No technique applied	0.03	0.01	0.00	-	-
[DE_025]_a {4}		No technique applied	0.00	0.00	0.00	-	-
[DE_025]_a {7}	Plating	No technique applied	0.03	0.01	0.00	-	-
[DE_025]_a {10}	Plating	No technique applied	0.02	0.01	0.00	-	-
[DE_025]_a {11}	Plating-Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting	No technique applied	0.02	0.01	0.00	-	-
[DE_025]_a {14}	Other	Scrubber- absorption (acid/alkaline)	0.02	0.01	0.00	0.05	-
[DE_045]_a {2}	Other-	Scrubber- absorption (acid/alkaline)	0.05	0.05	0.05	-	-

[DE_045]_a {4}	Other-	Scrubber- absorption (acid/alkaline)	0.05	0.05	0.05	-	-
[DE_048]_a {2}	Plating-	-	0.01	0.01	0.01	-	-
[DE_054]_a {1}	Alkaline degreasing-Other	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.50	0.00
[DE_054]_a {2}	Alkaline degreasing-Other	Aerosol/droplet separator	0.00	0.00	0.00	0.50	0.00
[DE_054]_a {3}	Plating-Other-	Aerosol/droplet separator	0.00	0.00	0.00	0.50	0.00
[DE_054]_a {6}	Other	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.50	0.00
[DE_077]_a {2}	Degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)- Other-	Scrubber- absorption (acid/alkaline)-Aerosol/droplet separator-	0.02	0.01	0.00	0.50	-
[DE_077]_a {3}	Degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Other-Electrocoating (e-coating)	Scrubber- absorption (acid/alkaline)	0.01	0.00	0.00	0.50	-
[DE_079]_a {7}	Plating	No technique applied	0.01	0.00	0.00	0.50	-
[DE_079]_a {14}	Other	No technique applied	0.01	-	-	1.00	-
			0.00	-	-	1.00	-
[ES_003]_a {1}	Plating	Scrubber- absorption (acid/alkaline)	0.08	0.07	0.01	0.10	-
			0.01	0.00	0.00	0.10	-
			0.00	0.00	0.00	0.10	-
[ES_003]_a {2}	Plating	Scrubber- absorption (acid/alkaline)	0.04	0.02	0.00	0.10	-
			0.01	0.00	0.00	0.10	-
			0.00	0.00	0.00	0.10	-
[ES_003]_a {3}	Plating	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.10	-
			0.00	0.00	0.00	0.10	-
			0.00	0.00	0.00	0.10	-
[ES_009]_a {1}	Alkaline degreasing-Other-Electrocoating (e-coating)-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.02	0.00
			0.00	0.00	0.00	0.02	0.00
			0.00	0.00	0.00	0.02	0.00
[ES_009]_a {2}	Alkaline degreasing-Other-Electrocoating (e-coating)-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.02	0.00
			0.00	0.00	0.00	0.02	0.00
			0.00	0.00	0.00	0.02	0.00
[ES_009]_a {3}	Alkaline degreasing-Other-Electrocoating (e-coating)-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.02	< 0,000 03
			0.00	0.00	0.00	0.02	0.00
			0.00	0.00	0.00	0.02	0.00
[ES_010]_a {1}	Metal stripping-Plating-	Scrubber- absorption (acid/alkaline)	0.04	0.04	0.04	-	-
			0.01	0.01	0.01	-	-
[ES_010]_a {2}	Metal stripping-Plating-	Scrubber- absorption (acid/alkaline)	0.04	0.04	0.04	-	-
			0.02	0.01	0.01	-	-
[ES_010]_a {3}	Metal stripping-Plating-	Scrubber- absorption (acid/alkaline)	0.07	0.07	0.07	-	-
			0.02	0.01	0.01	-	-
[ES_010]_a {4}	Etching or pickling of plastics-Plating-	Scrubber- absorption (acid/alkaline)	0.02	0.02	0.02	-	-

[ES_014]_a {1}	Electrocoating (e-coating)	Other	0.09	0.09	0.09	-	0.00
[ES_014]_a {2}	Electrocoating (e-coating)	Straight thermal oxidation-Other-	0.04	0.04	0.04	-	0.00
[ES_030]_a {1}	Plating-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	-	-
[ES_030]_a {2}	Etching or pickling of plastics-Plating-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	-	-
[FI_002]_a {1}	Aqueous cleaning-Plating-Aqueous cleaning-Plating	Scrubber- absorption (acid/alkaline)	-	0.00	-	-	-
[FI_002]_a {2}	Alkaline degreasing-Plating	Scrubber- absorption (acid/alkaline)	-	0.00	-	-	-
[FI_002]_a {3}	Plating	Scrubber- absorption (acid/alkaline)	-	0.00	-	-	-
[FI_003]_a {1}		-	0.03	-	-	-	-
[FR_009]_a {5}	Plating-Pickling (not electrically), descaling and desmutting-	-	-	0.01	-	5.00	0.00
		-	-	0.00	-	5.00	0.00
[FR_009]_a {6}	Plating	-	-	0.00	-	5.00	0.00
[FR_011]_a {1}	Alkaline degreasing-Alkaline degreasing-Other	No technique applied	0.00	0.00	0.00	5.00	-
[FR_014]_a {2}	Other	Other	0.01	0.01	0.01	0.10	-
[FR_014]_a {3}		Absorption	0.00	0.00	0.00	0.10	-
[FR_014]_a {4}		Absorption	0.01	0.01	0.01	0.10	-
[FR_014]_a {5}		Absorption	0.01	0.01	0.01	0.10	-
[FR_014]_a {6}		-	0.01	0.01	0.01	0.10	-
[FR_014]_a {7}		Absorption	0.01	0.01	0.01	0.10	-
[FR_014]_a {9}		Absorption	0.00	0.00	0.00	0.10	-
[FR_015]_a {1}	Electrolytically assisted pickling, activation and degreasing-Plating-	No technique applied	-	0.02	-	5.00	-
			-	0.01	-	5.00	-
[FR_015]_a {5}	Electrolytically assisted pickling, activation and degreasing-Plating-	No technique applied	-	0.01	-	5.00	-
[FR_015]_a {7}	Electrolytically assisted pickling, activation and degreasing-Plating-Other-	No technique applied	-	0.02	-	5.00	-
			-	0.02	-	5.00	-
[FR_015]_a {9}	Anodising-Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	0.03	-	5.00	-
			-	0.01	-	5.00	-
[FR_016]_a {1}	Other	No technique applied	0.00	0.00	0.00	5.00	0.00
[FR_016]_a {2}	Metal stripping	No technique applied	0.00	0.00	0.00	5.00	0.00
[FR_016]_a {3}	Anodising	No technique applied	0.00	0.00	0.00	5.00	0.00
[FR_016]_a {4}	Other	No technique applied	0.00	0.00	0.00	5.00	0.00
[FR_016]_a {5}	Etching or pickling of plastics	No technique applied	0.00	0.00	0.00	5.00	0.00
[FR_016]_a {8}	Plating	No technique applied	0.00	0.00	0.00	5.00	0.00
[FR_016]_a {9}	Plating	No technique applied	0.00	0.00	0.00	5.00	0.00

[FR_016]_a {10}	Plating	No technique applied	0.00	0.00	0.00	5.00	0.00
[FR_016]_a {11}	Plating	No technique applied	0.00	0.00	0.00	5.00	0.00
[FR_016]_a {12}	Plating	-	0.00	0.00	0.00	5.00	0.00
[FR_016]_a {13}	Plating	-	0.00	0.00	0.00	5.00	0.00
[FR_017]_a {1}	Alkaline degreasing--Rinsing	-	-	0.00	-	5.00	0.00
		-	-	0.00	-	5.00	0.00
		-	-	0.00	-	5.00	0.00
[FR_017]_a {2}	Rinsing-Plating--	-	-	0.01	-	5.00	0.00
		-	-	0.00	-	5.00	0.00
		-	-	0.00	-	5.00	0.00
[FR_018]_a {1}	Other-	Scrubber- absorption (acid/alkaline)	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {2}	Metal stripping-Conditioning of plastics-	Scrubber- absorption (acid/alkaline)	-	0.01	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {3}	Metal stripping-Conditioning of plastics-Etching or pickling of plastics-Other--Plating-	Scrubber- absorption (acid/alkaline)	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {4}	Plating-	Scrubber- absorption (acid/alkaline)	-	0.11	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {5}	Aqueous cleaning-Plating-Other-	Scrubber- absorption (acid/alkaline)	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {6}	Metal stripping	Scrubber- absorption (acid/alkaline)	-	0.04	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {7}	Other	Scrubber- absorption (acid/alkaline)	-	0.01	-	1.00	0.00
			-	0.01	-	1.00	0.00
[FR_018]_a {8}	Other-	Scrubber- absorption (acid/alkaline)	-	0.01	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {9}	Other	Scrubber- absorption (acid/alkaline)	-	0.02	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {10}	Other	Scrubber- absorption (acid/alkaline)	-	0.01	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {11}	Conditioning of plastics- Etching or pickling of plastics-Other	Scrubber- absorption (acid/alkaline)	-	0.00	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {12}	Plating	Scrubber- absorption (acid/alkaline)	29.7	14.8	0.00	1.00	0.27
			-	0.00	-	1.00	0.00
[FR_018]_a {13}	Plating-Other-	Scrubber- absorption (acid/alkaline)	-	0.18	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_018]_a {14}	Metal stripping-	Scrubber- absorption (acid/alkaline)	-	0.01	-	1.00	0.00
			-	0.00	-	1.00	0.00
[FR_020]_a {2}		Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
[FR_020]_a {3}	Alkaline degreasing-Rinsing-Chemical milling-Other-Rinsing-Anodising-degreasing-	Scrubber- absorption (acid/alkaline)	0.04	0.02	0.00	5.00	0.00
			0.01	0.01	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00

[FR_020]_a {4}	Metal stripping-Rinsing-Other-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
[FR_020]_a {5}	Metal stripping--Rinsing-Other-	Scrubber- absorption (acid/alkaline)	0.01	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
[FR_020]_a {6}	Chemical milling-Other-Rinsing-Alkaline degreasing	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.00	5.00	0.00
			0.01	0.00	0.00	5.00	0.00
			0.01	0.00	0.00	5.00	0.00
[FR_020]_a {7}	Alkaline degreasing-Rinsing-Other	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.01	5.00	0.00
[FR_020]_a {8}	Alkaline degreasing-Rinsing-Other	Scrubber- absorption (acid/alkaline)	0.02	0.01	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
[FR_024]_a {1}	Alkaline degreasing-Other-Plating	Aerosol/droplet separator	-	0.00	-	5.00	-
[FR_033]_a {1}	Plating-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Rinsing-Other	No technique applied	-	0.02	-	5.00	0.00
			-	0.00	-	5.00	0.00
			-	0.00	-	5.00	0.00
[FR_033]_a {7}	Plating	No technique applied	-	0.00	-	5.00	0.00
			-	0.00	-	5.00	0.00
			-	0.00	-	5.00	0.00
[FR_033]_a {10}	-Pickling (not electrically), descaling and desmutting-Other-Rinsing-	No technique applied	-	0.00	-	5.00	0.00
			-	0.00	-	5.00	0.00
			-	0.00	-	5.00	0.00
[FR_033]_a {19}	Abrasive blasting	Fabric filter	-	0.03	-	-	0.00
			-	0.02	-	-	0.00
			-	0.00	-	-	0.00
[FR_035]_a {1}	Plating--Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)-Other-Alkaline degreasing--Chemical polishing- Etching and descaling of aluminium-Etching – Alkaline etching of aluminium-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	5.00	0.00
			0.01	0.01	0.01	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
[FR_035]_a {2}	Plating--Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)-Other-Alkaline degreasing--Chemical polishing- Etching and descaling of aluminium-Etching – Alkaline etching of aluminium-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	-
[FR_035]_a {3}	Etching or pickling of plastics-Conditioning of plastics-Plating-Electrocoating (e-coating)- Rinsing-Degreasing-Metal stripping-Other-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
[FR_035]_a {4}	Pickling (not electrically), descaling and desmutting-Metal stripping-Degreasing- Electrolytically assisted pickling, activation and degreasing--Other-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00

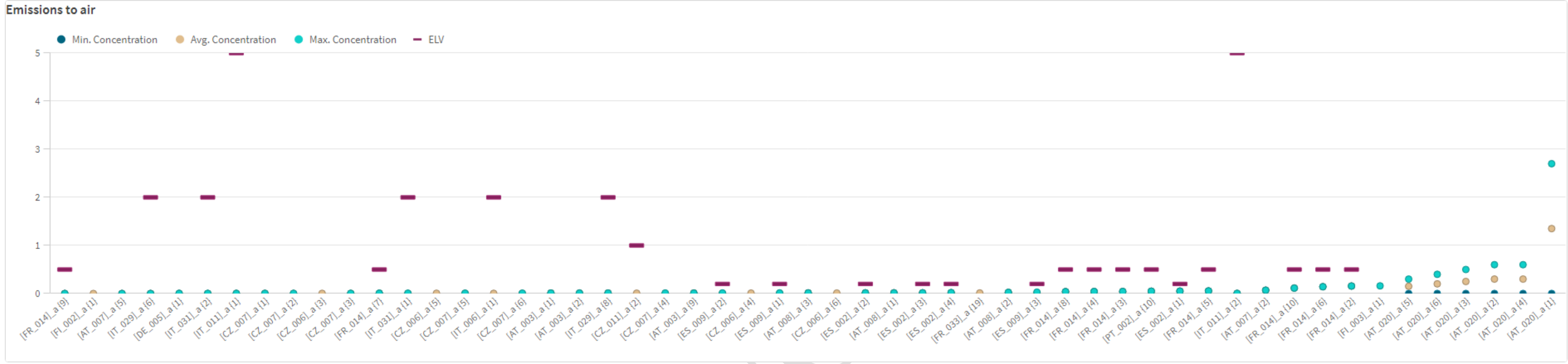
[FR_035]_a {5}	Plating--Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)-Other-Alkaline degreasing--Chemical polishing- Etching and descaling of aluminium-Etching – Alkaline etching of aluminium-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
[FR_035]_a {6}	Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing- Rinsing-Degreasing--Other	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	5.00	0.00
			0.01	0.01	0.01	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
[FR_035]_a {7}	Electrocoating (e-coating)-Other	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	-
[FR_036]_a {7}	Plating-	Scrubber- absorption (acid/alkaline)	-	0.01	-	-	-
[IT_002]_a {7}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating-Lacquering-Drying-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	1.00	0.00
			0.01	0.01	0.01	2.00	0.00
			0.00	0.00	0.00	1.00	0.00
[IT_002]_a {9}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing- Plating-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	1.00	0.00
			0.01	0.01	0.01	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[IT_002]_a {10}	Metal stripping-	Scrubber- absorption (acid/alkaline)	0.00	0.01	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[IT_002]_a {12}	Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Etching – Alkaline etching of aluminium-Etching and descaling of aluminium-Plating-	Scrubber- absorption (acid/alkaline)	0.01	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
[IT_002]_a {13}	Etching and descaling of aluminium-Plating-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
[IT_004]_a {3}	Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing- Plating-	-	0.01	0.01	0.01	0.10	0.00
		-	0.01	0.01	0.01	0.10	0.00
		-	0.01	0.01	0.01	0.10	0.00
[IT_004]_a {4}	Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing--Plating-	-	0.01	0.01	0.01	0.10	0.00
		-	0.01	0.01	0.01	0.10	0.00
[IT_008]_a {1}	Alkaline degreasing-Rinsing-Electrolytically assisted pickling, activation and degreasingPlating-	-	0.00	0.00	0.00	1.00	0.19
		-	0.00	0.00	0.00	1.00	0.20
[IT_008]_a {3}	Alkaline degreasing-Rinsing-Electrolytically assisted pickling, activation and degreasing- Plating--Electrocoating (e-coating)--	-	0.38	0.15	0.04	1.00	18.60
		-	0.00	0.00	0.00	1.00	0.54
[IT_008]_a {4}	Alkaline degreasing-Rinsing-Electrolytically assisted pickling, activation and degreasing-Plating--Other--Drying-	-	0.00	0.00	0.00	1.00	0.22
		-	0.00	0.00	0.00	1.00	0.28
[IT_008]_a {5}	Drying	-	0.00	0.00	0.00	1.00	0.03
		-	0.00	0.00	0.00	1.00	0.03
[IT_009]_a {1}	Degreasing-Alkaline degreasing-Electrolytically assisted pickling,	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	0.10	-

	activation and degreasing-Plating-Rinsing-						
[IT_009]_a {3}	Rinsing-Other-Degreasing-Alkaline degreasing-Metal stripping-Alkaline degreasing-Plating-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.00	0.10	-
[IT_009]_a {6}	Degreasing-Pickling (not electrically), descaling and desmutting-Alkaline degreasing-Plating	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	0.10	-
[IT_011]_a {1}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
[IT_011]_a {2}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
			0.00	0.00	0.00	1.00	0.00
[IT_013]_a {4}	Electrocoating (e-coating)-Pickling (not electrically), descaling and desmutting-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.08
			0.00	0.00	0.00	0.10	0.08
[IT_020]_a {1}	Anodising-Electrocoating (e-coating)-	Scrubber- absorption (acid/alkaline)	0.03	0.02	0.00	0.10	0.00
			0.02	0.02	0.00	0.10	0.00
			0.01	0.01	0.00	0.10	0.00
[IT_029]_a {12}	Other	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	0.10	-
[IT_029]_a {13}	Other	No technique applied	0.01	0.01	0.01	0.10	-
[IT_030]_a {1}	Plating-	-	0.00	0.00	0.00	0.10	0.00
		-	0.00	0.00	0.00	0.10	0.00
[IT_030]_a {3}	Plating-	-	0.01	0.01	0.00	0.10	0.00
		-	0.00	0.00	0.00	0.10	0.00
[IT_031]_a {1}	Plating-Rinsing- Electrolytically assisted pickling, activation and degreasing--Degreasing- Pickling (not electrically), descaling and desmutting-Other-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
[IT_031]_a {2}	Metal stripping-Degreasing-Rinsing-Pickling (not electrically), descaling and desmutting-Rinsing-Electrolytically assisted pickling, activation and degreasing-Other	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
[IT_032]_a {11}	Plating-	No technique applied	0.00	0.00	0.00	0.10	0.00
[IT_032]_a {12}	Plating	No technique applied	0.00	0.00	0.00	0.10	0.00
[IT_032]_a {18}	Plating-Other-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Plating-	No technique applied	0.00	0.00	0.00	0.10	0.00
			0.00	0.00	0.00	0.10	0.00
[IT_032]_a {20}	Other	Regenerative thermal oxidation	0.09	0.05	0.02	5.00	0.00
[PT_002]_a {10}	Other	Scrubber- absorption (acid/alkaline)	0.03	0.03	0.03	0.10	0.00
[SE_006]_a {1}	Pickling (not electrically), descaling and desmutting-	Scrubber- absorption (acid/alkaline)	-	0.00	-	-	0.00
[SE_006]_a {2}	Electropolishing	-	-	0.00	-	-	0.00
[SE_006]_a {4}	Electropolishing	-	-	0.00	-	-	0.00
[SE_006]_a {5}	Pickling (not electrically), descaling and desmutting-Electropolishing-	Scrubber- absorption (acid/alkaline)	-	0.02	-	-	0.00

[SE_006]_a {6}	Electropolishing	-	-	0.00	-	-	0.00

3.2.4.10 Zinc

The reported data for Zn emissions to air are presented in Figure 3-37. Emission data and contextual information are also presented in Table 3-38.



Source: [168, TWG 2023]

Figure 3-37: Zn emissions to air in electrolytic or chemical plating plants

Table 3-36: Reported data and contextual information for Zn emissions to air in electrolytic or chemical plating plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[AT_003]_a {1}	Pickling (not electrically), descaling and desmutting-Other-Metal stripping-Plating	Aerosol/droplet separator-Other-Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	-	-
[AT_003]_a {2}	Degreasing-Plating-	Scrubber- absorption (acid/alkaline)-Other-Aerosol/droplet separator	0.01	0.01	0.01	-	-
[AT_003]_a {9}	Alkaline degreasing-Plating-	Scrubber- absorption (acid/alkaline)-Other-Mist filter (demister)	0.01	0.01	0.01	-	-
[AT_007]_a {2}	Plating-Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-	Mist filter (demister)	0.07	0.07	0.07	-	-
[AT_007]_a {5}	Other	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	-	-
[AT_008]_a {1}	Other-Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing	Scrubber- absorption (acid/alkaline)	0.02	0.02	0.02	-	-
[AT_008]_a {2}	Pickling (not electrically), descaling and desmutting-Plating-Deburring and/or tumbling-Rinsing	Scrubber- absorption (acid/alkaline)	0.02	0.02	0.02	-	-
[AT_008]_a {3}	Pickling (not electrically), descaling and desmutting-Rinsing-Drying-Degreasing- Other-Electrolytically assisted pickling, activation and degreasing- Deburring and/or tumbling-Plating	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	-	-
[AT_020]_a {1}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Plating-	Aerosol/droplet separator	2.70	2.70	2.70	-	-
			0.00	0.00	0.00	-	-
[AT_020]_a {2}	Electropolishing	-	0.60	0.60	0.60	-	-
		-	0.00	0.00	0.00	-	-
[AT_020]_a {3}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Chemical polishing-Electrolytically assisted pickling, activation and degreasing-	-	0.50	0.50	0.50	-	-
		-	0.00	0.00	0.00	-	-
[AT_020]_a {4}	Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Plating- Alkaline degreasing-	-	0.60	0.60	0.60	-	-
		-	0.00	0.00	0.00	-	-
[AT_020]_a {5}	Plating-	Aerosol/droplet separator	0.30	0.30	0.30	-	-
			0.00	0.00	0.00	-	-
[AT_020]_a {6}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-	Aerosol/droplet separator	0.40	0.40	0.40	-	-
			0.00	0.00	0.00	-	-
[CZ_006]_a {3}		-	-	0.00	-	-	-
[CZ_006]_a {4}		-	-	0.01	-	-	-
[CZ_006]_a {5}		-	-	0.01	-	-	-
[CZ_006]_a {6}		-	-	0.01	-	-	-
[CZ_007]_a {1}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-	Aerosol/droplet separator-Cyclone	0.01	0.00	0.00	-	-
			0.01	0.00	0.00	-	-

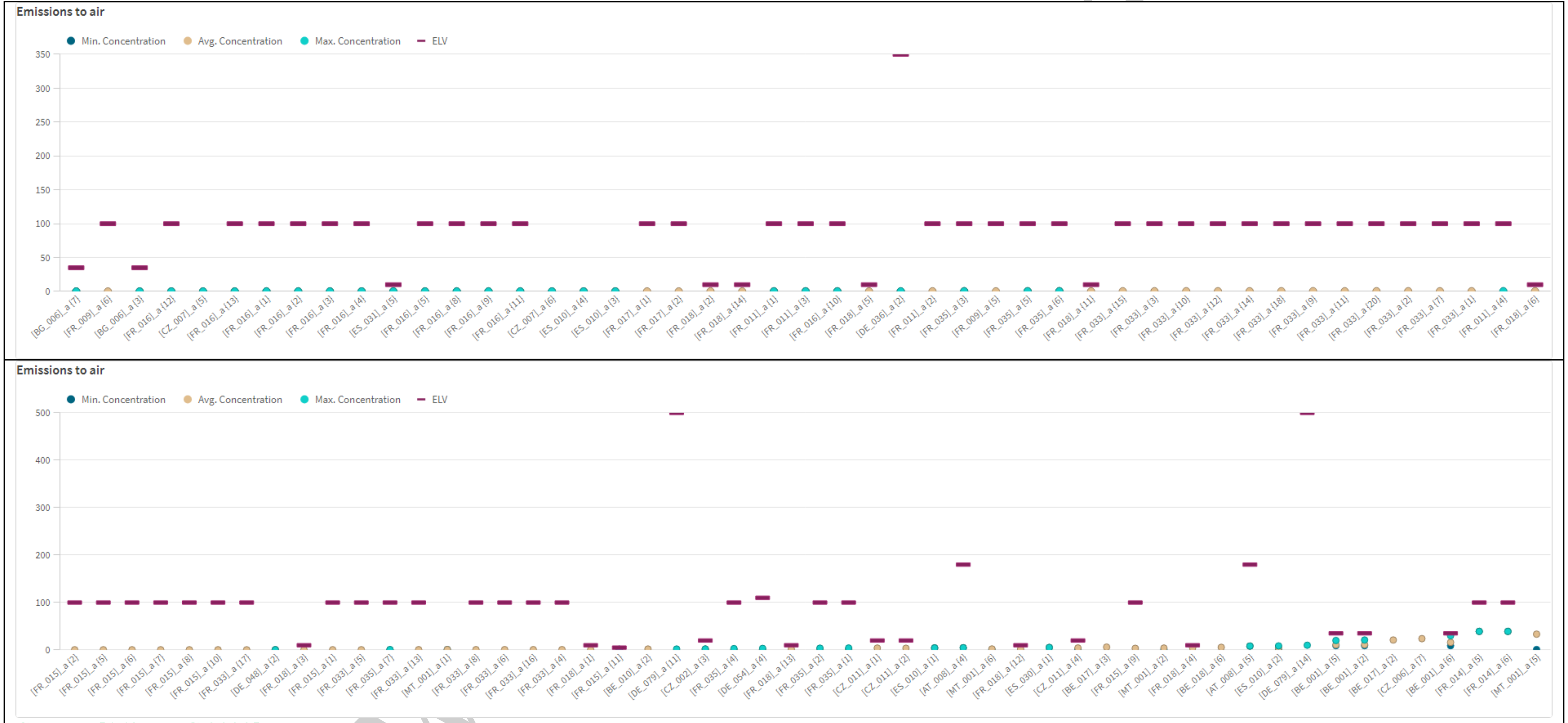
	Pickling (not electrically), descaling and desmutting-Rinsing-						
[CZ_007] _a {2}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	Aerosol/droplet separator-Cyclone	0.01	0.00	0.00	-	-
			0.01	0.00	0.00	-	-
			0.01	0.00	0.00	-	-
[CZ_007] _a {3}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.01	0.01	0.00	-	-
		-	0.01	0.00	0.00	-	-
		-	0.01	0.00	0.00	-	-
[CZ_007] _a {4}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.01	0.01	0.01	-	-
		-	0.01	0.00	0.00	-	-
		-	0.01	0.00	0.00	-	-
[CZ_007] _a {5}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.01	0.01	0.01	-	-
		-	0.01	0.01	0.00	-	-
		-	0.01	0.00	0.00	-	-
[CZ_007] _a {6}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.01	0.01	0.01	-	-
		-	0.01	0.00	0.00	-	-
		-	0.01	0.00	0.00	-	-
[CZ_011] _a {2}	Anodising-Pickling (not electrically), descaling and desmutting-Metal stripping-Plating	-	-	0.01	-	1.00	0.00
		-	-	0.01	-	1.00	0.00
		-	-	0.01	-	1.00	0.00
[DE_005] _a {1}		No technique applied	0.00	0.00	0.00	-	0.00
[DE_005] _a {2}		-	0.00	0.00	0.00	-	0.00
[DE_005] _a {3}		-	0.00	0.00	0.00	-	0.00
[DE_005] _a {4}		-	0.00	0.00	0.00	-	0.00
[DE_005] _a {5}		-	0.00	0.00	0.00	-	0.00
[DE_005] _a {6}		-	0.00	0.00	0.00	-	0.00
[DE_005] _a {7}		-	0.00	0.00	0.00	-	0.00
[DE_005] _a {8}		-	0.00	0.00	0.00	-	0.00
[DE_005] _a {9}		-	0.00	0.00	0.00	-	0.00
[ES_002] _a {1}	Pickling (not electrically), descaling and desmutting-Plating-Other-	No technique applied	0.05	0.05	0.05	0.20	0.00
[ES_002] _a {2}	Pickling (not electrically), descaling and desmutting-Plating-Other	No technique applied	0.01	0.01	0.01	0.20	0.00
[ES_002] _a {3}	Pickling (not electrically), descaling and desmutting-Alkaline degreasing-Other-Plating	No technique applied	0.02	0.02	0.02	0.20	0.00
[ES_002] _a {4}	Pickling (not electrically), descaling and desmutting-Alkaline degreasing-Other-Plating-	No technique applied	0.02	0.02	0.02	0.20	0.00
[ES_009] _a {1}	Alkaline degreasing-Other-Electrocoating (e-coating)-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	0.20	0.00
			0.01	0.01	0.01	0.20	0.00

			0.01	0.01	0.01	0.20	0.00
[ES_009]_a {2}	Alkaline degreasing-Other-Electrocoating (e-coating)-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	0.20	0.00
			0.00	0.00	0.00	0.20	0.00
			0.00	0.00	0.00	0.20	0.00
[ES_009]_a {3}	Alkaline degreasing-Other-Electrocoating (e-coating)-	Scrubber- absorption (acid/alkaline)	0.03	0.03	0.03	0.20	0.00
			0.01	0.01	0.01	0.20	0.00
			0.00	0.00	0.00	0.20	0.00
[FI_002]_a {1}	Aqueous cleaning-Plating	Scrubber- absorption (acid/alkaline)	-	0.00	-	-	-
[FI_002]_a {2}	Alkaline degreasing-Plating	Scrubber- absorption (acid/alkaline)	-	0.00	-	-	-
[FI_002]_a {3}	Plating	Scrubber- absorption (acid/alkaline)	-	0.00	-	-	-
[FI_003]_a {1}		-	0.16	-	-	-	-
[FR_014]_a {2}	Other	Other	0.16	0.16	0.16	0.50	-
[FR_014]_a {3}		Absorption	0.04	0.04	0.04	0.50	-
[FR_014]_a {4}		Absorption	0.04	0.04	0.04	0.50	-
[FR_014]_a {5}		Absorption	0.05	0.05	0.05	0.50	-
[FR_014]_a {6}		-	0.14	0.14	0.14	0.50	-
[FR_014]_a {7}		Absorption	0.01	0.01	0.01	0.50	-
[FR_014]_a {8}		-	0.04	0.04	0.04	0.50	-
[FR_014]_a {9}		Absorption	0.00	0.00	0.00	0.50	-
[FR_014]_a {10}		Absorption	0.11	0.11	0.11	0.50	-
[FR_033]_a {19}	Abrasive blasting-Abrasive blasting	Fabric filter	-	0.02	-	-	0.00
			-	0.01	-	-	0.00
			-	0.00	-	-	0.00
[IT_006]_a {1}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing- Plating-Other-	Scrubber- absorption (acid/alkaline)	-	0.01	-	2.00	-
			-	0.00	-	2.00	-
[IT_011]_a {1}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
[IT_011]_a {2}	Plating-Degreasing-Electrolytically assisted pickling, activation and degreasing-	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.06	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
			0.00	0.00	0.00	5.00	0.00
[IT_029]_a {6}	Other	Scrubber- absorption (acid/alkaline)	0.00	0.00	0.00	2.00	-
[IT_029]_a {8}	Other	No technique applied	0.01	0.01	0.01	2.00	-
[IT_031]_a {1}	Plating-Rinsing- Electrolytically assisted pickling, activation and degreasing- Degreasing- Pickling (not electrically), descaling and desmutting-Other	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	2.00	0.00
			0.00	0.00	0.00	2.00	0.00
			0.00	0.00	0.00	2.00	0.00
[IT_031]_	Metal stripping-Degreasing-Rinsing-	Scrubber- absorption	0.00	0.00	0.00	2.00	0.00

a {2}	Pickling (not electrically), descaling and desmutting- Electrolytically assisted pickling, activation and degreasing- Other	(acid/alkaline)	0.00	0.00	0.00	2.00	0.00
			0.00	0.00	0.00	2.00	0.00
[PT_002]_a {10}	Other	Scrubber- absorption (acid/alkaline)	0.05	0.05	0.05	0.50	0.00

3.2.4.11 SO_X

The reported data for SO_X emissions to air are presented in Figure 3-38. Emission data and contextual information are also presented in Table 3-39.



Source: [168, TWG 2023]

Figure 3-38: SO_X emissions to air in electrolytic or chemical plating plants

Table 3-37: Reported data and contextual information for SO_X emissions to air in electrolytic or chemical plating plants

.	Associated processes	Applied techniques	Max	Avg.	Min.	ELV	Load
[AT_008]_a {4}	Drying	-	4.60	4.60	4.60		-
[AT_008]_a {5}	Drying	-	8.20	8.20	8.20		-
[BE_001]_a {2}	Heat treatment	No technique applied	21.00	11.17	9.00	35.00	-
[BE_001]_a {5}	Drying	No technique applied	20.00	11.75	9.00	35.00	-
			9.00	9.00	9.00	35.00	-
[BE_001]_a {6}	Drying	No technique applied	30.00	16.00	9.00	35.00	-
[BE_010]_a {2}	Pickling (not electrically), descaling and desmutting	No technique applied	-	2.00	-	-	-
[BE_017]_a {2}	Lacquering	No technique applied	-	21.00	-	-	-
[BE_017]_a {3}	Lacquering	-	-	6.00	-	-	-
[BE_018]_a {6}	Drying	Regenerative thermal oxidation	-	5.50	-	-	-
[BG_006]_a {3}	Other	No technique applied	0.00	0.00	0.00	35.00	0.00
[BG_006]_a {7}	Other	No technique applied	0.00	0.00	0.00	35.00	0.00
[CZ_002]_a {3}	Plating	Aerosol/droplet separator	2.16	2.13	2.07	20.00	0.01
			1.82	1.89	1.96	20.00	0.01
			1.82	1.78	1.76	20.00	0.01
[CZ_006]_a {7}		-	-	23.87	-	-	-
[CZ_007]_a {5}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.04	0.04	0.00	-	-
		-	0.02	0.02	0.00	-	-
		-	0.02	0.02	0.00	-	-
[CZ_007]_a {6}	Alkaline degreasing-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing-Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.11	0.09	0.06	-	-
		-	0.04	0.04	0.00	-	-
		-	0.02	0.02	0.00	-	-
[CZ_011]_a {1}	Anodising-Anodising-Metal stripping-Pickling (not electrically), descaling and desmutting	-	-	4.20	-	20.00	0.01
		-	-	4.20	-	20.00	0.01
		-	-	3.70	-	20.00	0.02
[CZ_011]_a {2}	Anodising-Pickling (not electrically), descaling and desmutting-Metal stripping-Plating	-	-	4.20	-	20.00	0.01
		-	-	4.20	-	20.00	0.01
		-	-	2.50	-	20.00	0.02
[CZ_011]_a {4}	Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-Plating	-	-	5.90	0.80	20.00	0.13
		-	-	4.20	-	20.00	0.05
		-	-	2.50	-	20.00	0.06
[DE_036]_a {2}	Plating	Scrubber- absorption (acid/alkaline)	0.24	0.24	0.24		-
			0.00	0.00	0.00		-
[DE_048]_a {2}	Plating-	-	0.60	0.60	0.60	-	-
[DE_054]_a {4}	Alkaline degreasing-Other	Scrubber- absorption (acid/alkaline)	3.30	1.00	0.50		0.01
[DE_079]	Anodising	No technique applied	2.00	-	-		-

_a {11}			0.00	-	-		-
[DE_079]_a {14}	Other	No technique applied	10.00	-	-		-
[ES_010]_a {1}	Metal stripping-Plating-	Scrubber- absorption (acid/alkaline)	4.30	4.30	4.30	-	-
[ES_010]_a {2}	Plating-	Scrubber- absorption (acid/alkaline)	8.60	8.60	8.60	-	-
			0.12	0.12	0.12	-	-
[ES_010]_a {3}	Plating-	Scrubber- absorption (acid/alkaline)	0.12	0.12	0.12	-	-
[ES_010]_a {4}	Etching or pickling of plastics-Plating-	Scrubber- absorption (acid/alkaline)	0.12	0.12	0.12	-	-
[ES_030]_a {1}	Plating-	Scrubber- absorption (acid/alkaline)	5.16	5.16	5.16	-	-
[ES_031]_a {5}	Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and Degreasing-Degreasing--	Scrubber- absorption (acid/alkaline)	0.10	0.10	0.10	10.00	0.00
[FR_009]_a {5}	Plating-Pickling (not electrically), descaling and desmutting-	-	-	0.40	-		-
		-	-	0.14	-		0.00
		-	-	0.00	-		0.00
[FR_009]_a {6}	Plating	-	-	0.00	-		0.00
[FR_011]_a {1}	Alkaline degreasing-Alkaline degreasing-Other	No technique applied	0.20	0.20	0.20		-
[FR_011]_a {2}	Other	No technique applied	-	0.25	-		-
[FR_011]_a {3}	Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-	No technique applied	0.20	0.20	0.20		-
[FR_011]_a {4}		-	0.48	-	-		-
[FR_014]_a {5}		Absorption	39.10	39.10	39.10		-
[FR_014]_a {6}		-	39.10	39.10	39.10		-
[FR_015]_a {1}	Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	0.61	-		-
[FR_015]_a {2}	Electrolytically assisted pickling, activation and degreasing-Plating-Other-	No technique applied	-	0.55	-		-
[FR_015]_a {5}	Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	0.55	-		-
[FR_015]_a {6}	Electrolytically assisted pickling, activation and degreasing-Plating-Other-	No technique applied	-	0.55	-		-
[FR_015]_a {7}	Electrolytically assisted pickling, activation and degreasing-Plating-Other-	No technique applied	-	0.55	-		-
[FR_015]_a {8}	Electrolytically assisted pickling, activation and degreasing-Other	Other	-	0.55	-		-
[FR_015]_a {9}	Anodising-Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	3.53	-		-
[FR_015]_a {10}	Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	0.55	-		-
[FR_015]_a {11}	Use of fuel-fired burners (combustion)	Fabric filter	1.71	0.48	0.32	5.00	-
			-	0.32	-	5.00	-
[FR_016]_a {1}	Other	No technique applied	0.10	0.10	0.10		0.00

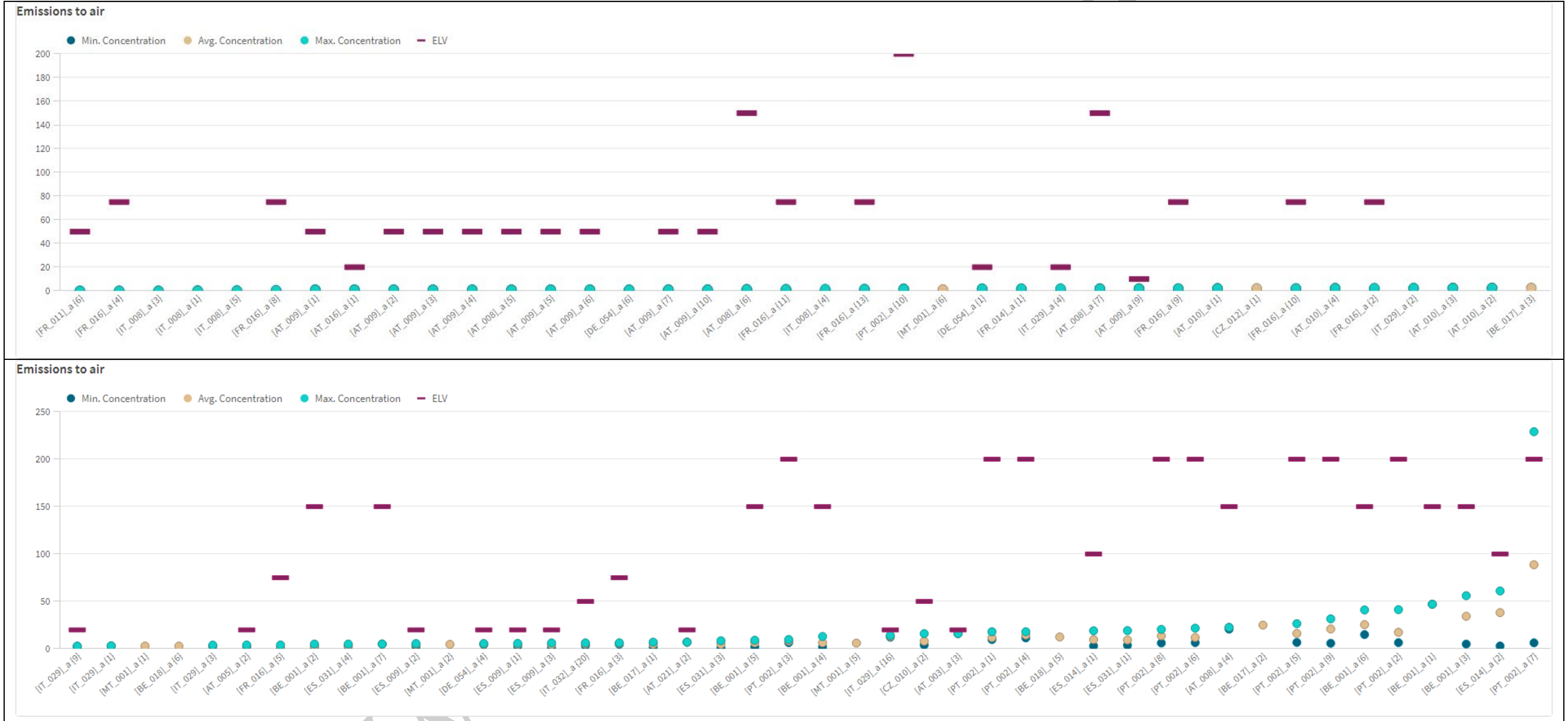
[FR_016] _a {2}	Metal stripping	No technique applied	0.10	0.10	0.10		0.00
[FR_016] _a {3}	Anodising	No technique applied	0.10	0.10	0.10		0.00
[FR_016] _a {4}	Other	No technique applied	0.10	0.10	0.10		0.00
[FR_016] _a {5}	Etching or pickling of plastics	No technique applied	0.10	0.10	0.10		0.00
[FR_016] _a {8}	Plating	No technique applied	0.10	0.10	0.10		0.00
[FR_016] _a {9}	Plating	No technique applied	0.10	0.10	0.10		0.00
[FR_016] _a {10}	Plating	No technique applied	0.20	0.20	0.20		0.00
[FR_016] _a {11}	Plating	No technique applied	0.10	0.10	0.10		0.00
[FR_016] _a {12}	Plating	-	0.04	0.04	0.04		-
[FR_016] _a {13}	Plating	-	0.05	0.05	0.05		0.00
[FR_017] _a {1}	Alkaline degreasing-Alkaline degreasing-Rinsing	-	-	0.13	-		0.00
		-	-	0.10	-		0.00
		-	-	0.09	-		0.00
[FR_017] _a {2}	Rinsing-Plating-	-	-	0.13	-		0.00
		-	-	0.05	-		0.00
		-	-	0.05	-		0.00
[FR_018] _a {1}	Other-	Scrubber- absorption (acid/alkaline)	-	1.25	-	10.00	0.01
			-	0.15	-	10.00	0.00
			-	0.10	-	10.00	0.00
[FR_018] _a {2}	Metal stripping-Conditioning of plastics-	Scrubber- absorption (acid/alkaline)	-	0.16	-	10.00	0.01
			-	0.13	-	10.00	0.00
			-	0.10	-	10.00	0.01
[FR_018] _a {3}	Metal stripping-Conditioning of plastics-Etching or pickling of plastics- Other-Plating-	Scrubber- absorption (acid/alkaline)	-	0.67	-	10.00	0.01
			-	0.20	-	10.00	0.00
			-	0.06	-	10.00	0.00
[FR_018] _a {4}	Plating-	Scrubber- absorption (acid/alkaline)	-	8.00	-	10.00	0.10
			-	4.63	-	10.00	0.07
			-	1.38	-	10.00	0.02
[FR_018] _a {5}	Aqueous cleaning-Plating-Other-	Scrubber- absorption (acid/alkaline)	-	0.22	-	10.00	0.00
			-	0.11	-	10.00	0.00
			-	0.10	-	10.00	0.00
[FR_018] _a {6}	Metal stripping	Scrubber- absorption (acid/alkaline)	-	0.50	-	10.00	0.00
			-	0.28	-	10.00	0.00
			-	0.25	-	10.00	0.00
[FR_018] _a {11}	Conditioning of plastics- Etching or pickling of plastics-Rinsing- Other	Scrubber- absorption (acid/alkaline)	-	0.40	-	10.00	0.01
			-	0.06	-	10.00	0.00
			-	0.05	-	10.00	0.00
[FR_018] _a {12}	Plating	Scrubber- absorption (acid/alkaline)	-	5.00	-	10.00	0.09
			-	0.14	-	10.00	0.00
			-	0.10	-	10.00	0.00
[FR_018] _a {13}	Plating-Other-	Scrubber- absorption (acid/alkaline)	-	3.60	-	10.00	0.05
			-	1.46	-	10.00	0.01

			-	0.12	-	10.00	0.00
[FR_018]_a {14}	Metal stripping-	Scrubber- absorption (acid/alkaline)	-	0.16	-	10.00	0.00
			-	0.10	-	10.00	0.00
			-	0.08	-	10.00	0.00
[FR_033]_a {1}	Plating-Metal stripping-Electrolytically assisted pickling, activation and degreasing- Rinsing-Other	-	-	0.48	-		0.00
		-	-	0.25	-		0.00
[FR_033]_a {2}	Plating-Metal stripping-Rinsing-	No technique applied	-	0.47	-		0.00
			-	0.26	-		0.00
[FR_033]_a {3}	Rinsing-Other-	No technique applied	-	0.44	-		0.00
			-	0.24	-		0.00
[FR_033]_a {4}	Plating-	Mist filter (demister)	-	1.20	-		0.02
			-	0.44	-		0.00
[FR_033]_a {5}	Plating-	Mist filter (demister)	-	0.81	-		0.01
			-	0.45	-		0.00
[FR_033]_a {6}	Plating	Mist filter (demister)	-	1.10	-		0.01
			-	0.48	-		0.00
[FR_033]_a {7}	Plating	No technique applied	-	0.47	-		0.00
			-	0.14	-		0.00
[FR_033]_a {8}	Plating	Mist filter (demister)	-	1.00	-		0.01
			-	0.46	-		0.00
[FR_033]_a {9}	Aqueous cleaning- Oiling-Alkaline degreasing- Rinsing	No technique applied	-	0.45	-		0.00
			-	0.43	-		0.00
[FR_033]_a {10}	Other-Pickling (not electrically), descaling and desmutting-Other-Rinsing-	No technique applied	-	0.44	-		0.00
			-	0.28	-		0.00
[FR_033]_a {11}	Metal stripping-Alkaline degreasing-Plating	-	-	0.45	-		0.00
		-	-	0.22	-		0.00
[FR_033]_a {12}	Other-Etching and descaling of aluminium-	No technique applied	-	0.44	-		0.00
			-	0.24	-		0.00
[FR_033]_a {13}	Metal stripping-	No technique applied	-	0.94	-		0.00
			-	0.44	-		0.00
[FR_033]_a {14}	Other-Pickling (not electrically), descaling and desmutting	No technique applied	-	0.44	-		0.00
			-	0.19	-		0.00
[FR_033]_a {15}	-Rinsing-Etching and descaling of aluminium-	No technique applied	-	0.43	-		0.00
			-	0.25	-		0.00
[FR_033]_a {16}	Pickling (not electrically), descaling and desmutting-Other	No technique applied	-	1.10	-		0.00
			-	0.45	-		0.00
[FR_033]_a {17}	Alkaline degreasing-Rinsing-	No technique applied	-	0.57	-		0.00
			-	0.24	-		0.00
[FR_033]_a {18}	Pickling (not electrically), descaling and desmutting-Other-	Mist filter (demister)	-	0.44	-		0.00
			-	0.30	-		0.00
[FR_033]_a {20}	-Rinsing-Other-Pickling (not electrically), descaling and desmutting	No technique applied	-	0.46	-		0.00
			-	0.24	-		0.00
[FR_035]_a {1}	Plating-Other-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)- Alkaline degreasing- Chemical polishing-Etching and descaling of aluminium-	Scrubber- absorption (acid/alkaline)	4.10	4.10	4.10		0.12
			1.40	1.40	1.40		0.03
			1.00	1.00	1.00		0.02

	Etching – Alkaline etching of aluminium-						
[FR_035]_a {2}	Plating-Other-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)- Alkaline degreasing- Chemical polishing-Etching and descaling of aluminium-Etching – Alkaline etching of aluminium-	Scrubber- absorption (acid/alkaline)	3.80	3.80	3.80		0.02
			1.10	1.10	1.10		0.02
			1.00	1.00	1.00		0.02
[FR_035]_a {3}	Etching or pickling of plastics-Conditioning of plastics- Plating-Electrocoating (e-coating)- Rinsing-Degreasing-Metal stripping-Other-	Scrubber- absorption (acid/alkaline)	0.40	0.40	0.40		0.01
			0.30	0.30	0.30		0.00
			0.20	0.20	0.20		-
[FR_035]_a {4}	Pickling (not electrically), descaling and desmutting-Metal stripping-Degreasing-Pickling (not electrically), descaling and desmutting-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Other-	Scrubber- absorption (acid/alkaline)	2.90	2.90	2.90		0.08
			0.30	0.30	0.30		0.01
			0.30	0.30	0.30		0.01
[FR_035]_a {5}	Plating-Other-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Electrocoating (e-coating)- Alkaline degreasing- Chemical polishing-Etching and descaling of aluminium-Etching – Alkaline etching of aluminium-	Scrubber- absorption (acid/alkaline)	0.40	0.40	0.40		0.00
			0.30	0.30	0.30		0.00
			0.10	0.10	0.10		0.00
[FR_035]_a {6}	Other-Electrocoating (e-coating)-Electrolytically assisted pickling, activation and degreasing- Rinsing-Degreasing- Other	Scrubber- absorption (acid/alkaline)	0.40	0.40	0.40		0.01
			0.40	0.40	0.40		-
			0.30	0.30	0.30		0.00
[FR_035]_a {7}	Electrocoating (e-coating)-Other	Scrubber- absorption (acid/alkaline)	0.90	0.90	0.90		0.00
			0.40	0.40	0.40		0.00
			0.20	0.20	0.20		0.00

3.2.4.12 TVOC

The reported data for TVOC emissions to air are presented in Figure 3-39. Emission data and contextual information are also presented in Table 3-37.



Source: [168, TWG 2023]

Figure 3-39: TVOC emissions to air in electrolytic or chemical plating plants

Table 3-38: Reported data and contextual information for TVOC emissions to air in electrolytic or chemical plating plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[AT_003]_a {3}	Electrocoating (e-coating)-Other	Other Scrubber-absorption (acid/alkaline)-Fabric filter	16.00	16.00	16.00	20.00	-
[AT_005]_a {2}	Heat treatment	Straight thermal oxidation	4.00	4.00	4.00	20.00	-
			2.00	2.00	2.00	20.00	-
[AT_008]_a {4}	Drying	Scrubber-absorption (acid/alkaline)	22.60	22.60	20.70		-
[AT_008]_a {5}	Drying	-	1.00	1.00	1.00	50.00	-
[AT_008]_a {6}	Degreasing- Rinsing-Plating- Electrocoating (e-coating)-	Scrubber-absorption (acid/alkaline)	1.30	1.30	1.30		-
[AT_008]_a {7}	Degreasing- Rinsing-Plating- Electrocoating (e-coating)-	Scrubber-absorption (acid/alkaline)	1.90	1.90	1.90		-
[AT_009]_a {1}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating-	Aerosol/droplet separator	1.00	1.00	1.00	50.00	-
[AT_009]_a {2}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Platin	Aerosol/droplet separator	1.00	1.00	1.00	50.00	-
[AT_009]_a {3}	Plating-	Aerosol/droplet separator	1.00	1.00	1.00	50.00	-
[AT_009]_a {4}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating	Aerosol/droplet separator	1.00	1.00	1.00	50.00	-
[AT_009]_a {5}	Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing-Plating	Aerosol/droplet separator	1.00	1.00	1.00	50.00	-
[AT_009]_a {6}	-Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing- Pickling (not electrically), descaling and desmutting-OtherPlating-	Aerosol/droplet separator	1.00	1.00	1.00	50.00	-

[AT_009]_a {7}	-Solvent degreasing-Pickling (not electrically), descaling and desmutting-Electrolytically assisted pickling, activation and degreasing- Pickling (not electrically), descaling and desmutting-OtherPlating-	Aerosol/droplet separator	1.00	1.00	1.00	50.00	-
[AT_009]_a {9}	Chemical polishing-Plating-Electrolytically assisted pickling, activation and degreasing-	Aerosol/droplet separator	1.90	1.90	1.90	10.00	-
[AT_009]_a {10}	Degreasing-Pickling (not electrically), descaling and desmutting- Anodising-Other	Aerosol/droplet separator	1.00	1.00	1.00	50.00	-
[AT_010]_a {1}	Alkaline degreasing-Aqueous cleaning-Drying-Electrolytically assisted pickling, activation and degreasing-Etching – Alkaline etching of aluminium-Hand wiping-Heat treatment-Mechanical polishing/linishing-Pickling (not electrically), descaling and desmutting-Plating	Scrubber-absorption (acid/alkaline)	2.10	2.10	2.10	-	-
[AT_010]_a {2}	Other Plating-	Scrubber-absorption (acid/alkaline)	2.50	2.50	2.50	-	-
[AT_010]_a {3}	Plating-Plating-	Scrubber-absorption (acid/alkaline)	2.40	2.40	2.40	-	-
[AT_010]_a {4}	Pickling (not electrically), descaling and desmutting-	Scrubber-absorption (acid/alkaline)	2.20	2.20	2.20	-	-
[AT_016]_a {1}	Electrocoating (e-coating)	Straight thermal oxidation	1.00	1.00	1.00	20.00	-
[AT_021]_a {2}	Heat treatment	No technique applied	7.00	7.00	7.00	20.00	-
[BE_001]_a {1}	Degreasing	Mist filter (demister)-Cyclone-Active carbon adsorption	47.00	47.00	47.00		-
[BE_001]_a {2}	Heat treatment-	No technique applied	5.00	3.00	2.00		-
[BE_001]_a {3}	Pickling (not electrically), descaling and desmutting	Scrubber-absorption (acid/alkaline)	56.00	34.33	5.00		-
[BE_001]_a {4}	Other Electrocoating (e-coating)-	Scrubber-absorption (acid/alkaline)	13.00	13.00	13.00		-
			6.00	3.00	2.00		-
[BE_001]_a {5}	Drying-	No technique applied	9.00	9.00	9.00		-
			8.00	5.00	2.00		-
[BE_001]_a {6}	Drying-	No technique applied	41.00	25.50	15.00		-
[BE_001]_a {7}	Degreasing-	Scrubber-absorption (acid/alkaline)	5.00	5.00	5.00		-
[BE_017]_a {1}	Electrocoating (e-coating)-Lacquering-	Active carbon adsorption	7.00	4.70	2.00	-	-

[BE_017] _a {2}	Lacquering-	No technique applied	-	25.00	-	-	-
[BE_017] _a {3}	Lacquering-	-	-	2.50	-	-	-
[BE_018] _a {5}	Electrocoating (e-coating)-	-	-	12.48	-	-	-
[BE_018] _a {6}	Drying	Regenerative thermal oxidation	-	2.86	-	-	-
[CZ_010] _a {2}	Alkaline degreasing-Other Electrocoating (e-coating)--	No technique applied	16.00	12.00	11.00	50.00	0.00
			8.00	6.00	4.00	50.00	0.03
[CZ_012] _a {1}	Electrolytically assisted pickling, activation and degreasing-	Recuperative thermal oxidation	-	2.10	-	-	-
[DE_054] _a {1}	Alkaline degreasing- Other	Scrubber-absorption (acid/alkaline)	1.90	1.80	1.60	20.00	0.01
[DE_054] _a {4}	Alkaline degreasing-Other (	Scrubber-absorption (acid/alkaline)	5.60	4.90	4.40	20.00	0.04
[DE_054] _a {6}	Other	Scrubber-absorption (acid/alkaline)	1.00	0.90	0.80	-	0.00
[ES_009] _a {1}	Alkaline degreasing-Other Electrocoating (e-coating)-	Scrubber-absorption (acid/alkaline)	5.70	5.40	5.10	20.00	0.22
			3.20	3.00	2.70	20.00	0.12
[ES_009] _a {2}	Alkaline degreasing-Other Electrocoating (e-coating)-	Scrubber-absorption (acid/alkaline)	5.50	5.50	5.50	20.00	0.22
			5.00	5.00	5.00		<0, 20
			3.20	3.00	2.50		0.13
[ES_009] _a {3}	Alkaline degreasing-Other	Scrubber-absorption (acid/alkaline)	6.20	6.10	5.90	20.00	0.22
			5.00	5.00	5.00		< 0,18
			1.70	1.60	1.40		0.06
[ES_014] _a {1}	Electrocoating (e-coating)-	Other	19.03	16.43	13.59		0.08
			9.76	9.47	9.03		0.02
			3.00	3.00	3.00		0.01
[ES_014] _a {2}	Electrocoating (e-coating)-	Straight thermal oxidation-Other	61.01	58.69	56.90		0.19
			55.68	52.81	51.17		0.18
			3.10	3.00	3.00		0.00
[ES_031] _a {1}	Alkaline degreasing-	Scrubber-absorption (acid/alkaline)	19.20	19.20	19.20	-	0.04
			5.00	5.00	5.00	-	0.01
			3.70	3.70	3.70	-	0.02
[ES_031] _a {3}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-	Scrubber-absorption (acid/alkaline)	8.50	8.50	8.50	-	0.04
			5.00	5.00	5.00	-	0.01
			1.00	1.00	1.00	-	0.00
[ES_031] _a {4}	Degreasing-Degreasing-	Scrubber-absorption (acid/alkaline)	5.00	5.00	5.00	-	0.02
			2.80	2.80	2.80	-	0.01
			2.70	2.70	2.70	-	0.01
[FR_011] _a {6}	Other	Regenerative thermal oxidation	0.00	-	0.00	50.00	0.00
[FR_014] _a {1}	Other	Absorption	1.90	1.60	1.50	-	-
[FR_016] _a {2}	Metal stripping-	No technique applied	2.30	2.00	1.60	75.00	0.01

[FR_016] _a {3}	Anodising-	No technique applied	6.30	5.70	4.70	75.00	0.04
[FR_016] _a {4}	Other	No technique applied	0.00	0.00	0.00	75.00	0.00
[FR_016] _a {5}	Etching or pickling of plastics-	No technique applied	4.00	1.50	0.00	75.00	0.01
[FR_016] _a {8}	Plating-	No technique applied	0.60	0.20	0.00	75.00	0.00
[FR_016] _a {9}	Plating-	No technique applied	2.00	1.90	1.60	75.00	0.03
[FR_016] _a {10}	Plating-	No technique applied	2.10	1.90	1.70	75.00	0.02
[FR_016] _a {11}	Plating-	No technique applied	1.40	1.30	1.20	75.00	0.02
[FR_016] _a {13}	Plating-	-	1.60	1.30	1.10	75.00	0.01
[IT_008] _a {1}	Alkaline degreasing-Rinsing-Electrolytically assisted pickling, activation and degreasing- Plating-Rinsing-	-	0.27	0.26	0.25	-	12.12
			0.01	0.01	0.01	-	0.49
[IT_008] _a {3}	Alkaline degreasing--Rinsing-Electrolytically assisted pickling, activation and degreasing- Other (Electrocoating (e-coating)-	-	0.01	0.01	0.01	-	1.22
			0.01	0.01	0.01	-	1.36
[IT_008] _a {4}	Alkaline degreasing-Rinsing-Electrolytically assisted pickling, activation and degreasing-Rinsing-Plating- Other Drying-	-	1.50	1.49	1.48	-	
			0.01	0.01	0.01	-	0.56
[IT_008] _a {5}	Drying-	-	0.30	0.29	0.29	-	0.07
			0.01	0.01	0.01	-	2.21
[IT_029] _a {1}	Other	No technique applied-	3.20	3.17	3.10	-	0.00
			3.20	3.13	3.10	-	0.00
			2.90	2.83	2.80	-	0.00
[IT_029] _a {2}	Other	-	2.40	2.37	2.30	-	0.00
			2.20	2.17	2.10	-	0.00
			2.20	2.13	2.10	-	0.00
[IT_029] _a {3}	Other	-	3.90	3.87	3.80	-	0.00
			3.20	3.13	3.10	-	0.00
			2.60	2.57	2.50	-	0.00
[IT_029] _a {4}	Other	No technique applied	1.90	1.87	1.80	20.00	0.00
			1.40	1.37	1.30	20.00	0.00
			0.40	0.37	0.30	20.00	0.00
[IT_029] _a {9}	Degreasing-	No technique applied	2.90	2.87	2.80	20.00	0.00
			2.40	2.33	2.30	20.00	0.00
[IT_029] _a {16}	Other	-	14.10	13.70	13.20	20.00	0.01
			12.30	12.23	12.20	20.00	0.01
[IT_032] _a {20}	Other	Regenerative thermal oxidation	6.20	6.20	6.20	50.00	0.00
			5.40	5.40	5.40	50.00	0.00
			3.20	3.20	3.20	50.00	0.00
[PT_002] _a {1}	Degreasing-	-	18.00	14.00	9.70		0.00
			9.20	9.50	9.80		0.00

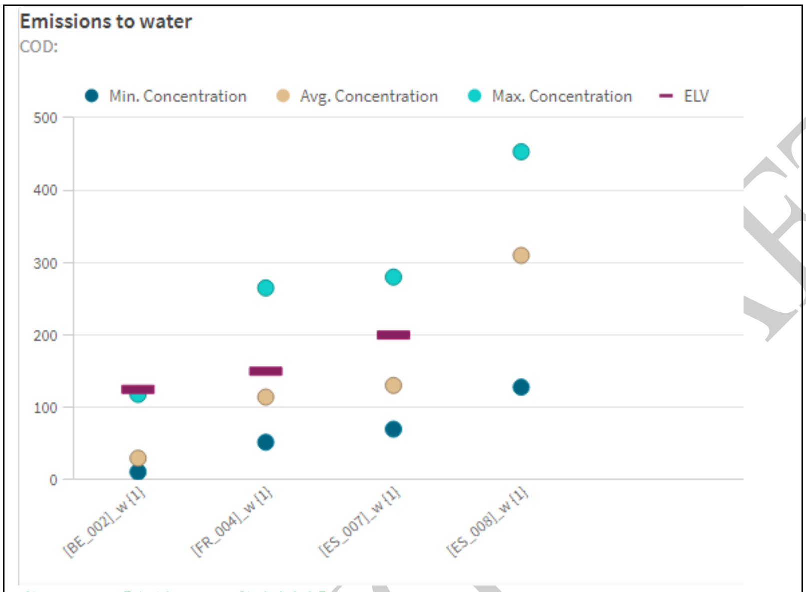
[PT_002]_a {2}	Degreasing-	No technique applied	41.30	26.85	12.40		0.00
			9.20	7.90	6.50		0.00
[PT_002]_a {3}	Degreasing-	No technique applie	9.80	8.45	7.10		0.00
			9.20	7.85	6.50		0.00
[PT_002]_a {4}	Degreasing-	No technique applied	18.00	16.25	14.50		0.00
			13.80	12.65	11.50		0.00
[PT_002]_a {5}	Degreasing-	No technique applied	26.50	24.25	22.00		0.00
			9.50	8.10	6.70		0.00
[PT_002]_a {6}	Other	No technique applied	21.70	17.15	12.60		0.00
			6.90	6.70	6.50		0.00
[PT_002]_a {7}	Electrocoating (e-coating)-	No technique applied					0.18
			36.40	30.70	25.00		0.00
			6.30	6.30	6.30		0.01
[PT_002]_a {8}	Drying-	No technique applied	20.50	17.30	14.10		0.00
			13.90	10.00	6.10		0.00
[PT_002]_a {9}	Drying-	No technique applied	31.60	31.60	31.60		0.04
			27.10	21.70	16.30		0.01
			13.00	9.40	5.80		0.00
[PT_002]_a {10}	Other	Scrubber-absorption (acid/alkaline)	1.70	1.70	1.70		0.05

3.3 Continuous steel coil coating

3.3.1 Emissions to water

3.3.1.1 COD

The reported data for COD emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-39.



Source: [168, TWG 2023]

Figure 3-40: COD emissions to water from continuous steel coil coating plants

Table 3-39: Reported data and contextual information for COD emissions to water from continuous steel coil coating plants

.	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[BE_002]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Adsorption techniques – activated carbon	11	30	118	125	-
[FR_004]_w {1}	Chemical reduction-Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation-Other-Precipitation-Coagulation and flocculation-Flotation-Filtration (e.g. gravel filter, sand filter)	52	114.3	265	150	-
[ES_007]_w {1}	Biological treatment- Activated sludge process-Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation-Flotation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Other-Coagulation and flocculation-Sedimentation	70	130.4	280	200	-
[ES_008]_w {1}	Chemical reduction-Coagulation and flocculation-Sedimentation-Flotation-Other	128	309.9	453	-	-

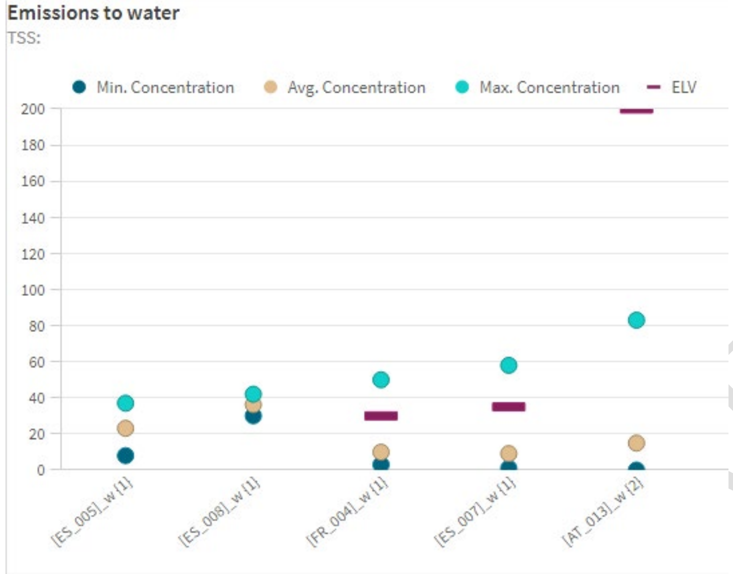
Source: [168, TWG 2023]

3.3.1.2 TOC

No data reported.

3.3.1.3 TSS

The reported data for TSS emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-40.



Source: [168, TWG 2023]

Figure 3-41: TSS emissions to water from continuous steel coil coating plants

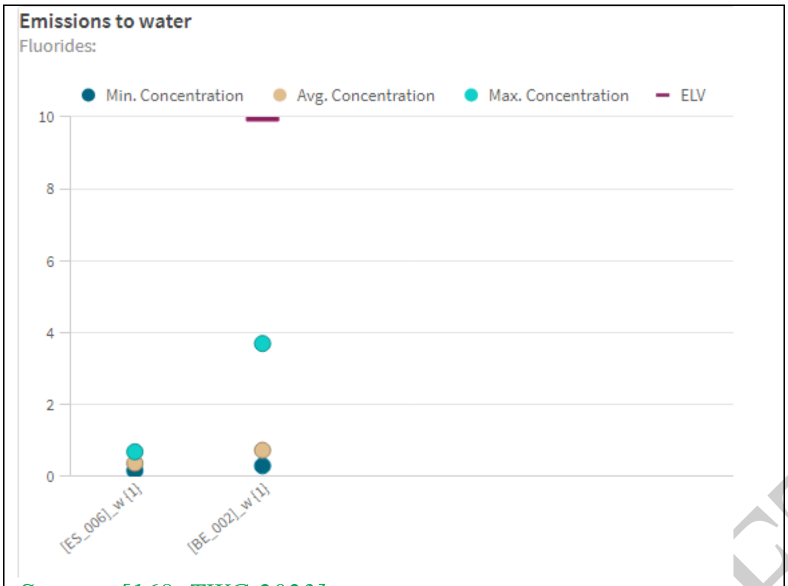
Table 3-40: Reported data and contextual information for TSS emissions to water from continuous steel coil coating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[ES_005]_w {1}	Coagulation and flocculation-Neutralisation-Other-Sedimentation-Filtration (e.g. gravel filter, sand filter)	8	23.1	37	-	-
[ES_008]_w {1}	Chemical reduction-Coagulation and flocculation-Sedimentation-Flotation-Other	30.04	36.21	42	-	-
[FR_004]_w {1}	Chemical reduction-Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation-Other-Precipitation-Coagulation and flocculation-Flotation-Filtration (e.g. gravel filter, sand filter)	3	9.91	50	30	-
[ES_007]_w {1}	Biological treatment- Activated sludge process-Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation-Flotation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Other-Coagulation and flocculation-Sedimentation	1	9.11	58	35	-
[AT_013]_w {2}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Other-Coagulation and flocculation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0	14.9	83	200	-

Source: [168, TWG 2023]

3.3.1.4 Fluorides

The reported data for fluorides emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-41.



Source: [168, TWG 2023]

Figure 3-42: Fluorides emissions to water from continuous steel coil coating plants

Table 3-41: Reported data and contextual information for fluorides emissions to water from continuous steel coil coating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[ES_006]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Flotation-Membrane micro/ultra/nano filtration-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Sedimentation-Reverse osmosis-Neutralisation	0.17	0.37	0.69	-	2206.5
[BE_002]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Adsorption techniques – activated carbon	0.3	0.73	3.7	10	-

Source: [168, TWG 2023]

3.3.1.5 AOX

The reported data for AOX emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-42.

Source: [168, TWG 2023]

Figure 3-43: AOX emissions to water from continuous steel coil coating plants

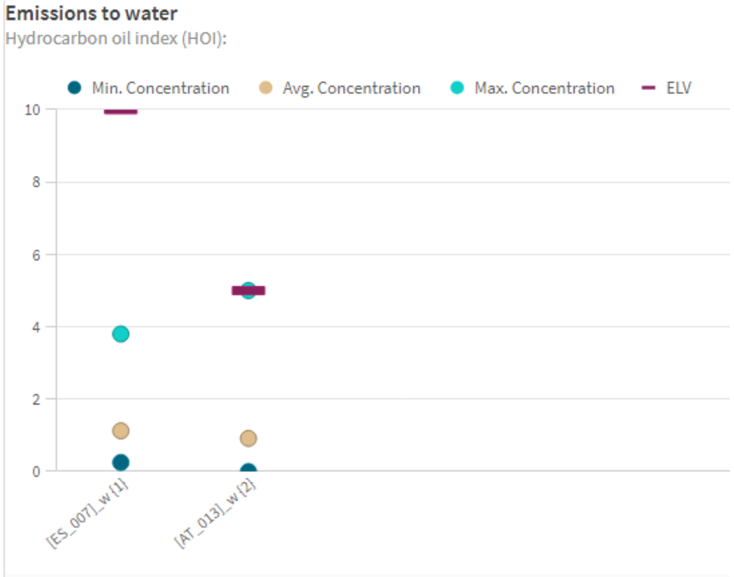
Table 3-42: Reported data and contextual information for AOX emissions to water from continuous steel coil coating plants

Emission Point	**Abatement technique(s)**	**Min.**	**Avg.**	**Max.**	**ELV**	**Load (g/day)**
[DE_031]_w {2}	No technique applied	-	-	0.2	-	-
[DE_031]_w {3}	Neutralisation-Coagulation and flocculation	-	-	0.3	1	-
[DE_031]_w {1}	No technique applied	-	-	0.5	-	-
[ES_006]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Flotation-Membrane micro/ultra/nano filtration-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Sedimentation-Reverse osmosis-Neutralisation	0.1	0.51	2	-	2315

Source: [168, TWG 2023]

3.3.1.6 HOI

The reported data for HOI emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-43.



Source: [168, TWG 2023]

Figure 3-44: HOI emissions to water from continuous steel coil coating plants

Table 3-43: Reported data and contextual information for HOI emissions to water from continuous steel coil coating plants

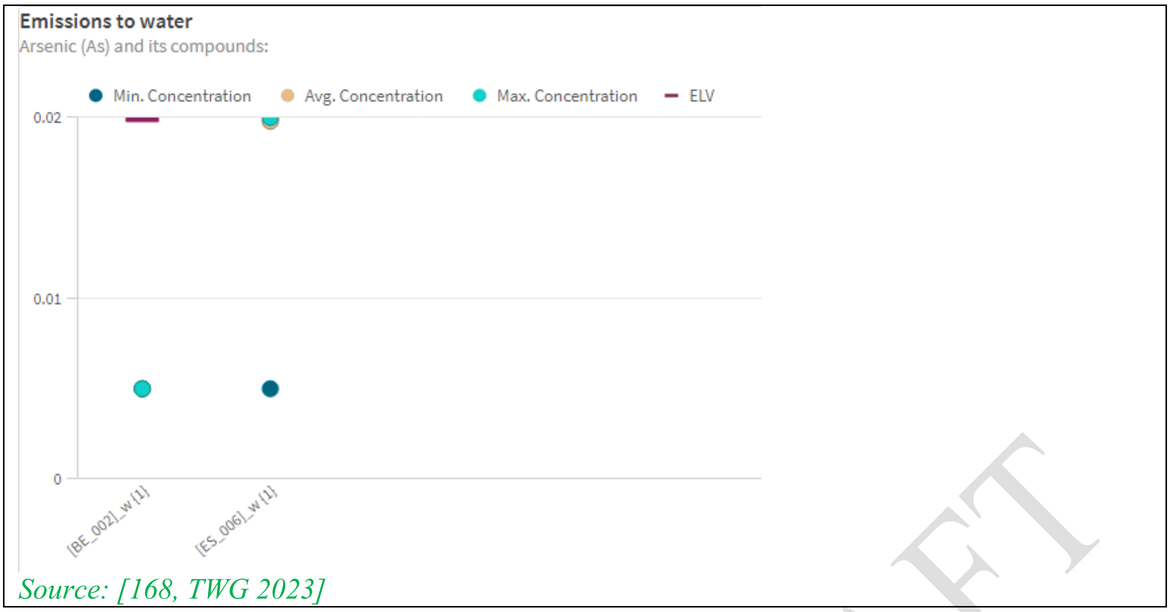
Emission Point	Abatement technique(s)	Min..	Avg	Max.	ELV	Load (g/day)
[ES_007]_w {1}	Biological treatment- Activated sludge process-Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation-Flotation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Other-Coagulation and flocculation-Sedimentation	0.25	1.12	3.8	10	-
[AT_013]_w {2}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Other-Coagulation and flocculation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0	0.91	5	5	-

Source: [168, TWG 2023]

3.3.1.7 Metals

3.3.1.7.1 As

The reported data for As emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-44.



Source: [168, TWG 2023]

Figure 3-45: As emissions to water from continuous steel coil coating plants

Table 3-44: Reported data and contextual information for As emissions to water from continuous steel coil coating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[BE_002]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Adsorption techniques – activated carbon	0.005	0.005	0.005	0.02	-
[ES_006]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Flotation-Membrane micro/ultra/nano filtration-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Sedimentation-Reverse osmosis-Neutralisation	0.005	0.020	0.02	-	4.53

Source: [168, TWG 2023]

3.3.1.7.2 Cd

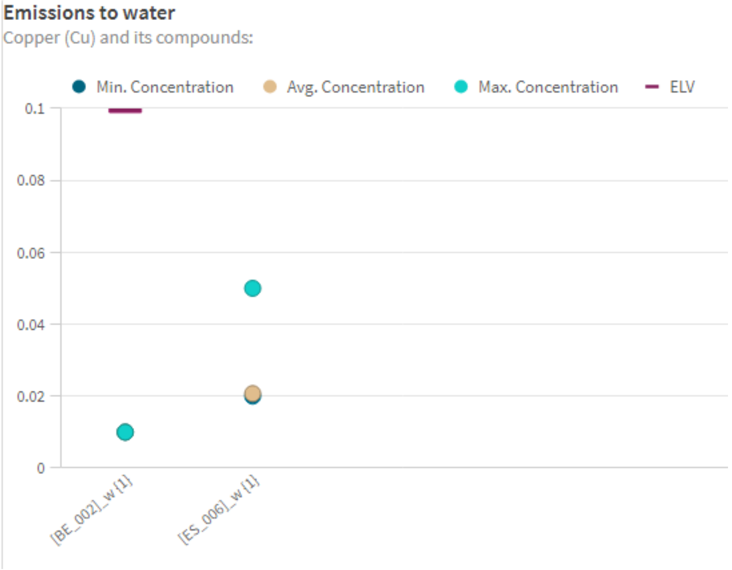
Cd emissions to water were reported by only 1 emission point (BE_002_w1) with a value of 0.0008 mg/l.

3.3.1.7.3 Co

Co emissions to water were reported by only 1 emission point (DE_031_w3) with a value of 0.5 mg/l.

3.3.1.7.4 Cu

The reported data for Cu emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-45.



Source: [168, TWG 2023]

Figure 3-46: Cu emissions to water from continuous steel coil coating plants

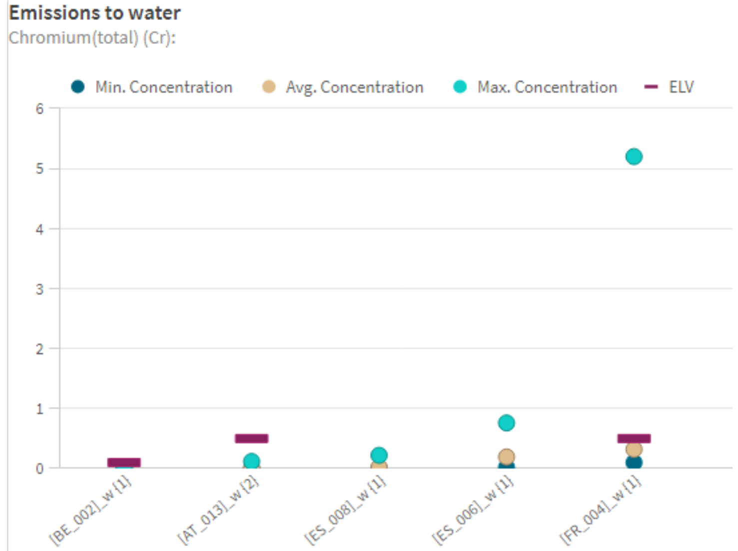
Table 3-45: Reported data and contextual information for Cu emissions to water from continuous steel coil coating plants.

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[BE_002]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Adsorption techniques – activated carbon	0.01	0.01	0.01	0.1	-
[ES_006]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Flotation-Membrane micro/ultra/nano filtration-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Sedimentation-Reverse osmosis-Neutralisation	0.020	0.021	0.050	-	35.836

Source: [168, TWG 2023]

3.3.1.7.5 Cr

The reported data for Cr emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-46.



Source: [168, TWG 2023]

Figure 3-47: Cr emissions to water from continuous steel coil coating plants

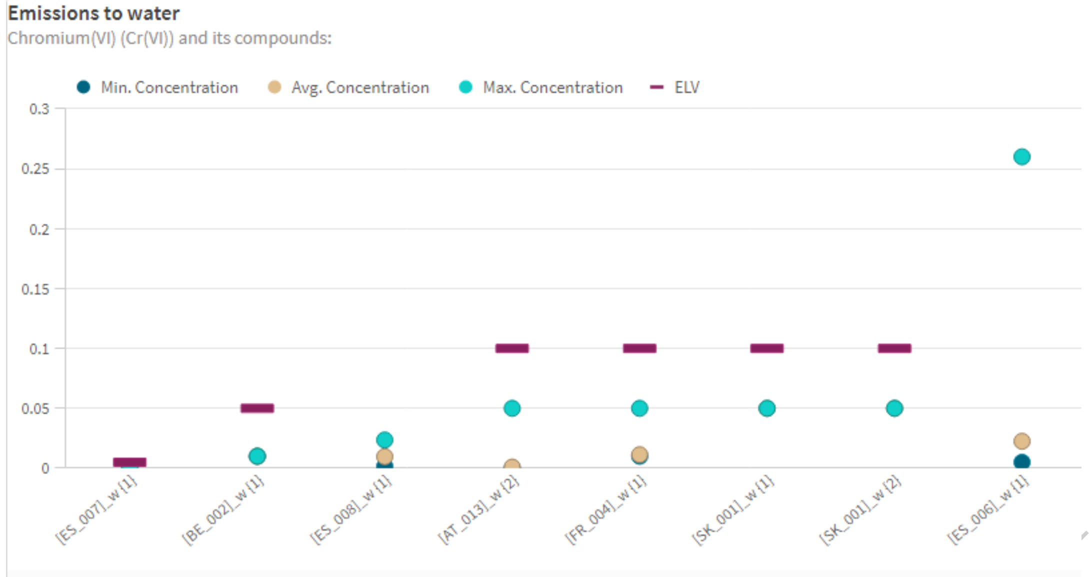
Table 3-46: Reported data and contextual information for Cr emissions to water from continuous steel coil coating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[BE_002]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Adsorption techniques – activated carbon	0.01	0.01	0.01	0.1	-
[AT_013]_w {2}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Other-Coagulation and flocculation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0	0.0103	0.118	0.5	-
[ES_008]_w {1}	Chemical reduction-Coagulation and flocculation-Sedimentation-Flotation-Other	0.0021	0.0233	0.22	-	-
[ES_006]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Flotation-Membrane micro/ultra/nano filtration-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Sedimentation-Reverse osmosis-Neutralisation	0.02	0.1939	0.76	-	703.64
[FR_004]_w {1}	Chemical reduction-Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation-Other-Precipitation-Coagulation and flocculation-Flotation-Filtration (e.g. gravel filter, sand filter)	0.1	0.321	5.2	0.5	-

Source: [168, TWG 2023]

3.3.1.7.6 Cr(VI)

The reported data for Cr(VI) emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-47.



Source: [168, TWG 2023]

Figure 3-48: Cr(VI) emissions to water from continuous steel coil coating plants

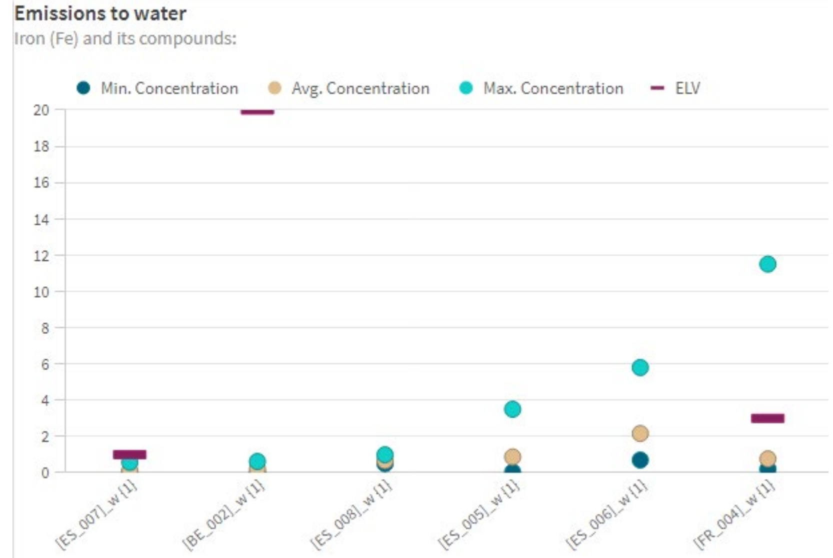
Table 3-47: Reported data and contextual information for Cr(VI) emissions to water from continuous steel coil coating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[ES_007]_w {1}	Biological treatment- Activated sludge process-Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation-Flotation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Other-Coagulation and flocculation-Sedimentation	0.001	0.001	0.001	0.005	-
[BE_002]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Adsorption techniques – activated carbon	0.01	0.01	0.01	0.05	-
[ES_008]_w {1}	Chemical reduction-Coagulation and flocculation-Sedimentation-Flotation-Other	0.002	0.010	0.024	-	-
[AT_013]_w {2}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Other-Coagulation and flocculation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0	0.001	0.05	0.1	-
[FR_004]_w {1}	Chemical reduction-Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation-Other-Precipitation-Coagulation and flocculation-Flotation-Filtration (e.g. gravel filter, sand filter)	0.01	0.0113	0.05	0.1	-
[SK_001]_w {1}	Chemical reduction-Neutralisation-Coagulation and flocculation	-	0.05	0.05	0.1	-
[SK_001]_w {2}	Chemical reduction-Neutralisation-Coagulation and flocculation	-	0.05	0.05	0.1	-
[ES_006]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Flotation-Membrane micro/ultra/nano filtration-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Sedimentation-Reverse osmosis-Neutralisation	0.005	0.023	0.26	-	35.1

Source: [168, TWG 2023]

3.3.1.7.7 Fe

The reported data for Fe emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-48.



Source: [168, TWG 2023]

Figure 3-49: Fe emissions to water from continuous steel coil coating plants

Table 3-48: Reported data and contextual information for Fe emissions to water from continuous steel coil coating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV con.c	Load (g/day)
[ES_007]_w {1}	Biological treatment- Activated sludge process-Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation-Flotation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Other-Coagulation and flocculation-Sedimentation	0.02	0.12	0.58	1	-
[BE_002]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Adsorption techniques – activated carbon	0.02	0.211	0.62	20	-
[ES_008]_w {1}	Chemical reduction-Coagulation and flocculation-Sedimentation-Flotation-Other	0.5	0.67	0.99	-	-
[ES_005]_w {1}	Coagulation and flocculation-Neutralisation-Other-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.03	0.87	3.5	-	-
[ES_006]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Flotation-Membrane micro/ultra/nano filtration-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Sedimentation-Reverse osmosis-Neutralisation	0.70	2.16	5.8	-	10675
[FR_004]_w {1}	Chemical reduction-Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation-Other-Precipitation-Coagulation and flocculation-Flotation-Filtration (e.g. gravel filter, sand filter)	0.2	0.77	11.5	3	-

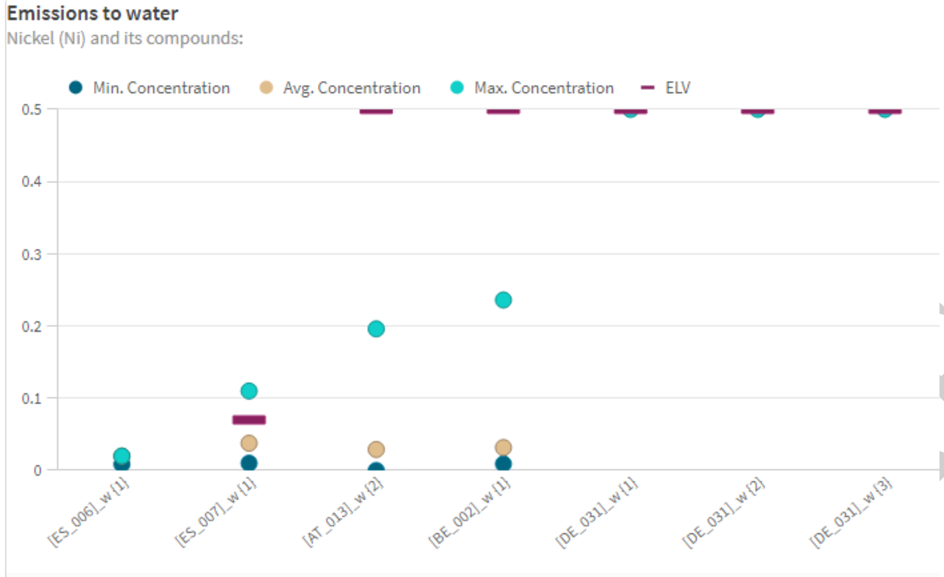
Source: [168, TWG 2023]

3.3.1.7.8 Pb

Pb emissions to water were reported by only 1 emission point (BE_002_w1) with a value of 0.01 mg/l.

3.3.1.7.9 Ni

The reported data for Ni emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-49.



Source: [168, TWG 2023]

Figure 3-50: Ni emissions to water from continuous steel coil coating plants

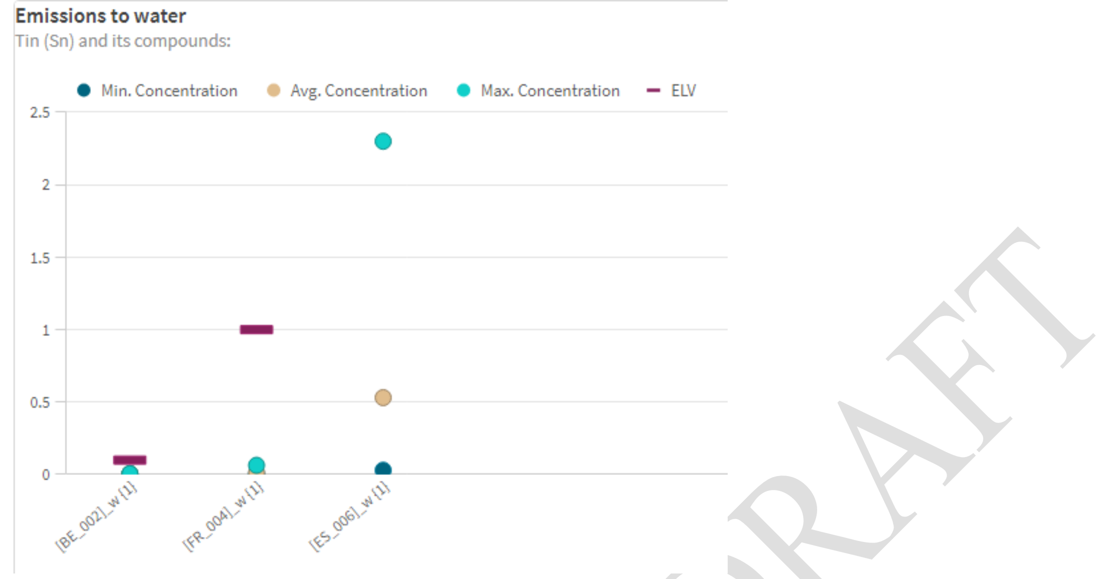
Table 3-49: Reported data and contextual information for Ni emissions to water from continuous steel coil coating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[ES_006]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Flotation-Membrane micro/ultra/nano filtration-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Sedimentation-Reverse osmosis-Neutralisation	0.0086	0.020	0.02	-	5.3
[ES_007]_w {1}	Biological treatment- Activated sludge process-Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation-Flotation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Other Coagulation and flocculation-Sedimentation	0.01	0.038	0.11	0.07	-
[AT_013]_w {2}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Other-Coagulation and flocculation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0	0.029	0.196	0.5	-
[BE_002]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Adsorption techniques – activated carbon	0.009	0.032	0.236	0.5	-
[DE_031]_w {1}	No technique applied	-	-	0.5	0.5	-
[DE_031]_w {2}	No technique applied	-	-	0.5	0.5	-
[DE_031]_w {3}	Neutralisation-Coagulation and flocculation	-	-	0.5	0.5	-

Source: [168, TWG 2023]

3.3.1.7.10 Sn

The reported data for Sn emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-50.



Source: [168, TWG 2023]

Figure 3-51: Sn emissions to water from continuous steel coil coating plants

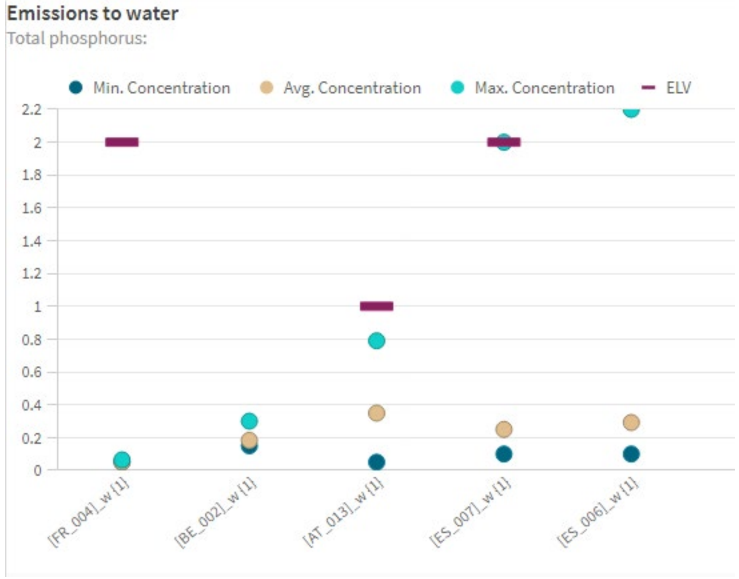
Table 3-50: Reported data and contextual information for Sn emissions to water from continuous steel coil coating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[BE_002]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Adsorption techniques – activated carbon	0.006	0.006	0.006	0.1	-
[FR_004]_w {1}	Chemical reduction-Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation-Other-Precipitation-Coagulation and flocculation-Flotation-Filtration (e.g. gravel filter, sand filter)	0.006	0.0127	0.064	1	-
[ES_006]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Flotation-Membrane micro/ultra/nano filtration-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Sedimentation-Reverse osmosis-Neutralisation	0.03	0.5308	2.3	-	2453

Source: [168, TWG 2023]

3.3.1.8 Total phosphorus

The reported data for total phosphorus (TP) emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-51.



Source: [168, TWG 2023]

Figure 3-52: TP emissions to water from continuous steel coil coating plants

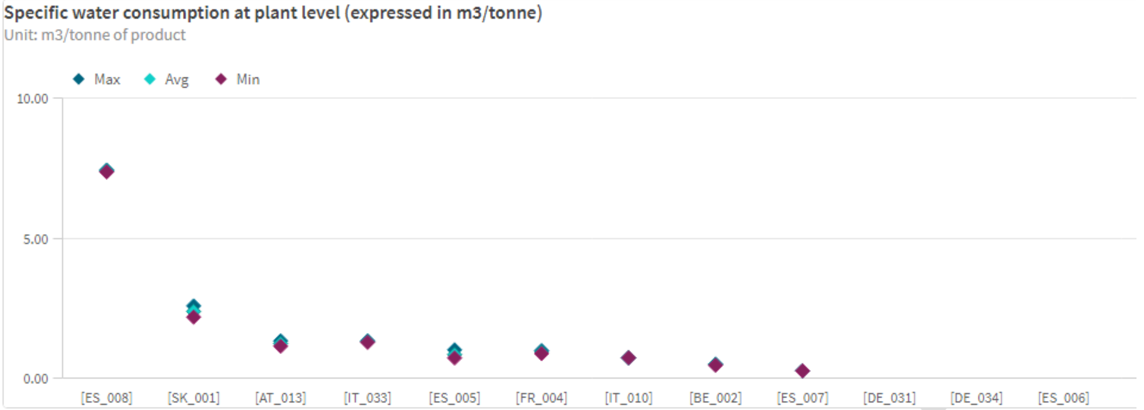
Table 3-51: Reported data and contextual information for TP emissions to water from continuous steel coil coating plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	ELV	Load (g/day)
[FR_004]_w {1}	Chemical reduction-Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation-Other-Precipitation-Coagulation and flocculation-Flotation-Filtration (e.g. gravel filter, sand filter)	0.05	0.050	0.064	2	-
[BE_002]_w {1}	Coagulation and flocculation-Precipitation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Adsorption techniques – activated carbon	0.15	0.183	0.3	-	-
[AT_013]_w {1}	No technique applied	0.05	0.349	0.79	1	-
[ES_007]_w {1}	Biological treatment- Activated sludge process-Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation-Flotation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Other Coagulation and flocculation-Sedimentation	0.1	0.250	2	2	-
[ES_006]_w {1}	Chemical reduction-Coagulation and flocculation-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Flotation-Membrane micro/ultra/nano filtration-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Sedimentation-Reverse osmosis-Neutralisation	0.100	0.292	2.2	-	1223

Source: [168, TWG 2023]

3.3.2 Water consumption and waste water discharge

The reported data for specific water consumption are presented in the following figure. Consumption data and contextual information are also presented in Table 3-52.



Source: [168, TWG 2023]

Figure 3-53: Specific water consumption expressed in m^3 per t of coil coated in continuous steel coil coating plants

Table 3-52: Reported data (expressed in m^3 per t of coil coated) and contextual information for specific water consumption in continuous steel coil coating plants

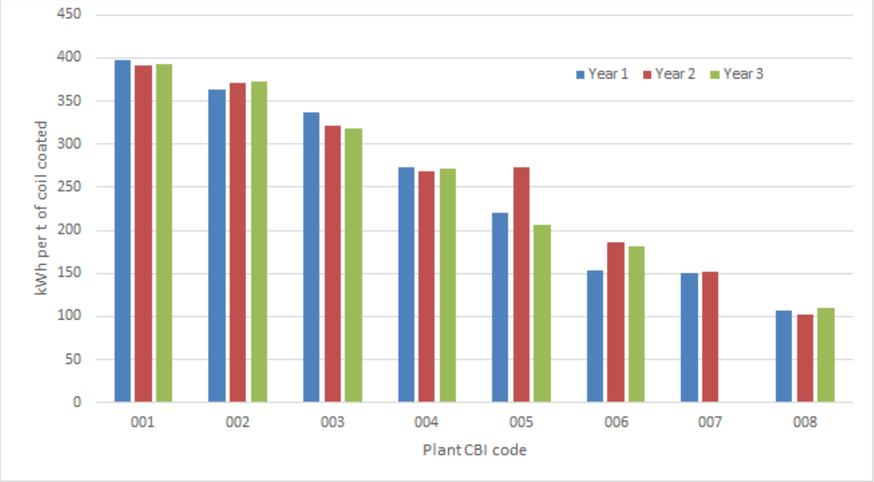
Plant code	Max.	Avg.	Min.	Associated process	Monitoring method	Technique	Year of implementation	Additional information
[AT_013]	1.35	1.25	1.16	Rinsing-	Measured	Reuse of water by using multiple rinsing steps	1985-	-
[BE_002]	0.52	0.50	0.48	Degreasing- Pickling- Plating- Rinsing-	Measured	Recirculating rinsing water from etching and surface treatment to surface treatment baths- -Reuse of purified water from evaporation (e.g. from waste water)-Reuse of water by using multiple rinsing steps	1993- 1993- 1993- 1993-	use of ultrafiltration-use of acid retardation-pre-treatment/ post treatment-
[ES_005]	1.03	0.87	0.74	Cleaning- Other-	Calculated	Reuse of water by using multiple rinsing steps-Use of closed cooling systems	-	-Electrocoating (e-coating)-
[ES_007]	0.282	0.28	0.281	Other- Cleaning-	Measured	Reuse of purified water from evaporation (e.g. from waste water)-Recirculating rinsing water from etching and surface treatment to surface treatment baths	2021- 2021-	condensate recovery steam pipes-
[ES_008]	7.45	7.41	7.38	Other	Calculated	Use of closed cooling systems-Reuse of water by using multiple rinsing steps-Recirculating rinsing water from etching and surface treatment to surface treatment baths	-	pickling section + quenching section + passivation section + tinning section-degreasing + pickling + passivation section. 2 rinsing steps . Water of first

Plant code	Max.	Avg.	Min.	Associated process	Monitoring method	Technique	Year of impleme-ntation	Additional information
								step uses overflow of second step-degreasing + pickling + passivation section. 2 rinsing steps in which water is recirculated
[FR_004]	1.002	0.935	0.896	Other-Rinsing-Other	Calculated	Reuse of water by using multiple rinsing steps-Recirculating rinsing water from etching and surface treatment to surface treatment baths-Use of closed cooling systems	-1993-~1981	Tous les rinçages : dégraissage, décapage, revêtement, passivation-Sur deuxième rinçages chromique (chromage et passivation)-Refroidissement des circuits secondaires sur Tours aéro-réfrigérantes
[IT_010]	0.75	0.75	0.75	Rinsing-	-	Other-	2007-	The demineralization system allows you to consume fresh water limited to the quantities necessary to replenish evaporation losses and to prepare the regenerating solutions-
[IT_033]	1.35	1.325	1.3	Degreasing-Pickling-Anodising	Measured	Other-	2020-2020-2020	replacement of water from the main supplier with ground water-
[SK_001]	2.6	2.4	2.2	Plating-Rinsing	Calculated	Reuse of purified water from evaporation (e.g. from waste water)-Use of closed cooling systems-Other	2000-1968-2000	-we use condensate from steam heating

Source: [168, TWG 2023]

3.3.3 Energy efficiency

The reported data for specific energy consumption are presented in the following figure.



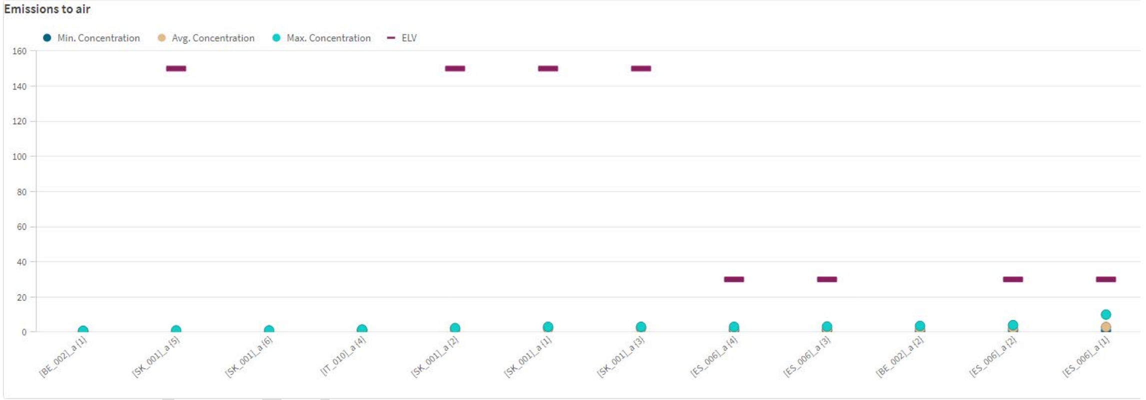
Source: [168, TWG 2023]

Figure 3-54: Specific energy consumption expressed in kWh per t of coil coated face in continuous steel coil coating plants

3.3.4 Emissions to air

3.3.4.1 Dust

The reported data for dust emissions to air are presented in the following figure. Emission data and contextual information are also presented in Table 3-53.



Source: [168, TWG 2023]

Figure 3-55: Dust emissions to air from continuous steel coil coating plants

Table 3-53: Reported data and contextual information for dust emissions to air from continuous steel coil coating plants

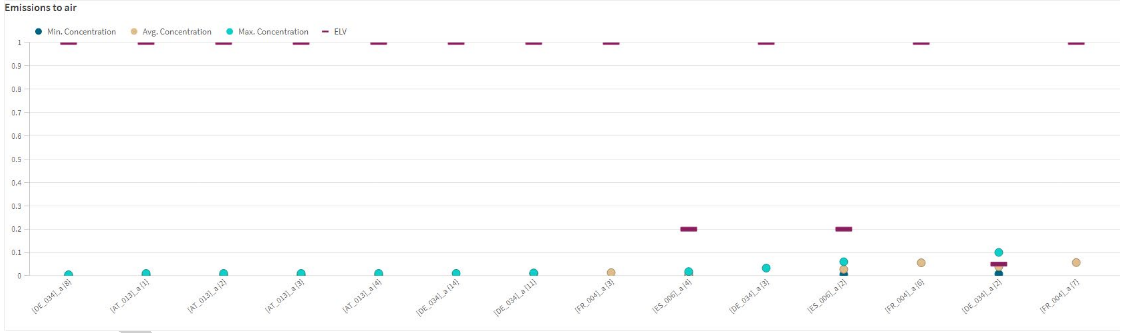
EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[BE_002]_a {1}		Scrubber- absorption (acid/alkaline)-	0.767	0.767	0.767	-	-
			0.407	0.407	0.407	-	-
			0.0616	0.0616	0.0616	-	-
[BE_002]_a {2}	Alkaline degreasing-Rinsing-Pickling (not electrically), descaling and desmutting-Plating-Other-	Scrubber- absorption (acid/alkaline)	3.55	3.55	3.55	-	-
			1.13	1.13	1.13	-	-
			0.513	0.513	0.513	-	-
[ES_006]_a {1}	Degreasing-Pickling (not electrically), descaling and desmutting-	Aerosol/droplet separator	10	4.67	2	30	0.08
			3.13	3.09	3.02	30	0.03
			1	1	1	30	0.01
[ES_006]_a	Electrocoating (e-coating)	Aerosol/droplet separator	4	2.67	1	30	0.04

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
{2}			3	3	3	30	0.05
			1	1	1	30	0.02
[ES_006]_a {3}	Degreasing-Pickling (not electrically), descaling and desmutting-	Aerosol/droplet separator -	3.22	3.2	3.18	30	0.07
			1	1	1	30	0.02
			1	1	1	30	0.11
[ES_006]_a {4}	Electrocoating (e-coating)	Aerosol/droplet separator	3	1.665	1	30	0.02
			2.2	2.03	1.9	30	0.01
[IT_010]_a {4}	Other	Cyclone-Other	1.48	1.21	0.96	-	-
[SK_001]_a {1}	Alkaline degreasing-Rinsing--	Scrubber- absorption (acid/alkaline)	3	2	-	150	0.023
			2.7	2	-	150	0.021
[SK_001]_a {2}	Plating-Pickling (not electrically), descaling and desmutting--Other-Rinsing-	Scrubber- absorption (acid/alkaline)	2.3	1.8	-	150	0.035
			0.7	0.4	-	150	0.026
[SK_001]_a {3}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting- Rinsing--	Scrubber- absorption (acid/alkaline)	3	2	-	150	0.018
			2	2	-	150	0.018
[SK_001]_a {5}	Other- Rinsing	Scrubber- absorption (acid/alkaline)	1	-	-	150	0.007
			0.7	-	-	150	0.016
[SK_001]_a {6}	Drying	-	1	-	-	-	-

Source: [168, TWG 2023]

3.3.4.2 Chromium

The reported data for chromium emissions to air are presented in the following figure. Emission data and contextual information are also presented in Table 3-54.



Source: [168, TWG 2023]

Figure 3-56: Cr emissions to air from continuous steel coil coating plants

Table 3-54: Reported data and contextual information for Cr emissions to air from continuous steel coil coating plants

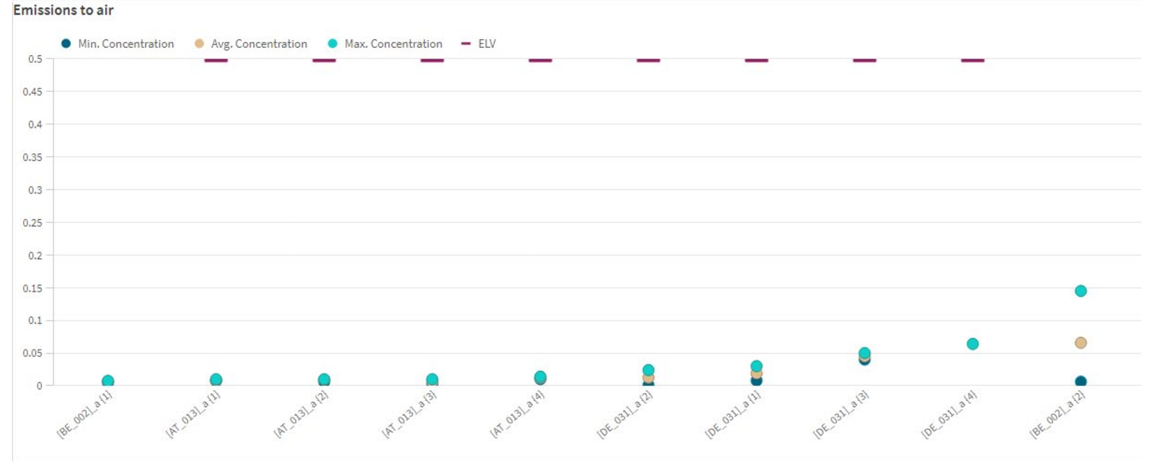
EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[AT_013]_a {1}	Other	Mist filter (demister)	0.01	0.01	0.01	1	-
[AT_013]_a {1}	Other	-	0.002	0.002	0.002	1	-
[AT_013]_a {2}	Other-Rinsing-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	1	-
			0.002	0.002	0.002	1	-

[AT_013]_a {3}	Rinsing-Other-	Scrubber-absorption (acid/alkaline)	0.01	0.01	0.01	1	-
			0.002	0.002	0.002	1	-
[AT_013]_a {4}	Other	No technique applied	0.01	0.01	0.01	1	-
			0.002	0.002	0.002	1	-
[DE_034]_a {2}	Electrocoating (e-coating)-Rinsing--Drying	Other	0.1001	0.1001	0.1001	0.05	-
		-	0.008	0.008	0.008	0.05	-
[DE_034]_a {3}	Other	Other	0.033	-	-	1	-
		-	0.0024	-	-	1	-
[DE_034]_a {8}	Other-Rinsing-	Other	0.0044	0.0044	0.0044	1	-
			0.0033	0.0033	0.0033	1	-
			0.0011	0.0011	0.0011	1	-
[DE_034]_a {11}	Other- Rinsing-	Other	0.012	0.012	0.012	1	-
			0.011	0.011	0.011	1	-
			0.0086	0.0086	0.0086	1	-
[DE_034]_a {14}	Other-Rinsing-	Other	0.0102	-	-	1	-
			0.0100	-	-	1	-
			0.0086	-	-	1	-
[ES_006]_a {2}	Electrocoating (e-coating)	Aerosol/droplet separator	0.06	0.06	0.06	0.2	0.00095
			0.017	0.017	0.017	0.2	0.00028
			0.0057	0.0057	0.0057	0.2	0.00087
[ES_006]_a {4}	Electrocoating (e-coating)	Aerosol/droplet separator	0.018	0.018	0.018	0.2	0.00019
			0.01	0.01	0.01	0.2	0.00012
			0.0029	0.0029	0.0029	0.2	1.0E-5
[FR_004]_a {3}	Other	No technique applied	-	0.0133	-	1	not concerned
[FR_004]_a {6}	Plating	Mist filter (demister)	-	0.0557	-	1	-
[FR_004]_a {7}	Plating	Mist filter (demister)	-	0.0566	-	1	not concerned

Source: [168, TWG 2023]

3.3.4.3 Nickel

The reported data for nickel emissions to air are presented in the following figure. Emission data and contextual information are also presented in Table 3-55.



Source: [168, TWG 2023]

Figure 3-57: Ni emissions to air from continuous steel coil coating plants

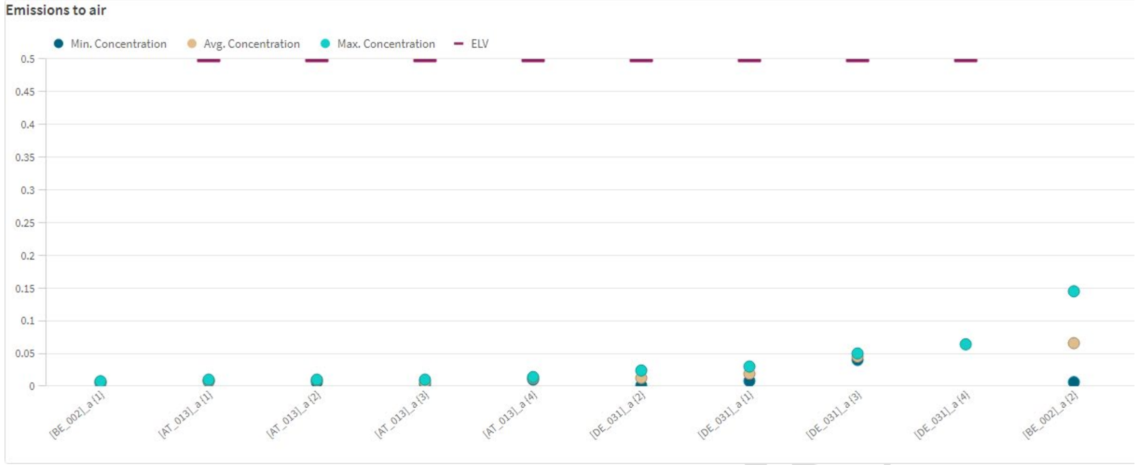
Table 3-55: Reported data and contextual information for Ni emissions to air from continuous steel coil coating plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[AT_013]_a {1}	Other	Mist filter (demister)	0.01	0.0085	0.007	0.5	-
[AT_013]_a {2}	Other-Rinsing-	Scrubber- absorption (acid/alkaline)	0.01	0.009	0.006	0.5	-
[AT_013]_a {3}	Rinsing-Other-	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	0.5	-
			0.003	0.003	0.003	0.5	-
[AT_013]_a {4}	Other	No technique applied	0.014	0.012	0.01	0.5	-
[BE_002]_a {1}		Scrubber- absorption (acid/alkaline)	0.0075	0.0075	0.0075	-	-
			0.00732	0.00732	0.00732	-	-
			0.00485	0.00485	0.00485	-	-
[BE_002]_a {2}	Alkaline degreasing-Rinsing-Pickling (not electrically), descaling and desmutting-Plating-Other	Scrubber- absorption (acid/alkaline)	0.145	0.145	0.145	-	-
			0.046	0.046	0.046	-	-
			0.0062	0.0062	0.0062	-	-
[DE_031]_a {1}	Plating-Pickling (not electrically), descaling and desmutting-	Scrubber- absorption (acid/alkaline)	0.03	0.03	0.03	0.5	0.0005
			0.008	0.008	0.008	0.5	0.0002
[DE_031]_a {2}	Plating	Scrubber- absorption (acid/alkaline)	0.024	0.024	0.024	0.5	0.0002
			0.001	0.001	0.001	0.5	1.0E-5
[DE_031]_a {3}	Plating	Scrubber- absorption (acid/alkaline)	0.05	0.05	0.05	0.5	0.001
			0.04	0.04	0.04	0.5	0.0009
[DE_031]_a {4}	Plating-Pickling (not electrically), descaling and desmutting-	Scrubber- absorption (acid/alkaline)	0.064	-	-	0.5	0.0014
			0.007	-	-	0.5	0.0002
[AT_013]_a {1}	Other	Mist filter (demister)	0.01	0.0085	0.007	0.5	-
[AT_013]_a {2}	Other-Rinsing-	Scrubber- absorption (acid/alkaline)	0.01	0.009	0.006	0.5	-
[AT_013]_a {3}	Rinsing-Other--	Scrubber- absorption (acid/alkaline)	0.01	0.01	0.01	0.5	-
			0.003	0.003	0.003	0.5	-
[AT_013]_a {4}	Other	No technique applied	0.014	0.012	0.01	0.5	-
[BE_002]_a {1}		Scrubber- absorption (acid/alkaline)	0.0075	0.0075	0.0075	-	-
			0.00732	0.00732	0.00732	-	-
			0.00485	0.00485	0.00485	-	-
[BE_002]_a {2}	Alkaline degreasing-Rinsing-Pickling (not electrically), descaling and desmutting- Plating-Other-	Scrubber- absorption (acid/alkaline)	0.145	0.145	0.145	-	-
			0.046	0.046	0.046	-	-
			0.0062	0.0062	0.0062	-	-
[DE_031]_a {1}	Plating-Pickling (not electrically), descaling and desmutting-	Scrubber- absorption (acid/alkaline)	0.03	0.03	0.03	0.5	0.0005
			0.008	0.008	0.008	0.5	0.0002
[DE_031]_a {2}	Plating-	Scrubber- absorption (acid/alkaline)	0.024	0.024	0.024	0.5	0.0002
			0.001	0.001	0.001	0.5	1.0E-5
[DE_031]_a {3}	Plating	Scrubber- absorption (acid/alkaline)	0.05	0.05	0.05	0.5	0.001
			0.04	0.04	0.04	0.5	0.0009
[DE_031]_a {4}	Plating-Pickling (not electrically), descaling and desmutting-	Scrubber- absorption (acid/alkaline)	0.064	-	-	0.5	0.0014
			0.007	-	-	0.5	0.0002

Source: [168, TWG 2023]

3.3.4.4 Zinc

The reported data for zinc emissions to air are presented in the following figure. Emission data and contextual information are also presented in Table 3-56.



Source: [168, TWG 2023]

Figure 3-58: Zn emissions to air from continuous steel coil coating plants

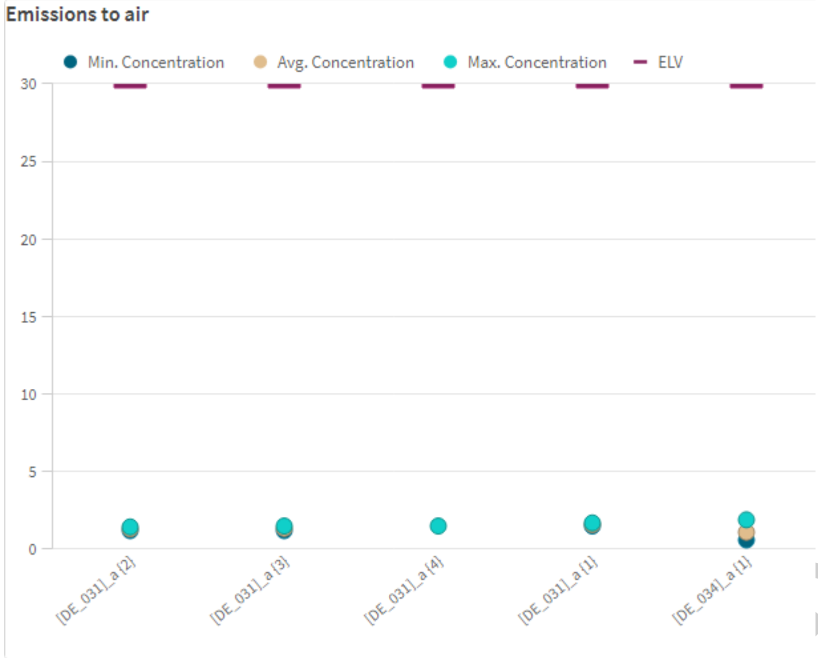
Table 3-56: Reported data and contextual information for Zn emissions to air from continuous steel coil coating plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[AT_013]_a {1}	Other	Mist filter (demister)	0.38	0.383	0.38	-	-
			0.03	0.03	0.03	-	-
[AT_013]_a {2}	Other-Rinsing-	Scrubber- absorption (acid/alkaline)	0.47	0.469	0.47	-	-
			0.01	0.01	0.01	-	-
[AT_013]_a {3}	Rinsing-Other-	Scrubber- absorption (acid/alkaline)-	0.22	0.218	0.22	-	-
			0.02	0.015	0.02	-	-
[AT_013]_a {4}	Other	No technique applied	0.704	0.704	0.704	-	-
			0.01	0.01	0.01	-	-
[BE_002]_a {1}		Scrubber- absorption (acid/alkaline)	0.0593	0.0593	0.0593	-	-
			0.0519	0.0519	0.0519	-	-
			0.0331	0.0331	0.0331	-	-
[BE_002]_a {2}	Alkaline degreasing-Rinsing-Pickling (not electrically), descaling and desmutting--Plating- Other	Scrubber- absorption (acid/alkaline)	0.56	0.56	0.56	-	-
			0.289	0.289	0.289	-	-
			0.0581	0.0581	0.0581	-	-
[ES_005]_a {2}	Electrocoating (e-coating)	Scrubber- absorption (acid/alkaline) -	0.37	0.3	0.27	0.5	0.012067
			0.1	0.1	0.1	0.5	0.00167
			0.072	0.0499	0.0349	0.5	0.002196
[ES_005]_a {3}	Electrocoating (e-coating)	Scrubber- absorption (acid/alkaline)	0.1096	0.074267	0.0428	0.5	0.03185
			0.1	0.1	0.1	0.5	0.00233
			0.0477	0.0477	0.0477	0.5	0.00206
[ES_005]_a {4}	Other	Scrubber- absorption (acid/alkaline)	0.46	0.39	0.27	0.5	6.5E-5
			0.3	0.23	0.1	0.5	0.001
			0.11	0.09377	0.0846	0.5	0.663

Source: [168, TWG 2023]

3.3.4.5 HCl

The reported data for HCl emissions to air are presented in the following figure. Emission data and contextual information are also presented in Table 3-57.



Source: [168, TWG 2023]

Figure 3-59: HCl emissions to air from continuous steel coil coating plants

Table 3-57: Reported data and contextual information for HCl emissions to air from continuous steel coil coating plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[DE_031]_a {1}	Plating-Pickling (not electrically), descaling and desmutting-	Scrubber- absorption (acid/alkaline)	1.7	1.6	1.5	30	-
[DE_031]_a {2}	Plating	Scrubber- absorption (acid/alkaline)	1.44	1.32	1.2	30	-
[DE_031]_a {3}	Plating	Scrubber- absorption (acid/alkaline)	1.5	1.35	1.2	30	-
[DE_031]_a {4}	Plating-Pickling (not electrically), descaling and desmutting-	Scrubber- absorption (acid/alkaline)	1.5	-	-	30	-
[DE_034]_a {1}	Pickling (not electrically), descaling and desmutting--Rinsing-	Other	1.9	1.9	1.9	30	-
[DE_034]_a {1}	Pickling (not electrically), descaling and desmutting-Rinsing-	-	0.8	0.7	0.6	30	-

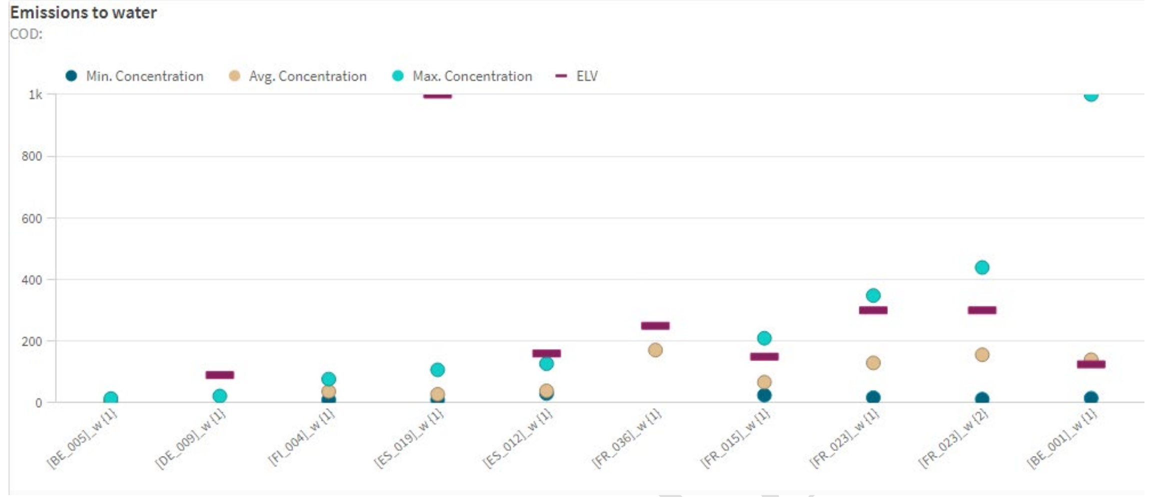
Source: [168, TWG 2023]

3.4 Aluminium coil, sheet conversion coating and anodising

3.4.1 Emissions to water

3.4.1.1 COD

The reported data for COD emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-58.



Source: [168, TWG 2023]

Figure 3-60: COD emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-58: Reported data and contextual information for COD emissions to water from aluminium coil, sheet conversion coating and anodising plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[BE_005]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation	0	6.15	13.7	-	-	-
[DE_009]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Other-Filtration (e.g. gravel filter, sand filter)-Other	-	-	22	-	90	-
[FI_004]_w {1}	Coagulation and flocculation-Flotation-Sedimentation-Ion exchange resins	9.6	36.83	77	-	-	-
[ES_019]_w {1}	Chemical reduction	10	27.61	107	-	1000	-
[ES_012]_w {1}	Neutralisation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	30	38.78	127	45	160	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	171.1	-	-	250	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	24.8	66.93	209.6	104.8	150	-

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	17	129.54	348	232	300	-
[FR_023]_w {2}	Neutralisation-Precipitation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	12	155.96	439	412.75	300	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	15	140	1000	-	125	-

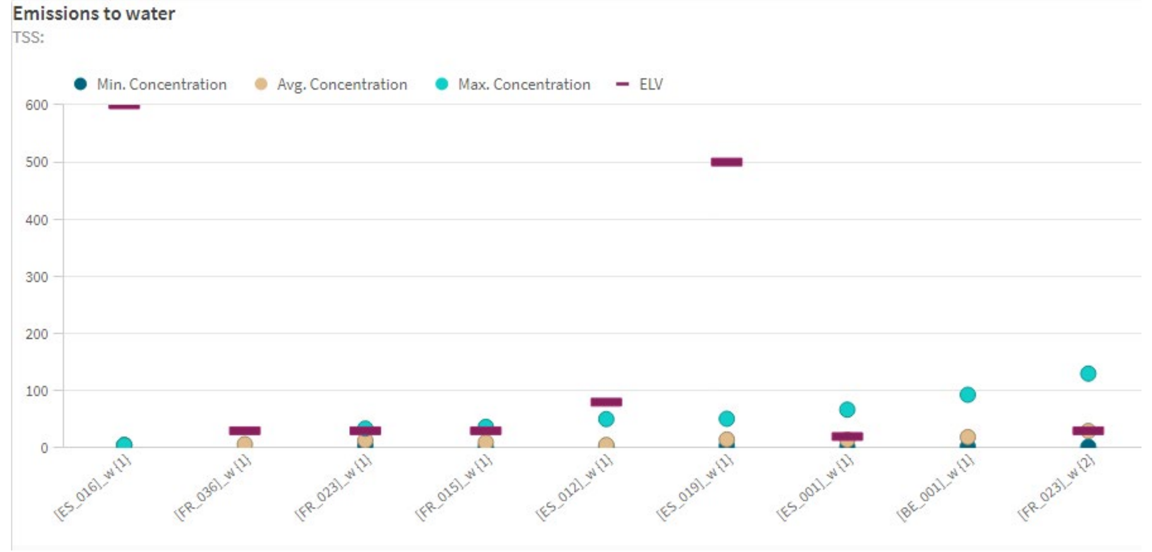
Source: [168, TWG 2023]

3.4.1.2 TOC

No data reported.

3.4.1.3 TSS

The reported data for TSS emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-59.



Source: [168, TWG 2023]

Figure 3-61: TSS emissions to water from aluminium coil, sheet conversion coating and anodising plants

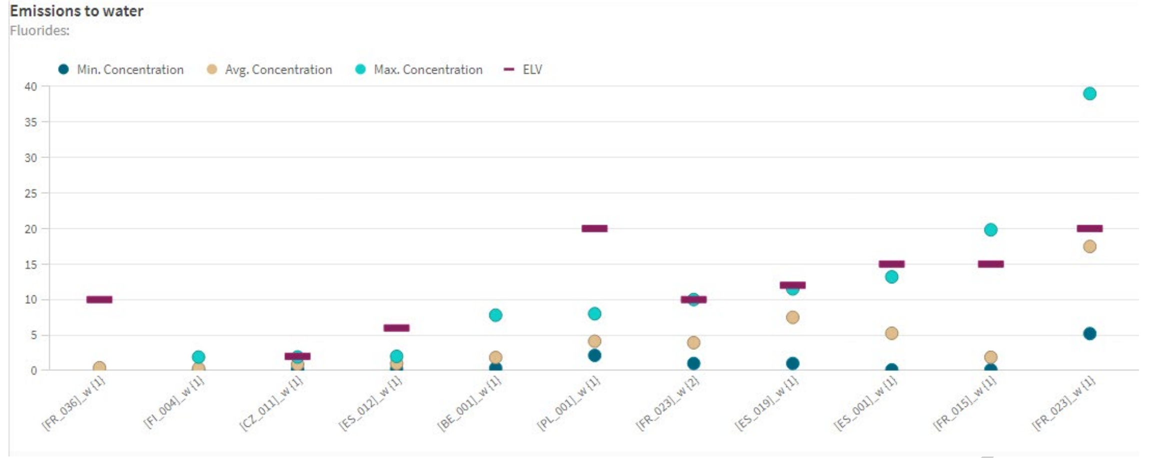
Table 3-59: Reported data and contextual information for TSS emissions to water from aluminium coil, sheet conversion coating and anodising plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[ES_016]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Filtration (e.g. gravel filter, sand filter)	5	5	5	-	600	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	6.62	-	-	30	-
[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	4	13.21	34	26.5	30	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	2	9.68	36.9	30.4	30	-
[ES_012]_w {1}	Neutralisation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	3	5.2	50.4	7	80	-
[ES_019]_w {1}	Chemical reduction	4	14.79	51	-	500	-
[ES_001]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	2	14.33	67	-	20	4692.48
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	2	19	93	-	-	-
[FR_023]_w {2}	Neutralisation-Precipitation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	2	29.71	130	94	30	-

Source: [168, TWG 2023]

3.4.1.4 Fluorides

The reported data for fluorides emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-60.



Source: [168, TWG 2023]

Figure 3-62: Fluorides emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-60: Reported data and contextual information for fluorides emissions to water from aluminium coil, sheet conversion coating and anodising plants

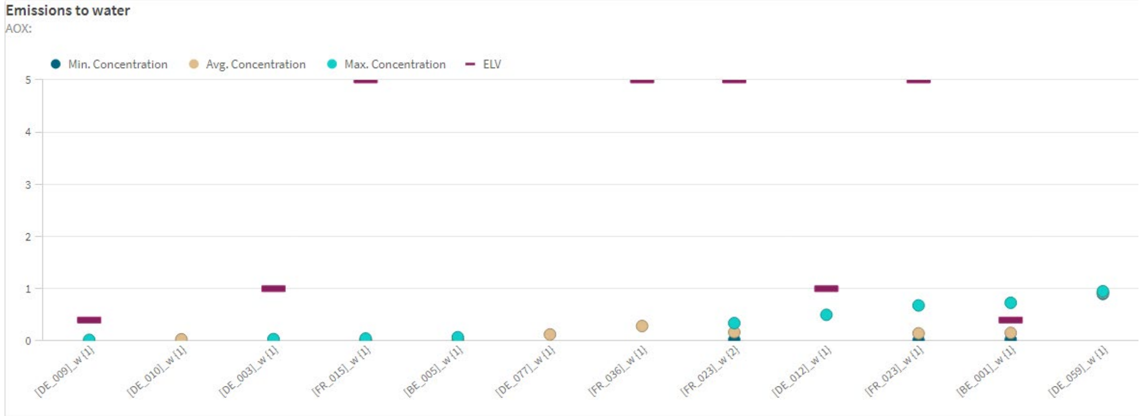
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	0.39	-	-	10	-
[FI_004]_w {1}	Coagulation and flocculation-Flotation-Sedimentation-Ion exchange resins	0.02	0.3	1.9	-	-	-
[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid	0.14	0.87	1.91	1.89	2	-
[ES_012]_w {1}	Neutralisation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.2	0.98	2	1.3	6	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.33	1.83	7.8	-	-	-
[PL_001]_w {1}	Neutralisation-Coagulation and flocculation	2.13	4.12	8	-	20	-
[FR_023]_w {2}	Neutralisation-Precipitation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	1	3.925	10	7.8	10	-
[ES_019]_w {1}	Chemical reduction	1	7.49	11.5	-	12	-
[ES_001]_w	Neutralisation-Coagulation and flocculation-	0.1	5.25	13.194	-	15	3534.024

{1}	Sedimentation-Filtration (e.g. gravel filter, sand filter)						
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.1	1.87	19.82	3.94	15	-
[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	5.2	17.47	39	18.25	20	-

Source: [168, TWG 2023]

3.4.1.5 AOX

The reported data for AOX emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-61.



Source: [168, TWG 2023]

Figure 3-63: AOX emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-61: Reported data and contextual information for AOX emissions to water from aluminium coil, sheet conversion coating and anodising plants

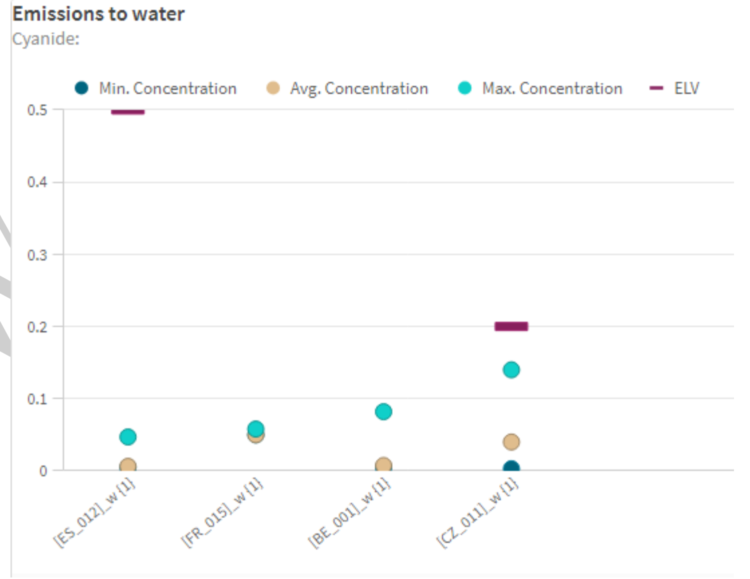
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[DE_009]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Other-Filtration (e.g. gravel filter, sand filter)	-	-	0.02	-	0.4	-
[DE_010]_w {1}	Coagulation and flocculation	-	0.031	-	-	-	-
[DE_003]_w {1}	Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Other	-	-	0.035	-	1	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.01	0.013	0.045	0.01	5	-
[BE_005]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation	0	0.023	0.07	-	-	-
[DE_077]_w {1}	-	-	0.123	-	-	-	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-	-	0.285	-	-	5	-

	Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)						
[FR_023]_w {2}	Neutralisation-Precipitation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.017	0.164	0.34	-	5	-
[DE_012]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation	-	-	0.5	-	1	-
[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.01	0.145	0.68	-	5	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.022	0.154	0.73	-	0.4	-
[DE_059]_w {1}	Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Precipitation	0.9	0.923	0.95	-	-	-

Source: [168, TWG 2023]

3.4.1.6 Cyanides

The reported data for cyanide emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-62.



Source: [168, TWG 2023]

Figure 3-64: Cyanide emissions to water from aluminium coil, sheet conversion coating and anodising plants

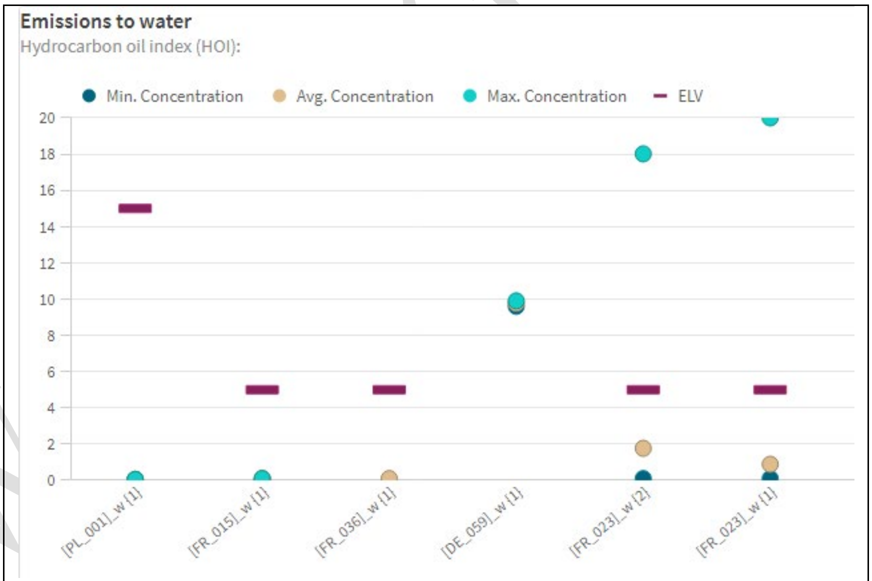
Table 3-62: Reported data and contextual information for cyanide emissions to water from aluminium coil, sheet conversion coating and anodising plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[ES_012]_w {1}	Neutralisation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.005	0.0063	0.047	0.009	0.5	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.05	0.05	0.058	-	-	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.005	0.0075	0.082	-	-	-
[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid	0.003	0.04	0.14	0.05	0.2	-

Source: [168, TWG 2023]

3.4.1.7 HOI

The reported data for HOI emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-63.



Source: [168, TWG 2023]

Figure 3-65: HOI emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-63: Reported data and contextual information for HOI emissions to water from aluminium coil, sheet conversion coating and anodising plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[PL_001]_w {1}	Neutralisation-Coagulation and flocculation	0.05	0.05	0.05	-	15	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-	0.03	0.1	0.1	0.1	5	-

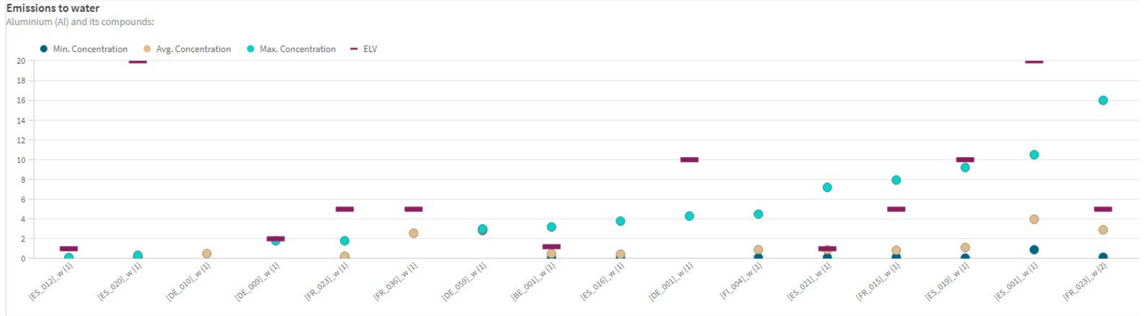
	Other-Precipitation-Filtration (e.g. gravel filter, sand filter)						
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks- Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.1	-	-	5	-
[DE_059]_w {1}	Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Precipitation	9.6	9.77	9.9	-	-	-
[FR_023]_w {2}	Neutralisation-Precipitation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.1	1.77	18.0125	12.0125	5	-
[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.1	0.88	20	0.5575	5	-

Source: [168, TWG 2023]

3.4.1.8 Metals and metaloids

3.4.1.8.1 Al

The reported data for aluminium emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-64.



Source: [168, TWG 2023]

Figure 3-66: Al emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-64: Reported data and contextual information for Al emissions to water from aluminium coil, sheet conversion coating and anodising plants

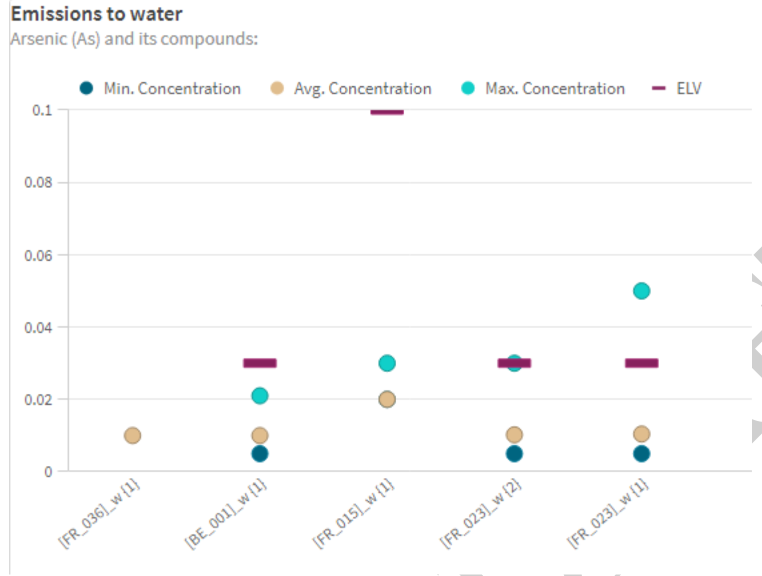
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[ES_012]_w {1}	Neutralisation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.048	0.106	0.05	1	-
[ES_020]_w {1}	Elimination and/or separation of the individual pollutants at the point of generation-Neutralisation-Coagulation and flocculation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.11	0.213	0.33	-	20	23

[DE_010]_w {1}	Coagulation and flocculation	-	0.507	-	-	-	-
[DE_009]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Other-Filtration (e.g. gravel filter, sand filter)	-	-	1.8	-	2	-
[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.018	0.238	1.8	0.34725	5	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	2.56	-	-	5	-
[DE_059]_w {1}	Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Precipitation	2.84	2.913	3	-	-	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.1	0.503	3.2	-	1.2	-
[ES_016]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.1	0.437	3.79	-	-	-
[DE_001]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Precipitation-Neutralisation-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	-	-	4.3	-	10	-
[FI_004]_w {1}	Coagulation and flocculation-Flotation-Sedimentation-Ion exchange resins	0.1	0.9	4.5	-	-	-
[ES_021]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Chemical reduction-Coagulation and flocculation-Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.111	0.894	7.2	-	1	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.15	0.833	7.94	3.26	5	-
[ES_019]_w {1}	Chemical reduction	0.06	1.12	9.21	-	10	-
[ES_001]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.9	3.977	10.5	-	20	2698.1
[FR_023]_w {2}	Neutralisation-Precipitation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.141	2.904	16	14.5	5	-

Source: [168, TWG 2023]

3.4.1.8.2 As

The reported data for arsenic emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-65.



Source: [168, TWG 2023]

Figure 3-67: As emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-65: Reported data and contextual information for As emissions to water from aluminium coil, sheet conversion coating and anodising plants

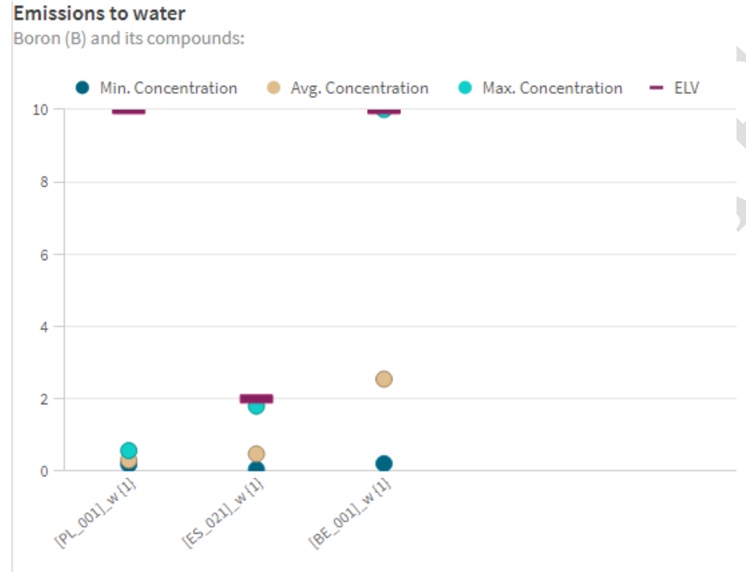
Emission Point	**Abatement technique(s)**	**Min.**	**Avg.**	**Ma.x**	**95th perc.**	**ELV**	**Load (g/day)**
[BE_005]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation	0	0	0	-	-	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.01	-	-	-	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.005	0.01	0.021	-	0.03	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.02	0.02	0.03	0.02	0.1	-
[FR_023]_w {2}	Neutralisation-Precipitation-Sedimentation-Adsorption techniques – activated carbon-Use	0.005	0.0102	0.03	0.015	0.03	-

	of buffer tanks to reduce waste water and emission load peaks						
[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.005	0.0104	0.05	0.0125	0.03	-

Source: [168, TWG 2023]

3.4.1.8.3 B

The reported data for boron emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-66.



Source: [168, TWG 2023]

Figure 3-68: B emissions to water from aluminium coil, sheet conversion coating and anodising plants

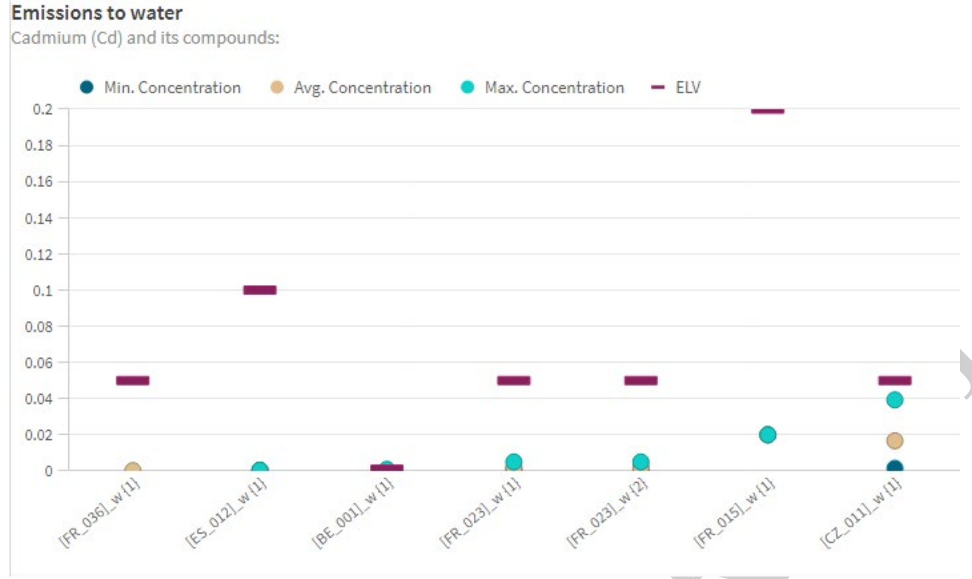
Table 3-66: Reported data and contextual information for B emissions to water from aluminium coil, sheet conversion coating and anodising plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[PL_001]_w {1}	Neutralisation-Coagulation and flocculation	0.19	0.303	0.57	-	10	-
[ES_021]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Chemical reduction-Coagulation and flocculation-Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.051	0.478	1.8	-	2	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.21	2.547	10	-	10	-

Source: [168, TWG 2023]

3.4.1.8.4 Cd

The reported data for cadmium emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-67.



Source: [168, TWG 2023]

Figure 3-69: Cd emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-67: Reported data and contextual information for Cd emissions to water from aluminium coil, sheet conversion coating and anodising plants

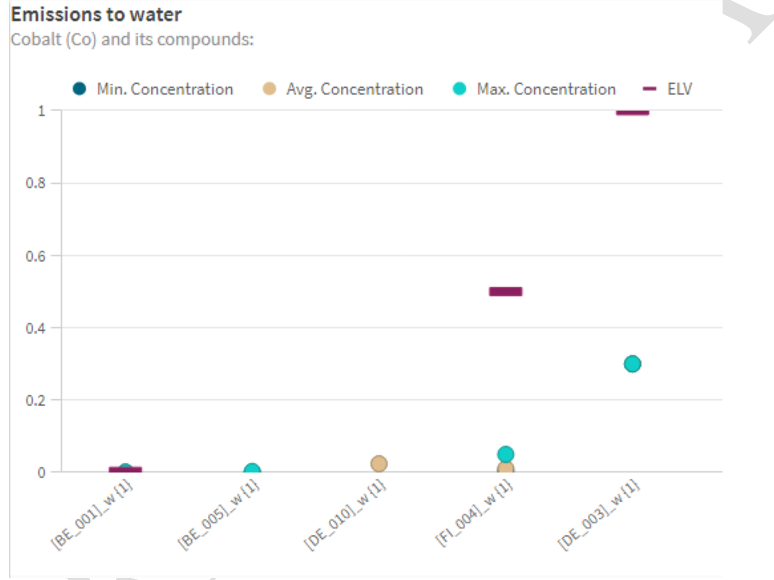
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[BE_005]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation	0	0	0	-	-	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.0002	-	-	0.05	-
[ES_012]_w {1}	Neutralisation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.0004	0.0004	0.0004	0.0004	0.1	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	8.0E-5	0.0001	0.00088	-	0.001	-
[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.001	0.0020	0.005	0.002	0.05	-
[FR_023]_w	Neutralisation-Precipitation-Sedimentation-	0.001	0.0020	0.005	0.002	0.05	-

{2}	Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks						
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.02	0.02	0.02	0.02	0.2	-
[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid	0.0015	0.0167	0.0393	0.03	0.05	-

Source: [168, TWG 2023]

3.4.1.8.5 Co

The reported data for cobalt emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-68.



Source: [168, TWG 2023]

Figure 3-70: Co emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-68: Reported data and contextual information for Co emissions to water from aluminium coil, sheet conversion coating and anodising plants

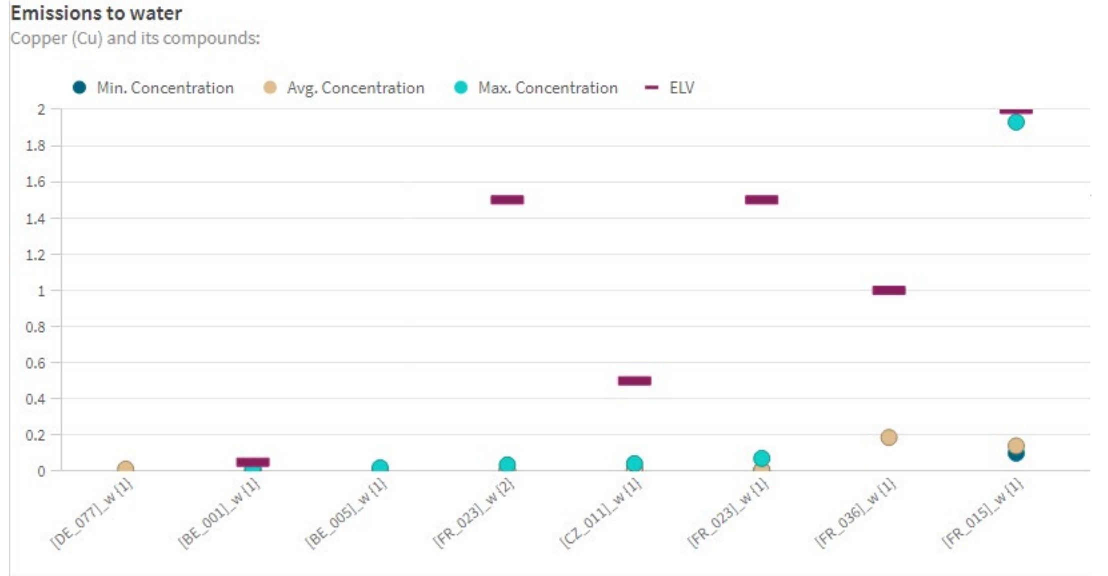
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.0006	0.0006	0.0006	-	0.003	-
[BE_005]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation	0	0	0.003	-	-	-
[DE_010]_w {1}	Coagulation and flocculation	-	0.024	-	-	-	-
[FI_004]_w	Coagulation and flocculation-Flotation-	0.005	0.0108	0.05	-	0.5	-

{1}	Sedimentation-Ion exchange resins						
[DE_003]_w {1}	Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Other	0.3	0.3	0.3	-	1	-

Source: [168, TWG 2023]

3.4.1.8.6 Cu

The reported data for copper emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-69.



Source: [168, TWG 2023]

Figure 3-71: Cu emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-69: Reported data and contextual information for Cu emissions to water from aluminium coil, sheet conversion coating and anodising plants

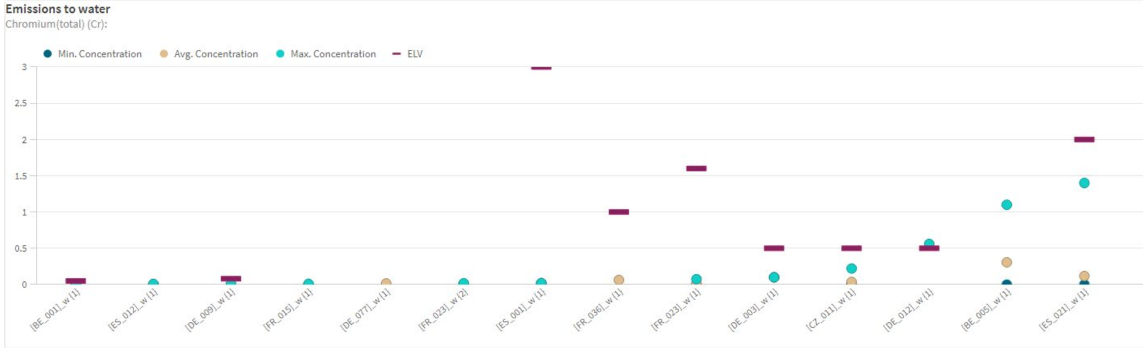
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[DE_077]_w {1}	-	-	0.0119	-	-	-	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.0015	0.0015	0.018	-	0.05	-
[BE_005]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation	0	0.00225	0.019	-	-	-
[FR_023]_w {2}	Neutralisation-Precipitation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.005	0.0062	0.035	0.00725	1.5	-
[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid	0.01	0.008	0.042	0.01	0.5	-
[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption	0.005	0.0067	0.071	0.005	1.5	-

	techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks						
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation- Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)- Neutralisation	-	0.1867	-	-	1	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.1	0.14	1.93	0.85	2	-

Source: [168, TWG 2023]

3.4.1.8.7 Cr

The reported data for chromium (total) emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-70.



Source: [168, TWG 2023]

Figure 3-72: Cr emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-70: Reported data and contextual information for Cr emissions to water from aluminium coil, sheet conversion coating and anodising plants

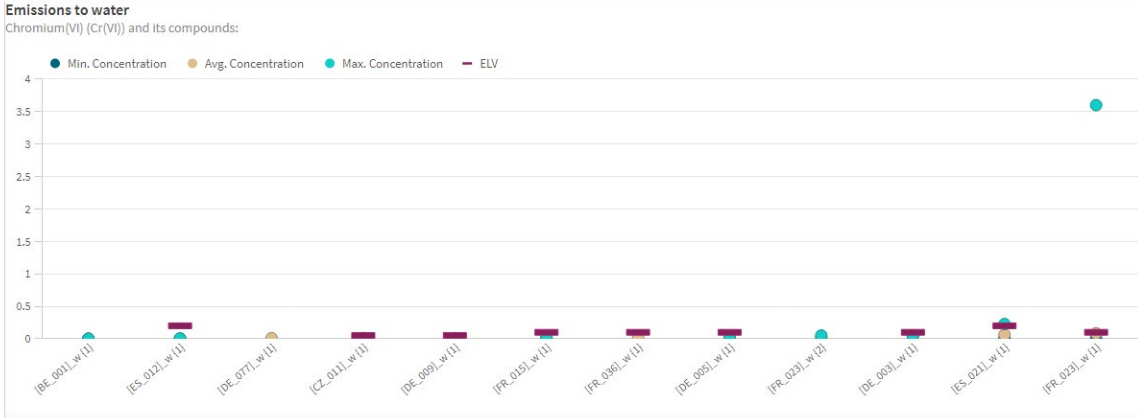
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.0015	0.002	0.0015	-	0.05	-
[ES_012]_w {1}	Neutralisation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.0012	0.003	0.0092	0.004	-	-
[DE_009]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Other-Filtration (e.g. gravel filter, sand filter)	-	-	0.01	-	0.08	-

[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.001	0.001	0.01	0.001	-	-
[DE_077]_w {1}	-	-	0.016	-	-	-	-
[FR_023]_w {2}	Neutralisation-Precipitation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.005	0.005	0.018	0.0055	-	-
[ES_001]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.02	0.02	0.02	-	3	11.731
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.063	-	-	1	-
[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.005	0.011	0.074	0.013	1.6	-
[DE_003]_w {1}	Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Other	0.1	0.1	0.1	-	0.5	-
[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid	0.0107	0.037	0.221	0.04	0.5	-
[DE_012]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation	-	-	0.56	-	0.5	-
[BE_005]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation	0	0.306	1.1	-	-	-
[ES_021]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Chemical reduction-Coagulation and flocculation-Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.004	0.117	1.4	-	2	-

Source: [168, TWG 2023]

3.4.1.8.8 Cr(VI)

The reported data for hexavalent chromium emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-71.



Source: [168, TWG 2023]

Figure 3-73: Cr(VI) emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-71: Reported data and contextual information for Cr(VI) emissions to water from aluminium coil, sheet conversion coating and anodising plants

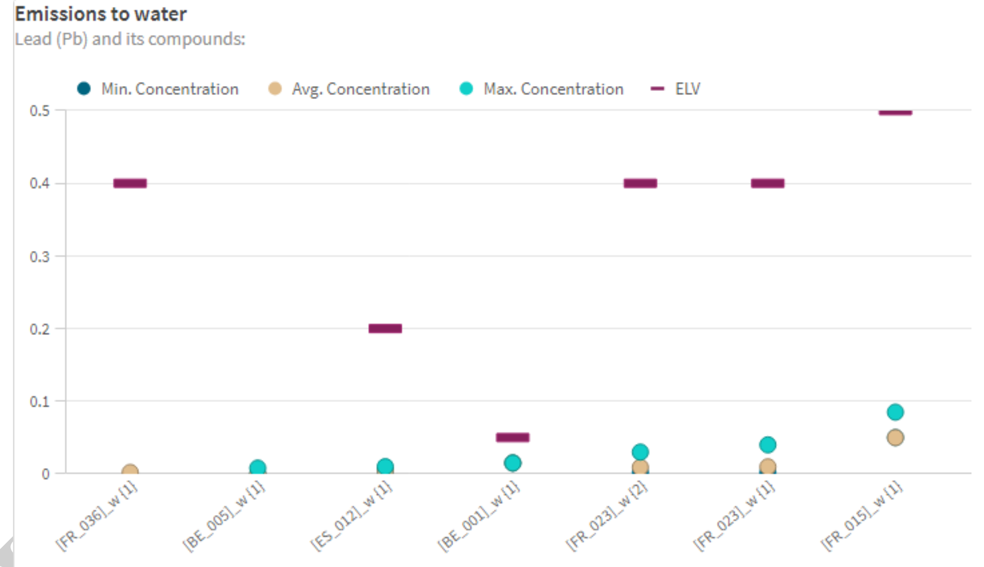
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.0005	0.0005	0.0005	-	-	-
[ES_012]_w {1}	Neutralisation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.0004	0.0017	0.004	0.003	0.2	-
[DE_077]_w {1}	-	-	0.0097	-	-	-	-
[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid	0.01	0.01	0.01	0.01	0.05	-
[DE_009]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Other-Filtration (e.g. gravel filter, sand filter)-	-	-	0.01	-	0.05	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.01	0.01	0.01	0.01	0.1	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.0133	-	-	0.1	-
[DE_005]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Precipitation-Membrane micro/ultra/nano filtration-Filtration (e.g. gravel	0.025	0.028	0.03	-	0.1	-

	filter, sand filter)-Other						
[FR_023]_w {2}	Neutralisation-Precipitation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.01	0.0117	0.05	0.02	-	-
[DE_003]_w {1}	Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Other	0.05	0.05	0.05	-	0.1	-
[ES_021]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Chemical reduction-Coagulation and flocculation-Neutralisation-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.017	0.065	0.227	-	0.2	-
[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.01	0.0848	3.6	0.01	0.1	-

Source: [168, TWG 2023]

3.4.1.8.9 Pb

The reported data for lead emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-72.



Source: [168, TWG 2023]

Figure 3-74: Pb emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-72: Reported data and contextual information for Pb emissions to water from aluminium coil, sheet conversion coating and anodising plants

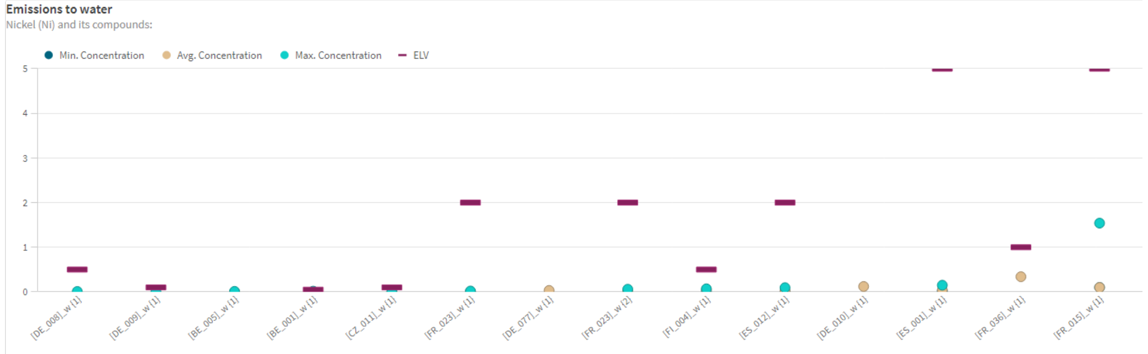
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation	-	0.002	-	-	0.4	-

	(e.g. screens, sieves, grit separators, grease separators, oil-water separation)						
[BE_005]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation	0	0	0.008	-	-	-
[ES_012]_w {1}	Neutralisation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.005	0.0052	0.01	0.005	0.2	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.015	0.015	0.015	-	0.05	-
[FR_023]_w {2}	Neutralisation-Precipitation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.002	0.0091	0.03	0.01	0.4	-
[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.002	0.0098	0.04	0.01	0.4	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.05	0.05	0.085	0.05	0.5	-

Source: [168, TWG 2023]

3.4.1.8.10 Ni

The reported data for nickel emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-73.



Source: [168, TWG 2023]

Figure 3-75: Ni emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-73: Reported data and contextual information for Ni emissions to water from aluminium coil, sheet conversion coating and anodising plants

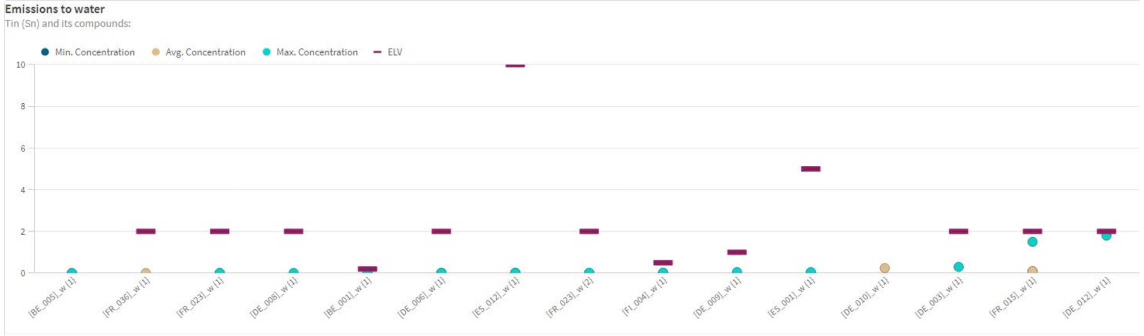
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[DE_008]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	-	0.01	-	0.5	-
[DE_009]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Other-	-	-	0.01	-	0.1	-

	Filtration (e.g. gravel filter, sand filter)						
[BE_005]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation	0	0	0.0119	-	-	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.009	0.0099	0.016	-	0.05	-
[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid	0.006	0.01	0.018	0.02	0.1	-
[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.005	0.0094	0.02	0.0125	2	-
[DE_077]_w {1}	-	-	0.0327	-	-	-	-
[FR_023]_w {2}	Neutralisation-Precipitation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.005	0.0109	0.06	0.0375	2	-
[FI_004]_w {1}	Coagulation and flocculation-Flotation-Sedimentation-Ion exchange resins	0.01	0.05	0.07	-	0.5	-
[ES_012]_w {1}	Neutralisation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.002	0.0245	0.0946	0.04	2	-
[DE_010]_w {1}	Coagulation and flocculation	-	0.1213	-	-	-	-
[ES_001]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.02	0.0367	0.15	-	5	17.597
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.34	-	-	1	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.1	0.1	1.54	0.25	5	-

Source: [168, TWG 2023]

3.4.1.8.11 Sn

The reported data for tin emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-74.



Source: [168, TWG 2023]

Figure 3-76: Sn emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-74: Reported data and contextual information for Sn emissions to water from aluminium coil, sheet conversion coating and anodising plants

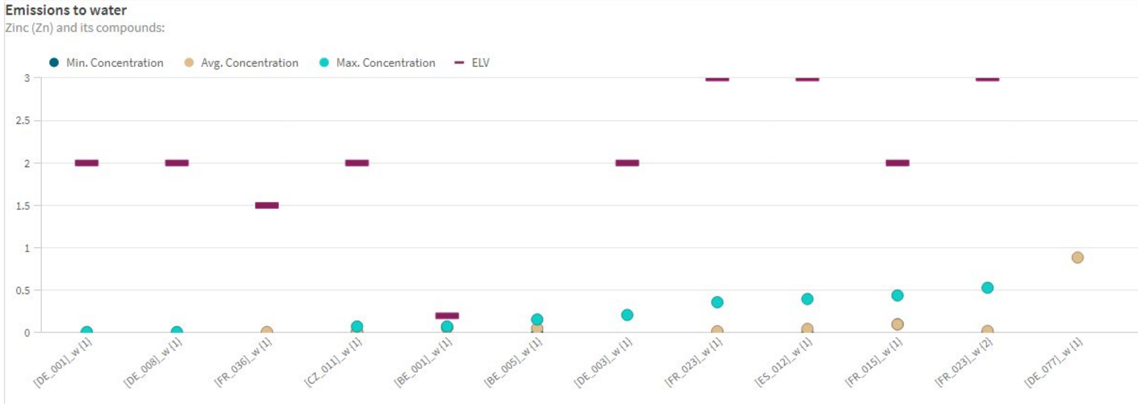
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[BE_005]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation	0	0	0.003	-	-	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.005	-	-	2	-
[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.001	0.002	0.008	-	2	-
[DE_008]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation	-	-	0.01	-	2	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.012	0.012	0.012	-	0.2	-
[DE_006]_w {1}	Precipitation-Sedimentation-Other-Neutralisation-Filtration (e.g. gravel filter, sand filter)	0.015	0.015	0.015	-	2	-
[ES_012]_w {1}	Neutralisation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.01	0.010	0.02	0.01	10	-
[FR_023]_w {2}	Neutralisation-Precipitation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.001	0.004	0.02	-	2	-
[FI_004]_w {1}	Coagulation and flocculation-Flotation-Sedimentation-Ion exchange resins	0	0.008	0.025	-	0.5	-
[DE_009]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Other-Filtration (e.g. gravel filter, sand filter)	-	-	0.05	-	1	-

[ES_001]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.02	0.026	0.05	-	5	19.356
[DE_010]_w {1}	Coagulation and flocculation	-	0.240	-	-	-	-
[DE_003]_w {1}	Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Other	-	-	0.3	-	2	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.1	0.1	1.5	0.14	2	-
[DE_012]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation	-	-	1.8	-	2	-

Source: [168, TWG 2023]

3.4.1.8.12 Zn

The reported data for zinc emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-75.



Source: [168, TWG 2023]

Figure 3-77: Zn emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-75: Reported data and contextual information for Zn emissions to water from aluminium coil, sheet conversion coating and anodising plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[DE_001]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Precipitation-Neutralisation-Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	-	-	0.01	-	2	-
[DE_008]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Neutralisation	-	-	0.01	-	2	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.01	-	-	1.5	-

[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid	0.01	0.013	0.074	0.02	2	-
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.06	0.060	0.075	-	0.2	-
[BE_005]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation	0	0.054	0.157	-	-	-
[DE_003]_w {1}	Neutralisation-Sedimentation-Filtration (e.g. gravel filter, sand filter)-Other	-	-	0.21	-	2	-
[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.005	0.018	0.36	0.020	3	-
[ES_012]_w {1}	Neutralisation-Precipitation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.002	0.046	0.398	0.05	3	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.1	0.1	0.44	0.08	2	-
[FR_023]_w {2}	Neutralisation-Precipitation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.005	0.022	0.53	0.017	3	-
[DE_077]_w {1}	-	-	0.886	-	-	-	-

Source: [168, TWG 2023]

3.4.1.9 Perfluoroalkyl and polyfluoroalkyl substances (PFAS)

The reported data for PFAS emissions to water are presented in the following table.

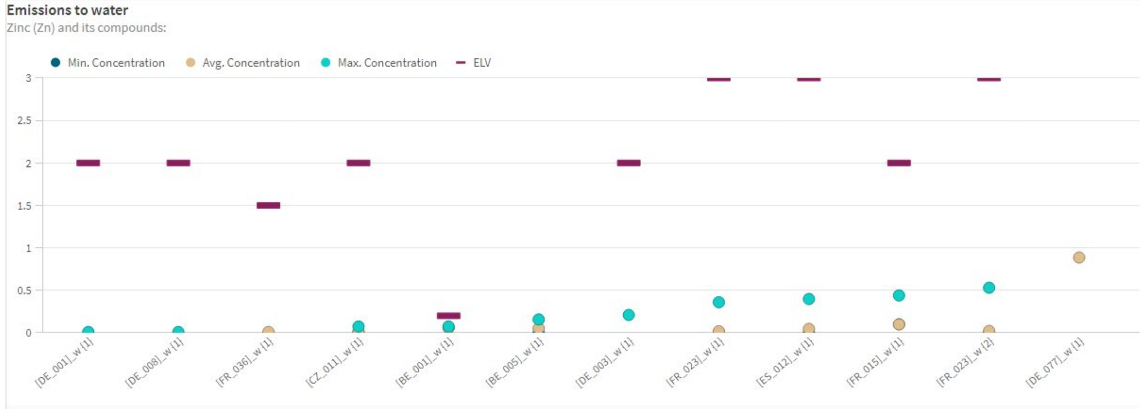
Table 3-76: Reported data and contextual information for PFAS emissions to water from aluminium coil, sheet conversion coating and anodising plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	LoQ	Additional information
[BE_005]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation	0	0.0076	0.5		Average = 0,0076 µg/l
[CZ_011]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Ion exchange liquid- liquid	-	22.7	-	0.5	Sum PFAS; PFOS 18,6; leaching resulting from historical use

Source: [168, TWG 2023]

3.4.1.10 Total phosphorus

The reported data for total phosphorus emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-77.



Source: [168, TWG 2023]

Figure 3-78: TP emissions to water from aluminium coil, sheet conversion coating and anodising plants

Table 3-77: Reported data and contextual information for TP emissions to water from aluminium coil, sheet conversion coating and anodising plants

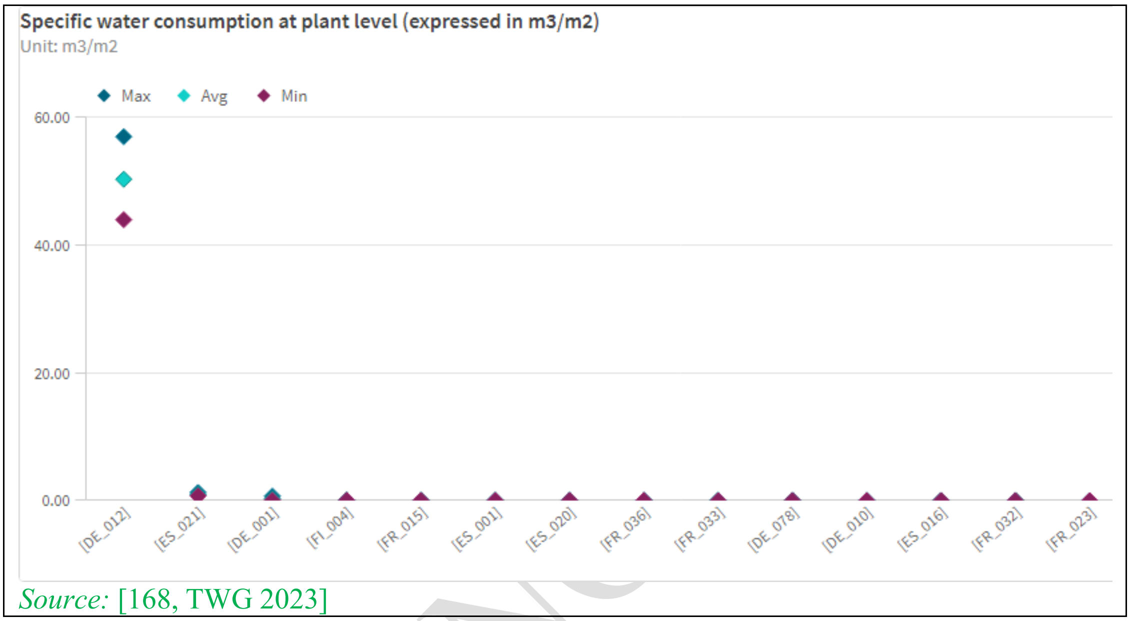
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[BE_005]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation	0	0	0	-	-	-
[FR_036]_w {1}	Coagulation and flocculation-Adsorption techniques – activated carbon-Elimination and/or separation of the individual pollutants at the point of generation-Filtration (e.g. gravel filter, sand filter)-Evaporation (e.g. vacuum evaporation)-Neutralisation-Precipitation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)	-	0.06	-	-	5	-
[DE_009]_w {1}	Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Neutralisation-Sedimentation-Other-Filtration (e.g. gravel filter, sand filter)-Other	-	-	0.11	-	0.2	-
[ES_020]_w {1}	Elimination and/or separation of the individual pollutants at the point of generation-Neutralisation-Coagulation and flocculation-Precipitation-Filtration (e.g. gravel filter, sand filter	0.05	0.09	0.16	-	50	3.5
[FI_004]_w {1}	Coagulation and flocculation-Flotation-Sedimentation-Ion exchange resins-	0	0.02	0.2	-	-	-
[ES_001]_w {1}	Neutralisation-Coagulation and flocculation-Sedimentation-Filtration (e.g. gravel filter, sand filter)	0.1	0.19	0.44	-	2	140.774
[BE_001]_w {1}	Use of buffer tanks to reduce waste water and emission load peaks-Coagulation and flocculation-Neutralisation-Sedimentation-Adsorption techniques – activated carbon-Sedimentation-Physical separation (e.g. screens, sieves, grit separators, grease separators, oil-water separation)-Filtration (e.g. gravel filter, sand filter)	0.3	0.96	3.6	-	2	-
[FR_023]_w {2}	Neutralisation-Precipitation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.04	1.63	11	8	10	-
[FR_015]_w {1}	Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Coagulation and flocculation-Other-Precipitation-Filtration (e.g. gravel filter, sand filter)	0.15	1.07	22.67	6.53	10	-

[FR_023]_w {1}	Neutralisation-Precipitation-Coagulation and flocculation-Sedimentation-Adsorption techniques – activated carbon-Use of buffer tanks to reduce waste water and emission load peaks	0.43	6.85	29	18.85	10	-

Source: [168, TWG 2023]

3.4.2 Water consumption and waste water discharge

The reported data for specific water consumption are presented in the following figure. Consumption data and contextual information are also presented in Table 3-78.



Source: [168, TWG 2023]

Figure 3-79: Specific water consumption expressed in m^3 per m^2 of treated surface inaluminium coil, sheet conversion coating and anodising plants

Table 3-78: Reported data (expressed in m^3 per m^2 of treated surface) and contextual information for specific water consumption in aluminium coil, sheet conversion coating and anodising plants

Plant code	Max.	Avg.	Min.	Associated process	Monitoring method	Technique	Year of impleme-ntation	Additional information
[DE_012]	57	50.3	44	-	Other	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Use of closed cooling systems-Other	-	use of cooling water for rinsing-Recycling with Ion exchanger
[ES_021]	1.28	0.93	0.7382	Anodising-	Estimated	Recirculating rinsing water from etching and surface treatment to surface treatment baths	2016-	-
[DE_001]	0.7	0.27	0.06	-	Measured	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Other	-	-Recycling with Ion exchanger-Recycling with reverse osmosis-

[FI_004]	0.06	0.054	0.05	-	Measured	Reuse of water by using multiple rinsing steps	2012-	-
[FR_015]	0.0387	0.03	0.0284	Plating-	Measured	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Reuse of water by using multiple rinsing steps-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Other	2000-1990-2020-2016-	Using the output water from the cooling system to re-new water in the next rinsing vats instead of the normal adding of water-Depending on the treatment vats, replacing "simple" rinsing by double or tripple cascades rinsing vats-Using treated water from WWTP for pre-treatment rinsing + water cooling système-> Dropout in 2022 because of salinity (clogging of pipes + inlet temperature to high for the cooling system)-Automation of lines (electrovalves + conductivity sensor to re-new rinsing bath)-
[ES_001]	0.0385	0.035	0.03151	Anodising-	Estimated	Use of closed cooling systems-Reuse of water by using multiple rinsing steps	2007-2007-	-
[ES_020]	0.037	0.035	0.033	Etching-Anodising-	Measured	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Use of closed cooling systems-Reuse of water by using multiple rinsing steps-Reuse of purified water from evaporation (e.g. from waste water)-	2010-	-
[FR_036]	0.0324	0.031	0.0299	Plating-	Measured	Recirculating rinsing water from etching and surface	before 2000-1995-	-

						treatment to surface treatment baths-Reuse of water by using multiple rinsing steps		
[FR_033]	0.03	0.0259	0.0247	Plating-Rinsing-	Measured	Other-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	2021- <2020-	Reused of rinsing water after physico chemical treatment to cool vats.-Reused of rinsing water after physico chemical treatment for main rinsing vats.-
[DE_078]	0.025	0.0217	0.02	-	Other	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Use of closed cooling systems-Other	-	use of rinsing water for cooling the etching bathes-Recycling with Ion exchanger
[DE_010]	0.021	0.0193	0.017	Etching-Anodising-	Measured	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Reuse of water by using multiple rinsing steps-Use of closed cooling systems	2009- 2009- 2009- 2009-	-
[ES_016]	0.0129	0.0117	0.0107	Rinsing-	Measured	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Reuse of water by using multiple rinsing steps	2014- 2014-	-
[FR_032]	0.0117	0.0113	0.0108	-	Measured	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Reuse of purified water from evaporation (e.g. from waste water)-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	1976- 2002- 2002	The process associated to the technique is demineralization.-The process associated to the technique is vacuum evaporator-The process associated to the technique is reuse of distillates in the circuit

[FR_023]	0.0004	0.0003	0.0002	Rinsing-Degreasing-	Measured	Reuse of water by using multiple rinsing steps-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	-	Cascade-DG5 and FT1 : A part of water from rinsing is reused to complete degreasing vats-

Source: [168, TWG 2023]

3.4.3 Energy efficiency

The reported data for specific energy consumption are presented in the following figure. Consumption data and contextual information are also presented in Table 3-79. The applied techniques to reduce energy consumption are presented in Table 3-80.

Source: [168, TWG 2023]

Figure 3-80: Specific energy consumption expressed in kWh per m^2 of treated surface in aluminium coil, sheet conversion coating and anodising plants

Table 3-79: Reported data (expressed in kWh^3 per m^2 of treated surface) and contextual information for specific energy consumption in aluminium coil, sheet conversion coating and anodising plants

Plant code	Net Energy (kWh/m^2)	Net Electricity (kWh/m^2)	Net Heat (kWh/m^2)	How the energy consum-ption is monitored	Proportion of energy recovered (%)	How the recovered energy is monitored	Total volume of workspace heated (m^3)	Additional information
[CZ_011]	-	904.55	-	Measured	-	Not monitored	1570.1	We have only consumption MWh, main unit for work is landing gear per year, we cannot more details about consumption.
[DE_001]	19.67	5.77	13.67	Measured	-	-	-	The specific consumptions are rough estimates only because the total surface treated cannot be determined exactly..

Plant code	Net Energy (kWh/m^2)	Net Electricity (kWh/m^2)	Net Heat (kWh/m^2)	How the energy consum-ption is monitored	Proportion of energy recovered (%)	How the recovered energy is monitored	Total volume of workspace heated (m^3)	Additional information
[DE_010]	4.78	3.75	1.03	Measured	-	-	-	-
[DE_012]	6.38	3.30	3.07	Measured	-	-	-	The specific consumptions are rough estimates only because the total surface treated cannot be determined.
[DE_078]	5.75	3.16	2.60	Measured	-	-	-	The specific consumptions are rough estimates only because the total surface treated cannot be determined.
[ES_001]	3.60	1.64	1.96	Estimated	-	-	405	-
[ES_016]	5.65	3.27	2.37	Measured	-	-	-	Data with ‘kWh/m^2’ units are measured, , whereas values with ‘kWh/t’ were estimated
[ES_020]	5.55	3.70	1.85	Measured	-	-	260.1	-
[ES_021]	329.82	156.96	172.87	Measured	0	Not monitored	131.7	Natural gas consumption is considered heat consumption. We only use electricity and natural gas as energy.
[FI_004]	10.00	-	5.00	Measured	-	-	46500	The total surface treated per year is only a rough estimate
[FR_015]	1.58	1.06	0.51	Measured	-	Not monitored	16300	Heating buildings thanks to hot water from the methanisation plant next to ours. Not monitored yet
[FR_016]	-	8.00	-	Calculated	-	-	9374	No data yet for the gas consumption. We are not able to separate our specific net heat consumption.
[FR_023]	0.12	0.04	0.09	Measured	0	-	83000	DG5 : Elec : 0,034 kWh/m2 // Gas : 0,060 kWh/m2 DG 5- Electricity : concerns only DG5 line (heaters, pumps, motors…) waste water treatment not included- heat consumption : only concerns oven for

Plant code	Net Energy (kWh/m²)	Net Electricity (kWh/m²)	Net Heat (kWh/m²)	How the energy consum-ption is monitored	Proportion of energy recovered (%)	How the recovered energy is monitored	Total volume of workspace heated (m³)	Additional information
								drying. Data fot heating other vats not available (usage of closed loop of hot water)FT1 : Gas=0,047 kWh/m2 (vats heating)FT3 : Gas=0,143 kWh/m2 (estimated base on burner power for vats heating and dryers)No specific data for electricity FT1/3
[FR_032]	44,009,591	22,805,549	21,204,042	Other	-	-	77004	The consumption (gas and electricity) taken into account is the total consumption of all the equipments of the site. Consumption is monitored via supplier invoices.For the specific enerfy consumption (kWh/m²)we have mentioned the general consumption of the production siteFor the specific enerfy consumption (kWh/t) we don't have information on the tonnages passed through the surface treatment plant, so we used surface data.
[FR_033]	1312.07	398.44	913.63	Estimated	0	-	22420	Surf. : 21990m² Conso gaz : 17912MWh Conso Elec : 8829MWh
[FR_036]	23.80	-	-	Measured	-	-	-	-

Source: [168, TWG 2023]

Table 3-80: Applied techniques to reduce energy consumption and contextual information for aluminium coil, sheet conversion coating and anodising plants

Plant code	Energy efficiency techniques	Additional information	Year of impleme-ntation
[BE_001]	Use of energy-efficient equipment (e.g. motors, lights)	-	2001

	Thermal insulation of process tanks	-	2001
	Temperature control of heating baths	-	2001
	Pipe insulation	-	2001
	Optimised ventilation, air conditioning and heating	-	2001
	Optimised heating of process solution (see Section 4.4.2)	-	2001
	Energy efficiency plan and energy audits	-	2002
	Energy balance record	-	2002
[BE_005]	Use of floating spheres to insulate the solution surface	-	1992
	Use of energy-efficient equipment (e.g. motors, lights)	-	2015
	Thermal insulation of process tanks	-	1990
	Temperature control of heating baths	-	1990
	Regular maintenance of equipment in the electrical supply system	-	1990
	Optimised ventilation, air conditioning and heating	-	2005
[DE_001]	Use of floating spheres to insulate the solution surface	-	-
	Use of energy-efficient equipment (e.g. motors, lights)	-	-
	Thermal insulation of process tanks	-	-
	Temperature control of heating baths	-	-
	Regular maintenance of equipment in the electrical supply system	-	-
	Pipe insulation	-	-
	Other	Ambient cooling with outside air in cold weather conditions (below 7°C)	-
	Other	Cooling with thermal capacity of ground water	-
	Increasing conductivity of process solutions by adding chemicals	-	-
	Energy savings by medium-temperature sealing systems for anodising of aluminium	-	-
	Combined heat and power plant installation	-	-
[DE_002]	Use of floating spheres to insulate the solution surface	-	-
	Use of energy-efficient equipment (e.g. motors, lights)	-	-
	Thermal insulation of process tanks	-	-
	Temperature control of heating baths	-	-
	Regular maintenance of equipment in the electrical supply system	-	-
	Pipe insulation	-	-
	Combined heat and power plant installation	-	-
[DE_003]	Use of floating spheres to insulate the solution surface	implemented more than 10 years ago	-
	Use of energy-efficient equipment (e.g. motors, lights)	implemented more than 10 years ago	-
	Thermal insulation of process tanks	implemented more than 10 years ago	-
	Temperature control of heating baths	implemented more than 10 years ago	-
	Regular maintenance of equipment in the	implemented more than 10	-

	electrical supply system	years ago	
	Pipe insulation	implemented more than 10 years ago	-
	Increasing conductivity of process solutions by adding chemicals	implemented more than 10 years ago	-
[DE_005]	Use of floating spheres to insulate the solution surface	-	-
	Use of energy-efficient equipment (e.g. motors, lights)	-	-
	Thermal insulation of process tanks	-	-
	Temperature control of heating baths	-	-
	Regular maintenance of equipment in the electrical supply system	-	-
	Pipe insulation	-	-
	Combined heat and power plant installation	-	-
[DE_006]	Use of floating spheres to insulate the solution surface	-	-
	Use of energy-efficient equipment (e.g. motors, lights)	-	-
	Thermal insulation of process tanks	-	-
	Temperature control of heating baths	-	-
	Regular maintenance of equipment in the electrical supply system	-	-
	Pipe insulation	-	-
	Increasing conductivity of process solutions by adding chemicals	-	-
	Combined heat and power plant installation	-	-
[DE_007]	Use of floating spheres to insulate the solution surface	-	-
	Use of energy-efficient equipment (e.g. motors, lights)	-	-
	Thermal insulation of process tanks	-	-
	Temperature control of heating baths	-	-
	Regular maintenance of equipment in the electrical supply system	-	-
	Pipe insulation	-	-
	Increasing conductivity of process solutions by adding chemicals	-	-
	Energy savings by medium-temperature sealing systems for anodising of aluminium	cold sealing	-
[DE_008]	Use of floating spheres to insulate the solution surface	since installation of the line	-
	Use of energy-efficient equipment (e.g. motors, lights)	since installation of the line	-
	Thermal insulation of process tanks	since installation of the line	-
	Temperature control of heating baths	since installation of the line	-
	Regular maintenance of equipment in the electrical supply system	since installation of the line	-
	Pipe insulation	since installation of the line	-
[DE_009]	Use of floating spheres to insulate the solution surface	-	-
	Use of energy-efficient equipment (e.g. motors, lights)	-	-
	Thermal insulation of process tanks	-	-
	Temperature control of heating baths	-	-
	Regular maintenance of equipment in the electrical supply system	-	-

	Pipe insulation	-	-
	Increasing conductivity of process solutions by adding chemicals	-	-
	Combined heat and power plant installation	BHKW	-
[DE_012]	Use of floating spheres to insulate the solution surface	-	-
	Use of energy-efficient equipment (e.g. motors, lights)	-	-
	Thermal insulation of process tanks	-	-
	Temperature control of heating baths	-	-
	Regular maintenance of equipment in the electrical supply system	-	-
	Pipe insulation	-	-
	Energy savings by medium-temperature sealing systems for anodising of aluminium	-	2019
[DE_059]	Using excess heat for workspace heating	-	2017
	Use of energy-efficient equipment (e.g. motors, lights)	-	2017
	Thermal insulation of process tanks	-	2017
	Temperature control of heating baths	-	2017
	Regular maintenance of equipment in the electrical supply system	-	2017
	Recovery of waste heat (e.g. re-heat of rinsing water, evaporator, extracted air)	-	2017
	Pipe insulation	-	2017
	Energy efficiency plan and energy audits	-	2017
	Combined heat and power plant installation	-	2018
[DE_077]	Use of energy-efficient equipment (e.g. motors, lights)	-	-
	Thermal insulation of process tanks	-	-
	Temperature control of heating baths	-	-
	Increasing conductivity of process solutions by adding chemicals	-	-
	Energy savings by medium-temperature sealing systems for anodising of aluminium	-	-
	Energy efficiency plan and energy audits	-	-
	Combined heat and power plant installation	-	-
[DE_078]	Use of floating spheres to insulate the solution surface	-	2019
	Use of energy-efficient equipment (e.g. motors, lights)	-	2015
	Thermal insulation of process tanks	-	2003
	Temperature control of heating baths	-	2003
	Regular maintenance of equipment in the electrical supply system	-	2005
	Pipe insulation	-	2014
[ES_001]	Use of floating spheres to insulate the solution surface	-	2007
	Temperature control of heating baths	-	2007
	Optimised design and handling of voltage supply and current demands (see Section 4.4.1.1)	-	2022
	Energy savings by medium-temperature sealing systems for anodising of aluminium	-	2022
[ES_012]	Use of floating spheres to insulate the solution surface	-	-

	Use of energy-efficient equipment (e.g. motors, lights)	-	-
	Temperature control of heating baths	-	-
	Regular maintenance of equipment in the electrical supply system	-	-
	Pipe insulation	-	-
	Energy efficiency plan and energy audits	-	-
	Combined heat and power plant installation	-	-
[ES_016]	Use of floating spheres to insulate the solution surface	-	2013
	Thermal insulation of process tanks	-	2022
[ES_020]	Use of floating spheres to insulate the solution surface	-	2010
	Use of energy-efficient equipment (e.g. motors, lights)	-	2015
	Regular maintenance of equipment in the electrical supply system	-	2010
	Pipe insulation	-	2010
	Optimised design and handling of voltage supply and current demands (see Section 4.4.1.1)	-	2010
	Energy savings by medium-temperature sealing systems for anodising of aluminium	main sealing in the process: cold sealed	2010
	Energy balance record	-	2013
[ES_021]	Energy efficiency plan and energy audits	-	2016
[FI_004]	Using excess heat for workspace heating	-	2017
	Use of energy-efficient equipment (e.g. motors, lights)	-	2012
	Temperature control of heating baths	-	2012
	Regular maintenance of equipment in the electrical supply system	-	2012
	Recovery of waste heat (e.g. re-heat of rinsing water, evaporator, extracted air))	-	2017
	Energy efficiency plan and energy audits	Energy audits every fourth years	2021
[FR_015]	Using excess heat for workspace heating	Building 1 + 3 are partly heated thanks to the heating of baths	1965
	Thermal insulation of process tanks	In the passt all the tank were insulated, today only the tarp is insulated (the working cell insulation in less efficent + issues in case of leaks)	2000
	Temperature control of heating baths	-	1965
	Regular maintenance of equipment in the electrical supply system	Regular maintenance of lines (1/3 months planned + if needed), check of efficiency thanks to thermography control	1990
	Pipe insulation	Insulation of boilers's pipes for heat transport	1992
	Other	Buy last generation motors that are energy-efficient	2015
	Other	Neon replacement by led light	2018
	Other	Vats full enclosure	1965
	Optimised ventilation, air conditioning and heating	Closed buildings + small room when air coditioning is needed (lab; control room…)	1965
[FR_023]	Use of energy-efficient equipment (e.g. motors, lights)	LED lights	-

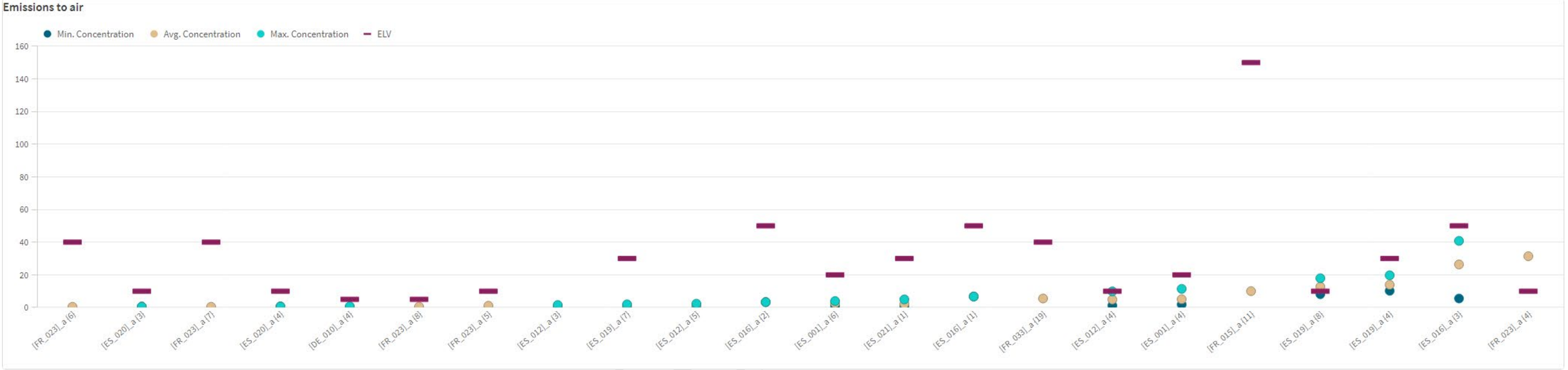
	Temperature control of heating baths	Temperature monitoring and regulation	-
	Regular maintenance of equipment in the electrical supply system	Preventive maintenance	-
	Recovery of waste heat (e.g. re-heat of rinsing water, evaporator, extracted air))	Heat recovered on other processes used to heat vats	-
	Pipe insulation	For hot water pipes	-
	Other	Heating of vats and oven is stopped during production stoppage	-
	Energy efficiency plan and energy audits	Action plan and ISO 50001 certification	-
[FR_032]	Energy efficiency plan and energy audits	-	-
[FR_033]	Use of floating spheres to insulate the solution surface	Done- Periodic verification of the state of the spheres	2022
	Use of energy-efficient equipment (e.g. motors, lights)	LED relamping in progress	2023
	Recovery of waste heat (e.g. re-heat of rinsing water, evaporator, extracted air))	In 2024- Heat recovery on paint booth extraction fumes	-
	Pipe insulation	80% campaign completed in 2022 (the rest in 2023)	2023
	Optimised ventilation, air conditioning and heating	In 2024- Ventilation of vats controlled by the closing of the lids (not existing today)	-
	Optimised heating of process solution (see Section 4.4.2)	The optimisation of the heating temperature of the vats and the superheated hot water network will be studied (summer of 2023)	2023
	Increasing conductivity of process solutions by adding chemicals	Subject to study	2023
	Energy efficiency plan and energy audits	Smart Montagne audit dated september 2022 + MP Energy energy study dated end of 2021	2022
	Energy balance record	Deployment of the energy metering plan in June 2023	2023
[FR_036]	Use of energy-efficient equipment (e.g. motors, lights)	a lot changes on site linked to the ISO 50001 program	2014
	Thermal insulation of process tanks	before 2000	2000
	Temperature control of heating baths	before 2000	2000
	Regular maintenance of equipment in the electrical supply system	before 2000	2000
	Pipe insulation	before 2000	2000
[PL_001]	Use of energy-efficient equipment (e.g. motors, lights)	-	2016
	Thermal insulation of process tanks	-	1991
	Temperature control of heating baths	-	1991
	Regular maintenance of equipment in the electrical supply system	-	1991
	Recovery of waste heat (e.g. re-heat of rinsing water, evaporator, extracted air))	on few furnances at Cast House, not for surface treatment lines	2022
	Pipe insulation	mainly fittings insulation	2020
	Energy efficiency plan and energy audits	-	2016
	Energy balance record	-	1991
[PT_012]	Energy efficiency plan and energy audits	ongoing	2023

Source: [168, TWG 2023]

3.4.4 Emissions to air

3.4.4.1 Dust

The reported data for dust emissions to air are presented in the following figure. Emission data and contextual information are also presented in Table 3-81.



Source: [168, TWG 2023]

Figure 3-81: Dust emissions to air from aluminium coil, sheet conversion coating and anodising plants

Table 3-81: Reported data and contextual information for dust emissions to air from aluminium coil, sheet conversion coating and anodising plants

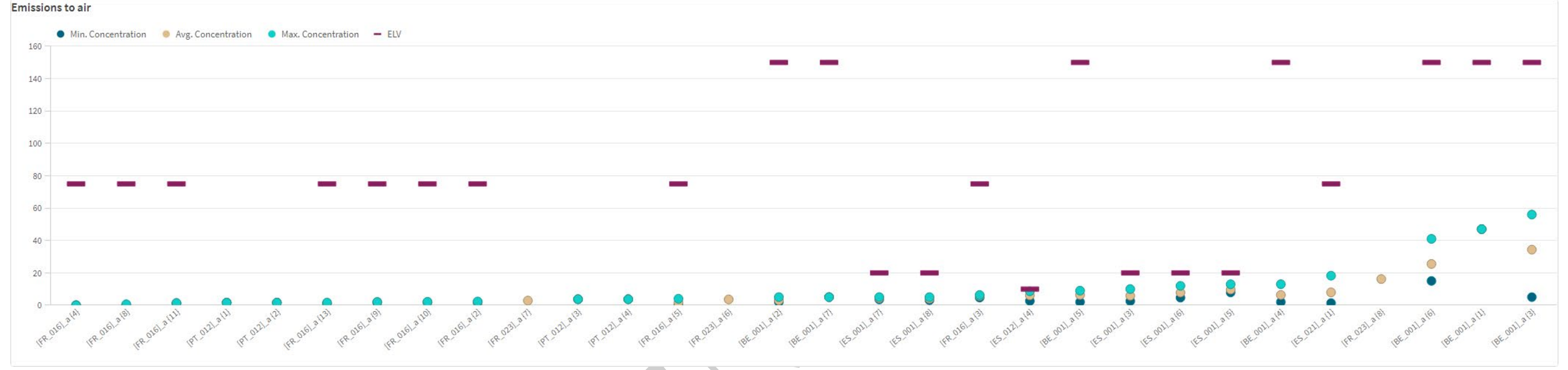
EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	95th perc.	Load
[DE_010]_a {4}	Use of fuel-fired burners (combustion)	-	0.7	0.51	0.2	5	-	-
[ES_001]_a {4}	Mechanical polishing/linishing	Mist filter (demister)	11.38	11.38	11.387	20	-	0.06132
			1.88	1.88	1.88	20	-	0.01118
			1.83	1.83	1.83	20	-	0.01116
[ES_001]_a {6}	Drying	No technique applied	3.93	3.93	3.93	20	-	0.00743
			2.69	2.693	2.69	20	-	0.00436
			1.10	1.10	1.10	20	-	0.00127
[ES_012]_a {3}	Lacquering	Cyclone-Fabric filter-	1.5	1.49	1.49	-	-	0.025
			0.63	0.62	0.62	-	-	0.01
[ES_012]_a {4}		No technique applied-	9.84	8.91	7.09	10	-	0.023
			5.6	4.42	3.18	10	-	0.016
			1.36	1.26	1.2	10	-	0.006
[ES_012]_a {5}	Etching and descaling of aluminium	Other technique	2.3	1.57	1.19	-	-	0.013
[ES_016]_a {1}	Mechanical polishing/linishing	Cyclone	6.7	6.7	6.7	50	-	0.06
[ES_016]_a {2}	Mechanical polishing/linishing	Cyclone	3.3	3.3	3.3	50	-	0.03
[ES_016]_a {3}	Mechanical polishing/linishing		40.8	40.8	40.8	50	-	0.11
			31.16	31.16	31.16	50	-	0.036
			8.3	7.1	5.5	50	-	0.02
[ES_019]_a {4}	Other	No technique applied	19.7	13.9	10.2	30	-	-
[ES_019]_a {7}	Other	No technique applied	1.9	1.37	1.1	30	-	-
[ES_019]_a {8}	Other	No technique applied	17.9	12.7	8.1	10	-	-
[ES_020]_a {3}	Degreasing-Alkaline degreasing-Etching – Alkaline etching of aluminium-Other	Scrubber-absorption (acid/alkaline)	0.51	0.51	0.51	10	-	0.47
[ES_020]_a {4}	Mechanical polishing/linishing	Cyclone	0.61	0.61	0.61	10	-	-
[ES_021]_a {1}	Aqueous cleaning-Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Etching – Alkaline etching of aluminium-Anodising-Chemical milling-Other	Scrubber-absorption (acid/alkaline)	4.94	4.94	4.94	30	-	0.394
			0.95	0.95	0.95	30	-	0.0764
			0.74	0.74	0.74	30	-	-
[FR_015]_a	Use of fuel-fired	Fabric filter	-	14	-	150	-	-

{11}	burners (combustion)		-	8	-	150	-	-
[FR_023]_a {4}	Alkaline degreasing	Aerosol/droplet separator	-	92.9	-	10	-	0.24
			-	0.5	-	10	-	0.0021
			-	0.8	-	10	-	-
[FR_023]_a {5}	Pickling (not electrically), descaling and desmutting-Other-	Absorption	-	1.4	-	10	-	0.0037
			-	0.6	-	10	-	0.0083
			-	1.1	-	10	-	-
[FR_023]_a {6}	Drying	No technique applied	-	0.3	-	40	-	0.00035165
			-	0.5	-	40	-	-
[FR_023]_a {7}	Drying	No technique applied	-	0.2	-	40	-	0.00049328
			-	0.6	-	40	-	-
[FR_023]_a {8}	Drying	No technique applied	-	0.3	-	5	-	0.001
			-	0.8	-	5	-	-
			-	0.4	-	5	-	-
[FR_033]_a {19}	Abrasive blasting	Fabric filter	-	9.8	-	40	-	0.028
			-	6	-	40	-	0.033
			-	0.7	-	40	-	0.0045
			31.16	31.16	31.16	50	-	0.036

Source: [168, TWG 2023]

3.4.4.2 TVOC

The reported data for TVOC emissions to air are presented in the following figure. Emission data and contextual information are also presented in Table 3-82.



Source: [168, TWG 2023]

Figure 3-82: TVOC emissions to air from aluminium coil, sheet conversion coating and anodising plants

Table 3-82: Reported data and contextual information for TVOC emissions to air from aluminium coil, sheet conversion coating and anodising plants

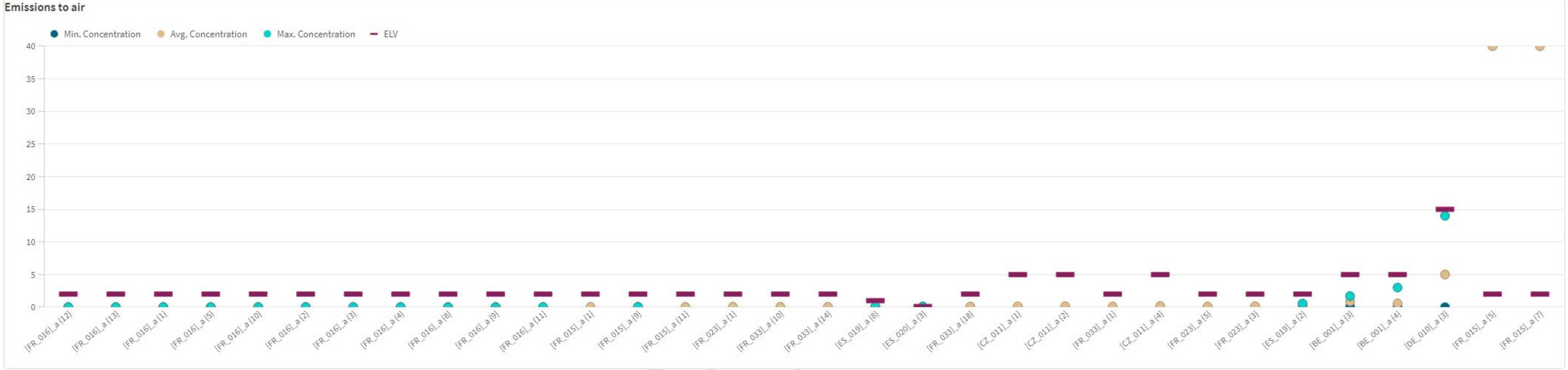
EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	95th perc.	Load
[BE_001]_a {1}	Degreasing	Mist filter (demister)-Cyclone-Mist filter (demister)-Active carbon adsorption	47	47	47	150	-	-
[BE_001]_a {2}	Heat treatment	No technique applied	5	3	2	150	-	-
[BE_001]_a {3}	Pickling (not electrically), descaling and desmutting-	Scrubber- absorption (acid/alkaline)	56	34.33	5	150	-	-
[BE_001]_a {4}	Other-Electrocoating (e-coating)-	Scrubber- absorption (acid/alkaline)	13	13	13	150	-	-
			6	3	2	150	-	-
[BE_001]_a {5}	Drying	No technique applied	9	9	9	150	-	-
	Drying	-	8	5	2	150	-	-
[BE_001]_a {6}	Drying	No technique applied	41	25.5	15	150	-	-
[BE_001]_a {7}	Degreasing	Scrubber- absorption (acid/alkaline)	5.00	5.00	5.00	150	-	-
[ES_001]_a {3}	Degreasing-Alkaline degreasing-Etching – Alkaline etching of aluminium-Etching – Anodising-Other	Scrubber- absorption (acid/alkaline)	9.98	9.98	9.98	20	-	
			5	5	5	20	-	
			2.56	2.56	2.56	20	-	
[ES_001]_a {5}	Alkaline degreasing-Other-	No technique applied	12.96	12.96	12.96	20	-	
			8.17	8.17	8.17	20	-	
			7.87	7.87	7.87	20	-	
[ES_001]_a {6}	Drying	No technique applied	11.98	11.98	11.98	20	-	
			6.85	6.85	6.85	20	-	
			4.65	4.65	4.65	20	-	
[ES_001]_a {7}	Other	No technique applied	5	5	5	20	-	
			3.57	3.57	3.57	20	-	
[ES_001]_a {8}	Other-	-	3.11	3.11	3.11	20	-	
[ES_012]_a {4}		No technique applied	8.62	7.54	6.55	10	-	-
			7.44	5.41	2.62	10	-	-
			6.42	5.2	4.25	10	-	-
[ES_021]_a {1}	Anodising-Aqueous cleaning-Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Etching – Alkaline etching of aluminium-Anodising-Chemical milling-Other-	Scrubber- absorption (acid/alkaline)	1.35	1.35	1.35	75	-	
			18.24	11.24	4.24	75	-	
[FR_016]_a {2}	Metal stripping	No technique applied	2.3	2	1.6	75	-	
[FR_016]_a {3}	Anodising	No technique applied	6.3	5.7	4.7	75	-	
[FR_016]_a {4}	Other	No technique applied	0	0	0	75	-	
[FR_016]_a {5}	Etching or pickling of plastics	No technique applied	4	1.5	0	75	-	
[FR_016]_a {8}	Plating-	No technique applied	0.6	0.2	0	75	-	
[FR_016]_a {9}	Plating-	No technique applied	2	1.9	1.6	75	-	

[FR_016]_a {10}	Plating-	No technique applied	2.1	1.9	1.7	75	-	
[FR_016]_a {11}	Plating-	No technique applied	1.4	1.3	1.2	75	-	
[FR_016]_a {13}	Plating-		1.6	1.3	1.1	75	-	
[FR_023]_a {6}	Drying	No technique applied-	-	4.5	-	-	-	
			-	2.7	-	-	-	
[FR_023]_a {7}	Drying	No technique applied	-	3.1	-	-	-	
		-	-	2.6	-	-	-	-
[FR_023]_a {8}	Drying	No technique applied-	-	20.46	-	-	-	-
			-	19	-	-	-	-
			-	9.04	-	-	-	-
[PT_012]_a {1}	Anodising-Degreasing-Alkaline degreasing-Etching – Alkaline etching of aluminium	Scrubber- absorption (acid/alkaline)	1.6	1.6	1.6	-	1.6	-
[PT_012]_a {2}	Anodising-Degreasing-Alkaline degreasing-Etching – Alkaline etching of aluminium	Scrubber- absorption (acid/alkaline)	1.6	1.6	1.6	-	1.6	-
[PT_012]_a {3}	Anodising-Degreasing-Alkaline degreasing-Etching – Alkaline etching of aluminium	Other technique	3.7	3.7	3.7	-	3.7	-
[PT_012]_a {4}	Anodising-Degreasing-Alkaline degreasing-Etching – Alkaline etching of aluminium	Other technique	3.7	3.7	3.7	-	3.7	-

Source: [168, TWG 2023]

3.4.4.3 HF

The reported data for HF emissions to air are presented in the following figure. Emission data and contextual information are also presented in Table 3-83.



Source: [168, TWG 2023]

Figure 3-83: HF emissions to air from aluminium coil, sheet conversion coating and anodising plants

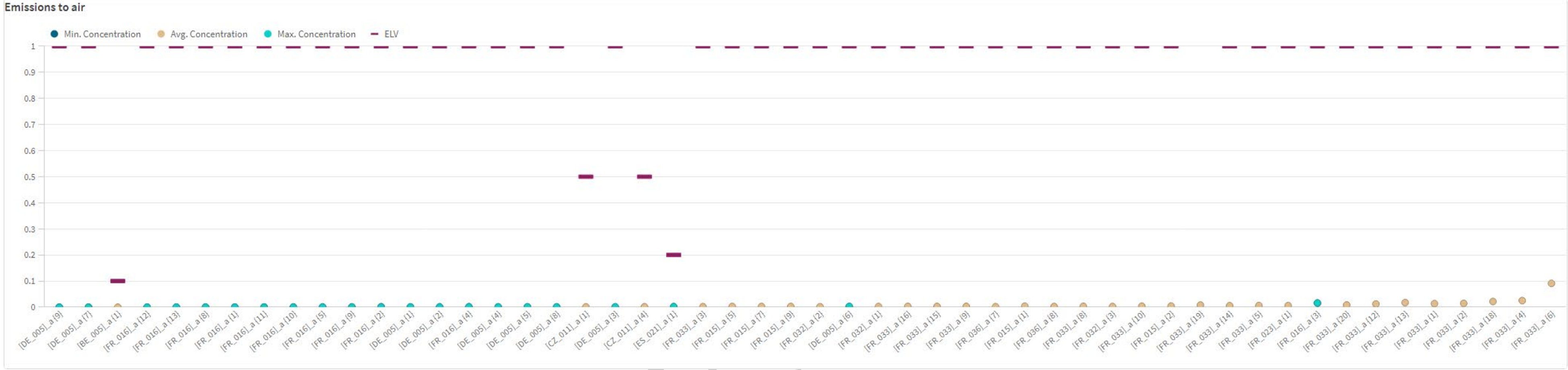
Table 3-83: Reported data and contextual information for HF emissions to air from aluminium coil, sheet conversion coating and anodising plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[BE_001]_a {3}	Pickling (not electrically), descaling and desmutting-	Scrubber-absorption (acid/alkaline)	1.69	0.87	0.09	5	-
[BE_001]_a {4}	Other-Electrocoating (e-coating)-	Scrubber-absorption (acid/alkaline)	3	0.575	0.09	5	-
[CZ_011]_a {1}	Anodising-Anodising-Metal stripping-Pickling (not electrically), descaling and desmutting	-	-	0.162	-	5	0.00037
			-	0.098	-	5	0.00022
			-	0.184	-	5	0.00064
[CZ_011]_a {2}	Anodising-Pickling (not electrically), descaling and desmutting-Metal stripping-Plating	-	-	0.1075	-	5	0.00038
[CZ_011]_a {4}	Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-Plating-	-	-	0.2	-	5	0.00257
			-	0.14	-	5	0.00154
			-	0.137	-	5	0.00155
[DE_010]_a {3}	Anodising-Other-Anodising-Anodising-Anodising-Anodising-	Aerosol/droplet separator	14	14	14	15	-
			1	0.5005	0.001	15	-
[ES_019]_a {2}	Other	No technique applied	0.56	0.21	0.03	2	-
[ES_019]_a {8}	Other	No technique applied	0.08	0.07	0.06	1	-
[ES_020]_a {3}	Degreasing-Alkaline degreasing-Etching – Alkaline etching of aluminium-Other	Scrubber-absorption (acid/alkaline)	0.09	0.09	0.09	0.1	-
[FR_015]_a {1}	Electrolytically assisted pickling, activation and degreasing-Plating-	No technique applied	-	0.04	-	2	-
[FR_015]_a {5}	Electrolytically assisted pickling, activation and degreasing-Plating-	No technique applied	-	40	-	2	-
[FR_015]_a {7}	Electrolytically assisted pickling, activation and degreasing-Plating-Other-	No technique applied	-	40	-	2	-
[FR_015]_a {9}	Anodising-Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	0.04	0.04	0.04	2	-
[FR_015]_a {11}	Use of fuel-fired burners (combustion)	Fabric filter	-	0.0425	-	2	-
[FR_016]_a {1}	Other	No technique applied	4.0E-5		4.0E-5	2	1.6E-7
[FR_016]_a {2}	Metal stripping	No technique applied	7.0E-5		7.0E-5	2	3.6E-7
[FR_016]_a {3}	Anodising	No technique applied	0.0001	0.0001	0.0001	2	7.0E-7
[FR_016]_a {4}	Other	No technique applied	0.0001	0.0001	0.0001	2	6.0E-7
[FR_016]_a {5}	Etching or pickling of plastics	No technique applied	5.0E-5		5.0E-5	2	4.6E-7
[FR_016]_a {8}	Plating-	No technique applied	0.0001	0.0001	0.0001	2	1.4E-6
[FR_016]_a {9}	Plating-	No technique applied	0.0002	0.0002	0.0002	2	3.2E-6
[FR_016]_a {10}	Plating-	No technique applied	6.0E-5		6.0E-5	2	7.0E-7
[FR_016]_a {11}	Plating-	No technique applied	0.0002	0.0002	0.0002	2	0.0031

[FR_016]_a {12}	Plating-	-	2.0E-5		2.0E-5	2	3.3E-7
[FR_016]_a {13}	Plating-	-	3.0E-5		3.0E-5	2	2.5E-7
[FR_023]_a {1}	Other-Rinsing-	Absorption	-	0.07	-	2	0.00061
			-	0.04	-	2	-
[FR_023]_a {3}	Pickling (not electrically), descaling and desmutting-Other-	Absorption	-	0.4	-	2	0.0012
			-	0.00016	-	2	4.5E-7
			-	0.04	-	2	-
[FR_023]_a {5}	Pickling (not electrically), descaling and desmutting-Other-	Absorption	-	0.3	-	2	0.004
			-	0.00013	-	2	9.9E-7
			-	0.0049	-	2	-
[FR_033]_a {1}	Plating-Metal stripping-Electrolytically assisted pickling, activation and degreasing- Rinsing-Other	No technique applied-	-	0.19	-	2	0.0031
			-	0.06	-	2	0
			-	0.02	-	2	0.0029
[FR_033]_a {10}	Pickling (not electrically), descaling and desmutting-Other-Rinsing-	No technique applied	-	0.07	-	2	0
			-	0.06	-	2	0
			-	0.022	-	2	0.00011
[FR_033]_a {14}	Other- Pickling (not electrically), descaling and desmutting	-	-	0.07	-	2	0
			-	0.05	-	2	0
			-	0.015	-	2	6.0E-5
[FR_033]_a {18}	Pickling (not electrically), descaling and desmutting-Other-	Mist filter (demister)	-	0.15	-	2	0.0008
			-	0.07	-	2	0
			-	0.05	-	2	0

3.4.4.4 Chromium

The reported data for Cr emissions to air are presented in the following figure. Emission data and contextual information are also presented in Table 3-84.



Source: [168, TWG 2023]

Figure 3-84: Cr emissions to air from aluminium coil, sheet conversion coating and anodising plants

Table 3-84: Reported data and contextual information for Cr emissions to air from aluminium coil, sheet conversion coating and anodising plants

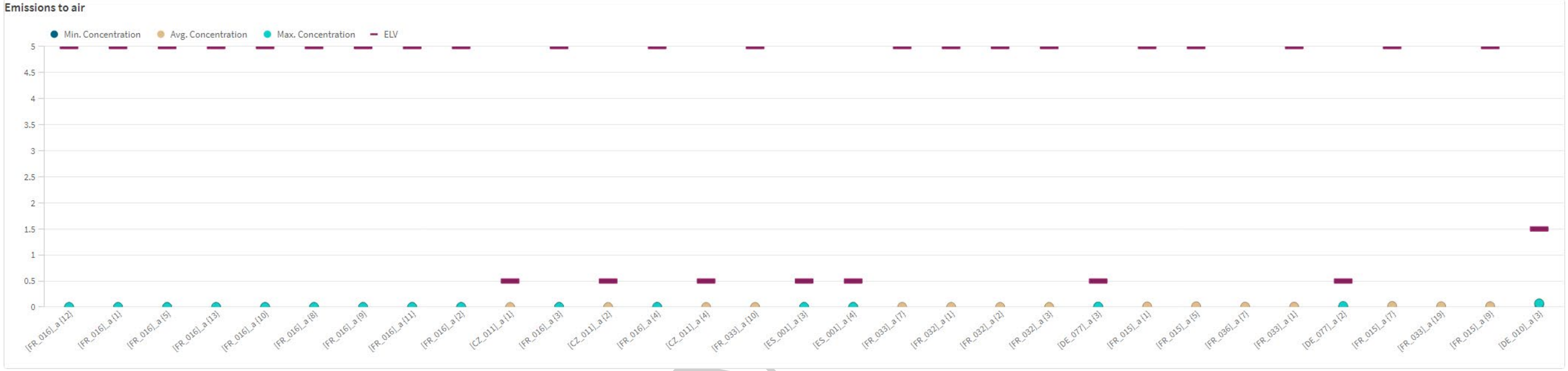
EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[BE_005]_a {1}	Anodising-Degreasing-Electrocoating (e-coating)-	Fabric filter	-	0	-	0.1	0
[CZ_011]_a {1}	Anodising-Metal stripping-Pickling (not electrically), descaling and desmutting	-	-	0.0014	-	0.5	3.2E-6
			-	0.00134	-	0.5	3.0E-6
			-	0.00079	-	0.5	1.8E-6
[CZ_011]_a {4}	Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-Plating-	-	-	0.0018	-	0.5	2.1E-5
		-	-	0.00106	-	0.5	1.2E-5
[DE_005]_a {1}		No technique applied	0.0011	0.0011	0.0011	1	0
			0	0	0	-	0
[DE_005]_a {2}		-	0.0012	0.0012	0.0012	1	0
			0.0006	0.0006	0.0006	-	0
[DE_005]_a {3}		-	0.0014	0.0014	0.0014	1	0
		-	0	0	0	-	0
[DE_005]_a {4}		-	0.0013	0.0013	0.0013	1	0
		-	0	0	0	-	0
[DE_005]_a {5}		-	0.0013	0.0013	0.0013	1	0
		-	0	0	0	-	0
[DE_005]_a {6}		-	0.003	0.003	0.003	1	0
		-	0	0	0	-	0
[DE_005]_a {7}		-	0	0	0	1	0
		-	0	0	0	-	0
[DE_005]_a {8}		-	0.0013	0.0013	0.0013	1	0
		-	0	0	0	-	0
[DE_005]_a {9}		-	0	0	0	1	0
		-	0	0	0	-	0
[ES_021]_a {1}	Aqueous cleaning-Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Etching – Alkaline etching of aluminium-Anodising-Chemical milling-Other-	Scrubber-absorption (acid/alkaline)	0.00217	0.00217	0.00217	0.2	0.000195
			0.002	0.002	0.002	0.2	0.00019
			0.0006	0.0006	0.0006	0.2	0.0001
[FR_015]_a {1}	Electrolytically assisted pickling, activation and degreasing-Plating-	No technique applied	-	0.0053	-	1	-
			-	0.00316	-	1	-
[FR_015]_a {2}	Electrolytically assisted pickling, activation and degreasing-Plating- Other--	No technique applied	-	0.00421	-	1	-
[FR_015]_a {5}	Electrolytically assisted pickling, activation and degreasing- Plating	-	-	0.00252	-	1	-
[FR_015]_a {7}	Electrolytically assisted pickling, activation and degreasing-Plating- Other-	No technique applied	-	0.00252	-	1	-
[FR_015]_a {9}	Anodising-Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	0.00252	-	1	-
[FR_016]_a {1}	Other	No technique applied	0.000356	0.000356	0.000356	1	1.0E-6

[FR_016]_a {2}	Metal stripping	No technique applied	0.00097	0.00097	0.00097	1	5.0E-6
[FR_016]_a {3}	Anodising	No technique applied	0.01559	0.01559	0.01559	1	1.0E-5
[FR_016]_a {4}	Other	No technique applied	0.001231	0.001231	0.001231	1	8.0E-6
[FR_016]_a {5}	Etching or pickling of plastics	No technique applied	0.0007	0.0007	0.0007	1	6.0E-6
[FR_016]_a {8}	Plating-	No technique applied	0.000341	0.000341	0.000341	1	5.0E-6
[FR_016]_a {9}	Plating	No technique applied	0.000713	0.000713	0.000713	1	1.4E-5
[FR_016]_a {10}	Plating	No technique applied	0.000528	0.000528	0.000528	1	6.0E-6
[FR_016]_a {11}	Plating	No technique applied	0.000464	0.000464	0.000464	1	7.0E-6
[FR_016]_a {12}	Plating	-	0.000169	0.000169	0.000169	1	3.0E-6
[FR_016]_a {13}	Plating	-	0.000299	0.000299	0.000299	1	3.0E-6
[FR_023]_a {1}	Other-Rinsing	-	-	0.01507	-	1	0.00014
		-	-	0.00164	-	1	1.0E-5
		-	-	0.00124	-	1	1.091E-5
[FR_032]_a {1}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Anodising-Other-	Active carbon adsorption-Mist filter (demister)	-	0.00393	-	1	-
			-	0.00287	-	1	-
			-	0.00028	-	1	-
[FR_032]_a {2}	Pickling (not electrically), descaling and desmutting-Anodising-	Active carbon adsorption-Mist filter (demister)	-	0.00285	-	1	-
			-	0.00111	-	1	-
			-	0.00042	-	1	-
[FR_032]_a {3}	Degreasing-Pickling (not electrically), descaling and desmutting-Anodising-	Active carbon adsorption-Mist filter (demister)	-	0.00644	-	1	-
			-	0.0008	-	1	-
			-	0.00021	-	1	-
[FR_033]_a {1}	Plating-Metal stripping-Electrolytically assisted pickling, activation and degreasing--Rinsing-Other	No technique applied	-	0.038	-	1	0.00041
			-	0.0013	-	1	1.5E-5
			-	0.00094	-	1	0.01
[FR_033]_a {2}	Plating-Metal stripping-Rinsing-	No technique applied-	-	0.039	-	1	0.0016
			-	0.0023	-	1	0.0001
			-	0.0019	-	1	4.0E-5
[FR_033]_a {3}	Rinsing-Other-	No technique applied	-	0.0023	-	1	3.0E-5
			-	0.0021	-	1	1.0E-5
			-	0.0017	-	1	2.0E-5
[FR_033]_a {4}	Plating-	Mist filter (demister)	-	0.071	-	1	0.0012
			-	0.002	-	1	0
			-	0.0019	-	1	2.0E-5
[FR_033]_a {5}	Plating	Mist filter (demister)	-	0.014	-	1	0.00019
			-	0.002	-	1	1.5E-5
			-	0.0019	-	1	1.0E-5
[FR_033]_a {6}	Plating	Mist filter (demister)	-	0.269	-	1	0.0023
			-	0.0021	-	1	1.0E-5
			-	0.002	-	1	7.0E-6
[FR_033]_a {8}	Plating	Mist filter (demister)	-	0.0061	-	1	6.0E-5
			-	0.002	-	1	1.1E-5

			-	0.0019	-	1	5.0E-6
[FR_033]_a {9}	Aqueous cleaning-Oiling-Alkaline degreasing-Rinsing	No technique applied	-	0.005	-	1	6.0E-5
			-	0.0021	-	1	1.0E-5
			-	0.002	-	1	0
[FR_033]_a {10}	Pickling (not electrically), descaling and desmutting-Other-Rinsing-	No technique applied	-	0.0074	-	1	3.0E-5
			-	0.002	-	1	4.0E-6
			-	0.002	-	1	1.1E-5
[FR_033]_a {12}	Other-Etching and descaling of aluminium-	No technique applied	-	0.032	-	1	7.0E-5
			-	0.0021	-	1	3.0E-6
			-	0.002	-	1	3.0E-6
[FR_033]_a {13}	Metal stripping-Metal stripping-	No technique applied	-	0.034	-	1	0.00012
			-	0.016	-	1	7.0E-5
			-	0.002	-	1	0
[FR_033]_a {14}	Other-Pickling (not electrically), descaling and desmutting-	No technique applied	-	0.013	-	1	6.0E-5
			-	0.002	-	1	0
			-	0.002	-	1	3.0E-6
[FR_033]_a {15}	-Rinsing-Etching and descaling of aluminium-Rinsing	No technique applied	-	0.0047	-	1	3.0E-5
		-	-	0.0021	-	1	1.0E-5
		-	-	0.002	-	1	1.1E-5
[FR_033]_a {16}	Pickling (not electrically), descaling and desmutting-Other	No technique applied	-	0.0044	-	1	2.0E-5
			-	0.0021	-	1	9.0E-6
			-	0.002	-	1	6.0E-6
[FR_033]_a {18}	Pickling (not electrically), descaling and desmutting-Other-	Mist filter (demister)	-	0.061	-	1	0.00031
			-	0.002	-	1	0
			-	0.002	-	1	1.0E-5
[FR_033]_a {19}	Abrasive blasting-	Fabric filter	-	0.012	-	-	6.0E-5
			-	0.01	-	-	3.0E-5
			-	0.002	-	-	1.3E-5
[FR_033]_a {20}	-Rinsing-Other-Pickling (not electrically), descaling and desmutting	No technique applied	-	0.02	-	1	0.00013
			-	0.0026	-	1	2.0E-5
			-	0.0024	-	1	1.0E-5
[FR_036]_a {7}	Plating-	Scrubber-absorption (acid/alkaline)	-	0.001966667	-	1	-
[FR_036]_a {8}	Plating-	Scrubber-absorption (acid/alkaline)-Aerosol/droplet separator	-	0.002533333	-	1	-

3.4.4.5 Ni

The reported data for Ni emissions to air are presented in the following figure. Emission data and contextual information are also presented in Table 3-85.



Source: [168, TWG 2023]

Figure 3-85: Ni emissions to air from aluminium coil, sheet conversion coating and anodising plants

Table 3-85: Reported data and contextual information for Ni emissions to air from aluminium coil, sheet conversion coating and anodising plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[CZ_011]_a {1}	Anodising-Anodising-Metal stripping-Pickling (not electrically), descaling and desmutting	-	-	0.0014	-	0.5	3.2E-6
		-	-	0.0013	-	0.5	3.0E-6
		-	-	0.0008	-	0.5	1.8E-6
[CZ_011]_a {2}	Anodising-Pickling (not electrically), descaling and desmutting-Metal stripping-Plating	-	-	0.0016	-	0.5	5.4E-6
		-	-	0.0014	-	0.5	4.9E-6
		-	-	0.0007	-	0.5	5.1E-6
[CZ_011]_a {4}	Alkaline degreasing-Electrolytically assisted pickling, activation and degreasing-Plating	-	-	0.0018	-	0.5	2.1E-5
		-	-	0.0011	-	0.5	1.2E-5
[DE_010]_a {3}	Anodising-Other--	Aerosol/droplet separator	0.07	0.0723	0.047	1.5	-
[DE_077]_a {2}	Degreasing-Pickling (not electrically), descaling and desmutting- Electrolytically assisted pickling, activation and degreasing-Other-Electrocoating (e-coating)-	Scrubber-absorption (acid/alkaline)-Aerosol/droplet separator	0.02	0.0101	0.0004	0.5	-
[DE_077]_a {3}	Degreasing-Pickling (not electrically), descaling and desmutting- Electrolytically assisted pickling, activation and degreasing-Other-	Scrubber-absorption (acid/alkaline)	0.01	0.004	0.001	0.5	-
[ES_001]_a {3}	Degreasing-Alkaline degreasing-Etching – Alkaline etching of aluminium-Etching –Anodising-Other	Scrubber-absorption (acid/alkaline)	0.0025	0.0025	0.0025	0.5	0.00017
			0.0003	0.00026	0.00026	0.5	2.0E-5
[ES_001]_a {4}	Mechanical polishing/linishing	Mist filter (demister)	0.0035	0.0035	0.0035	0.5	1.88E-5
			0.0011	0.0011	0.0011	0.5	6.36E-6
			0.001	0.001	0.001	0.5	7.77E-6
[FR_015]_a {1}	Electrolytically assisted pickling, activation and degreasing-Plating-	No technique applied	-	0.016	-	5	-
			-	0.0078	-	5	-
[FR_015]_a {5}	Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied	-	0.0145	-	5	-
[FR_015]_a {7}	Electrolytically assisted pickling, activation and degreasing-Other-Plating	No technique applied-	-	0.021	-	5	-
			-	0.019	-	5	-
[FR_015]_a {9}	Anodising-Electrolytically assisted pickling, activation and degreasing-Plating	No technique applied-	-	0.027	-	5	-
			-	0.0068	-	5	-
[FR_016]_a {1}	Other	No technique applied	0.0003	0.0003	0.0003	5	1.0E-6
[FR_016]_a {2}	Metal stripping	No technique applied	0.0009	0.0009	0.0009	5	5.0E-6
[FR_016]_a {3}	Anodising	No technique applied	0.0014	0.0014	0.0014	5	1.0E-5
[FR_016]_a {4}	Other	No technique applied	0.0019	0.0019	0.0019	5	1.1E-5
[FR_016]_a {5}	Etching or pickling of plastics	No technique applied	0.0004	0.0004	0.0004	5	4.0E-6
[FR_016]_a {8}	Plating	No technique applied	0.0007	0.0007	0.0007	5	1.0E-5
[FR_016]_a {9}	Plating	No technique applied	0.0008	0.0008	0.0008	5	1.2E-5

[FR_016]_a {10}	Plating	No technique applied	0.0006	0.0006	0.0006	5	7.0E-6
[FR_016]_a {11}	Plating	No technique applied	0.0009	0.0009	0.0009	5	1.3E-5
[FR_016]_a {12}	Plating	-	0.0001	0.0001	0.0001	5	2.0E-6
[FR_016]_a {13}	Plating	-	0.0004	0.0004	0.0004	5	4.0E-6
[FR_032]_a {1}	Alkaline degreasing-Pickling (not electrically), descaling and desmutting-Anodising-Other-Pickling (not electrically), descaling and desmutting-Pickling (not electrically), descaling and desmutting-	Active carbon adsorption-Mist filter (demister)	-	0.0058	-	5	-
			-	0.0024	-	5	-
			-	0.0007	-	5	-
[FR_032]_a {2}	Pickling (not electrically), descaling and desmutting-Anodising-- -	Active carbon adsorption-Mist filter (demister)	-	0.0060	-	5	-
			-	0.0021	-	5	-
			-	0.0006	-	5	-
[FR_032]_a {3}	Degreasing-Pickling (not electrically), descaling and desmutting-Anodising-	Active carbon adsorption-Mist filter (demister)	-	0.0069	-	5	-
			-	0.0014	-	5	-
			-	0.0007	-	5	-
[FR_033]_a {1}	Plating-Metal stripping-Electrolytically assisted pickling, activation and degreasing-Rinsing-Other	No technique applied	-	0.0200	-	5	0.00021
			-	0.0020	-	5	0
			-	0.0019	-	5	5.0E-5
[FR_033]_a {7}	Plating	No technique applied	-	0.0043	-	5	3.0E-5
			-	0.0030	-	5	1.0E-5
			-	0.0020	-	5	0
[FR_033]_a {10}	OtherPickling (not electrically), descaling and desmutting-Other-Rinsing-Other-Other-	No technique applied	-	0.0022	-	5	1.0E-5
			-	0.0020	-	5	0
			-	0.0020	-	5	4.0E-6
[FR_033]_a {19}	Abrasive blasting-	Fabric filter	-	0.0250	-	-	0.00014
			-	0.0170	-	-	5.0E-5
			-	0.0029	-	-	2.0E-5
[FR_036]_a {7}	Plating-	Scrubber-absorption (acid/alkaline)	-	0.0070	-	-	-

3.5 Sheet processing for aluminium lithography plates

No data reported.

3.6 Porcelain (vitreous) enamelling of metals

Only 1 installation (AT014) for the porcelain (vitrous) enamelling of metals participated in the data collection [168, TWG 2013].

3.6.1 Emissions to water

The reported levels for emissions to water for Plant AT014 are presented in the following table.

Table 3-86: Reported data for emissions to water for Plant AT014

Parameter	Unit	Year	Monitoring frequency	Number of measurements	Minimum	Average	Maximum	Monitoring standard	Measurement uncertainty	ELV	Additional information
Chromium (total) (Cr)	**mg/l**	2022	Yearly	1		0.00		EN ISO 17294-2	0.0006	0.50	
		2021	Yearly	1		0.01			0.0006	0.50	
		2020	Yearly	1		0.02			0.0006	0.50	
Copper (Cu) and its compounds	**mg/l**	2022	Yearly	1		0.00		EN ISO 17294-2	0.0004	0.50	
		2021	Yearly	1		0.08			0.0004	0.50	
Nickel (Ni) and its compounds	**mg/l**	2022	Twice per month	24	0.00	0.03	0.30	EN ISO 17294-2	0.003	0.50	
		2021		24	0.07	0.36	0.50		0.003	0.50	exceedance due to OTNOC
		2020		24	0.04	0.22	0.50		0.003	0.50	
Zinc (Zn) and its compounds	**mg/l**	2022	Yearly			0.01		EN ISO 17294-2	0.004	1.00	
		2021	Yearly			0.00			0.004	1.00	
		2020	Yearly			0.00			0.004	1.00	<
COD	**mg/l**	2022	Yearly			80.00			12		DIN 38409 H44, No limit declared
		2021	Yearly			234.00			12		
		2020	Yearly			25.00			12		
Fluorides	**mg/l**	2022	Yearly			1.34		EN ISO 10304-1	0.15	20.00	
		2021	Yearly			0.98			0.15	20.00	
		2020	Yearly			5.10			0.15	20.00	
TSS	**mg/l**	2022	Twice per month	24	0.60	6.65	28.00		0.5	150.00	DIN 38409-5 2
		2021		24	0.40	3.60	42.00		0.5	150.00	DIN 38409-5 2
		2020		35	2.80	12.80	26.80		0.5	150.00	DIN 38409-5 2, 2 per week
Hydrocarbon oil index (HOI)	**mg/l**	2022	Yearly		0.06	0.06	0.06			15.00	< ÖNORM EN ISO 9377-2
		2021	Yearly		0.08	0.08	0.08			15.00	<ÖNORM EN ISO 9377-2
		2020	Yearly		0.08	0.08	0.08			15.00	<ÖNORM EN ISO 9377-2
Sulphate as SO_4	**mg/l**	2022	Yearly			170.00			20	200.00	EN-ISO 10304-1
		2021	Yearly			185.00			20	200.00	EN-ISO 10304-1

Source: [168, TWG 2013]

3.6.2 Water consumption and waste water discharge

The reported levels of specific water consumption expressed in m^3/m^2 for Plant AT014 are presented in the following table. It is noted that the reported levels refer to the entire enamelling process (including treatment baths and rinsing baths) and not to the overall plant-specific consumption.

Table 3-87: Reported data for specific water consumption for Plant AT014

Year	Value (m^3/m^2)	Source of water	Monitoring method
2022	0.0049	Groundwater	Calculated
2022	0.0005	Water supply network	Calculated
2021	0.0055	Groundwater	Calculated
2021	0.0006	Water supply network	Calculated
2020	0.0055	Groundwater	Calculated
2020	0.0007	Water supply network	Calculated
Source: [168, TWG 2013]			

3.6.3 Energy efficiency

The reported levels of specific energy consumption expressed in kWh/m^2 for Plant AT014 are presented in the following table.

Table 3-88: Reported data for specific energy consumption for Plant AT014

Year	Specific net energy consumption (kWh/m^2)	Specific net electricity consumption (kWh/m^2)	Specific net heat (e.g. steam) consumption (kWh/m^2)	Monitoring method
2022	14.39	0.88	13.51	Calculated
2021	13.68	0.76	12.92	Calculated
2020	14.41	0.71	13.70	Calculated
Source: [168, TWG 2013]				

3.7 Printed circuit board manufacturing

3.7.1 Overview

The following table gives a summary of substances used in the individual production steps, as well as the resulting emissions to air and water, as well as wastes produced.

Table 3-89: Printed circuit boards: summary of types of consumptions and waste outputs

Process step	Significant substances					
	In the individual product	**In the effluent of the process**	**In the exhaust air**	**Effluent resulting from air scrubbing**	**In the waste**	**Possible waste management route**
Generation of phototools	Fixing: emulsions, ammonium thiosulphate, acidic acid, sodium sulphite, sodium tetraborate, aluminium sulphate, sulphuric acid Developer: potassium sulphite, potassium phosphate, hydroquinone, n-butyl diethanol amine	Fixing: emulsions, ammonium thiosulphate, acidic acid, sodium sulphite, sodium tetra borate, aluminium sulphate, sulphuric acid Developer: potassium sulphite, potassium phosphate, hydroquinone, n-butyl diethanol amine, silver	Acidic acid, sulphites		Silver	Good potential for recycling as silver can be retrieved
Generation of sieves for screen printing, stripping	Emulsions, hypochlorite, iodine compound, halogen free solvent	Emulsions, hypochlorite, iodine compound	Hypochlorite, iodine compound			Disposal
Treatment of surfaces	Copper clad laminate, aluminium, wood	Mechanical processes: abrasion of brush rollers, copper Chemical processes (micro etch, etch back, desmear): sodium persulphate, sulphuric acid, copper, hydrogen peroxide, sodium permanganate	SO_2	SO_2	Mechanical processes: drill dust (consisting of epoxy resin/glass fibre, copper, aluminium) Chemical processes: copper hydroxide, potassium sulphate	Mechanical processes: disposal Chemical processes: recycling in waste water equipment with recycling of sludge
Brown oxide process	Hydrogen peroxide, sulphuric acid, copper compounds		SO_2 vapours	SO_3	Copper hydroxide	Recycling in waste water equipment with recycling

Process step	**Significant substances**					
	In the individual product	**In the effluent of the process**	**In the exhaust air**	**Effluent resulting from air scrubbing**	**In the waste**	**Possible waste management route**
						of sludge
Mechanical processing	Copper clad laminate		Dusts (epoxy resin and glass fibre)		Drilling and routing dust consisting of copper, glass fibre and epoxy resin Drill back boards made of aluminium and drill parts	Hazardous waste disposal recycling by specialised companies Return to manufacturer or disposal
	Cut-to-size and processing of outline				Laminate and PCB waste	Recycling
Electroplating of PCBs						
Plating in electroless copper process	Sulphuric acid, sodium persulphate, tin compounds, palladium, hydrochloric acid, formaldehyde, EDTA/tartrate/Quadrol, sodium hydroxide, copper compounds		HCl, SO_2		Copper sulphide	Recycling in waste water equipment with recycling of sludge Recovery of palladium
Direct plating	Thiophene derivate, sulphuric acid, potassium permanganate		SO_2			
Generation of primary image by screen printing or photo printing	Dry film, photo sensible screen printing inks	Polyacrylates, sodium carbonate	Acrylates		Sludge of solder mask Protective films (PE, PES), packing material, dry film, inks	Treatment of effluents with disposal of ink sludge Recycling of plastics and packing materials
Electroplating of primary image	Sulphuric acid, sodium persulphate, tin sulphate, copper sulphate, hydrochloric acid, tetrafluoroboric acid, nitric acid		SO_2, HCl, NO_X		Copper hydroxide sludge, tin hydroxide sludge	Recycling in waste water equipment with recycling of sludge
Stripping of photo resist and screen printing ink	Sodium hydroxide, polymerised acrylates	Polyacrylates, sodium hydroxide	Acrylates		Sludge of solder mask	Recycling in waste water equipment and disposal of sludge
Etching						

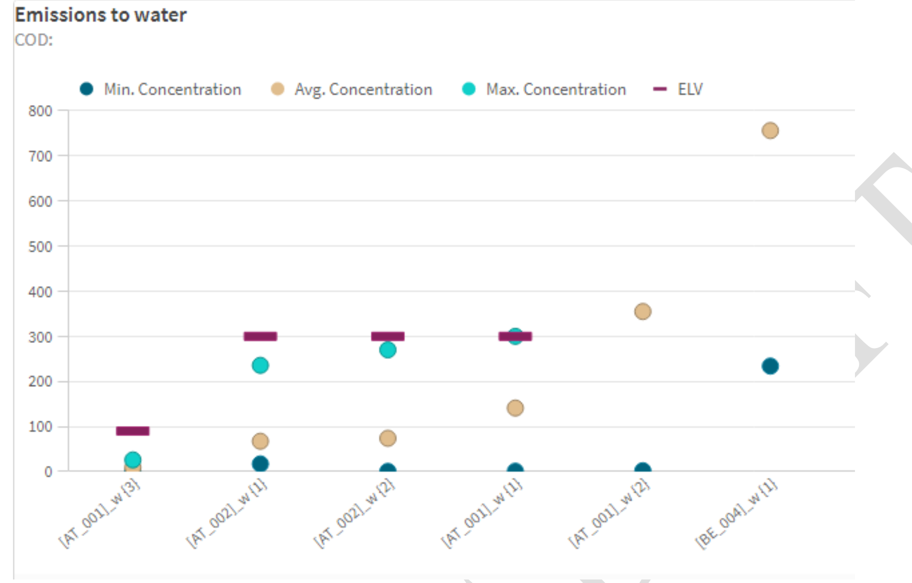
Process step	**Significant substances**					
	In the individual product	**In the effluent of the process**	**In the exhaust air**	**Effluent resulting from air scrubbing**	**In the waste**	**Possible waste management route**
Acidic, etching	Hydrochloric acid, copper compounds, hydrogen peroxide		Hydrochloric acid, copper compounds, hydrogen peroxide		Hydrochloric acid, copper compounds, hydrogen peroxide	Recycling of concentrates
Alkaline, etching	Ammonium compounds, copper compounds		Ammonium compounds, copper compounds		Ammonium compounds, copper compounds	Recycling
Stripping of metal resist	Nitric acid, metal compounds (tin)		NO_X		Metal compounds, especially tin hydroxide	Recycling in waste water equipment with recycling of sludge
Application of solder mask	Multifunctional acrylates, methoxypropylacetate, ketones, sodium carbonate	Monomeric and polymeric acrylates, sodium carbonate	Halogen free solvent (MPA)		Sludge of solder mask	Recycling in waste water equipment with recycling of sludge
Hot air levelling	Tin-lead alloy, hydrogen bromide, polyethylene glycol	Bromide, tin, lead	Polyethylene glycol (decomposition products)		Polyethylene glycol (decomposition products), tin-lead dross	Hazardous waste incineration Recycling
Nickel/gold surface	Sodium peroxide sulphate, sulphuric acid, hydrochloric acid, nickel salt, sodium phosphite, organic acids, gold salt		HCl, SO_2		Nickel, gold, sulphate	Selective ion exchange with subsequent refining of gold, precipitation in waste water equipment with recycling of sludge
Organic surface passivation	Acidic acid, imidazole derivate, ammonium compounds		CO_2, NO_X, NH_4	Acidic acid, ammonium		Effluent treatment

Source: [122, UBA, 2003]

3.7.2 Emissions to water

3.7.2.1 COD

The reported data for COD emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-90.



Source: [168, TWG 2023]

Figure 3-86: COD emissions to water from PCB manufacturing plants

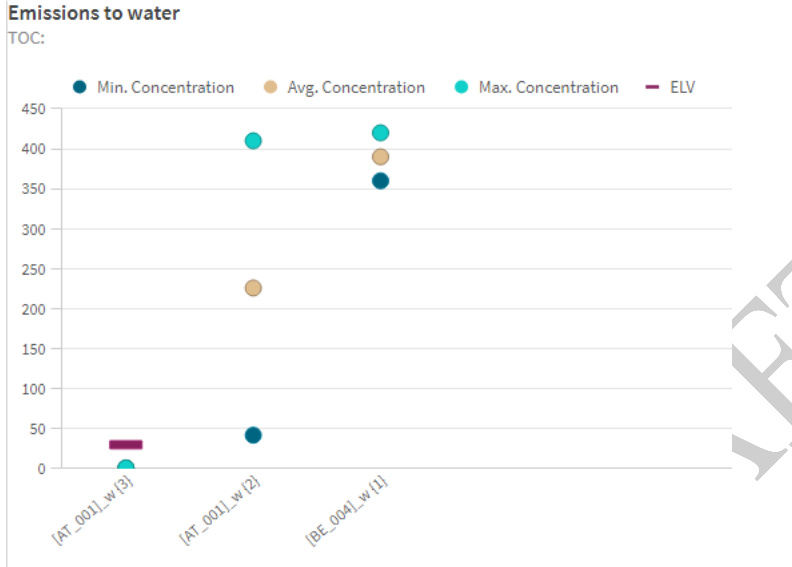
Table 3-90: Reported data and contextual information for COD emissions to water from PCB manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[AT_001]_w {3}	Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation	0	9.2	26	-	90	-
[AT_002]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Precipitation-Chemical reduction-Ion exchange resins	17.2	67.4	235.7	138	300	-
[AT_002]_w {2}	Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Sedimentation-Chemical reduction-Precipitation	0.6	73.9	270	-	300	-
[AT_001]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	1	141	300	-	300	-
[AT_001]_w {2}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	2	355	-	-	-	-
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	234	756.16	-	-	-	63256

Source: [168, TWG 2023]

3.7.2.2 TOC

The reported data for TOC emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-91.



Source: [168, TWG 2023]

Figure 3-87: TOC emissions to water from PCB manufacturing plants

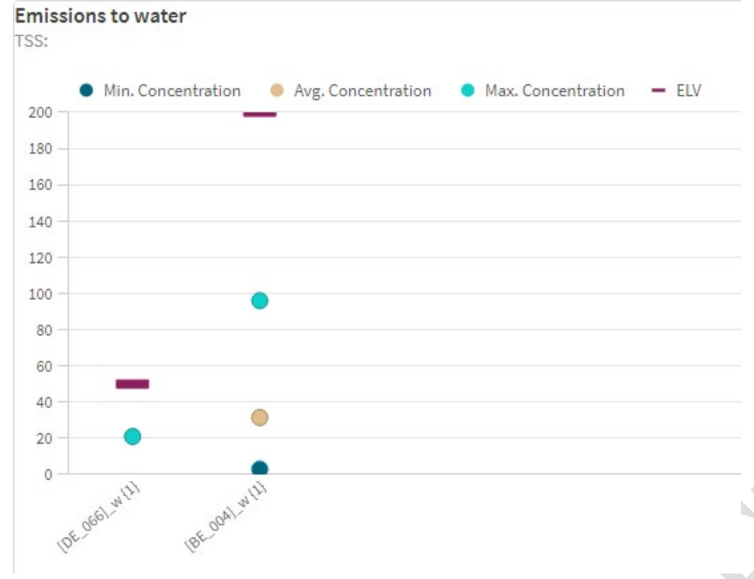
Table 3-91: Reported data and contextual information for TOC emissions to water from PCB manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[AT_001]_w {3}	Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation	0.89	0.995	1.1	-	30	-
[AT_001]_w {2}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	42	226	410	-	-	-
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	360	390	420	-	-	-

Source: [168, TWG 2023]

3.7.2.3 TSS

The reported data for TSS emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-92.



Source: [168, TWG 2023]

Figure 3-88: TSS emissions to water from PCB manufacturing plants

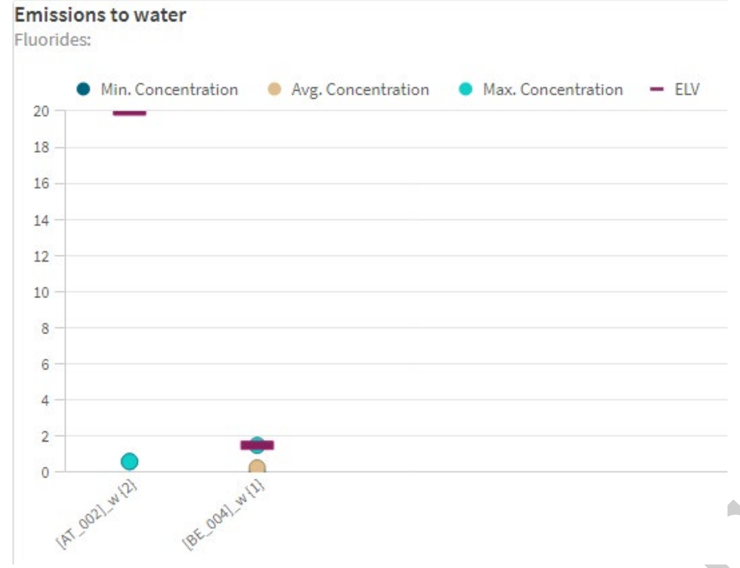
Table 3-92: Reported data and contextual information for TSS emissions to water from PCB manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[DE_066]_w {1}	Precipitation-sedimentation-Filtration (e.g. gravel filter, sand filter)-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Ion exchange resins-Membrane micro/ultra/nano filtration-Ion exchange resins-Neutralisation	-	-	21	-	50	-
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	3	31.49	96	-	200	1717.6

Source: [168, TWG 2023]

3.7.2.4 Fluorides

The reported data for fluorides emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-93.



Source: [168, TWG 2023]

Figure 3-89: Fluorides emissions to water from PCB manufacturing plants

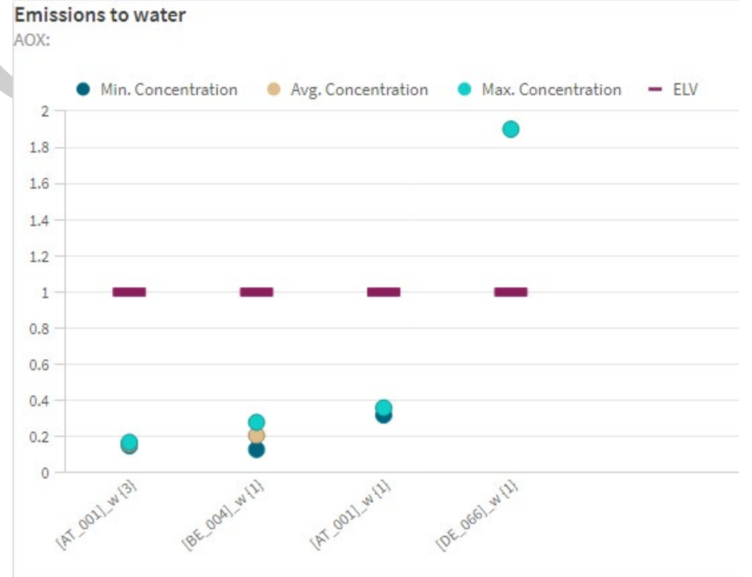
Table 3-93: Reported data and contextual information for fluorides emissions to water from PCB manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[AT_002]_w {2}	Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Sedimentation-Chemical reduction-Precipitation	0.6	-	0.6	-	20	-
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0	0.252	1.5	-	1.5	5.44

Source: [168, TWG 2023]

3.7.2.5 AOX

The reported data for AOX emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-94.



Source: [168, TWG 2023]

Figure 3-90: AOX emissions to water from PCB manufacturing plants

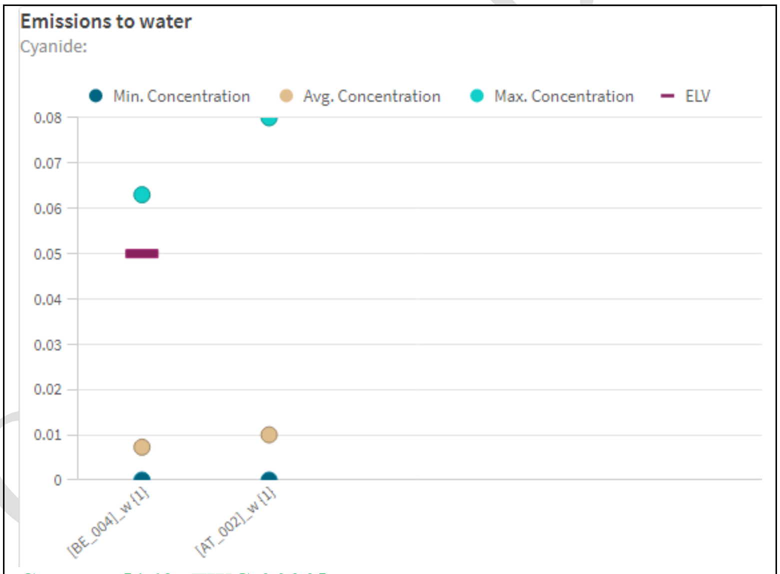
Table 3-94: Reported data and contextual information for AOX emissions to water from PCB manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[AT_001]_w {3}	Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation	0.15	0.16	0.17	-	1	-
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.13	0.208	0.28	-	1	15.68
[AT_001]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.32	-	0.36	-	1	-
[DE_066]_w {1}	Precipitation-sedimentation- Filtration (e.g. gravel filter, sand filter)-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Ion exchange resins-Membrane micro/ultra/nano filtration-Ion exchange resins-Neutralisation	-	-	1.9	-	1	-

Source: [168, TWG 2023]

3.7.2.6 Cyanides

The reported data for cyanide emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-95.



Source: [168, TWG 2023]

Figure 3-91: Cyanide emissions to water from PCB manufacturing plants

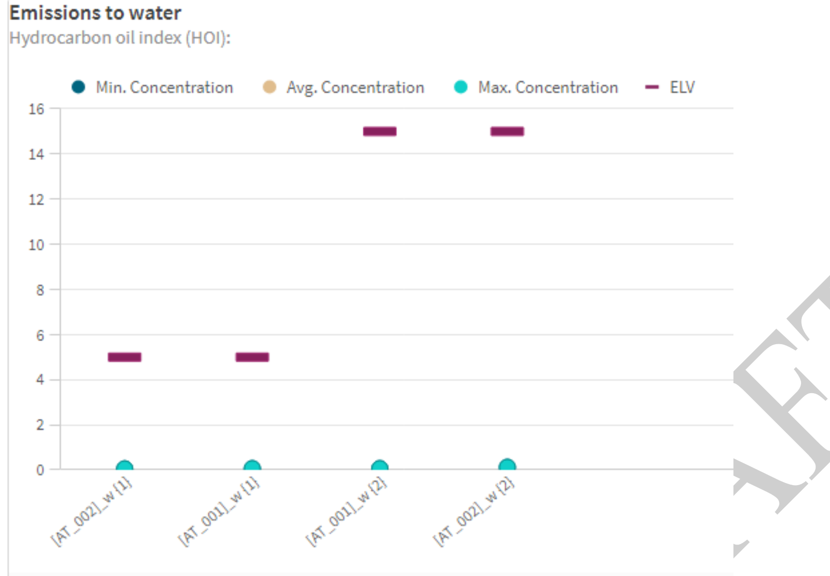
Table 3-95: Reported data and contextual information for cyanide emissions to water from PCB manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0	0.0073	0.063	-	0.05	0.16
[AT_002]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Precipitation-Chemical reduction-Ion exchange resins	0	0.01	0.08	0.02	-	-

Source: [168, TWG 2023]

3.7.2.7 HOI

The reported data for HOI emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-96.



Source: [168, TWG 2023]

Figure 3-92: HOI emissions to water from PCB manufacturing plants

Table 3-96: Reported data and contextual information for HOI emissions to water from PCB manufacturing plants

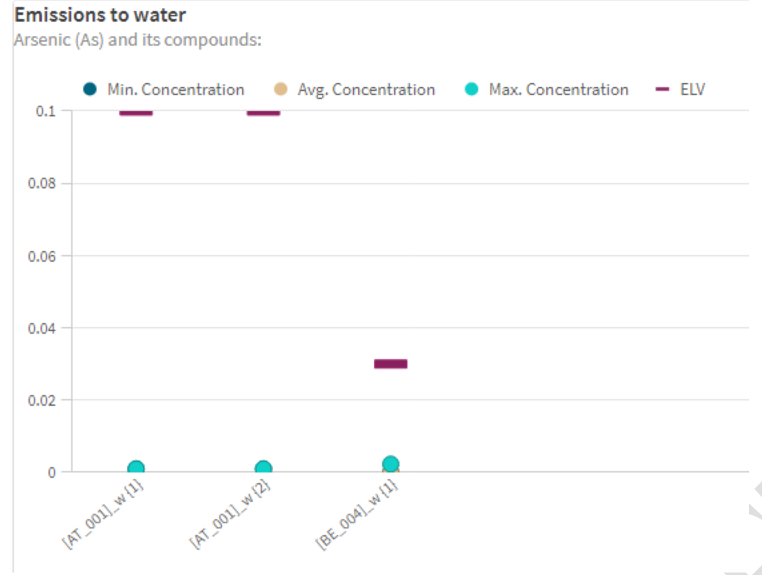
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[AT_002]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Precipitation-Chemical reduction-Ion exchange resins	0.05	-	0.05	-	5	-
[AT_001]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.06	-	0.06	-	5	-
[AT_001]_w {2}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.06	-	0.06	-	15	-
[AT_002]_w {2}	Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Sedimentation-Chemical reduction-Precipitation	0.12	-	0.12	-	15	-

Source: [168, TWG 2023]

3.7.2.8 Metals

3.7.2.8.1 As

The reported data for arsenic emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-97.



Source: [168, TWG 2023]

Figure 3-93: As emissions to water from PCB manufacturing plants

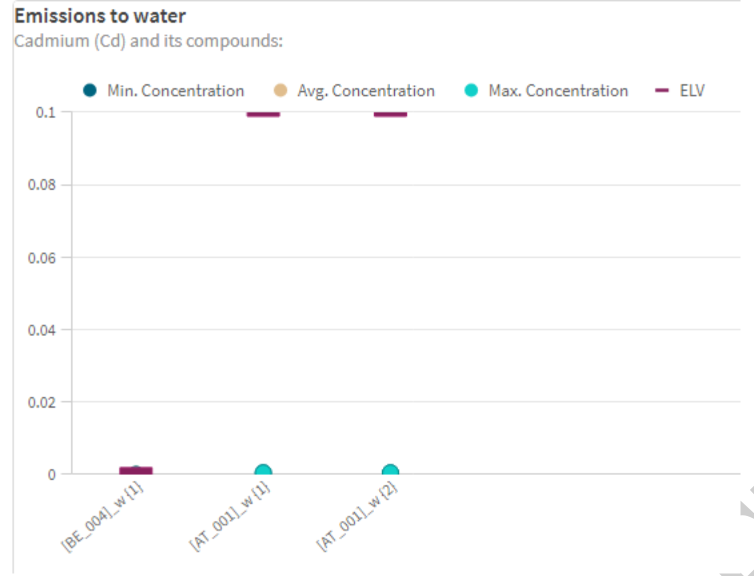
Table 3-97: Reported data and contextual information for As emissions to water from PCB manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc..	ELV conc	Load (g/day)
[AT_001]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.001	-	0.001	-	0.1	-
[AT_001]_w {2}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.001	-	0.001	-	0.1	-
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0	0	0.0023	-	0.03	0

Source: [168, TWG 2023]

3.7.2.8.2 Cd

The reported data for cadmium emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-98.



Source: [168, TWG 2023]

Figure 3-94: Cd emissions to water from PCB manufacturing plants

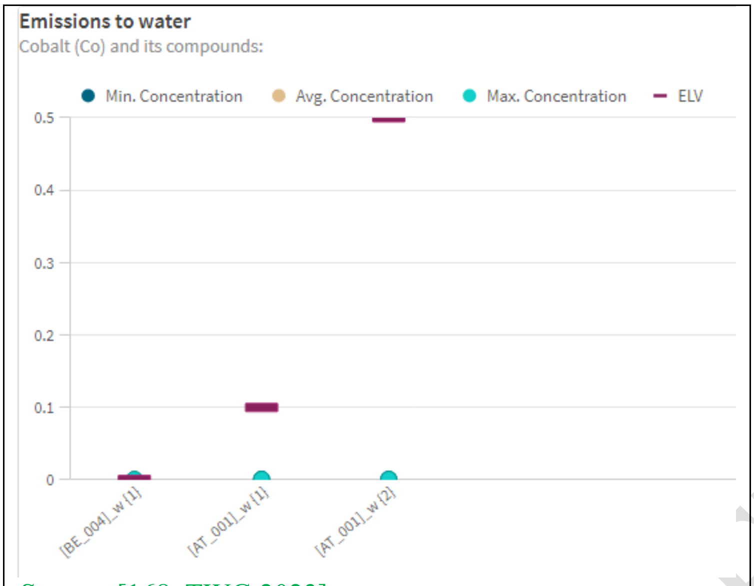
Table 3-98: Reported data and contextual information for Cd emissions to water from PCB manufacturing plants

Emission Point	**Abatement technique(s)**	**Min.**	**Avg.**	**Max.**	**95th perc.**	**ELV**	**Load (g/day)**
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0	0	0	-	0.0008	0
[AT_001]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.0005	-	0.0005	-	0.1	-
[AT_001]_w {2}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.0005	-	0.0005	-	0.1	-

Source: [168, TWG 2023]

3.7.2.8.3 Co

The reported data for cobalt emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-99.



Source: [168, TWG 2023]

Figure 3-95: Co emissions to water from PCB manufacturing plants

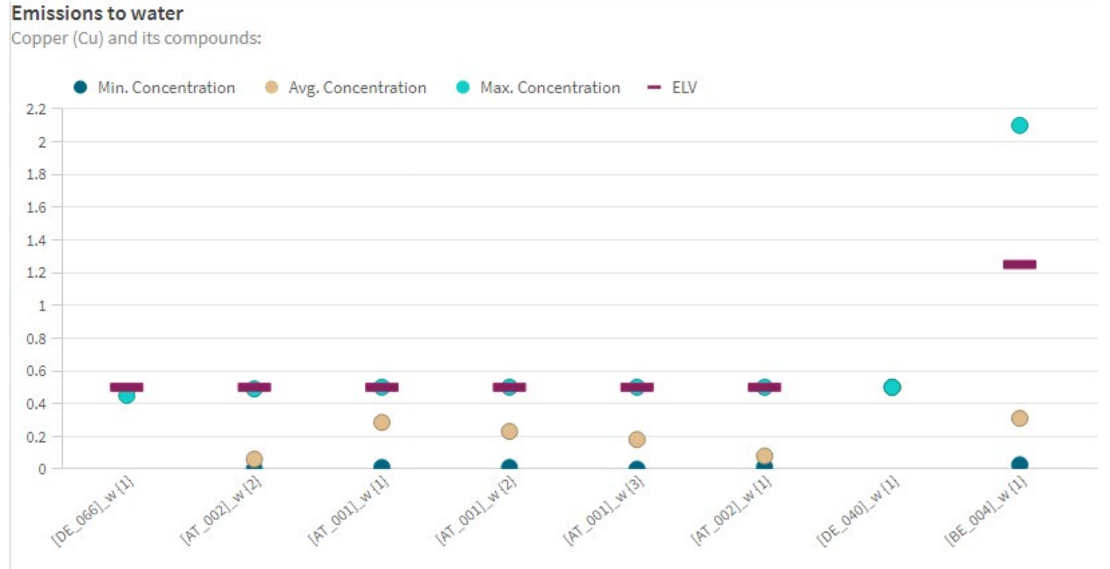
Table 3-99: Reported data and contextual information for Co emissions to water from PCB manufacturing plants

Emission Point	**Abatement technique(s)**	**Min.**	**Avg.**	**Max.**	**95th perc.**	**ELV**	**Load (g/day)**
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0	0.000288	0.00092	-	0.0006	0.024
[AT_001]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.001	-	0.001	-	0.1	-
[AT_001]_w {2}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.001	-	0.001	-	0.5	-

Source: [168, TWG 2023]

3.7.2.8.4 Cu

The reported data for copper emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-100.



Source: [168, TWG 2023]

Figure 3-96: Cu emissions to water from PCB manufacturing plants

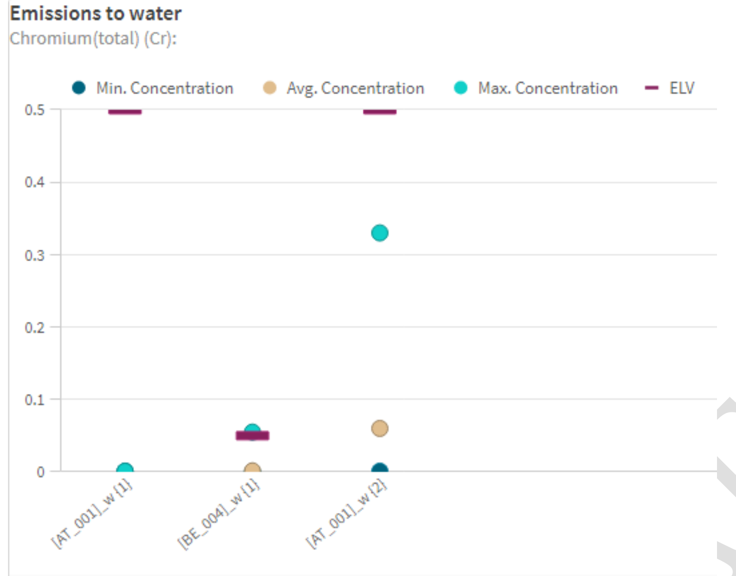
Table 3-100: Reported data and contextual information for Cu emissions to water from PCB manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[DE_066]_w {1}	Precipitation-sedimentation-Filtration (e.g. gravel filter, sand filter)- Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Ion exchange resins-Membrane micro/ultra/nano filtration-Ion exchange resins-Neutralisation	-	-	0.45	-	0.5	-
[AT_002]_w {2}	Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Sedimentation-Chemical reduction-Precipitation	0	0.06	0.49	-	0.5	-
[AT_001]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.01	0.285	0.5	-	0.5	-
[AT_001]_w {2}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation-	0.01	0.23	0.5	-	0.5	-
[AT_001]_w {3}	Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation	0	0.18	0.5	-	0.5	-
[AT_002]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Precipitation-Chemical reduction-Ion exchange resins	0.012	0.08	0.5	-	0.5	-
[DE_040]_w {1}	Chemical reduction-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Flotation-Biological treatment-Activated sludge process-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks	0.5	0.5	0.5	-	-	-
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.026	0.310	2.1	-	1.25	15.6

Source: [168, TWG 2023]

3.7.2.8.5 Cr

The reported data for chromium emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-101.



Source: [168, TWG 2023]

Figure 3-97: Cr emissions to water from PCB manufacturing plants

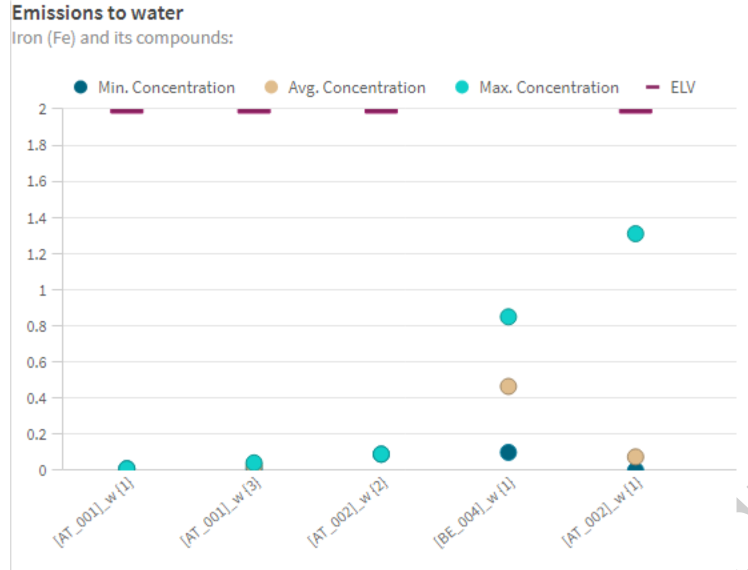
Table 3-101: Reported data and contextual information for Cr emissions to water from PCB manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[AT_001]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.001	-	0.001	-	0.5	-
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0	0.0015	0.055	-	0.05	0.24
[AT_001]_w {2}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.001	0.06	0.33	-	0.5	-

Source: [168, TWG 2023]

3.7.2.8.6 Fe

The reported data for iron emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-102.



Source: [168, TWG 2023]

Figure 3-98: Fe emissions to water from PCB manufacturing plants

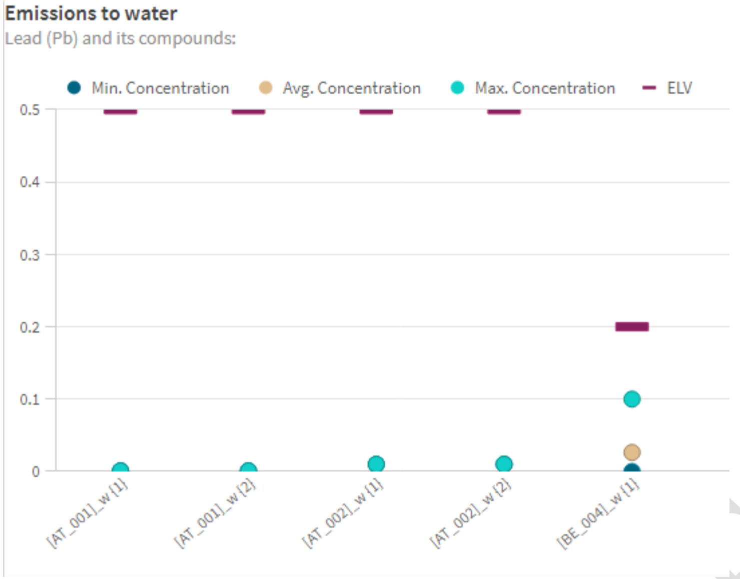
Table 3-102: Reported data and contextual information for Fe emissions to water from PCB manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[AT_001]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.01	-	0.01	-	2	-
[AT_001]_w {3}	Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation	0.01	0.026	0.042	-	2	-
[AT_002]_w {2}	Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Sedimentation-Chemical reduction-Precipitation	0.09	-	0.09	-	2	-
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.1	0.465	0.85	-	-	17.6
[AT_002]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Precipitation-Chemical reduction-Ion exchange resins	0	0.075	1.31	-	2	-

Source: [168, TWG 2023]

3.7.2.8.7 Pb

The reported data for lead emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-103.



Source: [168, TWG 2023]

Figure 3-99: Pb emissions to water from PCB manufacturing plants

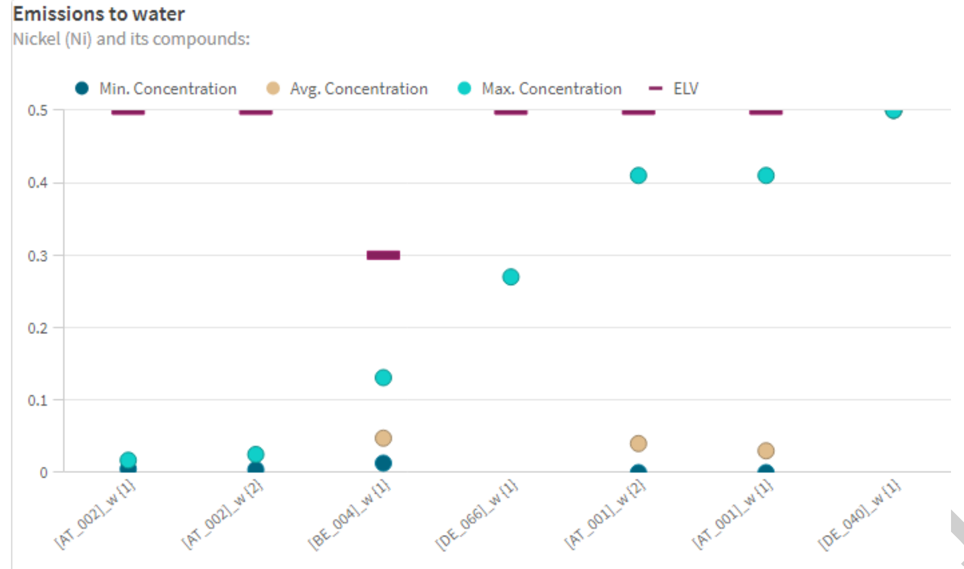
Table 3-103: Reported data and contextual information for Pb emissions to water from PCB manufacturing plants

Emission Point	**Abatement technique(s)**	**Min.**	**Avg.**	**Max.**	**95th perc.**	**ELV**	**Load (g/day)**
[AT_001]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.001	-	0.001	-	0.5	-
[AT_001]_w {2}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.001	-	0.001	-	0.5	-
[AT_002]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Precipitation-Chemical reduction-Ion exchange resins	0.01	-	0.01	-	0.5	-
[AT_002]_w {2}	Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Sedimentation-Chemical reduction-Precipitation	0.01	-	0.01	-	0.5	-
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0	0.026	0.1	-	0.2	1.6

Source: [168, TWG 2023]

3.7.2.8.8 Ni

The reported data for nickel emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-104.



Source: [168, TWG 2023]

Figure 3-100: Ni emissions to water from PCB manufacturing plants

Table 3-104: Reported data and contextual information for Ni emissions to water from PCB manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[AT_002]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Precipitation-Chemical reduction-Ion exchange resins	0.005	-	0.017	-	0.5	-
[AT_002]_w {2}	Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Sedimentation-Chemical reduction-Precipitation	0.004	-	0.025	-	0.5	-
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0.013	0.047	0.131	-	0.3	3.2
[DE_066]_w {1}	Precipitation-sedimentation-Filtration (e.g. gravel filter, sand filter)-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Ion exchange resins-Membrane micro/ultra/nano filtration-Ion exchange resins-Neutralisation	-	-	0.27	-	0.5	-
[AT_001]_w {2}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0	0.04	0.41	-	0.5	-
[AT_001]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0	0.03	0.41	-	0.5	-
[DE_040]_w {1}	Chemical reduction-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Flotation-Biological treatment-Activated sludge process-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks	0.5	0.5	0.5	-	-	-

Source: [168, TWG 2023]

3.7.2.8.9 Sn

The reported data for tin emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-105.

Source: [168, TWG 2023]

Figure 3-101: Sn emissions to water from PCB manufacturing plants

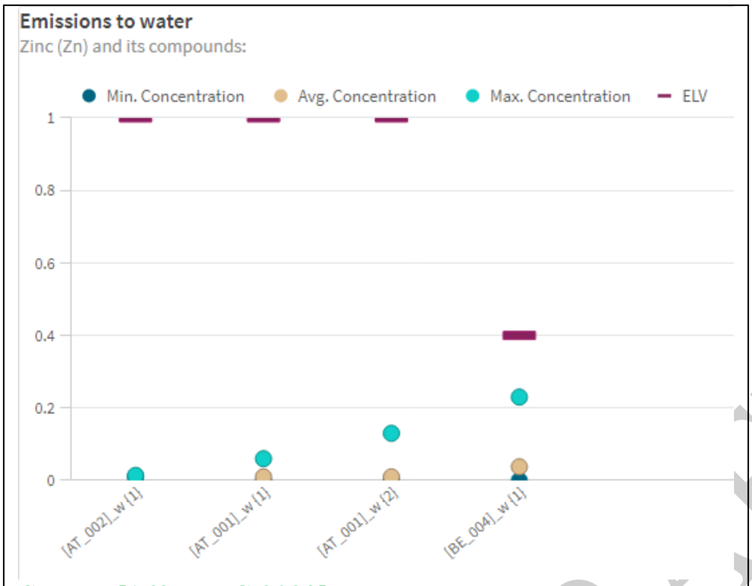
Table 3-105: Reported data and contextual information for Sn emissions to water from PCB manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[AT_001]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.001	-	0.001	-	1	-
[AT_001]_w {2}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.001	0.001	0.001	-	1	-
[AT_002]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Precipitation-Chemical reduction-Ion exchange resins	0.01	-	0.01	-	1	-
[DE_066]_w {1}	Precipitation-sedimentation-Filtration (e.g. gravel filter, sand filter)-Chemical oxidation (e.g. Electrolytic/anodic, radiation assisted)-Chemical reduction-Ion exchange resins-Membrane micro/ultra/nano filtration-Ion exchange resins-Neutralisation	-	-	0.04	-	2	-
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0	0.0097	0.048	-	0.4	0.72
[AT_002]_w {2}	Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Sedimentation-Chemical reduction-Precipitation	0.012	-	0.06	-	1	-
[DE_040]_w {1}	Chemical reduction-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Flotation-Biological treatment- Activated sludge process-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks	2	2	2	-	-	-

Source: [168, TWG 2023]

3.7.2.8.10 Zn

The reported data for zinc emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-106.



Source: [168, TWG 2023]

Figure 3-102: Zn emissions to water from PCB manufacturing plants

Table 3-106: Reported data and contextual information for Zn emissions to water from PCB manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[AT_002]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Precipitation-Chemical reduction-Ion exchange resins	0.01	-	0.014	-	1	-
[AT_001]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0	0.01	0.06	-	1	-
[AT_001]_w {2}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.001	0.01	0.13	-	1	-
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0	0.0377	0.23	-	0.4	4

Source: [168, TWG 2023]

3.7.2.9 Perfluoroalkyl and polyfluoroalkyl substances (PFAS)

The reported data for PFAS emissions to water are presented in the following table.

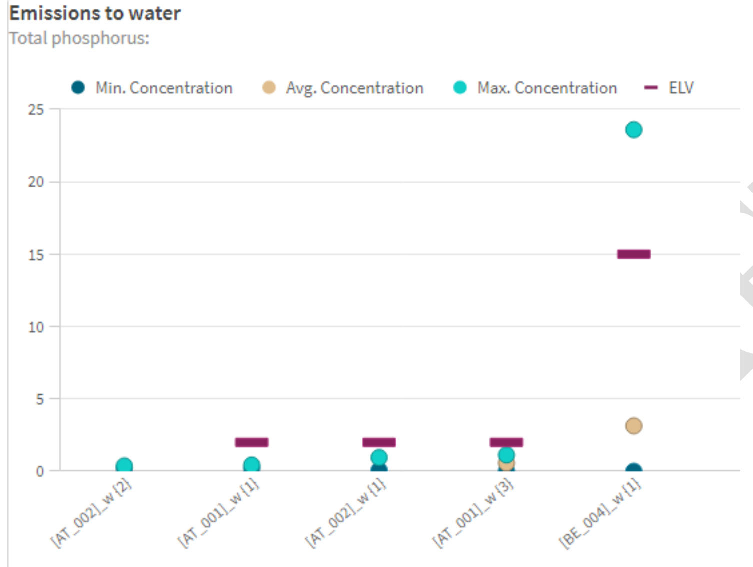
Table 3-107: Reported data and contextual information for PFAS emissions to water from PCB manufacturing plants

Emission Point	Parameter	Abatement technique(s)	Min.	Avg.	Max.	ELV	Additional information
[BE_004]_w {1}	PFBA	Filtration (e.g. gravel filter, sand filter)-Ion exchange	-	-	0.3	-	PFBA : 2 times < 0.02; 4 times <0.1 and 1 time < 0.2 µg/l

[BE_004]_w {1}	PFOS	resins-Neutralisation-Precipitation	-	-	0.041	0.02	PFOS : 6 times below 0.1 µg/l and 2 times below 0.02 µg/l

3.7.2.10 Total phosphorus

The reported data for total phosphorus emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-108.



Source: [168, TWG 2023]

Figure 3-103: TP emissions to water from PCB manufacturing plants

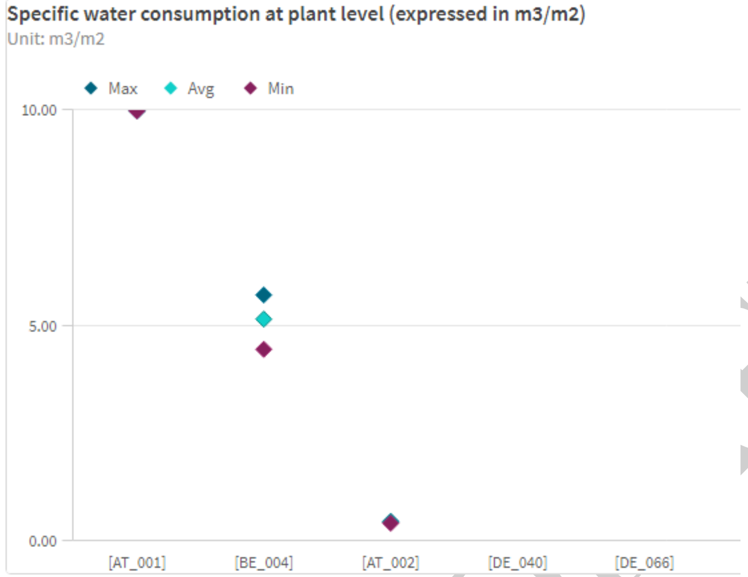
Table 3-108: Reported data and contextual information for TP emissions to water from PCB manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[AT_002]_w {2}	Adsorption techniques – activated carbon-Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Neutralisation-Sedimentation-Chemical reduction-Precipitation	0.23	-	0.37	-	-	-
[AT_001]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Sedimentation-Use of buffer tanks to reduce waste water and emission load peaks-Precipitation	0.22	-	0.43	-	2	-
[AT_002]_w {1}	Adsorption techniques – activated carbon-Coagulation and flocculation-Sedimentation-Neutralisation-Filtration (e.g. gravel filter, sand filter)-Precipitation-Chemical reduction-Ion exchange resins	0.07	-	0.95	-	2	-
[AT_001]_w {3}	Use of buffer tanks to reduce waste water and emission load peaks-Neutralisation	0.016	0.573	1.13	-	2	-
[BE_004]_w {1}	Filtration (e.g. gravel filter, sand filter)-Ion exchange resins-Neutralisation-Precipitation	0	3.137	23.6	-	15	150.4

Source: [168, TWG 2023]

3.7.3 Water consumption and waste water discharge

The reported data for specific water consumption are presented in the following figure. Consumption data and contextual information are also presented in Table 3-109.



Source: [168, TWG 2023]

Figure 3-104: Specific water consumption expressed in m^3 per m^2 of final product in PCB manufacturing plants

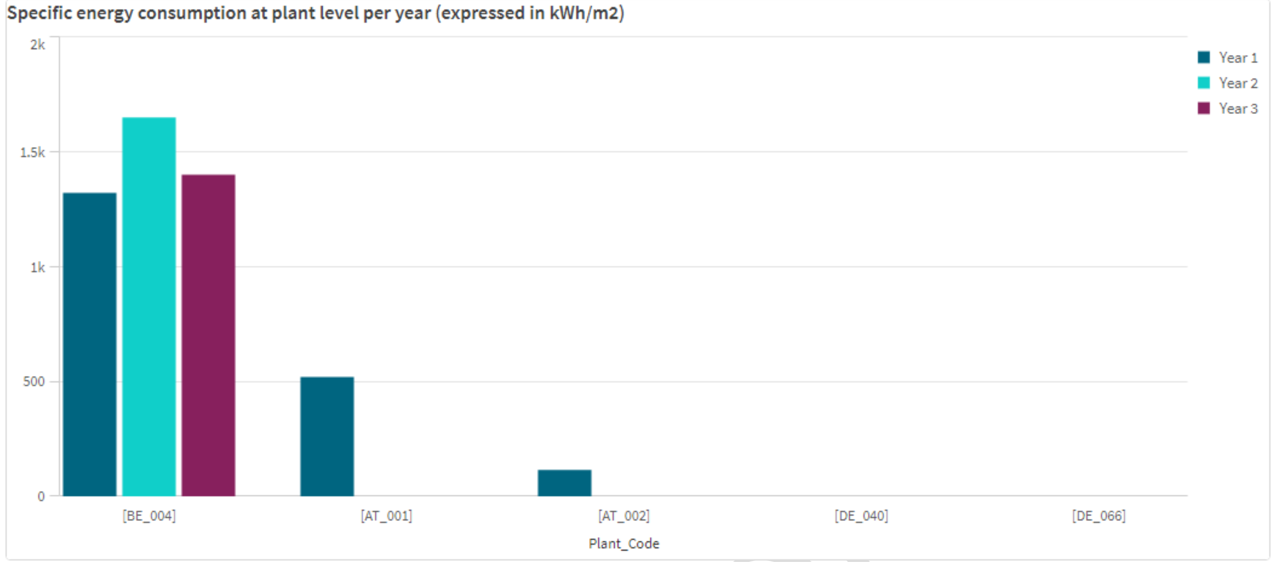
Table 3-109: Reported data (expressed in m^3 per m^2 of final product) and contextual information for specific water consumption in PCB manufacturing plants

Plant code	Max.	Avg.	Min.	Associated process	Monitoring method	Technique	Year of implementation	Additional information
[AT_001]	9.98	9.98	9.98	Rinsing-Other	Measured	Reuse of water by using multiple rinsing steps-Use of closed cooling systems	-	cascade rinse-cooling water reused after circulation through production-
[AT_002]	0.46	0.442	0.415	-	Measured	Use of closed cooling systems-Reuse of water by using multiple rinsing steps	-	-
[BE_004]	5.71	5.15	4.45	Other	Measured	Use of closed cooling systems-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	-	for all process baths which requires cooling-Acid etching, alkaline etching (replenisher), permanganate desmear, photoresist stripper OL (dosing of rinsing water to main process tank to compensate evaporation losses or as part of autodosing system)

Source: [168, TWG 2023]

3.7.4 Energy efficiency

The reported data for specific energy consumption are presented in the following figure. Consumption data and contextual information are also presented in Table 3-110. The applied techniques to reduces energy consumption are presented in Table 3-111.



Source: [168, TWG 2023]

Figure 3-105: Specific energy consumption expressed in kWh per m^2 of final product in PCB manufacturing plants

Table 3-110: Reported data (expressed in kWh^3 per m^2 of final product) and contextual information for specific energy consumption in PCB manufacturing plants

Plant code	Net Energy (kWh/m^2)	Net Electricity (kWh/m^2)	Net Heat (kWh/m^2)	How the energy consumption is monitored	Proportion of energy recovered (%)	How the recovered energy is monitored	Total volume of workspace heated (m^3)	Additional information
[AT_001]	519.16	448.74	70.42	Measured	-	-	120538.48	-
[AT_002]	114.46	99.10	15.36	Measured	-	-	24468	-
[BE_004]	1 458.13	1 136.72	321.41	Measured	-	-	6575	-

Source: [168, TWG 2023]

Table 3-111: Applied techniques to reduce energy consumption and contextual information for PCB manufacturing plants

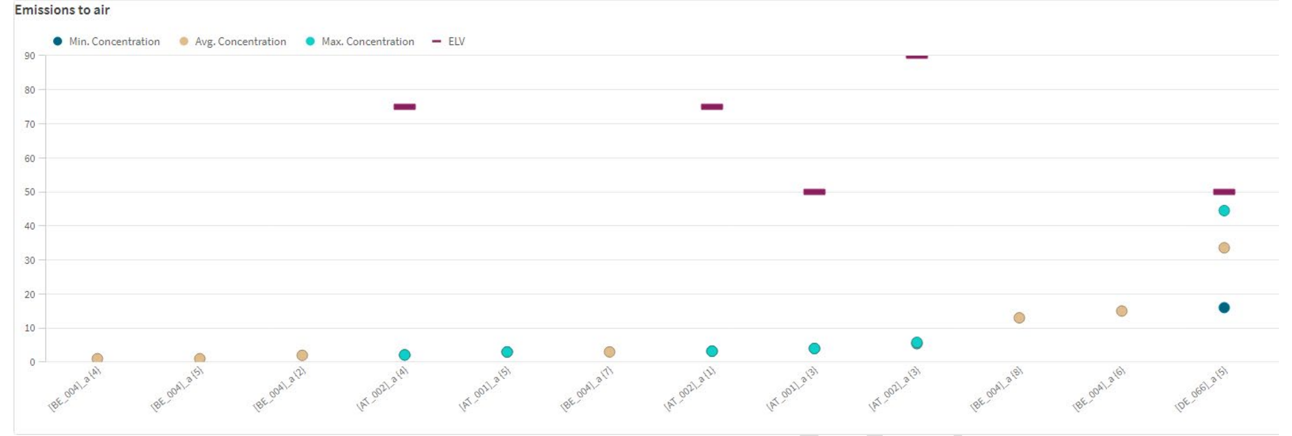
Plant code	Energy efficiency techniques	Additional information	Year of impleme-ntation
[AT_001]	Use of energy-efficient equipment (e.g. motors, lights)	continuous projetcs	-
	Temperature control of heating baths	continuous projetcs	-
	Regular maintenance of equipment in the electrical supply system	continuous projetcs	-
	Recovery of waste heat (e.g. re-heat of rinsing water, evaporator, extracted air))	continuous projetcs	-
	Optimised ventilation, air conditioning and heating	continuous projetcs	-
	Energy efficiency plan and energy audits	ISO 50001	2015
	Energy balance record	continuous projetcs	-
[AT_002]	Optimised ventilation, air conditioning and heating	ongoing	2015
	Energy efficiency plan and energy audits	-	2015

[BE_004]	Use of energy-efficient equipment (e.g. motors, lights)	LED lightening (production hall and offices)	2019
	Thermal insulation of process tanks	standard	-
	Temperature control of heating baths	standard	-
[DE_040]	Use of energy-efficient equipment (e.g. motors, lights)	-	-
	Temperature control of heating baths	-	-
	Regular maintenance of equipment in the electrical supply system	-	-
	Recovery of waste heat (e.g. re-heat of rinsing water, evaporator, extracted air))	-	-
	Pipe insulation	-	-
	Optimised ventilation, air conditioning and heating	-	-
	Energy efficiency plan and energy audits	-	-
	Energy balance record	-	-
	Combined heat and power plant installation	-	-
[DE_066]	Use of energy-efficient equipment (e.g. motors, lights)	-	-
	Temperature control of heating baths	-	-
	Regular maintenance of equipment in the electrical supply system	-	-
	Other	check stand by	-
	Other	in summer: heat of CHP is used to cool	-
	Optimised ventilation, air conditioning and heating	-	-
	Energy efficiency plan and energy audits	-	2013
	Energy balance record	-	-
	Combined heat and power plant installation	combined heat and power plant (CHP)	2016

3.7.5 Emissions to air

3.7.5.1 TVOC

The reported data for TVOC emissions to air are presented in the following figure. Emission data and contextual information are also presented in Table 3-112.



Source: [168, TWG 2023]

Figure 3-106: TVOC emissions to air from PCB manufacturing plants

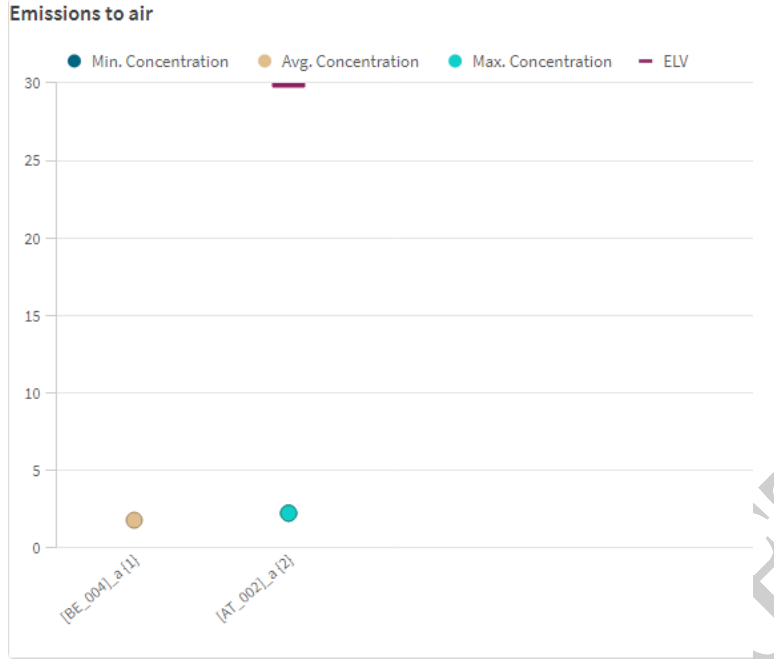
Table 3-112: Reported data and contextual information for TVOC emissions to air from PCB manufacturing plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[AT_001]_a {3}	Solder mask application	Biofilter	4	4	4	50	0.031
[AT_001]_a {5}	Other	Scrubber- absorption (acid/alkaline)	3	3	3	-	0.024
[AT_002]_a {1}	Degreasing-Pickling (not electrically), descaling and desmutting-	Scrubber- absorption (acid/alkaline)	3.2	3.2	3.2	75	-
[AT_002]_a {3}	Solder mask application-Photo developing (PCB)-Heat treatment-	Biofilter	5.8	5.6	5.4	90	-
[AT_002]_a {4}	Plating	Scrubber- absorption (acid/alkaline)	2.1	2.1	2.1	75	-
[BE_004]_a {2}	Aqueous cleaning-Conditioning of plastics-Other- Plating-Pickling (not electrically), descaling and desmutting-	No technique applied	-	2	-	-	0.051
[BE_004]_a {4}	Aqueous cleaning-Other-	No technique applied	-	1	-	-	0.005
[BE_004]_a {5}	Plating	No technique applied	-	1	-	-	0.0003
[BE_004]_a {6}	Solder mask application	Active carbon adsorption	-	15	-	-	0.013
[BE_004]_a {7}	Solder mask application	No technique applied	-	3	-	-	0.005
[BE_004]_a {8}	Solder mask application	No technique applied	-	13	-	-	0.019
[DE_066]_a {5}	Solder mask application	Biofilter	44.5	42.35	40.2	50	-
[DE_066]_a {5}	Solder mask application	Biofilter	16	16	16	50	-

Source: [168, TWG 2023]

3.7.5.2 Gaseous chlorides

The reported data for gaseous chlorides emissions to air are presented in the following figure. Emission data and contextual information are also presented in Table 3-113.



Source: [168, TWG 2023]

Figure 3-107: Gaseous chlorides emissions to air from PCB manufacturing plants

Table 3-113: Reported data and contextual information for gasous chlorides emissions to air from PCB manufacturing plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[AT_002]_a {2}	Etching or pickling of plastics	Scrubber-absorption (acid/alkaline)	2.25	2.25	2.25	30	-
[BE_004]_a {1}	Aqueous cleaning-Other- Pickling (not electrically), descaling and desmutting-Plating- Metal stripping-Alkaline degreasing-Photo developing- Etching or pickling of plastics- Solder mask application	No technique applied	-	1.8	-	-	0.0225

Source: [168, TWG 2023]

3.7.5.3 NH_3

The reported data for ammonia emissions to air are presented in the following figure. Emission data and contextual information are also presented in Table 3-114.

Source: [168, TWG 2023]

Figure 3-108: NH$_3$ emissions to air from PCB manufacturing plants

Table 3-114: Reported data and contextual information for NH$_3$ emissions to air from PCB manufacturing plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[AT_001]_a {2}	Plating	Scrubber-absorption (acid/alkaline)	1.1	1.1	1.1	5	0.0072
[AT_002]_a {6}	Etching or pickling of plastics	Scrubber-absorption (acid/alkaline)	2.35	2.35	2.35	5	-
[BE_004]_a {1}	Aqueous cleaning-Other-Pickling (not electrically), descaling and desmutting-Plating- Metal stripping-Alkaline degreasing-Photo developing-Etching or pickling of plastics- Solder mask application	No technique applied	-	7.2	-	-	0.09
[DE_066]_a {1}	Pickling (not electrically), descaling and desmuttingEtching – Alkaline etching of aluminium-Etching or pickling of plastics-Chemical polishing-Conditioning of plastics-Plating-	Scrubber-absorption (acid/alkaline)	7.08	7.08	7.08	30	-
[DE_066]_a {1}	Pickling (not electrically), descaling and desmuttingEtching – Alkaline etching of aluminium-Etching or pickling of plastics-Chemical polishing- Conditioning of plastics-Plating-	Scrubber-absorption (acid/alkaline)	2.29	2.29	2.29	30	-
[DE_066]_a {2}	Pickling (not electrically), descaling and desmutting- Etching – Alkaline etching of aluminium-Etching or pickling of plastics-Chemical polishing- Conditioning of plastics-Plating-	Scrubber-absorption (acid/alkaline)	26.53	26.53	26.53	30	-
[DE_066]_a {2}	Pickling (not electrically), descaling and desmutting Etching – Alkaline etching of aluminium-Etching or pickling of plastics-Chemical polishing- Conditioning of plastics-Plating-descaling and desmutting-Other –Rinsing Metal stripping-	Scrubber-absorption (acid/alkaline)	3.29	3.29	3.29	30	-
[DE_066]_a {3}	Plating-Pickling (not electrically), descaling and desmutting-Metal stripping-	Scrubber-absorption	4.44	4.44	4.44	30	-

		(acid/alkaline)					
[DE_066]_a {3}	Plating-Pickling (not electrically), descaling and desmutting-Metal stripping	Scrubber-absorption (acid/alkaline)	2.79	2.79	2.79	30	-
[DE_066]_a {4}	Plating-Pickling (not electrically), descaling and desmutting-Metal stripping =- Other-	Scrubber-absorption (acid/alkaline)	2.31	2.31	2.31	30	-

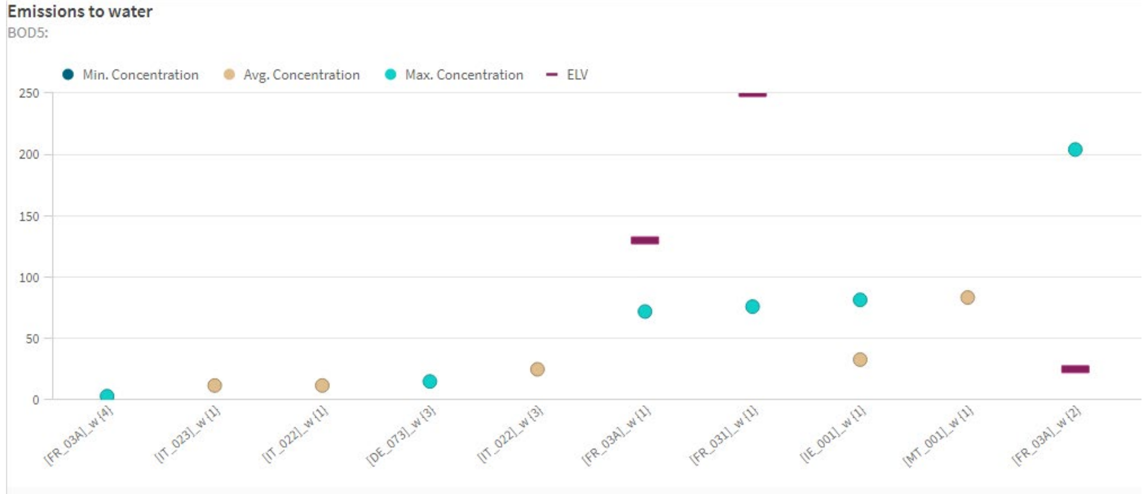
3.8 Semiconductor manufacturing

3.8.1 Emissions to water

Data for emissions to water were reported for 28 discharge points from 12 semiconductor manufacturing plants.

3.8.1.1 BOD$_5$

The reported data for BOD$_5$ emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-115.



Source: [168, TWG 2023]

Figure 3-109: BOD$_5$ emissions to water from semiconductor manufacturing plants

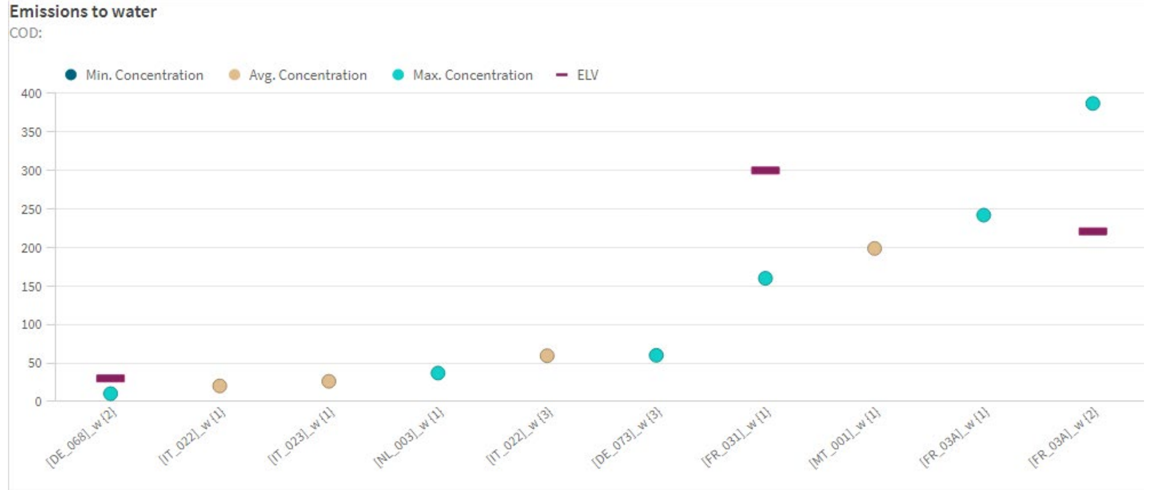
Table 3-115: Reported data and contextual information for BOD$_5$ emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[FR_03A]_w {4}	-	-	-	3	-	-	-
[IT_023]_w {1}	Neutralisation, Coagulation and flocculation, Precipitation-Sedimentation	-	11.69	-	-	-	-
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration-	-	11.72	-	-	-	-
[DE_073]_w {3}	Other	-	-	15	-	-	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	24.9	-	-	-	-
[FR_03A]_w {1}		-	-	72	-	130	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	76	-	250	14.65
[IE_001]_w {1}		-	32.8	81.5	-	-	-
[MT_001]_w {1}	Coagulation and flocculation	-	83.41	-	-	-	-
[FR_03A]_w {2}	Ion exchange resins	-	-	204	-	25	-

Source: [168, TWG 2023]

3.8.1.2 COD

The reported data for COD emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-116.



Source: [168, TWG 2023]

Figure 3-110: COD emissions to water from semiconductor manufacturing plants

Table 3-116: Reported data and contextual information for COD emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[DE_068]_w {2}	Filtration (e.g. gravel filter, sand filter)	-	-	10.2	-	30	-
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	20.30	-	-	-	-
[IT_023]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation	-	26.27	-	-	-	-
[NL_003]_w {1}	Neutralisation-Coagulation and flocculation	-	-	37	-	-	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	59.5	-	-	-	-
[DE_073]_w {3}	Other	-	-	60	-	-	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	160	-	300	50.87
[MT_001]_w {1}	Coagulation and flocculation	-	198.7	-	-	-	-
[FR_03A]_w {1}	-	-	-	242	-	-	0.47
[FR_03A]_w {2}	Ion exchange resins	-	-	387	-	221	3.21

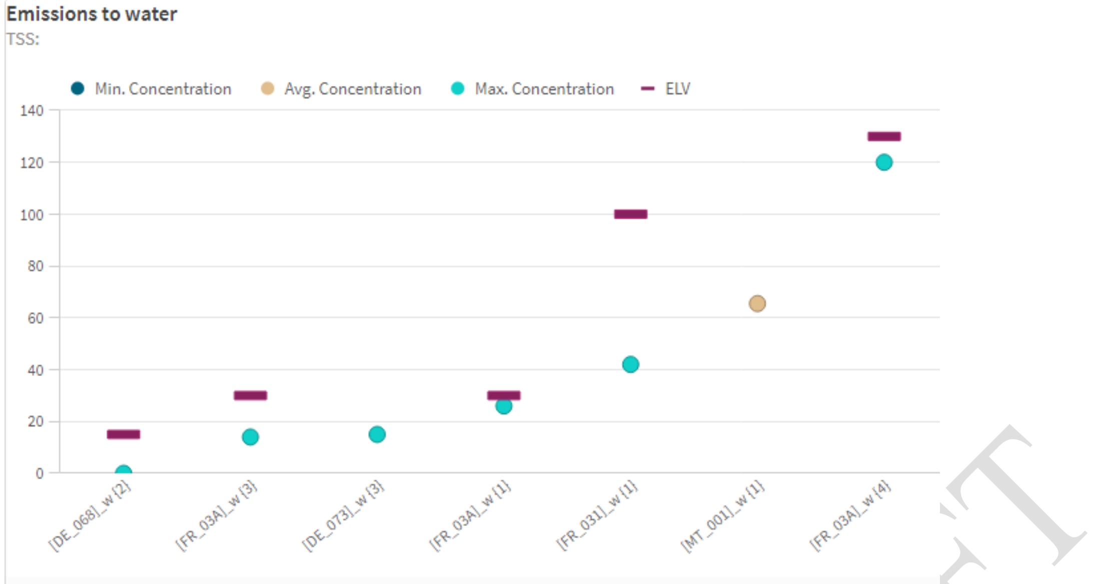
Source: [168, TWG 2023]

3.8.1.3 TOC

Data for TOC emissions to water were reported by only 1 emission point (DE073_w3) with a maximum value of 15 mg/l [168, TWG 2023].

3.8.1.4 TSS

The reported data for TSS emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-117.



Source: [168, TWG 2023]

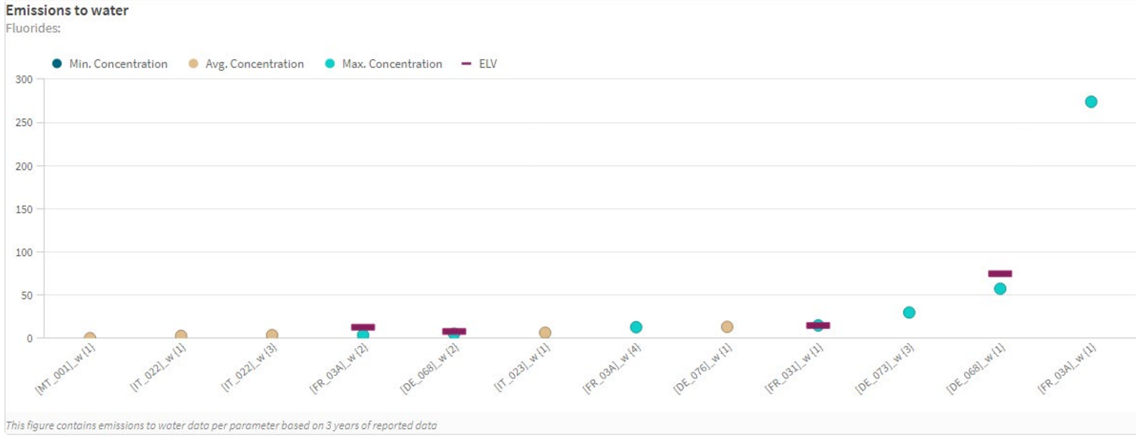
Figure 3-111: TSS emissions to water from semiconductor manufacturing plants

Table 3-117: Reported data and contextual information for TSS emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[DE_068]_w {2}	Filtration (e.g. gravel filter, sand filter)	-	-	0	-	15	-
[FR_03A]_w {3}	-	-	-	14	-	30	19
[DE_073]_w {3}	Other	-	-	15	-	-	-
[FR_03A]_w {1}	-	-	-	26	-	30	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	42	-	100	15.79
[MT_001]_w {1}	Coagulation and flocculation	-	65.5	-	-	-	-
[FR_03A]_w {4}	-	-	-	120	-	130	-

3.8.1.5 Fluorides

The reported data for fluorides emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-118.



Source: [168, TWG 2023]

Figure 3-112: Fluorides emissions to water from semiconductor manufacturing plants

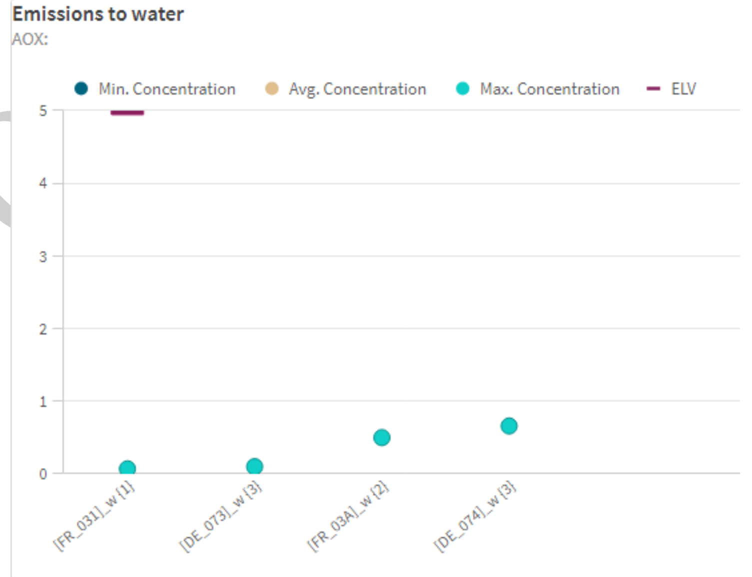
Table 3-118: Reported data and contextual information for fluorides emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[MT_001]_w {1}	Coagulation and flocculation	-	0.235	-	-	-	-
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	2.92	-	-	-	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	3.76	-	-	-	-
[FR_03A]_w {2}	Ion exchange resins	-	-	3.85	-	13	19.57
[DE_068]_w {2}	Filtration (e.g. gravel filter, sand filter)	-	-	5.52	-	8	-
[IT_023]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation	-	6.59	-	-	-	-
[FR_03A]_w {4}	-	-	-	13	-	-	-
[DE_076]_w {1}	Precipitation-Neutralisation-Ion exchange resins	-	13.4	-	-	-	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	15	-	15	11.29
[DE_073]_w {3}	Other	-	-	30	-	-	-
[DE_068]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Membrane micro/ultra/nano filtration-Neutralisation-Neutralisation-Reverse osmosis-Elimination and/or separation of the individual pollutants at the point of generation	-	-	57.5	-	75	-
[FR_03A]_w {1}	-	-	-	274	-	-	3.67

Source: [168, TWG 2023]

3.8.1.6 AOX

The reported data for AOX emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-119.



Source: [168, TWG 2023]

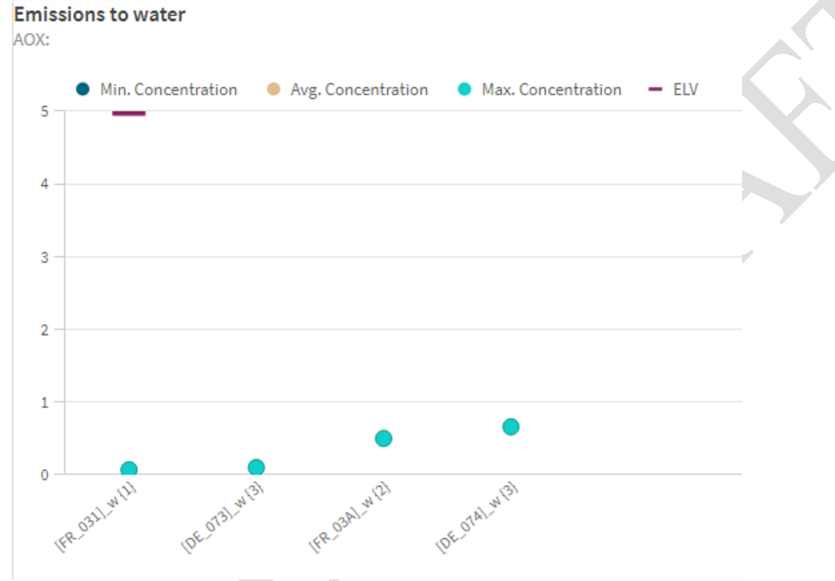
Figure 3-113: AOX emissions to water from semiconductor manufacturing plants

Table 3-119: Reported data and contextual information for AOX emissions to water from semiconductor manufacturing plants

Emission Point	**Abatement technique(s)**	**Min.**	**Avg.**	**Max.**	**95th perc.**	**ELV**	**Load (g/day)**
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.07	-	5	-
[DE_073]_w {3}	Other-	-	-	0.1	-	-	-
[FR_03A]_w {2}	Ion exchange resins	-	-	0.5	-	-	-
[DE_074]_w {3}	No technique applied	-	-	0.66	-	-	-

3.8.1.7 Cyanides

The reported data for cyanides emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-120.



Source: [168, TWG 2023]

Figure 3-114: Cyanides emissions to water from semiconductor manufacturing plants

Table 3-120: Reported data and contextual information for cyanides emissions to water from semiconductor manufacturing plants

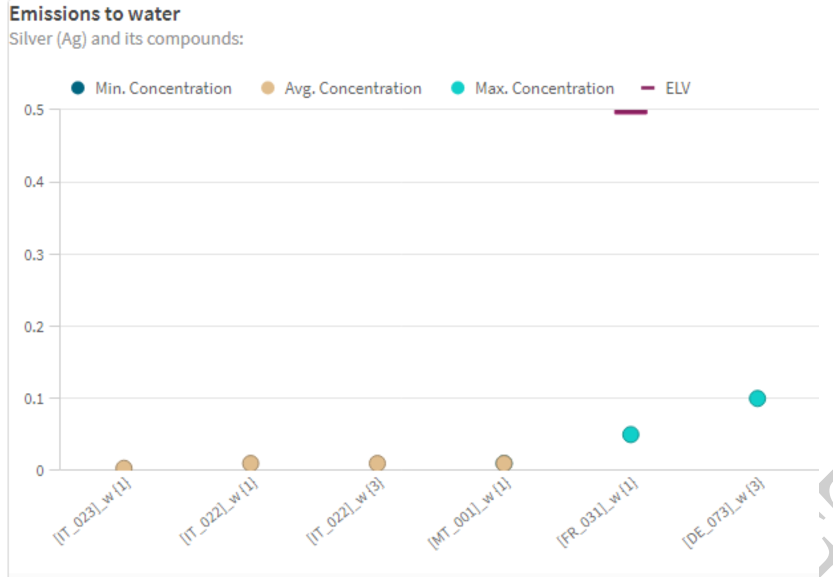
Emission Point	**Abatement technique(s)**	**Min.**	**Avg.**	**Max.**	**95th perc.**	**ELV**	**Load (g/day)**
[MT_001]_w {1}	Coagulation and flocculation	0.01	0.0129	-	-	-	-
[FR_03A]_w {1}	-	-	-	0.025	-	0.05	-
[FR_03A]_w {2}	Ion exchange resins	-	-	0.025	-	0.05	-
[FR_03A]_w {3}	-	-	-	0.025	-	0.05	-
[FR_03A]_w {4}	-	-	-	0.025	-	0.05	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.031	-	0.05	20

Source: [168, TWG 2023]

3.8.1.8 Metals

3.8.1.8.1 Ag

The reported data for silver emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-121.



Source: [168, TWG 2023]

Figure 3-115: Silver emissions to water from semiconductor manufacturing plants

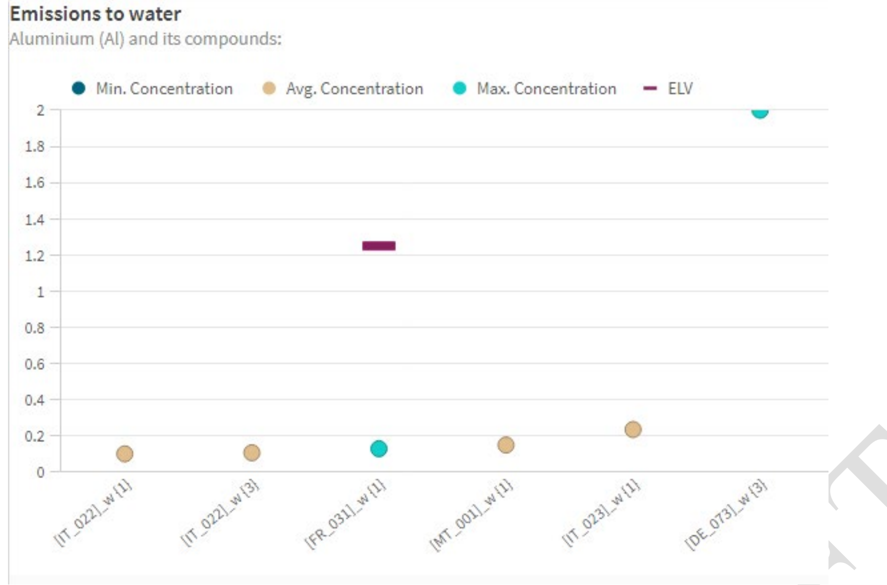
Table 3-121: Reported data and contextual information for silver emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[IT_023]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation	-	0.0032	-	-	-	-
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.01	-	-	-	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	0.01	-	-	-	-
[MT_001]_w {1}	Coagulation and flocculation	0.01	0.01	-	-	-	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.05	-	0.5	-
[DE_073]_w {3}	Other	-	-	0.1	-	-	-

Source: [168, TWG 2023]

3.8.1.8.2 Al

The reported data for aluminium emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-122.



Source: [168, TWG 2023]

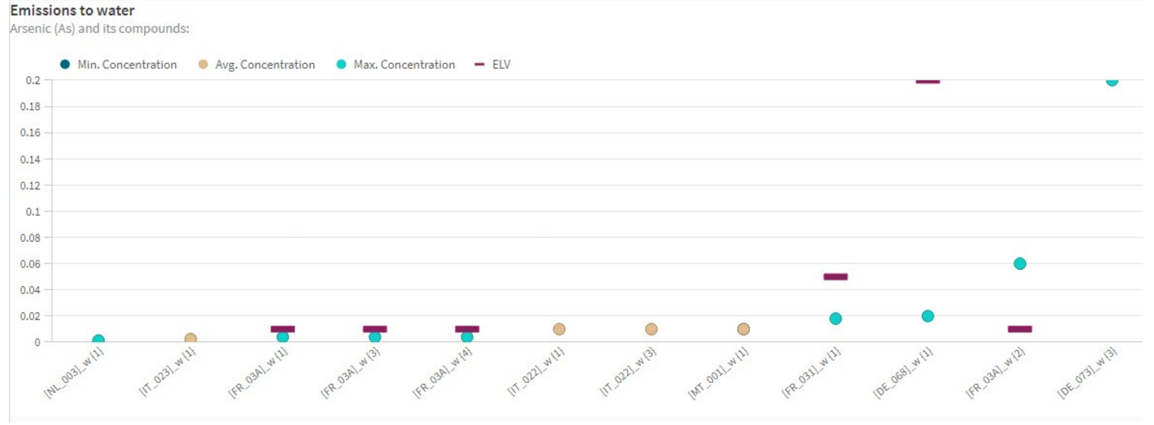
Figure 3-116: Aluminium emissions to water from semiconductor manufacturing plants

Table 3-122: Reported data and contextual information for aluminium emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.101	-	-	-	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.13	-	1.25	70
[MT_001]_w {1}	Coagulation and flocculatio	-	0.15	-	-	-	-
[IT_023]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation-	-	0.236	-	-	-	-
[DE_073]_w {3}	Other	-	-	2	-	-	-

3.8.1.8.3 As

The reported data for arsenic emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-123.



Source: [168, TWG 2023]

Figure 3-117: Arsenic emissions to water from semiconductor manufacturing plants

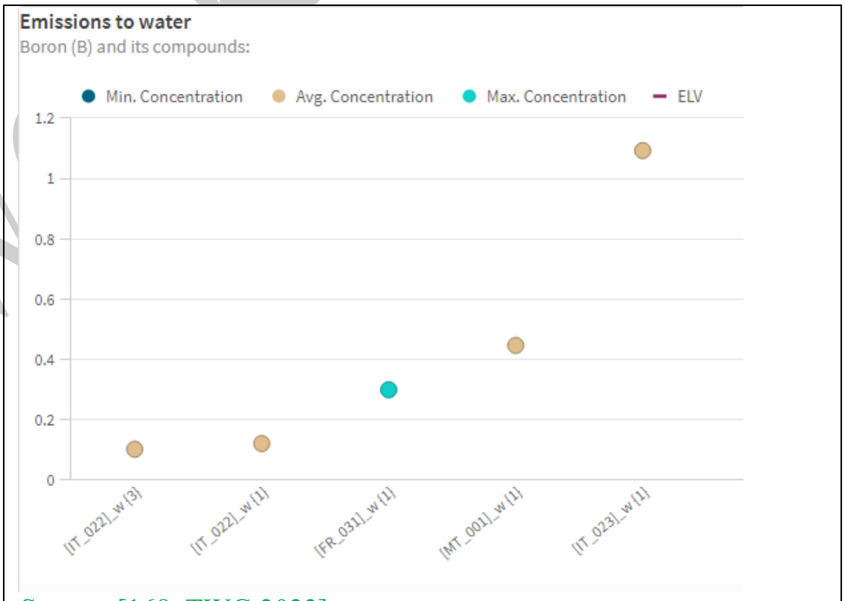
Table 3-123: Reported data and contextual information for arsenic emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[NL_003]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.0013	-	-	-
[IT_023]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation	-	0.0024	-	-	-	-
[FR_03A]_w {1}	-	-	-	0.004	-	0.01	-
[FR_03A]_w {3}	-	-	-	0.004	-	0.01	-
[FR_03A]_w {4}	-	-	-	0.004	-	0.01	-
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.01	-	-	-	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	0.01	-	-	-	-
[MT_001]_w {1}	Coagulation and flocculation	0.01	0.01	-	-	-	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.018	-	0.05	6
[DE_068]_w {1}	Coagulation and flocculation-Filtration (e.g. gravel filter, sand filter)-Membrane micro/ultra/nano filtration-Neutralisation-Neutralisation-Reverse osmosis-Elimination and/or separation of the individual pollutants at the point of generation	-	-	0.02	-	0.2	-
[FR_03A]_w {2}	Ion exchange resins	-	-	0.06	-	0.01	-
[DE_073]_w {3}	Other	-	-	0.2	-	-	-

Source: [168, TWG 2023]

3.8.1.8.4 B

The reported data for boron emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-124.



Source: [168, TWG 2023]

Figure 3-118: Boron emissions to water from semiconductor manufacturing plants

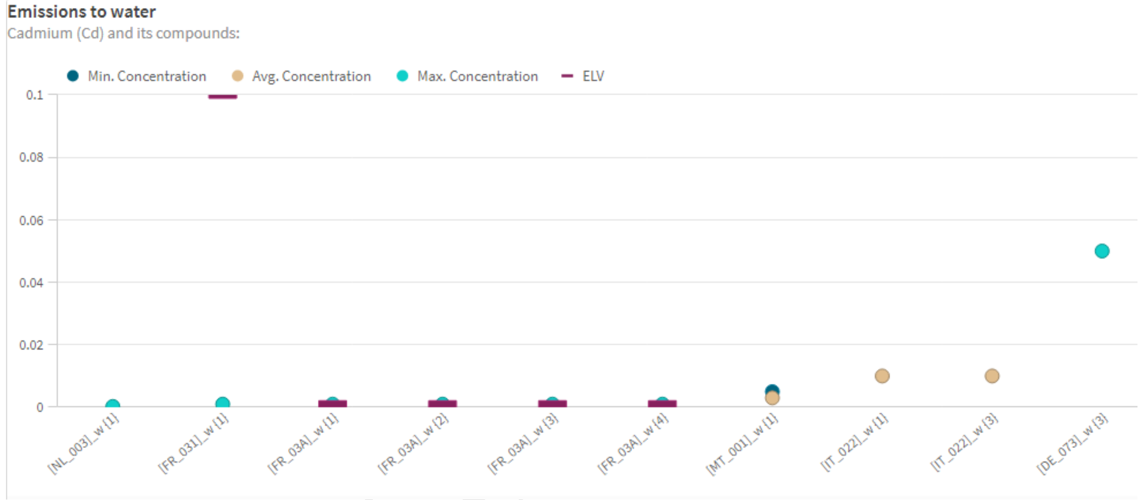
Table 3-124: Reported data and contextual information for boron emissions to water from semiconductor manufacturing plants

Emission Point		Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[IT_022]_w {3}		-	0.102	-	-	-	-
[IT_022]_w {1}		-	0.121	-	-	-	-
[FR_031]_w {1}		-	-	0.3	-	-	-
[MT_001]_w {1}		-	0.446	-	-	-	-
[IT_023]_w {1}		-	1.092	-	-	-	-

Source: [168, TWG 2023]

3.8.1.8.5 Cd

The reported data for cadmium emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-125.



Source: [168, TWG 2023]

Figure 3-119: Cadmium emissions to water from semiconductor manufacturing plants

Table 3-125: Reported data and contextual information for cadmium emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[NL_003]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.00026	-	-	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.001	-	0.1	-
[FR_03A]_w {1}	-	-	-	0.001	-	0.001	-
[FR_03A]_w {2}	Ion exchange resins	-	-	0.001	-	0.001	-
[FR_03A]_w {3}	-	-	-	0.001	-	0.001	-
[FR_03A]_w {4}	-	-	-	0.001	-	0.001	-
[MT_001]_w {1}	Coagulation and flocculation	0.005	0.003	-	-	-	-
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.01	-	-	-	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	0.01	-	-	-	-
[DE_073]_w {3}	Other	-	-	0.05	-	-	-

Source: [168, TWG 2023]

3.8.1.8.6 Co

The reported data for cobalt emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-126.

Source: [168, TWG 2023]

Figure 3-120: Cobalt emissions to water from semiconductor manufacturing plants

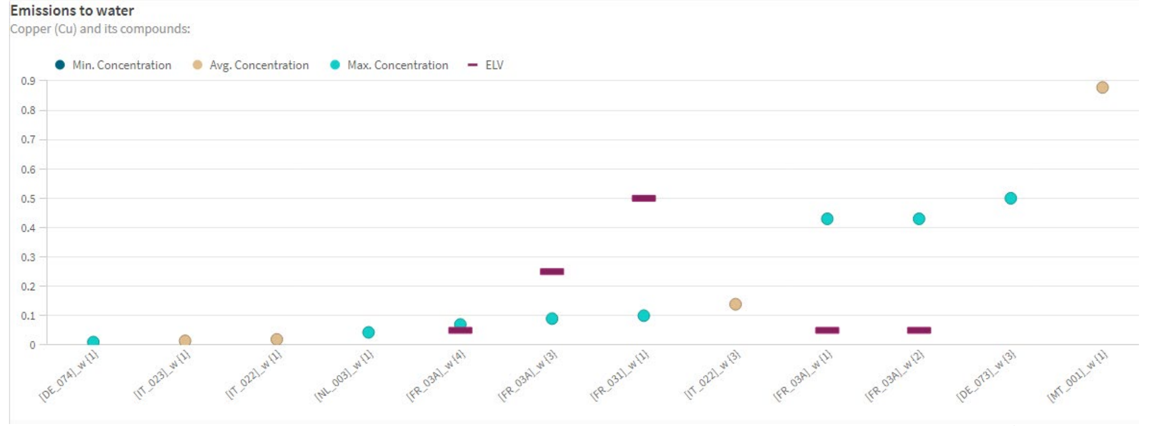
Table 3-126: Reported data and contextual information for cobalt emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.01	-	-	-	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	0.01	-	-	-	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.011	-	2	-
[DE_073]_w {3}	Other	-	-	1	-	-	-

Source: [168, TWG 2023]

3.8.1.8.7 Cu

The reported data for copper emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-127.



Source: [168, TWG 2023]

Figure 3-121: Copper emissions to water from semiconductor manufacturing plants

Table 3-127: Reported data and contextual information for copper emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[DE_074]_w {1}	Neutralisation-Precipitation-Precipitation-Filtration (e.g. gravel filter, sand filter)	-	-	0.01	-	-	-
[IT_023]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation	-	0.014	-	-	-	-
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.019	-	-	-	-
[NL_003]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.0431	-	-	-
[FR_03A]_w {4}	-	-	-	0.07	-	0.05	-
[FR_03A]_w {3}	-	-	-	0.09	-	0.25	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.1	-	0.5	30
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	0.138	-	-	-	-
[FR_03A]_w {1}	-	-	-	0.43	-	0.05	-
[FR_03A]_w {2}	Ion exchange resins	-	-	0.43	-	0.05	-
[DE_073]_w {3}	Other	-	-	0.5	-	-	-
[MT_001]_w {1}	Coagulation and flocculation	-	0.8775	-	-	-	-

Source: [168, TWG 2023]

3.8.1.8.8 Cr

The reported data for chromium emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-128.

Source: [168, TWG 2023]

Figure 3-122: Chromium emissions to water from semiconductor manufacturing plants

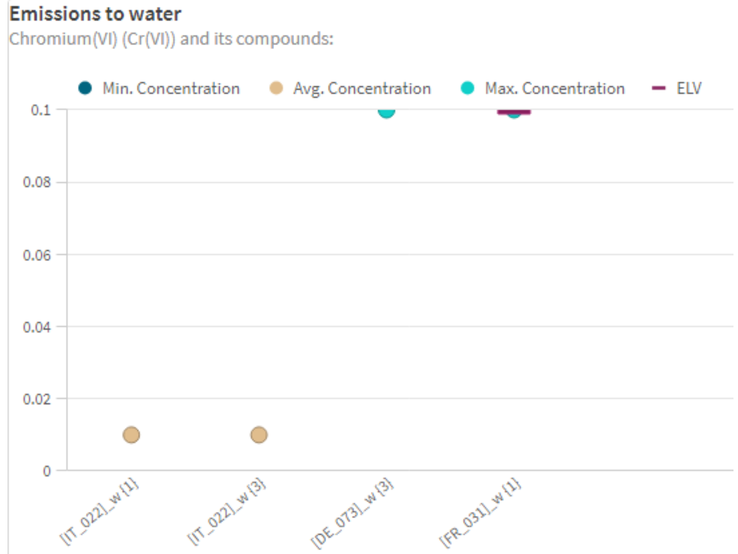
Table 3-128: Reported data and contextual information for chromium emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[NL_003]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.0022	-	-	-
[FR_03A]_w {1}	-	-	-	0.005	-	0.05	-
[FR_03A]_w {2}	Ion exchange resins	-	-	0.005	-	0.05	-
[FR_03A]_w {3}	-	-	-	0.005	-	0.05	-
[FR_03A]_w {4}	-	-	-	0.005	-	0.05	-
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.01	-	-	-	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	0.01	-	-	-	-
[IT_023]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation	-	0.0141	-	-	-	-
[MT_001]_w {1}	Coagulation and flocculation	0.05	0.063	-	-	-	-
[DE_073]_w {3}	Other	-	-	0.2	-	-	-

Source: [168, TWG 2023]

3.8.1.8.9 Cr(VI)

The reported data for hexavalent chromium emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-129.



Source: [168, TWG 2023]

Figure 3-123: Hexavalent chromium emissions to water from semiconductor manufacturing plants

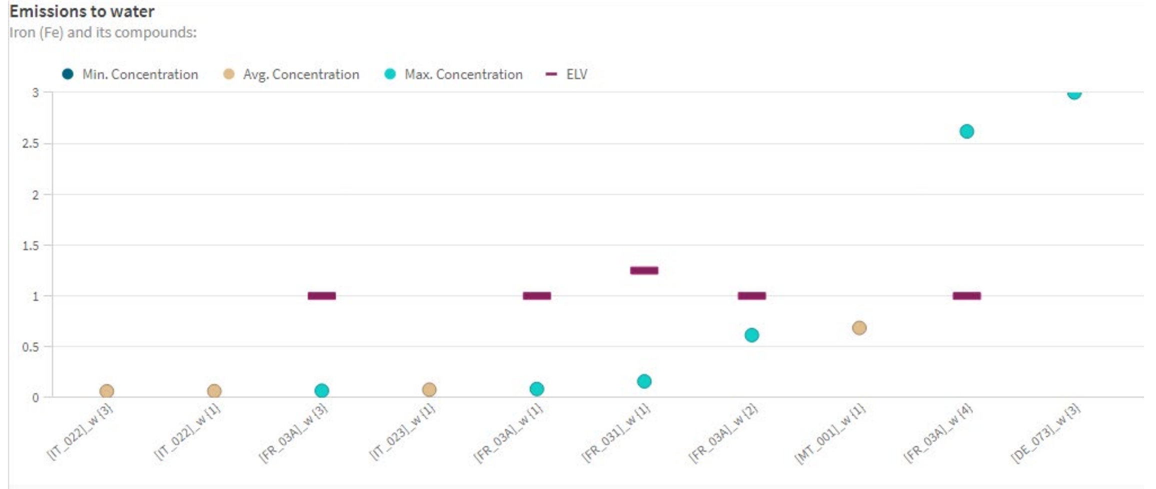
Table 3-129: Reported data and contextual information for hexavalent chromium emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.01	-	-	-	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	0.01	-	-	-	-
[DE_073]_w {3}	Other	-	-	0.1	-	-	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.1	-	0.1	-

Source: [168, TWG 2023]

3.8.1.8.10 Fe

The reported data for iron emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-130.



Source: [168, TWG 2023]

Figure 3-124: Iron emissions to water from semiconductor manufacturing plants

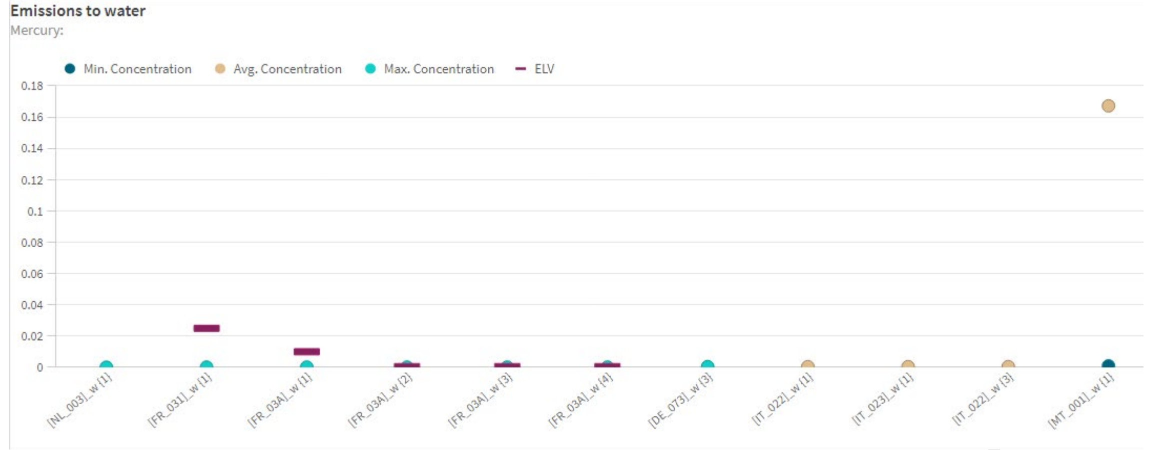
Table 3-130: Reported data and contextual information for iron emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	0.062	-	-	-	-
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.064	-	-	-	-
[FR_03A]_w {3}	-	-	-	0.068	-	1	-
[IT_023]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation	-	0.078	-	-	-	-
[FR_03A]_w {1}	-	-	-	0.085	-	1	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.16	-	1.25	30
[FR_03A]_w {2}	Ion exchange resins	-	-	0.615	-	1	-
[MT_001]_w {1}	Coagulation and flocculation	-	0.685	-	-	-	-
[FR_03A]_w {4}	-	-	-	2.618	-	1	-
[DE_073]_w {3}	Other	-	-	3	-	-	-

Source: [168, TWG 2023]

3.8.1.8.11 Hg

The reported data for mercury emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-131.



Source: [168, TWG 2023]

Figure 3-125: Mercury emissions to water from semiconductor manufacturing plants

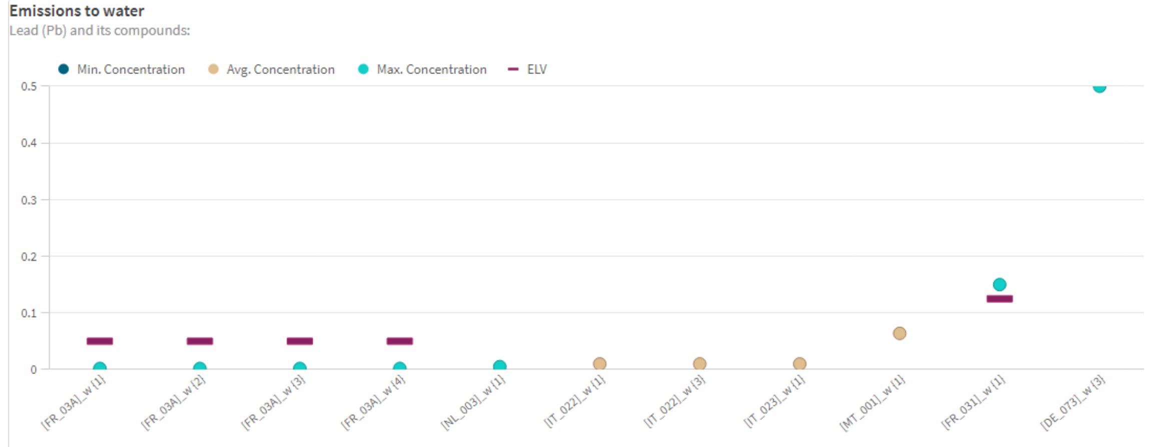
Table 3-131: Reported data and contextual information for mercury emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[NL_003]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.0001	-	-	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.0002	-	0.025	0.2
[FR_03A]_w {1}	-	-	-	0.0002	-	0.01	-
[FR_03A]_w {2}	Ion exchange resins	-	-	0.0002	-	0.0005	-
[FR_03A]_w {3}	-	-	-	0.0002	-	0.0005	-
[FR_03A]_w {4}	-	-	-	0.0002	-	0.0005	-
[DE_073]_w {3}	Other	-	-	0.0005	-	-	-
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.0005	-	-	-	-
[IT_023]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation	-	0.0005	-	-	-	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	0.0005	-	-	-	-
[MT_001]_w {1}	Coagulation and flocculation	0.001	0.167	-	-	-	-

Source: [168, TWG 2023]

3.8.1.8.12 Pb

The reported data for lead emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-132.



Source: [168, TWG 2023]

Figure 3-126: Lead emissions to water from semiconductor manufacturing plants

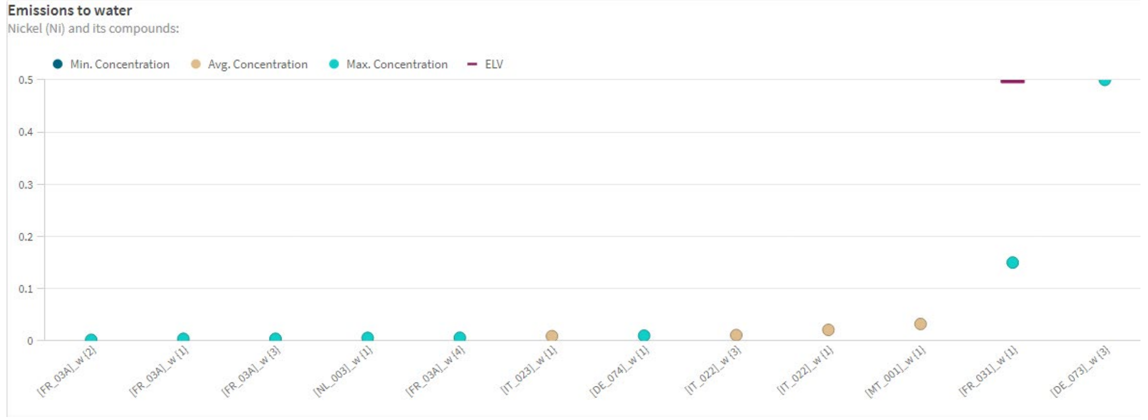
Table 3-132: Reported data and contextual information for lead emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[FR_03A]_w {1}	-	-	-	0.002	-	0.05	-
[FR_03A]_w {2}	Ion exchange resins	-	-	0.002	-	0.05	-
[FR_03A]_w {3}	-	-	-	0.002	-	0.05	-
[FR_03A]_w {4}	-	-	-	0.002	-	0.05	-
[NL_003]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.0053	-	-	-
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.01	-	-	-	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	0.01	-	-	-	-
[IT_023]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation	-	0.01	-	-	-	-
[MT_001]_w {1}	Coagulation and flocculation	-	0.064	-	-	-	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.15	-	0.125	10
[DE_073]_w {3}	Other	-	-	0.5	-	-	-

Source: [168, TWG 2023]

3.8.1.8.13 Ni

The reported data for nickel emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-133.



Source: [168, TWG 2023]

Figure 3-127: Nickel emissions to water from semiconductor manufacturing plants

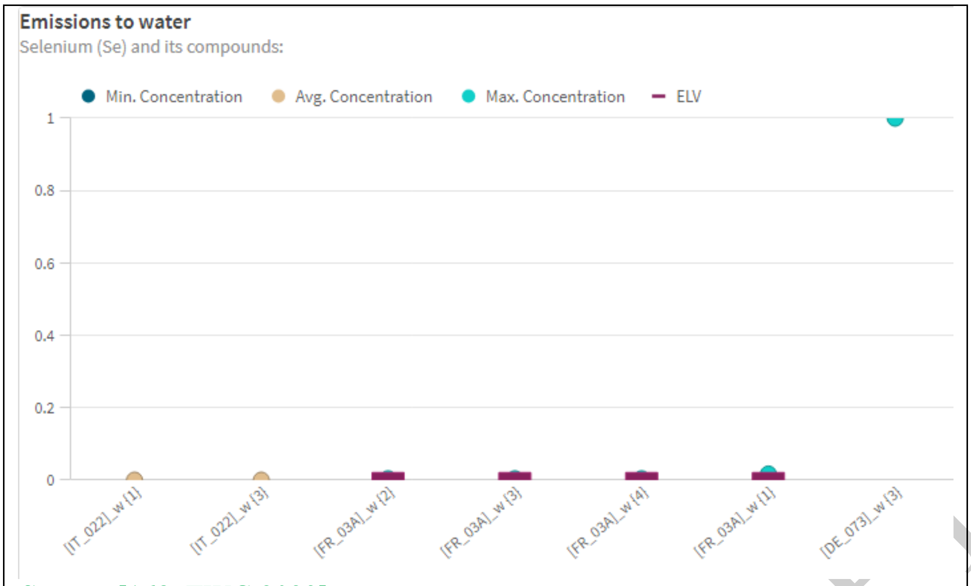
Table 3-133: Reported data and contextual information for nickel emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[FR_03A]_w {2}	Ion exchange resins	-	-	0.002	-	-	-
[FR_03A]_w {1}	-	-	-	0.004	-	-	-
[FR_03A]_w {3}	-	-	-	0.004	-	-	-
[NL_003]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.0058	-	-	-
[FR_03A]_w {4}	-	-	-	0.006	-	-	-
[IT_023]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation	-	0.009	-	-	-	-
[DE_074]_w {1}	Neutralisation-Precipitation-Precipitation-Filtration (e.g. gravel filter, sand filter)	-	-	0.01	-	-	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	0.011	-	-	-	-
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.021	-	-	-	-
[MT_001]_w {1}	Coagulation and flocculation	-	0.032	-	-	-	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.15	-	0.5	100
[DE_073]_w {3}	Other	-	-	0.5	-	-	-

Source: [168, TWG 2023]

3.8.1.8.14 Se

The reported data for selenium emissions to water are presented in the following figure. Emission data and contextual information are also presented in **Table 3-134**.



Source: [168, TWG 2023]

Figure 3-128: Selenium emissions to water from semiconductor manufacturing plants

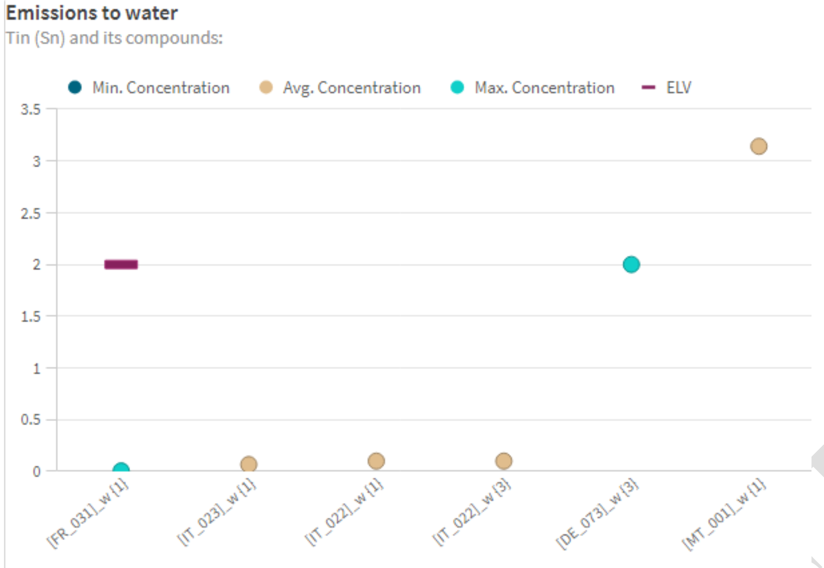
Table 3-134: Reported data and contextual information for selenium emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.0001	-	-	-	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	0.0001	-	-	-	-
[FR_03A]_w {2}	Ion exchange resins	-	-	0.004	-	0.01	-
[FR_03A]_w {3}	-	-	-	0.004	-	0.01	-
[FR_03A]_w {4}	-	-	-	0.004	-	0.01	-
[FR_03A]_w {1}	-	-	-	0.017	-	0.01	-
[DE_073]_w {3}	Other	-	-	1	-	-	-

Source: [168, TWG 2023]

3.8.1.8.15 Sn

The reported data for tin emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-135.



Source: [168, TWG 2023]

Figure 3-129: Tin emissions to water from semiconductor manufacturing plants

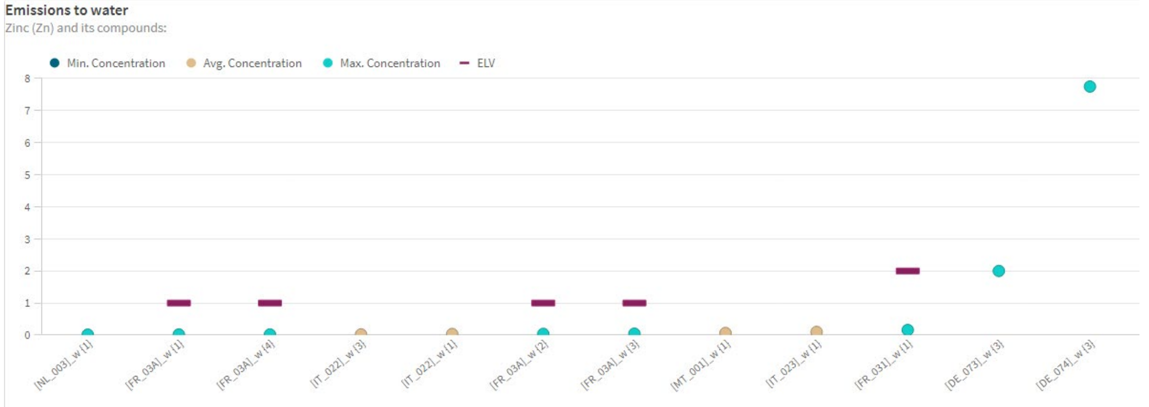
Table 3-135: Reported data and contextual information for tin emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.005	-	2	-
[IT_023]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation	-	0.067	-	-	-	-
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.1	-	-	-	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	0.1	-	-	-	-
[DE_073]_w {3}	Other	-	-	2	-	-	-
[MT_001]_w {1}	Coagulation and flocculation	-	3.142	-	-	-	-

Source: [168, TWG 2023]

3.8.1.8.16 Zn

The reported data for zinc emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-136.



Source: [168, TWG 2023]

Figure 3-130: Zinc emissions to water from semiconductor manufacturing plants

Table 3-136: Reported data and contextual information for zinc emissions to water from semiconductor manufacturing plants

Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[NL_003]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.0141	-	-	-
[FR_03A]_w {1}	-	-	-	0.019	-	1	-
[FR_03A]_w {4}	-	-	-	0.019	-	1	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	0.0223	-	-	-	-
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.0337	-	-	-	-
[FR_03A]_w {2}	Ion exchange resins	-	-	0.037	-	1	-
[FR_03A]_w {3}	-	-	-	0.045	-	1	-
[MT_001]_w {1}	Coagulation and flocculation	-	0.0662	-	-	-	-
[IT_023]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation	-	0.0993	-	-	-	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	0.16	-	2	20
[DE_073]_w {3}	Other	-	-	2	-	-	-
[DE_074]_w {3}	No technique applied	-	-	7.75	-	-	-

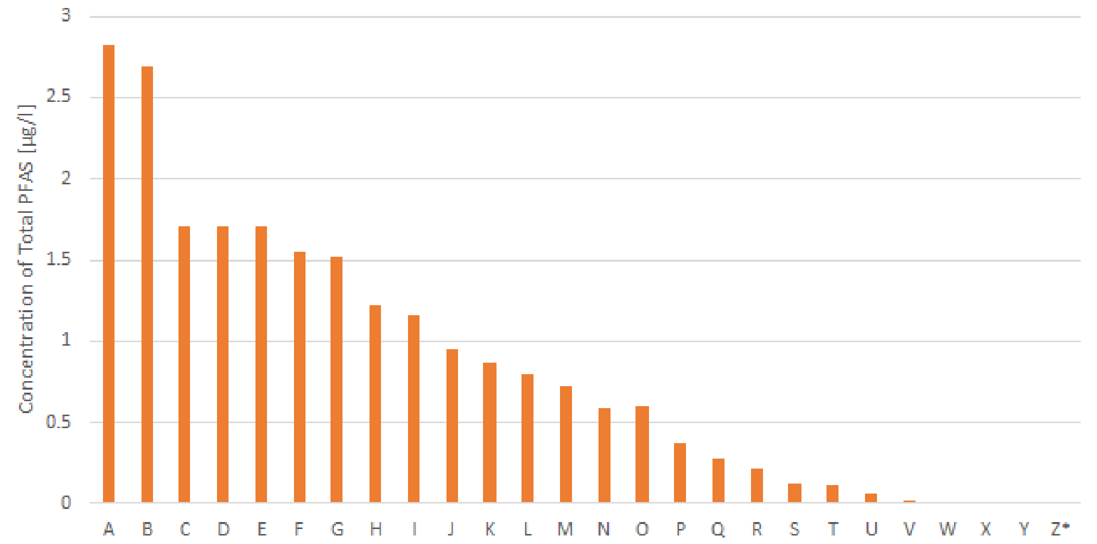
Source: [168, TWG 2023]

3.8.1.9 Perfluoroalkyl and polyfluoroalkys Substances (PFAS)

No data for PFAS emissions to water were provided from semiconductor manufacturing plants through the plant-specific questionnaires. However, various sources of information indicate that PFAS emission to water is an issue for the semiconductor manufacturing sector, as a result of PFAS use in various processes.

The *2023 'Semiconductor PFAS Consortium Survey Results: PFAS in Semiconductor Fabrication Facility Waste water'* is a study recently published (2025) by the Semiconductor PFAS Consortium, a group of companies under the auspices of the Semiconductor Industry Association (SIA) to address technical matters associated with the industry's use of PFAS. For the survey, semiconductor manufacturing member companies were asked to provide information on PFAS in process waste water. In total, 11 semiconductor manufacturers made data available for 26 semiconductor facilities in the US and Europe and 1 in Asia-Pacific.

The survey results reveal a wide range of PFAS emissions to water. The total PFAS emissions to water range from 0.009 µg/l to 2.824 µg/l. The average PFAS emissions to water are 0.840 µg/l. Taking into account the amount of waste water, ranging between 3 000 m^3/day (≤ 200-mm sites) and 9 500 m^3/day (300-mm sites), the mentioned concentrations result in a total PFAS release that ranges from 0.002 grams/day to 13 grams/day. It must be noted that conventional on-site waste water treatment systems are not adjusted to remove PFAS from effluents and that none of the reported semiconductor manufacturing installations were subject to PFAS discharge limits.

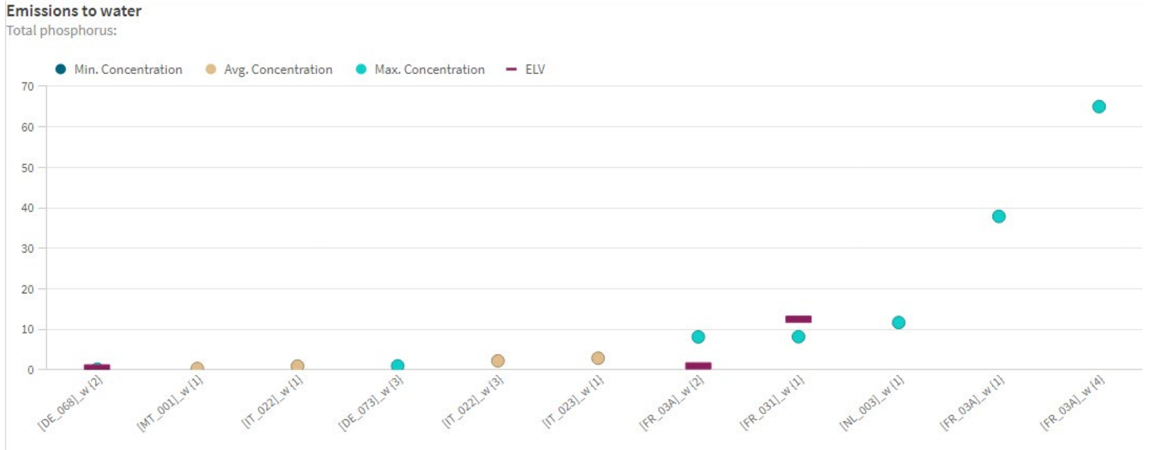


Source: [2023 Semiconductor PFAS Consortium Survey Results: PFAS in Semiconductor Fabrication Facility Waste water]

Figure 3-131: PFAS emissions to water from semiconductor manufacturing plants

3.8.1.10 Total phosphorus

The reported data for total phosphorus emissions to water are presented in the following figure. Emission data and contextual information are also presented in Table 3-137.



Source: [168, TWG 2023]

Figure 3-132: Total phosphorus emissions to water from semiconductor manufacturing plants

Table 3-137: Reported data and contextual information for total phosphorus emissions to water from semiconductor manufacturing plants

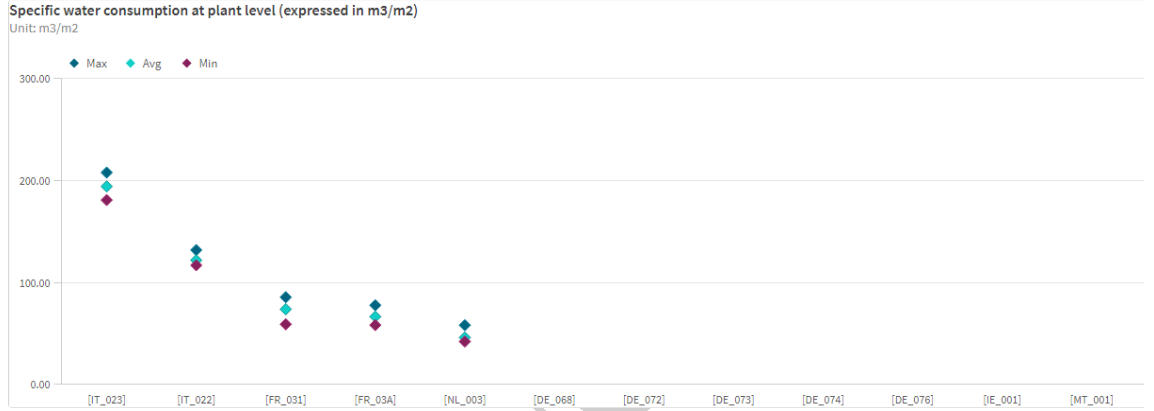
Emission Point	Abatement technique(s)	Min.	Avg.	Max.	95th perc.	ELV	Load (g/day)
[DE_068]_w {2}	Filtration (e.g. gravel filter, sand filter)	-	-	0.2	-	0.5	-
[MT_001]_w {1}	Coagulation and flocculation	-	0.3433	-	-	-	-
[IT_022]_w {1}	Neutralisation-Coagulation and flocculation-Membrane micro/ultra/nano filtration	-	0.9417	-	-	-	-
[DE_073]_w {3}	Other	-	-	1	-	-	-
[IT_022]_w {3}	Neutralisation-Membrane micro/ultra/nano filtration	-	2.2331	-	-	-	-

[IT_023]_w {1}	Neutralisation-Coagulation and flocculation-Precipitation-Sedimentation	-	2.897	-	-	-	-
[FR_03A]_w {2}	Ion exchange resins	-	-	8.16	-	1	-
[FR_031]_w {1}	Neutralisation-Coagulation and flocculation	-	-	8.2	-	12.5	2.63
[NL_003]_w {1}	Neutralisation-Coagulation and flocculation	-	-	11.7	-	-	-
[FR_03A]_w {1}	-	-	-	37.9	-	-	0.47
[FR_03A]_w {4}	-	-	-	65	-	-	-

Source: [168, TWG 2023]

3.8.2 Water consumption and waste water discharge

The reported data for specific water consumption are presented in the following figure. Consumption data and contextual information are also presented in Table 3-138.



Source: [168, TWG 2023]

Figure 3-133: Specific water consumption expressed in m^3 per m^2 of wafer in semiconductor manufacturing plants

Table 3-138: Reported data (expressed in m^3 per m^2 of wafer) and contextual information for specific water consumption in semiconductor manufacturing plants

Plant code	Max.	Avg.	Min.	Associated process	Monitoring method	Technique	Year of impleme-ntation	Additional information
[DE_068]	-	-	-	Rinsing-Other	-	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Use of closed cooling systems	-	rinsing for ultra pure water-Ultra pure water generation water reduction by reclaim (use for air scrubber) and recycling of water-cooling water for cooling systems
[DE_072]	-	-	-	-	Measured	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Use of closed cooling	-	Recycling rinse water in a separate Recycling plant-Recycling rinse water in a separate Recycling plant-

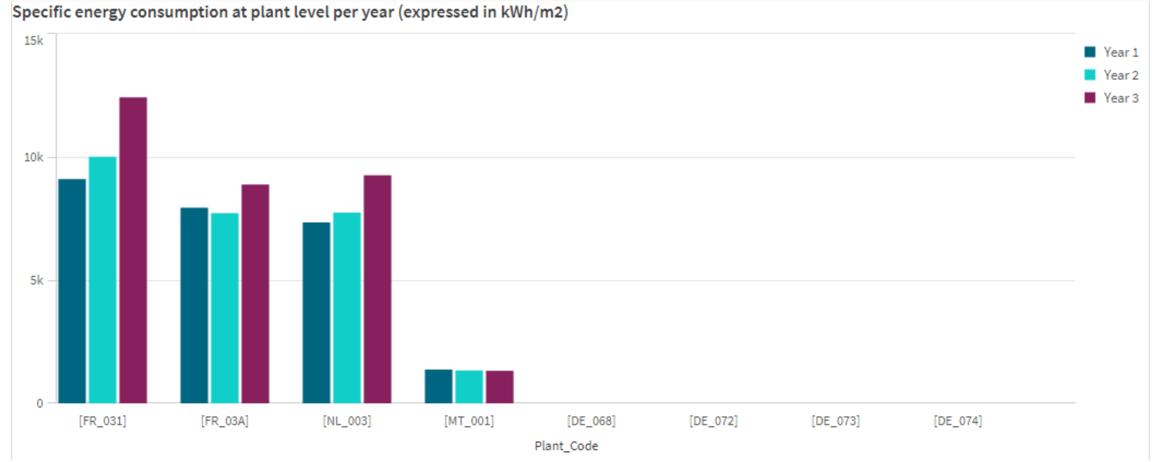
						systems-Other-		
[DE_073]	-	-	-	-	Measured	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Use of closed cooling systems-Other	-	Heat recovery systems, heat pumps-well water recovery by free cooling in winter-
[DE_074]	-	-	-	Cleaning-Other--	-	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Use of closed cooling systems-Reuse of water by using multiple rinsing steps	-	-reuse of water from UPW generation in cooling tower-
[DE_076]	-	-	-	Cleaning-Other-	-	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Use of closed cooling systems-Reuse of water by using multiple rinsing steps	-	-reuse of water from UPW generation for cooling purpose-
[FR_03A]	77.76	72.55	69.75	-	Measured	Use of closed cooling systems-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	-	-
[FR_031]	81.74	76.50	67.72	Other-	Measured	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Use of closed cooling systems	1995-	Part of water with few pollutants is recovered treated (reverse osmosis) and reused on site-as per requirement-
[IE_001]	-	-	-	Etching-Rinsing-Other-	Measured	Recirculating rinsing water from etching and surface treatment to surface treatment baths-Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Reuse of water by using multiple rinsing steps-Other	2000-	This technique exludes water returned to the surface treatment baths-contamination risk (copper)-Recovery exists from rinsing-Recovery of the UPW reject water for further

								on-site use.-Take the idle status of equipment and reuse the water for an alternative function-
[IT_022]	132	122	117	-	Measured	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)	-	-
[IT_023]	208	194.33	181	-	Measured	Recovery and/or re-use of water (e.g. from cooling, rinsing or after waste water treatment)-Other	2004-	-Recycle of brine from reverse osmosis systems for other services (e.g. wet scrubbers)-
[MT_001]	-	-	-	Cleaning-	Calculated	Other	2007	Recycling system by Microfiltration-
[NL_003]	58.2	49.53	43.7	Rinsing	Measured	Reuse of water by using multiple rinsing steps-Use of closed cooling systems	-	Continous process looking for improvement opportinities-

Source: [168, TWG 2023]

3.8.3 Energy efficiency

The reported data for specific energy consumption are presented in the following figure. Consumption data and contextual information are also presented in Table 3-139. The applied techniques to reduces energy consumption are presented in Table 3-140.



Source: [168, TWG 2023]

Figure 3-134: Specific energy consumption expressed in kWh per m^2 of wafer in semiconductor manufacturing plants

Table 3-139: Reported data (expressed in kWh^3 per m^2 of wafer) and contextual information for specific energy consumption in semiconductor manufacturing plants

Plant code	Net Energy (kWh/m^2)	Net Electricity (kWh/m^2)	Net Heat (kWh/m^2)	How the energy consumption is monitored	Proportion of energy recovered (%)	How the recovered energy is monitored	Total volume of workspace heated (m^3)	Additional information
[DE_072]	-	-	-	Measured	25	Measured	-	n.a.
[DE_073]	-	321	-	Measured	-	-	-	kWh/m2 produced layer
[FR_03A]	8181	-	-	Measured	-	-	-	Electricity: 188 GWh Gaz CH4: 13,6 GWhConsumption in GWh (natural gas and Electricity / (number of WOeq 20 ML * 0.031416 m2 (WO surface))
[FR_03A]	8181	-	-	Measured	-	-	-	Electricity: 190 GWh Gaz CH4: 14,4 GWhConsumption in GWh (natural gas and Electricity / (number of WOeq 20 ML * 0.031416 m2 (WO surface))
[FR_03A]	8181	-	-	Measured	-	-	-	Electricity: 191 GWh Gaz CH4: 16 GWh Consumption in GWh (natural gas and Electricity / (number of WOeq 20 ML * 0.031416 m2 (WO surface))
[FR_031]	10511	-	-	-	-	-	-	Consumption in GWh (natural gas and Electricity / (number of WOeq 20 ML * 0.031416 m2 (WO surface))
[IE_001]	-	-	-	-	-	-	-	1,017,701,203 kWh of electricity per annum
[IE_001]	-	-	-	-	-	-	-	865,883,268 kWh of electricity per annum
[IE_001]	-	-	-	-	-	-	-	922,002,172 kWh of electricity per annum
[IT_022]	-	12480	3833	Measured	-	-	-	-
[IT_023]	-	16376	2858	Measured	-	-	-	-
[MT_001]	1341	-	-	Measured	-	-	-	-
[NL_003]	8114	6968	1146	Measured	-	-	48000	much lower fab usage because of pandemic
[NL_003]	8114	6968	1146	Measured	-	-	48000	Specific energy use depends on: 1. fab usage (80% or more of energy use is fixed, while m2 produced is directly related to fab usage) 2. product and technology mix (e.g. # mask layers, # and type of production steps)

Table 3-140: Applied techniques to reduce energy consumption and contextual information for semiconductor manufacturing plants

Plant code	Energy efficiency techniques	Additional information	Year of impleme-ntation
[DE_068]	Other	e.g. switch to LED light, high efficiency pumps	-
	Optimised ventilation, air conditioning and heating	-	-
	Optimised heating of process solution	-	-
	Optimised design and handling of voltage supply and current demands	-	-
	Energy efficiency plan and energy audits	EMAS / ISO 14001 since 1996	-
[DE_072]	Use of energy-efficient equipment (e.g. motors, lights)	-	1995
	Recovery of waste heat (e.g. re-heat of rinsing water, evaporator, extracted air))	-	1995
	Pipe insulation	-	1995
	Energy efficiency plan and energy audits	-	2015
	Energy balance record	-	2010
	Combined heat and power plant installation	-	2015
[DE_073]	Use of energy-efficient equipment (e.g. motors, lights)	-	-
	Thermal insulation of process tanks	-	-
	Regular maintenance of equipment in the electrical supply system	-	-
	Recovery of waste heat (e.g. re-heat of rinsing water, evaporator, extracted air))	-	-
	Pipe insulation	-	-
	Optimised ventilation, air conditioning and heating	-	-
	Optimised design and handling of voltage supply and current demands)	-	-
	Energy balance record	-	-
	Combined heat and power plant installation	-	-
[DE_074]	Recovery of waste heat (e.g. re-heat of rinsing water, evaporator, extracted air))	-	2022
	Energy efficiency plan and energy audits	-	2020
	Energy balance record	-	2021
[DE_076]	Regular maintenance of equipment in the electrical supply system	-	-
	Recovery of waste heat (e.g. re-heat of rinsing water, evaporator, extracted air))	-	-
	Optimised ventilation, air conditioning and heating	-	-
	Energy efficiency plan and energy audits	-	-
	Energy balance record	-	-
[FR_03A]	Regular maintenance of equipment in the electrical supply system	-	-
	Other	Aerofreecooling	-
	Other: Fab cleanliness at wafer level: each equipment got a specific air filter system called SMIF (Standard Mechanical Interface) which allow to transfer wafers from the POD to the equipment without exposition to the ambient air: Wafers never leave small environment (class 1). (ambiance fab class 1000). So with this system we need less energy than if we have to maintain all the ambiance		-

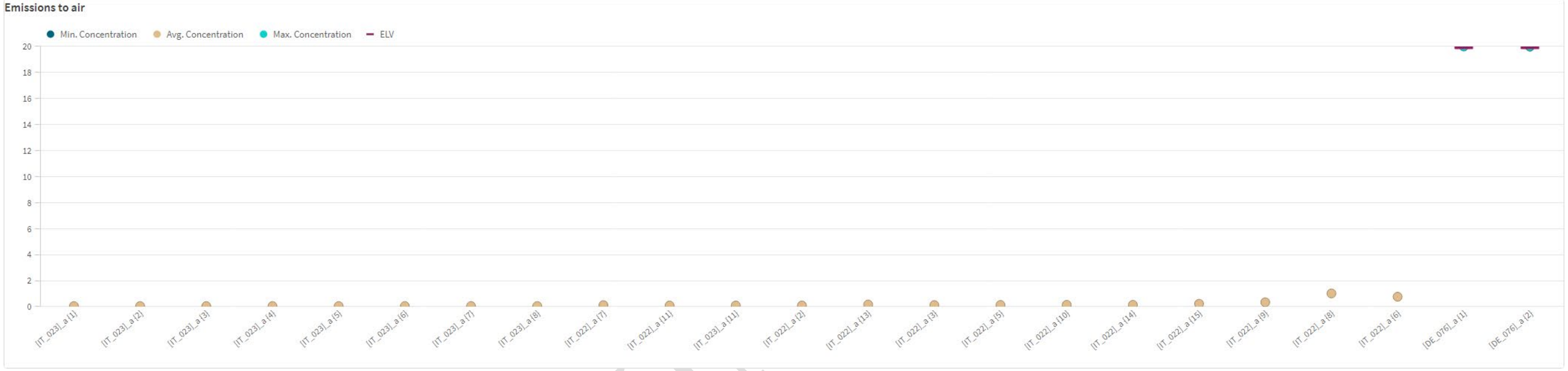
	at class1. Old fab concept of clean room was to clean and maintain the air of the full room in Class 1.		
	Other	Heat recovery from chillers	-
	Other	Replacement of old materials by new more efficient	-
	Other	Use of speed variator	-
	Energy efficiency plan and energy audits	-	-
	Energy balance record	-	-
[FR_031]	Regular maintenance of equipment in the electrical supply system	-	-
	Other	Aerofreecooling	-
	Other	Heat recovery from chillers	-
	Other	Replacement of old materials by new more efficient	-
	Other	Use of speed variator	-
	Other	-	-
	Energy efficiency plan and energy audits	-	-
	Energy balance record	-	-
[IE_001]	Use of energy-efficient equipment (e.g. motors, lights)	-	-
	Thermal insulation of process tanks	In place for NaOH tanks.	-
	Temperature control of heating baths	Temperature control of some tool operation chemical baths.	-
	Regular maintenance of equipment in the electrical supply system	-	-
	Recovery of waste heat (e.g. re-heat of rinsing water, evaporator, extracted air))	Heat recovery on RCTOs.	-
	Pipe insulation	-	-
	Optimised ventilation, air conditioning and heating	-	-
	Optimised design and handling of voltage supply and current demands	-	-
	Energy efficiency plan and energy audits	Integral part of the ISO 50,001 process.	-
[IT_022]	Regular maintenance of equipment in the electrical supply system	-	-
	Optimised ventilation, air conditioning and heating	-	-
	Energy efficiency plan and energy audits	-	-
[IT_023]	Use of energy-efficient equipment (e.g. motors, lights)	-	-
	Regular maintenance of equipment in the electrical supply system	-	-
	Recovery of waste heat (e.g. re-heat of rinsing water, evaporator, extracted air))	-	-
	Pipe insulation	-	-
	Optimised ventilation, air conditioning and heating	-	-
	Energy efficiency plan and energy audits	-	-
[MT_001]	Use of energy-efficient equipment (e.g. motors, lights)	Automatic light switching using presence sensors.	2021
	Use of energy-efficient equipment (e.g. motors, lights)	Dry Boxes Seal Improvement	2022
	Use of energy-efficient equipment (e.g. motors, lights)	Installation of inverter in Primary Pumps	2021
	Use of energy-efficient equipment (e.g. motors, lights)	Intallation of Controller to optimise the use of the	2022

		compressors by chosing the most efficient to operate according to the demand	
	Use of energy-efficient equipment (e.g. motors, lights)	Modification in pipe line in order to reach the pressure required in production allows to switch off one compressor (300kW)	2022
	Use of energy-efficient equipment (e.g. motors, lights)	Replacement existing lighting for LED lights	2021
	Use of energy-efficient equipment (e.g. motors, lights)	Switch off unit (AHU, Chilled Water Pump, fan coil units, extractors) after office hours	2021
	Other	CDA leaks inspection	2023
[NL_003]	Use of energy-efficient equipment (e.g. motors, lights)	Number of projects for vacuum pumps, cooling water pumps, LED lighting	-
	Recovery of waste heat (e.g. re-heat of rinsing water, evaporator, extracted air))	Diverse e.g. heat recovery process/cooling water for UPW production and preheating boiler water	-
	Pipe insulation	Part of (re)design of all heating/cooling, also improvement projects during MJA-3	-
	Other	2010- 2022: Centralizing/optimizing production from 4 fabs to 1 fab and increasing production in the single fab with same or only very small increase in energy use	-
	Optimised ventilation, air conditioning and heating	2017 and more efficient filters in 2019/2020	-
	Energy efficiency plan and energy audits	EEP's every 4 year related to Industry-Governement convenants (MJA-3 2001-2020)	2002
	Energy balance record	Part of EEP's, see next line	2002

3.8.4 Emissions to air

3.8.4.1 Dust

The reported data for dust emissions to air are presented in the following figure. Emission data and contextual information are also presented in Table 3-141.



Source: [168, TWG 2023]

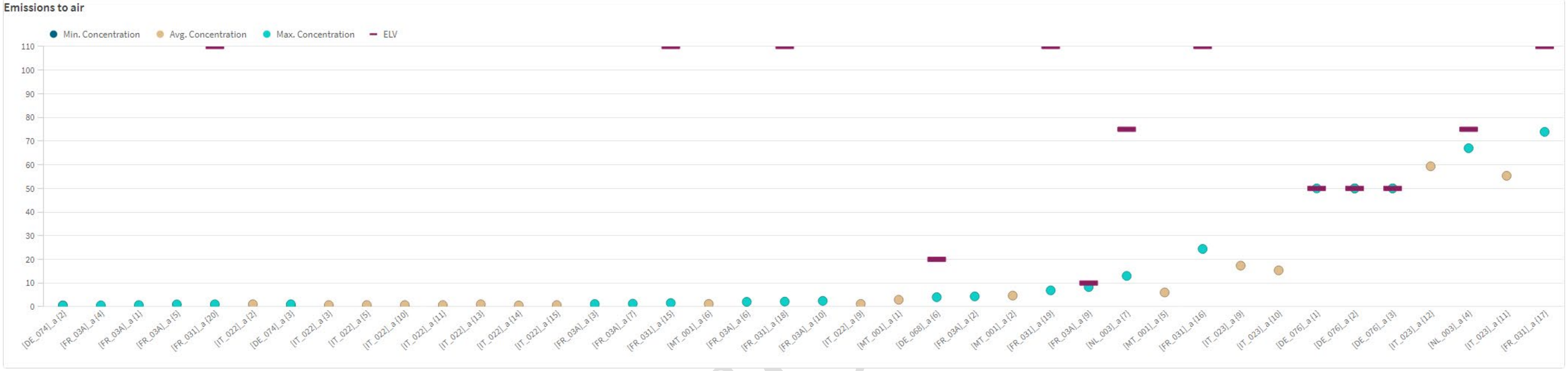
Figure 3-135: Dust emissions to air from semiconductor manufacturing plants

Table 3-141: Reported data and contextual information for dust emissions to air from semiconductor manufacturing plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[DE_076]_a {1}		Scrubber- absorption (acid/alkaline)-Electrostatic pecipitator-Other	20	-	-	20	-
[DE_076]_a {2}		Scrubber- absorption (acid/alkaline)-Electrostatic pecipitator-	20	20	20	20	-
[IT_022]_a {2}		No technique applied	-	0.0935	-	-	-
[IT_022]_a {3}		No technique applied	-	0.1582	-	-	-
			-	0.108	-	-	-
[IT_022]_a {5}		No technique applied	-	0.21	-	-	-
			-	0.09595	-	-	-
[IT_022]_a {6}		Scrubber- absorption (acid/alkaline)	-	0.76667	-	-	-
[IT_022]_a {7}		Scrubber- absorption (acid/alkaline)	-	0.12	-	-	-
[IT_022]_a {8}		Scrubber- absorption (acid/alkaline)	-	1.02	-	-	-
[IT_022]_a {9}		Scrubber- absorption (acid/alkaline)	-	0.34167	-	-	-
[IT_022]_a {10}		Scrubber- absorption (acid/alkaline)	-	0.14467	-	-	-
[IT_022]_a {11}		Scrubber- absorption (acid/alkaline)	-	0.09167	-	-	-
[IT_022]_a {13}		Scrubber- absorption (acid/alkaline)	-	0.17	-	-	-
[IT_022]_a {14}		Scrubber- absorption (acid/alkaline)	-	0.2322	-	-	-
				0.049	-	-	-
[IT_022]_a {15}		Scrubber- absorption (acid/alkaline)	-	0.223	-	-	-
[IT_023]_a {1}		Scrubber- absorption (acid/alkaline)	-	0.05	-	-	-
[IT_023]_a {2}		Scrubber- absorption (acid/alkaline)	-	0.05	-	-	-
[IT_023]_a {3}		Scrubber- absorption (acid/alkaline)	-	0.05	-	-	-
[IT_023]_a {4}		Scrubber- absorption (acid/alkaline)	-	0.05	-	-	-
[IT_023]_a {5}		Scrubber- absorption (acid/alkaline)	-	0.05	-	-	-
[IT_023]_a {6}		Scrubber- absorption (acid/alkaline)	-	0.05	-	-	-
[IT_023]_a {7}		Scrubber- absorption (acid/alkaline)	-	0.05	-	-	-

3.8.4.2 TVOC

The reported data for TVOC emissions to air are presented in the following figure. Emission data and contextual information are also presented in the table below.



Source: [168, TWG 2023]

Figure 3-136: TVOC emissions to air from semiconductor manufacturing plants

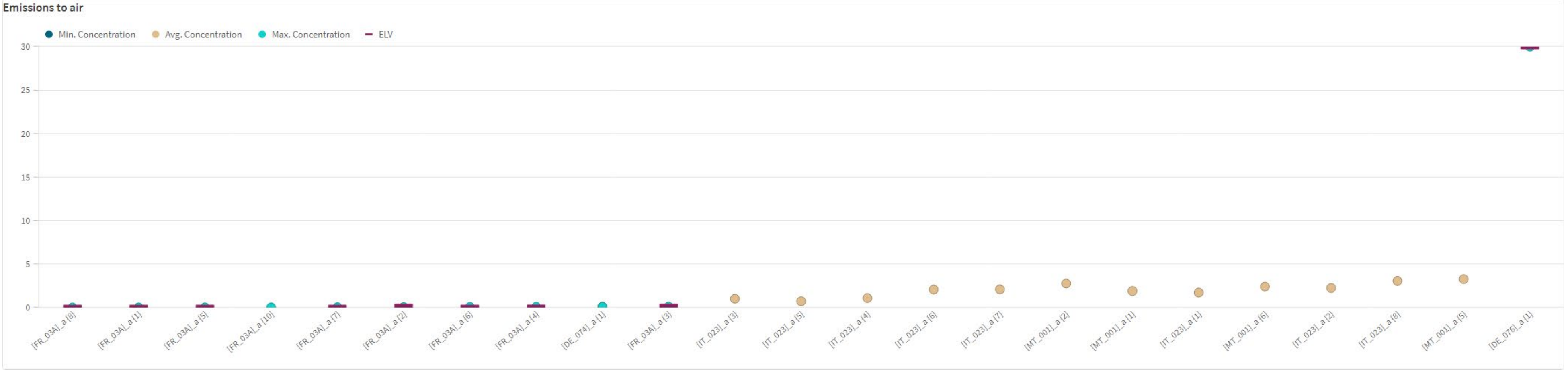
Table 3-142: Reported data and contextual information for TVOC emissions to air from semiconductor manufacturing plants

EP	Associated processes	Applied techniques	Max.	Avg..	Min	ELV	Load
[DE_068]_a {6}	-	Regenerative thermal oxidation	4	-	-	20	-
[DE_074]_a {2}	-	Scrubber- absorption (acid/alkaline)	0.5	0.5	0.5	-	-
[DE_074]_a {3}	-	Active carbon adsorption-Regenerative thermal oxidation-	1	0.65	0.3	-	-
[DE_076]_a {1}	-	Scrubber- absorption (acid/alkaline)-Electrostatic pecipitator-Other	50	-	-	50	-
[DE_076]_a {2}	-	Scrubber- absorption (acid/alkaline)-Electrostatic pecipitator	50	50	50	50	-
[DE_076]_a {3}	-	Straight thermal oxidation	50	50	-	50	-
[FR_03A]_a {1}	-	Scrubber- absorption (acid/alkaline)	0.658	-	-	-	-
[FR_03A]_a {2}	-	Scrubber- absorption (acid/alkaline)	4.339	-	-	-	-
[FR_03A]_a {3}	-	Scrubber- absorption (acid/alkaline)	1.094	-	-	-	-
[FR_03A]_a {4}	-	Scrubber- absorption (acid/alkaline)	0.553	-	-	-	-
[FR_03A]_a {5}	-	Scrubber- absorption (acid/alkaline)	0.961	-	-	-	-
[FR_03A]_a {6}	-	Scrubber- absorption (acid/alkaline)	2.016	-	-	-	-
[FR_03A]_a {7}	-	Scrubber- absorption (acid/alkaline)	1.26	-	-	-	-
[FR_03A]_a {9}	-	Other	8.3	-	-	10	-
[FR_03A]_a {10}	-	Scrubber- absorption (acid/alkaline)	2.432	-	-	-	-
			0.369	-	-	-	-
[FR_031]_a {15}	-	No technique applied	1.54	-	-	110	-
[FR_031]_a {16}	-	No technique applied	24.4	-	-	110	-
[FR_031]_a {17}	-	No technique applied	73.9	-	-	110	-
[FR_031]_a {18}	-	No technique applied	2.14	-	-	110	-
[FR_031]_a {19}	-	No technique applied	6.89	-	-	110	-
[FR_031]_a {20}	-	No technique applied	0.99	-	-	110	-
[IT_022]_a {2}	-	No technique applied	-	1	-	-	-
[IT_022]_a {3}	-	No technique applied	-	0.669	-	-	-
[IT_022]_a {5}	-	No technique applied	-	0.670	-	-	-
[IT_022]_a {9}	-	Scrubber- absorption (acid/alkaline)	-	2.49	-	-	-
[IT_022]_a {9}	-	-	-	0.505	-	-	-
[IT_022]_a {10}	-	Scrubber- absorption (acid/alkaline)	-	1	-	-	-
[IT_022]_a {10}	-	-	-	0.505	-	-	-
[IT_022]_a {11}	-	Scrubber- absorption (acid/alkaline)	-	0.670	-	-	-
[IT_022]_a {13}	-	Scrubber- absorption (acid/alkaline)	-	1	-	-	-
[IT_022]_a {14}	-	Scrubber- absorption (acid/alkaline)	-	0.505	-	-	-
[IT_022]_a {15}	-	Scrubber- absorption (acid/alkaline)	-	0.670	-	-	-
[IT_023]_a {9}	-	No technique applied	-	17.333	-	-	-
[IT_023]_a {10}	-	No technique applied	-	15.333	-	-	-
[IT_023]_a {11}	-	No technique applied	-	55.333	-	-	-
[IT_023]_a {12}	-	No technique applied	-	59.333	-	-	-
[MT_001]_a {1}	-	Scrubber- absorption (acid/alkaline)	-	2.9	-	-	-
[MT_001]_a {2}	-	Scrubber- absorption (acid/alkaline)	-	4.675	-	-	-
[MT_001]_a {5}	-	Scrubber- absorption (acid/alkaline)	-	14	-	-	-
[MT_001]_a {5}	-	-	-	2	-	-	-
[MT_001]_a {6}	-	Active carbon adsorption	-	1.458	-	-	-
[MT_001]_a {6}	-	-	-	0.52	-	-	-

[NL_003]_a {4}	-	-	67	-	-	75	-
[NL_003]_a {7}	-	Regenerated thermal oxidation	13	-	-	75	-

3.8.4.3 Gaseous chlorides

The reported data for HCl emissions to air are presented in the following figure. Emission data and contextual information are also presented in the table below.



Source: [168, TWG 2023]

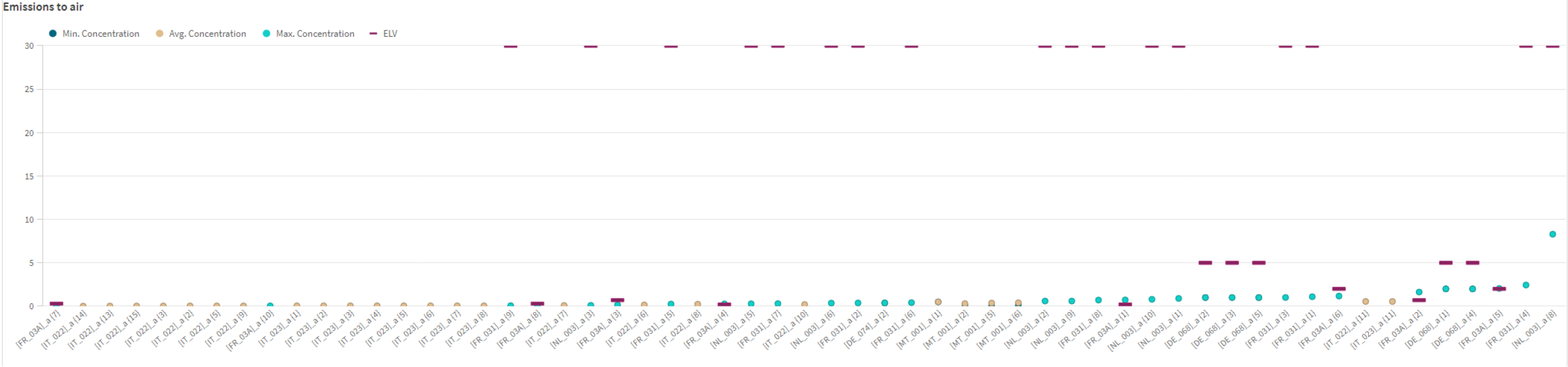
Figure 3-137: HCl emissions to air from semiconductor manufacturing plants

Table 3-143: Reported data and contextual information for HCl emissions to air from semiconductor manufacturing plants

EP	Applied techniques	Max.	Avg.	Min.	ELV	Load
[DE_074]_a {1}	Scrubber- absorption (acid/alkaline)-	0.09	0.09	0.09	-	-
[DE_076]_a {1}	Scrubber- absorption (acid/alkaline)-Electrostatic pecipitator-Other	30	-	-	30	-
[FR_03A]_a {1}	Scrubber- absorption (acid/alkaline)	0.012	-	-	0.02	-
		0.003	-	-	0.02	-
[FR_03A]_a {2}	Scrubber- absorption (acid/alkaline)	0.05	-	-	0.15	-
[FR_03A]_a {3}	Scrubber- absorption (acid/alkaline)	0.105	-	-	0.15	-
[FR_03A]_a {4}	Scrubber- absorption (acid/alkaline)	0.081	-	-	0.05	-
[FR_03A]_a {5}	Scrubber- absorption (acid/alkaline)	0.014	-	-	0.02	-
[FR_03A]_a {6}	Scrubber- absorption (acid/alkaline)	0.072	-	-	0.02	-
[FR_03A]_a {7}	Scrubber- absorption (acid/alkaline)	0.033	-	-	0.02	-
[FR_03A]_a {8}	Scrubber- absorption (acid/alkaline)	0.008	-	-	0.02	-
[FR_03A]_a {10}	Scrubber- absorption (acid/alkaline)	0.015	-	-	-	-
[IT_023]_a {1}	Scrubber- absorption (acid/alkaline)	-	1.72333	-	-	-
[IT_023]_a {2}	Scrubber- absorption (acid/alkaline)	-	2.25	-	-	-
[IT_023]_a {3}	Scrubber- absorption (acid/alkaline)	-	1.01667	-	-	-
[IT_023]_a {4}	Scrubber- absorption (acid/alkaline)	-	1.09333	-	-	-
[IT_023]_a {5}	Scrubber- absorption (acid/alkaline)	-	0.72667	-	-	-
[IT_023]_a {6}	Scrubber- absorption (acid/alkaline)	-	2.06667	-	-	-
[IT_023]_a {7}	Scrubber- absorption (acid/alkaline)	-	2.08333	-	-	-
[IT_023]_a {8}	Scrubber- absorption (acid/alkaline)	-	3.06	-	-	-
[MT_001]_a {1}	Scrubber- absorption (acid/alkaline)	-	1.9025	-	-	-
[MT_001]_a {2}	Scrubber- absorption (acid/alkaline)	-	2.7575	-	-	-
[MT_001]_a {5}	Scrubber- absorption (acid/alkaline)	-	3.6625	-	-	-
[MT_001]_a {5}		-	2.5	-	-	-
[MT_001]_a {6}	Active carbon adsorption	-	2.9975	-	-	-
		-	1.2	-	-	-

3.8.4.4 NH_3

The reported data for ammonia emissions to air are presented in the following figure. Emission data and contextual information are also presented in the table below.



Source: [168, TWG 2023]

Figure 3-138: NH_3 emissions to air from semiconductor manufacturing plants

Table 3-144: Reported data and contextual information for NH_3 emissions to air from semiconductor manufacturing plants

EP	Associated processes	Applied techniques	Max.	Avg.	Min.	ELV	Load
[DE_068]_a {1}		Scrubber- absorption (acid/alkaline)	2	2	2	5	-
[DE_068]_a {2}		Scrubber- absorption (acid/alkaline)	1	1	1	5	-
[DE_068]_a {3}		Scrubber- absorption (acid/alkaline)	1	1	-	5	-
[DE_068]_a {4}		Scrubber- absorption (acid/alkaline)	2	2	2	5	-
[DE_068]_a {5}		Scrubber- absorption (acid/alkaline)	1	1	1	5	-
[DE_074]_a {2}		Scrubber- absorption (acid/alkaline)	0.38	0.38	0.38	-	-
[FR_03A]_a {1}		Scrubber- absorption (acid/alkaline)	0.723	-	-	0.2	-
[FR_03A]_a {2}		Scrubber- absorption (acid/alkaline)	1.633	-	-	0.7	-
			1.072	-	-	0.7	-
[FR_03A]_a {3}		Scrubber- absorption (acid/alkaline)	0.16	-	-	0.7	-
			0.128	-	-	0.7	-
			0.105	-	-	0.7	-
[FR_03A]_a {4}		Scrubber- absorption (acid/alkaline)	0.272	-	-	0.2	-
[FR_03A]_a {5}		Scrubber- absorption (acid/alkaline)	2.048	-	-	2	-
[FR_03A]_a {6}		Scrubber- absorption (acid/alkaline)	1.172	-	-	2	-
[FR_03A]_a {7}		Scrubber- absorption (acid/alkaline)	0.004	-	-	0.3	-
			0.004	-	-	0.3	-
[FR_03A]_a {8}		Scrubber- absorption (acid/alkaline)	0.066	-	-	0.3	-
			0.042	-	-	-	-
			0.005	-	-	-	-
[FR_031]_a {1}		Scrubber- absorption (acid/alkaline)- Straight thermal oxidation-	1.1	-	-	30	-
[FR_031]_a {2}		Scrubber- absorption (acid/alkaline)- Straight thermal oxidation-	0.378	-	-	30	-
[FR_031]_a {3}		Scrubber- absorption (acid/alkaline)- Straight thermal oxidation-	1.01	-	-	30	-
[FR_031]_a {4}		Scrubber- absorption (acid/alkaline)- Straight thermal oxidation-	2.44	-	-	30	-
[FR_031]_a {5}		Scrubber- absorption (acid/alkaline)- Straight thermal oxidation-	0.257	-	-	30	-
[FR_031]_a {6}		Scrubber- absorption (acid/alkaline)- Straight thermal oxidation-	0.417	-	-	30	-
[FR_031]_a {7}		Scrubber- absorption (acid/alkaline)- Straight thermal oxidation-	0.306	-	-	30	-
[FR_031]_a {8}		Scrubber- absorption (acid/alkaline)- Straight thermal oxidation-	0.714	-	-	30	-
[FR_031]_a {9}		Scrubber- absorption (acid/alkaline)	0.063	-	-	30	-
[IT_022]_a {2}		No technique applied	-	0.037	-	-	-
			-	0.028	-	-	-
[IT_022]_a {3}		No technique applied	-	0.0364	-	-	-
			-	0.0285	-	-	-
[IT_022]_a {5}		No technique applied	-	0.037	-	-	-
			-	0.028	-	-	-
[IT_022]_a {6}		Scrubber- absorption (acid/alkaline)	-	0.2138	-	-	-
			-	0.1135	-	-	-
[IT_022]_a {7}		Scrubber- absorption (acid/alkaline)	-	0.086	-	-	-
[IT_022]_a {8}		Scrubber- absorption (acid/alkaline)	-	0.2319	-	-	-
[IT_022]_a {9}		Scrubber- absorption (acid/alkaline)	-	0.034	-	-	-

[IT_022]_a {10}		Scrubber- absorption (acid/alkaline)	-	0.29	-	-	-
			-	0.0121	-	-	-
[IT_022]_a {11}		Scrubber- absorption (acid/alkaline)	-	0.548	-	-	-
[IT_022]_a {13}		Scrubber- absorption (acid/alkaline)	-	0.028	-	-	-
[IT_022]_a {14}		Scrubber- absorption (acid/alkaline)	-	0.0126	-	-	-
[IT_022]_a {15}		Scrubber- absorption (acid/alkaline)	-	0.0308	-	-	-
			-	0.0245	-	-	-
[IT_023]_a {1}		Scrubber- absorption (acid/alkaline)	-	0.05	-	-	-
[IT_023]_a {2}		Scrubber- absorption (acid/alkaline)	-	0.05	-	-	-
[IT_023]_a {3}		Scrubber- absorption (acid/alkaline)	-	0.05	-	-	-
[IT_023]_a {4}		Scrubber- absorption (acid/alkaline)	-	0.05	-	-	-
[IT_023]_a {5}		Scrubber- absorption (acid/alkaline)	-	0.05	-	-	-
[IT_023]_a {6}		Scrubber- absorption (acid/alkaline)	-	0.05	-	-	-
[IT_023]_a {7}		Scrubber- absorption (acid/alkaline)	-	0.05	-	-	-
[IT_023]_a {8}		Scrubber- absorption (acid/alkaline)	-	0.05	-	-	-
[IT_023]_a {11}		No technique applied	-	0.548	-	-	-
[MT_001]_a {1}		Scrubber- absorption (acid/alkaline)	-	0.5	0.5	-	-
[MT_001]_a {2}		Scrubber- absorption (acid/alkaline)	-	0.3	0.1	-	-
[MT_001]_a {5}		Scrubber- absorption (acid/alkaline)	-	0.5	0.1	-	-
[MT_001]_a {5}		-	-	0.1	0.1	-	-
[MT_001]_a {6}		Active carbon adsorption	-	0.5	0.5	-	-
[MT_001]_a {6}		-	-	0.2	0.1	-	-
[NL_003]_a {1}		Scrubber- absorption (acid/alkaline)	0.9	-	-	30	-
[NL_003]_a {2}		Scrubber- absorption (acid/alkaline)	0.6	-	-	30	-
[NL_003]_a {3}		Scrubber- absorption (acid/alkaline)	0.1	-	-	30	-
[NL_003]_a {5}		Scrubber- absorption (acid/alkaline)	0.29	-	-	30	-
[NL_003]_a {6}		Scrubber- absorption (acid/alkaline)	0.36	-	-	30	-
[NL_003]_a {8}		Scrubber- absorption (acid/alkaline)	8.3	-	-	30	-
[NL_003]_a {9}		Scrubber- absorption (acid/alkaline)	0.6	-	-	30	-
[NL_003]_a {10}		Scrubber- absorption (acid/alkaline)	0.8	-	-	30	-

4 TECHNIQUES TO CONSIDER IN THE DETERMINATION OF BAT AND ET

[Note to the TWG: This section has been completely reordered compared to the original BREF]

4.1 Introduction

This section describes techniques (or combinations thereof), and the associated monitoring, considered to have the potential for achieving a high level of environmental protection for the activities covered by this BREF. The techniques described will include both the technology used and the way in which the installations are designed, built, maintained, operated and decommissioned.

This section covers environmental management systems as well as process-integrated and end-of-pipe techniques. Waste prevention and management, including waste minimisation and recycling procedures, are also considered, as well as techniques that reduce the consumption of raw materials, water and energy by optimising use and reuse. The techniques described also cover measures used to prevent or to limit the environmental consequences of accidents and incidents, as well as site remediation measures. They also cover the prevention or reduction of emissions under other than normal operating conditions (such as start-up and shutdown operations, leaks, malfunctions, momentary stoppages and the definitive cessation of operations).

Annex III to the Directive lists a number of criteria for determining BAT, and the information within this chapter will address these considerations. As far as possible, the standard structure in Table 4-1 is used to outline the information on each technique, to enable a comparison of techniques and the assessment against the definition of BAT in the Directive.

This section does not necessarily provide an exhaustive list of techniques that could be applied in the surface treatment of metals and plastics industry. Other techniques may exist, or may be developed, which could be considered in the determination of BAT for an individual installation.

Table 4-1: Information for each technique to consider in the determination of BAT and ET

Type of information considered	Type of information included
Description	A brief description of the technique with a view to being used in the BAT conclusions.
Technical description	A more detailed and yet concise technical description using, as appropriate, chemical or other equations, pictures, diagrams and flow charts.
Achieved environmental benefits	The main potential environmental benefits to be gained through implementing the technique (including reduced consumption of energy, reduced consumptionof water; reduced emissions to water, air and land; raw material savings; as well as production yield increases, reduced waste, etc.).
Environmental performance and operational data	Actual and plant-specific performance data (including emission levels, consumption levels – of raw materials, water, energy – and amounts of residues/wastes generated) from well-performing installations/plants (with respect to the environment taken as a whole) applying the technique accompanied by the relevant contextual information. Any other useful information on the following items: • how to design, operate, maintain, control and decommission the technique; • emission monitoring issues related to the use of the technique; • sensitivity and durability of the technique; • issues regarding accident prevention. Links between inputs (e.g. nature and quantity of raw material and fuel, energy, water) and outputs (emissions, residues/wastes, products) are highlighted, in particular where relevant to enhancing an understanding of different environmental impacts and their interaction, for example where trade-offs have been made between different

	outputs such that certain environmental performance levels cannot be achieved at the same time. Emission and consumption data are qualified as far as possible with details of relevant operating conditions (e.g. percentage of full capacity, fuel composition, bypassing of the (abatement) technique, inclusion or exclusion of other than normal operating conditions, reference conditions), sampling and analytical methods, and statistical presentation (e.g. short- and long-term averages, maxima, ranges and distributions). Information is included on conditions/circumstances hampering the use of the (abatement) technique at full capacity and/or necessitating full or partial bypassing of the (abatement) technique and measures taken to restore full (abatement) capacity.
Cross-media effects	Relevant negative effects on the environment due to implementing the technique, allowing a comparison between techniques in order to assess the impact on the environment as a whole. This may include issues such as: • consumption and nature of raw materials and water; • energy consumption and contribution to climate change; • stratospheric ozone depletion potential; • photochemical ozone creation potential; • acidification resulting from emissions to air; • presence of particulate matter in ambient air (including microparticles and metals); • eutrophication of land and waters resulting from emissions to air or water; • oxygen depletion potential in water; • persistent/toxic/bioaccumulable components (including metals); • generation of residues/waste; • limitation of the ability to reuse or recycle residues/waste; • generation of noise and/or odour; • increased risk of accidents. The Reference Document on Economics and Cross-media Effects (ECM) should be taken into account.
Technical considerations relevant to applicability	It is indicated whether the technique can be applied throughout the sector. Otherwise, the main general technical restrictions on the use of the technique within the sector are indicated. These may be: • an indication of the type of plants or processes within the sector to which the technique cannot be applied; • constraints to implementation in certain generic cases, considering, e.g.: ○ whether it concerns a new or an existing plant, taking into account factors involved in retrofitting (e.g. space availability) and interactions with techniques already installed; ○ plant size, capacity or load factor; ○ quantity, type or quality of product manufactured; ○ type of fuel or raw material used; ○ animal welfare; ○ climatic conditions. These restrictions are indicated together with the reasons for them. These restrictions are not meant to be a list of the possible local conditions that could affect the applicability of the technique for an individual plant.
Economics	Information on the costs (capital/investment, operating and maintenance costs including details on how they have been calculated/estimated) and any possible savings (e.g. reduced raw material or energy consumption, waste charges, reduced payback time compared to other techniques), or revenues or other benefits including details on how these have been calculated/estimated. Cost data are preferably given in euros (EUR). If a conversion is made from another currency, the data in the original currency and the year when the data were collected are indicated. The price/cost of the equipment or service is accompanied by the year it was purchased. Information on the market for the sector is given in order to put costs of techniques into context. Information relevant to both newly built, retrofitted and existing plants is included. This should allow assessment, where possible, of the economic viability of the technique for the sector concerned and possible economic limitations to its application. Information on the cost-effectiveness of the technique (e.g. in EUR per mass of

	pollutant abated) and related assumptions for its calculation can be reported. The Reference Document on Economics and Cross-media Effects (ECM) and the Reference Report on Monitoring of Emissions to Air and Water from IED Installations (ROM) are taken into account with regard to economic aspects and monitoring costs, respectively.
Driving force for implementation	Where applicable, specific local conditions, requirements (e.g. legislation, safety measures) or non-environmental triggers (e.g. increased yield, improved product quality, economic incentives – e.g. subsidies, tax breaks) which have driven or stimulated the implementation of the technique to date are provided. This subsection should be very short and use a list of bullet points.
Example plants	Reference(s) to a plant(s) where the technique has been implemented and from which information has been collected and used in writing the section. An indication may be provided of the degree to which the technique is in use in the EU or worldwide.
Reference literature	Literature or other reference material (e.g. books, reports, studies) that was used in writing the section and that contains more detailed information on the technique. When the reference material consists of many pages, reference will be made to the relevant page(s) or section(s).

4.2 Techniques to consider in the determination of BAT for all sectors (or for more than one sector)

4.2.1 Overall environmental performance

4.2.1.1 Environmental Management System (EMS) ~~tools~~

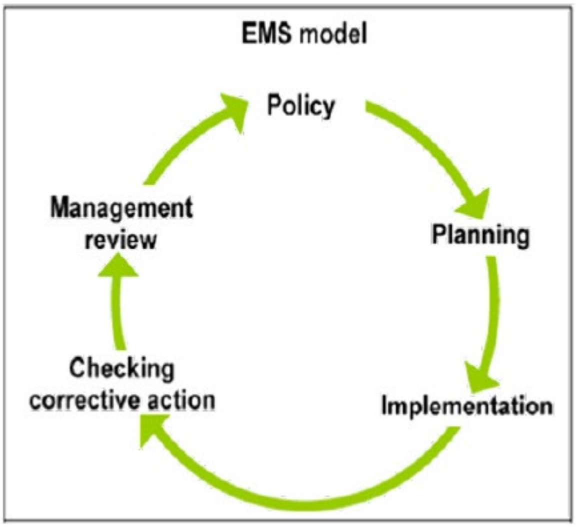
Description
A formal system to demonstrate compliance with environmental objectives.

Technical description
The Industrial Emissions Directive defines ‘techniques’ (under the definition of ‘best available techniques’) as ‘both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned’.

In this respect, an environmental management system (EMS) is a technique allowing operators of installations to address environmental issues in a systematic and demonstrable way. EMSs are most effective and efficient where they form an inherent part of the overall management and operation of an installation.

An EMS focuses the attention of the operator on the environmental performance of the installation; in particular through the application of clear operating procedures for both normal and other than normal operating conditions, and by setting out the associated lines of responsibility.

All effective EMSs incorporate the concept of continuous improvement, meaning that environmental management is an ongoing process, not a project which eventually comes to an end. There are various process designs, but most EMSs are based on the plan-do-check-act cycle (which is widely used in other company management contexts). The cycle is an iterative dynamic model, where the completion of one cycle flows into the beginning of the next (see Figure 4-1).



Source: [87, COM 2016]

Figure 4-1: Continuous improvement in an EMS model

An EMS can take the form of a standardised or non-standardised (‘customised’) system. Implementation and adherence to an internationally accepted standardised system, such as EN ISO 14001:2015, can give higher credibility to the EMS especially when subjected to a properly performed external verification. The European Union eco-management and audit scheme (EMAS) according to Regulation (EC) No 1221/2009 provides additional credibility due to the interaction with the public through the environmental statement and the mechanism to ensure compliance with the applicable environmental legislation. However, non-standardised systems can, in principle, be equally effective provided that they are properly designed and implemented.

While both standardised systems (EN ISO 14001:2015 or EMAS) and non-standardised systems apply in principle to organisations, this document takes a narrower approach, not including all activities of an organisation, e.g. with regard to their products and services, due to the fact that the Directive only regulates installations.

An EMS can contain the following features:

i. commitment, leadership, and accountability of the management, including senior management, for the implementation of an effective EMS;
ii. an analysis that includes the determination of the organisation's context, the identification of the needs and expectations of interested parties, the identification of characteristics of the installation that are associated with possible risks for the environment (or human health) as well as of the applicable legal requirements relating to the environment and human health;
~~iii. development of an environmental policy that includes the continuous improvement of the environmental performance of the installation;~~ *Strikethrough as it is included in Art. 14.a(2) of the IED*
~~iv. establishing objectives and performance indicators in relation to significant environmental aspects, including safeguarding compliance with applicable legal requirements;~~ *Strikethrough as it is included in Art. 14.a(2) of the IED*
~~v. planning and implementing the necessary procedures and actions (including corrective and preventive actions where needed), to achieve the environmental objectives and avoid environmental risks;~~ *Strikethrough as it is included in Art. 14.a(2) of the IED*
vi. determination of structures, roles and responsibilities in relation to environmental aspects and objectives and provision of the financial and human resources needed;
vii. ensuring the necessary competence and awareness of staff whose work may affect the environmental performance of the installation (e.g. by providing information and training);
viii. internal and external communication on the environmental performance of the installation;
ix. fostering employee involvement in good environmental management practices;
x. establishing and maintaining a management manual and written procedures to control activities with significant environmental impact as well as relevant records;
xi. effective operational planning and process control;
xii. implementation of appropriate maintenance programmes;
xiii. emergency preparedness and response protocols, including the prevention and/or mitigation of the adverse (environmental) impacts of emergency situations;
xiv. when (re)designing a (new) installation or a part thereof, consideration of its environmental impacts throughout its life, which includes construction, maintenance, operation and decommissioning;
xv. implementation of a monitoring and measurement programme; if necessary, information can be found in the Reference Report on Monitoring of Emissions to Air and Water from IED Installations;
xvi. application of sectoral benchmarking on a regular basis;
xvii. periodic independent (as far as practicable) internal auditing ~~and periodic independent external auditing~~ in order to assess the environmental performance and to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained; *[The external auditing is included in Article 14a (4) and it is therefore in strikethrough]*

xviii. evaluation of causes of nonconformities, implementation of corrective actions in response to nonconformities, review of the effectiveness of corrective actions, and determination of whether similar nonconformities exist or could potentially occur;

xix. ~~periodic review, by senior management, of the EMS and its continuing suitability, adequacy and effectiveness;~~ *[The external auditing is included in Article 14a (4) and it is therefore in strikethrough]*

xx. following and taking into account the development of cleaner techniques.

Specifically for the surface treatment of metals and platics, the following features are included in the EMS:

xx. benchmarks for the surface treatment of metals and plastics industry;
xxi. an inventory of inputs and outputs (see Section 4.2.1.2);
xxii. a chemicals management system (see Section 4.2.1.3);
xxiii. a plan for the prevention and control of leaks and spillages (see Section 4.2.1.4);
xxiv. an OTNOC management plan (see Section 4.2.1.5);
xxv. an energy efficiency plan and audits (see Section 4.2.3.1);
xxvi. a residues management plan (see Section 4.2.11.1);
xxvii. a water management plan and audits (see Section 4.2.5.1);
xxviii. a noise management plan (see Section 4.2.9.12);
xxix. an odour management plan (see Section 4.2.8.3.1).

Achieved environmental benefits

An EMS promotes and supports the continuous improvement of the environmental performance of the installation. If the installation already has a good overall environmental performance, an EMS helps the operator to maintain the high performance level.

Environmental performance and operational data

[Note to the TWG: please provide information]

Cross-media effects

None reported. The systematic analysis of the initial environmental impacts and scope for improvements in the context of the EMS sets the basis for assessing the best solutions for all environmental media.

Technical considerations relevant to applicability

The components described above can typically be applied to all installations within the scope of this document. The level of detail and the degree of formalisation of the EMS will generally be related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have.

Economics

It is difficult to accurately determine the costs and economic benefits of introducing and maintaining a good EMS. There are also economic benefits that are the result of using an EMS and these vary widely from sector to sector.

[Note to the TWG: please provide information]

Driving forces for implementation

The driving forces for the implementation of an EMS include:

- improved environmental performance;
- improved insight into the environmental aspects of the company which can be used to fulfil the environmental requirements of customers, regulatory authorities, banks, insurance companies or other stakeholders (e.g. people living or working in the vicinity of the installation);
- improved basis for decision-making;

- improved motivation of personnel (e.g. managers can have confidence that environmental impacts are controlled and employees can feel that they are working for an environmentally responsible company);
- additional opportunities for operational cost reduction and product quality improvement;
- improved company image;
- reduced liability, insurance and non-compliance costs.

Example plants
EMSs are applied in a number of installations throughout the EU. A total of 123 installations in the data collection reported applying an environmental management system according to the EMAS Regulation or ISO 14000.

Reference literature
[168, TWG, 2023]

4.2.1.2 Inventory of inputs and outputs

Description
The compilation of relevant basic data on input and ouput streams of resources (e.g. inputs like raw materials, chemicals, energy, water, and outputs like waste gases, waste waters, residues, energy losses, greenhouse gases). Basic data for streams include information on environmentally important characteristics, like the presence of hazardous substances, their toxicity, composition and quantities. These data are used in mass balances, efficiency plans and for monitoring of emissions.

Technical description
All environmental impacts and environmental risks are directly linked to input/output streams. In the interests of identifying options and priorities for improving environmental and economic performance, it is therefore vital to know as much as possible about their quality and quantity.

Input/output stream inventories can be drawn up on different levels. The most general level is an annual site-specific overview.

As part of the EMS (see Section 4.2.1.1), an inventory of inputs and outputs that incorporates all of the following features has to be established, maintained and regularly reviewed (including when a significant change occurs):

i. information about the production processes, including:
   (a) simplified process flow sheets that show the origin of the emissions to air, water and soil and the associated emission point(s);
   (b) descriptions of process-integrated techniques and waste gas/waste water treatment techniques to prevent or reduce emissions, including their performance (e.g. abatement efficiency);
ii. information about the quantity and characteristics of raw materials (e.g. chemicals) and fuels (e.g. natural gas, electricity) used;
iii. information about water consumption and usage (e.g. flow diagrams and water mass balances);
iv. information about energy consumption and usage;
v. information about the quantity and origin of CO_2 equivalent emissions;
vi. information about the characteristics of the waste water streams, such as:
   (a) average values and variability of flow, pH, temperature and conductivity;
   (b) average concentration and mass flow of relevant substances/parameters (e.g. total suspended solids, TOC or COD, hydrocarbon oil index, metals) and their variability;
vii. information about the characteristics of the waste gas streams, such as:

  (a) average values and variability of flow and temperature;
  (b) average concentration and mass flow values of relevant substances/parameters (e.g. dust, NOX, SOX, TVOC) and their variability;
  (c) presence of other substances that may affect the waste gas treatment system (e.g. oxygen, water vapour) or installation safety;

viii. information about the quantity and characteristics of residues generated.

Achieved environmental benefits
The evaluation and inventory of input/output mass streams described is an essential management tool for the identification of optimisation potential, both environmental and economic. It is a prerequisite for a continuous improvement process.

Environmental performance and operational data
The application of such a management tool requires qualified staff and the commitment of the management.

The input/output streams inventory allows cross-media effects to be taken into consideration during the assessment of potential optimisation options. This means the achievement of a high level of protection of the environment as a whole.

Such inventory may be based on a digital support and can include mapping of resource used.

Cross-media effects
None identified.

Technical considerations relevant to applicability
The technique is applicable to both new and existing installations. The level of detail and the degree of formalisation of the inventory will generally be related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have.

Economics
Associated personnel cost.

Driving force for implementation

- Legal requirements.
- Local conditions.

Example plant
Widely used.

Reference literature
[168, TWG, 2023]

4.2.1.3 Chemicals Management System

Description
The chemicals management system (CMS) is part of the EMS (see Section 4.2.1) and is a set of technical and organisational measures to limit the impact of the use of process chemicals or potentially relevant used raw materials (e.g. residues with hazardous properties) on the environment.

Technical description
In order to improve the overall environmental performance, a chemicals management system (CMS), as part of the EMS, is drawn up and implemented.

The CMS contains the following features:

i. A policy to reduce the consumption of and risks associated with process chemicals, including a procurement policy to select less harmful process chemicals and their suppliers with the aim of minimising the use of and risks associated with hazardous substances, with special regard given to the substances fulfilling the criteria referred to in Article 57 of Regulation (EC) No 1907/2006 and substances addressed in restrictions referred to in Annex XVII to Regulation (EC) No 1907/2006 as well as to avoid the procurement of an excess amount of process chemicals. The selection of process chemicals is based on:
   a) the comparative analysis of their bioeliminability/biodegradability, eco-toxicity and potential to be released into the environment in order to reduce emissions to the environment;
   b) ~~the characterisation of the risks associated with the process chemicals, based on the chemicals' hazards classification, pathways through the plant, potential release and level of exposure;~~ *[In strikethrough as it is included in Article 14a (2)(d)]*
   c) the potential for recovery and reuse (See Section 4.5);
   d) the regular (e.g. annual) analysis of the potential for substitution with the aim to identify potentially new available and safer alternatives to the use of hazardous substances ~~and substances of very high concern~~; this may be achieved by changing process(es) or using other process chemicals with no or lower environmental impacts (See Section 4.7); *[In strikethrough as it is included in Article 14a (2)(d)]*
   e) the anticipatory monitoring of regulatory changes related to hazardous substances ~~and substances of very high concern~~, and the safeguarding of compliance with applicable legal requirements.

   The inventory of process chemicals (see Section 4.2.2) may be used to provide and keep the information needed for the selection of process chemicals.

ii. Goals and action plans to avoid or reduce the use of and risks associated with hazardous substances.

iii. Development and implementation of procedures for the procurement, handling, storage and use of process chemicals, disposal of waste containing process chemicals and return of unused process chemicals, to prevent or reduce emissions to the environment.

Achieved environmental benefits

- Improvement of the overall environmental performance.
- Reduction of the use of hazardous chemicals.
- Reduction of emissions of hazardous chemicals to the environment.
- Reduction of the amount of hazardous chemicals in waste.

Environmental performance and operational data

[Note to the TWG: please provide information.]

Cross-media effects

None.

Technical considerations relevant to applicability

The level of detail and degree of formalisation of the CMS will generally be related to the nature, scale and complexity of the installation.

Economics

[Note to the TWG: please provide information.]

Driving force for implementation

- Legal requirements.
- Local conditions.

Example plants

Widely used.

Reference literature
[168, TWG, 2023]

4.2.1.4 Prevention or reduction of emissions to soil and groundwater

4.2.1.4.1 Set-up and implementation of a plan for the prevention and control of leaks and spillages

Description
A plan for the prevention and control of leaks and spillages is part of the EMS (see Section 4.2.1) and includes techniques such as:

- site incident plans for small and large spillages;
- identification of the roles and responsibilities of persons involved;
- ensuring staff are environmentally aware and trained to prevent and deal with spillage incidents;
- identification of areas at risk of spillage and/or leaks of hazardous materials and substances of very high concern e.g. polychlorinated biphenyls, cadmium, other materials that do not or are slow to degrade, such as other metals in soluble form (such as nickel, chromium, zinc, copper, lead), VOCs used for degreasing (including C10-C13 chloralkanes), cyanides, acids and alkalis, and ranking them according to the risk;
- identification of suitable spillage containment and clean-up equipment and regularly ensuring it is available, in good working order and close to points where these incidents may occur;
- waste management guidelines for dealing with waste arising from spillage control;
- regular inspections (at least on a monthly basis) of storage and handling areas, testing and calibration (at least on an annual basis) of leak detection equipment and prompt repair of leaks from valves, glands, flanges, etc.

Achieved environmental benefits
This technique prevents or minimises the contamination of surface waters, groundwaters and soils, and assists in site decontamination on cessation of activities.

Environmental performance and operational data
Small spills are likely to happen more often and the sum effect of these if not detected and dealt with is significant increases of fugitive emissions to air, soil and groundwater.

Cross-media effects
None.

Technical considerations relevant to applicability
The level of detail and the degree of formalisation of the plan will generally be related to the nature, scale and complexity of the installation, as well as to the type and quantity of liquids used.

Economics
The following costs need to be considered:

- staff time for training and updating plans;
- materials savings through the minimisation of spillage;
- use of materials for spillage clean-up.

Driving force for implementation

- Reduced risks of liability from contamination.
- Reduced risks of associated accidents, e.g. preventing slippery floors, risk of fire.

Example plants

Widely used; 76 plants from the data collection reported the use of this technique.

Reference literature
[168, TWG, 2023]

4.2.1.4.2 Structuring and management of process areas and raw material storage areas

Description
Process areas and raw material storage areas are structured and managed.

This includes techniques such as:

- impermeable (e.g. cemented) floors for process areas and for fuel yards;
- containment bunds for storage tanks;
- double wall storage tanks;
- automated detection of possible leakage/spillage in retention areas, separate storage for various types of raw materials, close to the production lines; this can be achieved using, for example, compartments or boxes in the storage areas, bunkers;
- dedicated area for unloading process chemicals and fuels.

Technical description
Structuring and management of process areas and storage areas, ensuring that raw materials and fuels are efficiently stored and handled.

The materials are well sorted, kept in a dry area under roofing (see Section 4.2.4.2) or in closed storage containers and can be quickly delivered to the production line.

Achieved environmental benefits
- Prevention or minimisation of the contamination of surface water, groundwater and soil.
- Efficient raw material management.

Environmental performance and operational data
No information provided.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Economics
No information provided.

Driving force for implementation
- Efficient raw material management.
- Local conditions.

Example plants
Widely used. In the data collection, 90 plants reported the use of automated detection of possible spillage/leakage, 105 plants reported the use of a dedicated area for unloading process chemicals and fuels and 128 plants reported the use of segregated storage of raw materials.

Reference literature
[168, TWG, 2023]

4.2.1.4.3 Prevention of contamination of surface run-off water

Description

Production areas and/or areas where process chemicals, fuels, residues or waste are stored or handled are protected against surface run-off water. This is achieved by using at least the following techniques:

- drainage channels and/or an outer kerb bund around the plant;
- roofing with roof guttering of process and/or storage areas.

Technical description

By using drainage channels and/or an outer kerb bund around the plant, surface run-off water is collected and process areas and storage areas (for fuels, process chemicals, residues and waste) are protected against surface run-off water.

A roof constructed over the storage area can help keep rainwater out.

Achieved environmental benefits

- Prevention of contamination of surface run-off water.
- Reduction of waste water generation.

Environmental performance and operational data

No information provided.

Cross-media effects

None.

Technical considerations relevant to applicability

Generally applicable.

Economics

No information provided.

Driving force for implementation

- Protection of process and storage areas against surface run-off water.
- Legal requirements.
- Local conditions.

Example plants

Widely used.

Reference literature

[168, TWG, 2023]

4.2.1.4.4 Collection of potentially contaminated surface run-off water

Description

Surface run-off water from areas that are potentially contaminated is collected separately and only discharged after appropriate measures are taken, e.g. monitoring (see Section 4.2.2.3), treatment (see Section 4.2.10), reuse (see Section 4.2.5).

Achieved environmental benefits

- Avoidance of cross-contamination of uncontaminated water streams.
- Reduction of waste water generation.

Environmental performance and operational data

No information provided.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Economics
Costs associated with the collection and potential treatment processes.

Driving force for implementation

- Legal requirements.
- Local conditions.

Example plants
Widely used.

Reference literature
[168, TWG, 2023]

4.2.1.4.5 Safe handling and storage process chemicals and treatment vats

Description
Storage and handling of process chemicals avoiding leakages and penetration into the ground.

Accidental releases are prevented by periodic checks and preventive maintenance of seals, gaskets, pumps and piping.

Technical description
This includes techniques such as the following:

- Storage of chemicals in roofed and well ventilated areas with floors impermeable to the chemicals concerned.
- Use of oil-tight trays or cellars for hydraulic stations and oil- or grease-lubricated equipment.
- Immediate collection of spilled liquids. Materials used for spill cleaning that are contaminated with hazardous substances are handled as hazardous waste.
- Loading/unloading areas, e.g. for fuels, process chemicals, lubricants, coatings, are designed and constructed in such a way that potential leaks and spillages are contained and either reused or sent to on-site treatment or off-site treatment. Facilities for loading/unloading of substances fulfilling the criteria referred to in Article 57 of Regulation (EC) No 1907/2006 are equipped with vapour recovery systems.
- Acids are stored separately from alkalis and cyanides (to avoid generation of free cyanide).
- Flammable chemicals are stored separately from oxidising agents.
- Chemicals which are spontaneously combustible when damp, are stored in dry conditions. The loading and unloading areas, as well as process and storage areas of these chemicals, are marked appropriately to avoid the use of water in fire-fighting.
- Organic peroxides are stored separately from other materials such as acids, alkalis, amines, accelerators, combustible materials, metals, and reducing agents.

Achieved environmental benefits

- Prevention or minimisation of the contamination of surface water, groundwater and soil.
- Avoidance/reduction of generation of waste chemicals.

- Reduction of the amount of waste chemicals unsuitable for further use.

Environmental performance and operational data
No information provided.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable. This technique applies to all new and existing installations.

Economics
No information provided.

Driving force for implementation

- Safety measures and optimisation of operations.
- Legal requirements.
- Local conditions.

Example plants
Widely used.

Reference literature
[168, TWG, 2023]

4.2.1.4.6 Good housekeeping

Description
A set of measures aiming at preventing, or reducing, the generation of emissions (e.g. regular maintenance and cleaning of equipment, work surfaces, floors and transport routes, and containment as well as rapid clean-up of spillages).

Technical description
This includes techniques such as:

- regular maintenance and cleaning of equipment;
- regular cleaning of work surfaces, floors and transport routes and vehicle tyres;
- visual inspections;
- containment as well as rapid clean-up of any spillages.

Inspections and maintenance operations are facilitated by:

- keeping visible tank bottoms and pipes, with no accrual of dirt, rubbish, old jigs, anode ends, etc. in contained areas and around tanks or pipes;
- keeping all process areas clean and painted to allow chronic leakages to be readily identified;
- the use of high level alarms in both process vats and waste water treatment where overflow is possible.

Achieved environmental benefits

- Prevention or reduction of fugitive and diffuse emissions.
- Positive impact on occupational health.

Environmental performance and operational data
No information provided.

Cross-media effects
When maintenance is carried out, additional residues may occur.

Technical considerations relevant to applicability
Generally applicable.

Economics
For many companies, simple, affordable good housekeeping measures are being effectively applied to minimise diffuse emissions, improve efficiency, achieve a cleaner workplace and reduce costs.

Driving force for implementation

- Legal requirements.
- Local conditions.

Example plants
Widely used; 149 plants from the data collection reported regular inspections and maintenance of plant equipment.

Reference literature
[168, TWG, 2023]

4.2.1.5 Other than normal operating conditions (OTNOC) management plan

Description
A risk-based OTNOC management plan is part of the EMS (see Section 4.2.1) and is a set of measures to reduce the frequency of the occurrence of OTNOC and to reduce emissions during OTNOC.

Technical description
A risk-based OTNOC management plan includes all of the following elements:

i. identification of potential OTNOC (e.g. failure of equipment critical to the protection of the environment ('critical equipment')), of their root causes and of their potential consequences;
ii. appropriate design of critical equipment (e.g. off-gas treatment, waste water treatment);
iii. set-up and implementation of an inspection plan and preventive maintenance programme for critical equipment (see Section iii.);
iv. monitoring (i.e. estimating or, where possible, measuring) and recording of emissions during OTNOC and of associated circumstances;
v. periodic assessment of the emissions occurring during OTNOC (e.g. frequency of events, duration, amount of pollutants emitted) and implementation of corrective actions if necessary;
vi. regular review and update of the list of identified OTNOC under point i. following the periodic assessment of point v.;
vii. implementation of backup systems (where appropriate) and regular testing of them.

Other than normal operating conditions (OTNOC) are associated (among others) with the following periods/instances:

- start-up;
- shutdown;
- momentary stoppages;
- leaks (chemicals or water solutions);

- malfunction or breakdown of the abatement equipment or part of the equipment, if available;
- malfunction of instruments related to process control or emission monitoring;
- testing of new apparatus;
- calibration of the monitoring system.

Achieved environmental benefits

Emissions associated with shutdown and start-up operations and other OTNOC are in part avoided. Planning for and achieving a reduced number of shutdowns is likely to reduce the mass of pollutants emitted.

Environmental performance and operational data

Preventive maintenance and regular maintenance checks can prevent or avoid malfunctions regarding process control or emission abatement and monitoring equipment.

Preventive maintenance

Preventive maintenance is used to:

- ensure that any maintenance requiring switching off to deactivate emissions control equipment/systems (e.g. containment, extraction systems, off-gas treatment) is planned to take place when there are no emissions (e.g. during shutdown times) or when emission levels are low;
- replace parts and technical components that have suffered wear and tear and that require replacement on a regular basis, preferably planned to take place before breakdowns are likely;
- ensure that parts that are essential to the normal running of emission control equipment are kept in stock, can be replaced or repaired rapidly with minimum call-off times;
- carry out routine and non-routine maintenance including maintenance of covers and pipe joints for liquid and gaseous fuels, lubricants/chemicals storage and delivery systems.

Regular maintenance checks

A maintenance schedule and record of all inspections and maintenance activities is kept and includes the following:

- visually checking for leaking seals, flanges, valves, welds, tanks and vats;
- inspections by external experts where necessary;
- monitoring of key equipment for problems such as vibration, emission leaks and planning repairs (as above);
- test programmes, e.g. pressure-test pipelines and tanks, calibration of metering and monitoring equipment;
- checking the tightness of nuts and bolts;
- checking for wear and tear on machinery, valves and bunds, over-heating bearings, etc.;
- recalibrating metering systems;
- ensuring that extraction and abatement equipment is fully serviceable, if available.

Unplanned maintenance

Process operators and maintenance staff identify and report leaks, broken equipment, fractured pipes, etc. to focus unscheduled maintenance. Installing and identifying valves in all pipes facilitates the establishment of operational instructions to be used for shutdown sequences for example.

Cross-media effects

None.

Technical considerations relevant to applicability

The level of detail and degree of formalisation of the OTNOC management plan will generally be related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have.

Economics

Avoiding plant shutdowns can reduce costs by allowing continuous throughput and hence greater installation utilisation.

Driving force for implementation

- Reduction of downtime.
- Maintains product quality and throughput.

Example plants

Widely used. The majority of plants reported the implementation of an (OTNOC) management plan.

Reference literature

[168, TWG, 2023]

4.2.1.6 Retention and handling of waste fire-extinguishing material

Description

Equipment and procedures are in place for the separate collection of contaminated firefighting water and/or foam, its storage in watertight storage basins indoors or outdoors, and its appropriate handling (treatment or disposal). Firefighting water bulkheads are installed for sealing of process or storage areas and the capacity of the retention system is based on the volume of treatment vats and the estimated volume of firefighting water and/or foam.

Technical description

Appropriate design of the installation and use of firefighting equipment allowing the separate collection, proper storage and handling of contaminated water and/or foam used for firefighting in the event of a fire. The system is designed to minimise the release of firefighting materials into the environment and ensure their retention, allowing proper handling and disposal, e.g. on-site treatment of water and/or foam or external disposal.

Fires in electroplating facilities and surface treatment plants have been reported regularly in recent years. High currents in combination with corrosive atmospheres in the surface treatment industry often heat contacts considerably. This may lead to electrical short circuits and thus to the start of fires. Also, certain chemicals used in surface treatment and hydrogen produced by electrolysis make the outbreak of fires more likely than in other sectors. In the event of a fire, both the quantity and the hazardousness potential of the firefighting water are significantly increased by the liquid chemicals present in treatment vats, waste water and stored chemicals, compared to in other industrial sectors. Therefore the volume of water/foam to be used in the event of a fire as well as the volume of process liquids are taken into consideration for the calculation of the total retention volume needed.

Containment systems

The main aim is to generate a containment system as close as possible to the production or storage units to prevent firefighting water run-off from leaving the STM plant area, increasing the pollution. When capacity restrictions on site do not allow the establishment of an on-site containment system, mobile devices such as firefighting water bulkheads are available which can be automatically lowed to the ground with a small time delay in the event of a major fire after the evacuation of the building. They seal the production or storage building as shown in the pictures below.

© Wolfram Willand

Figure 4-2: Firefighting water bulkhead for a door

In the event of a fire, the firefighting water bulkhead closes hydraulically in two receiving brackets. Quick-release clamps generate the tightness by pressing on the sealing lips.

© Wolfram Willand

Figure 4-3: Bulkhead for sectional door and pass door

The sectional door and the pass door would allow leaks in the extinguishing water catch basin. The firefighting water bulkhead (red) is lowered on rails and seals the retention basin.

Achieved environmental benefits

Reduced environmental contamination of soils and improved water quality of surface water and groundwater, e.g.:

- less or no contamination of soil and groundwater during percolation of uncontained firefighting water;

- less or no release of hazardous firefighting water (containing heavy metals, strong acids, PFAS, etc.) into the sewerage system, biological waste water treatment plants and surface water.

Environmental performance and operational data

The volumes of the required retention system vary and may reach up to several thousand m^3 per fire event. A suitable calculation method allows an appropriate design to minimise the release of firefighting materials into the environment and ensure their retention, allowing proper handling and disposal, e.g. on-site treatment of water and/or foam, or external disposal.

Factors influencing the calculation of the retention volume are:

- the total capacity of the processing baths and storage units including rinsing and waste water in the area;
- maximum expected firefighting and cooling water volume;
- volume of firefighting foam;
- the potential amount of rainfall during the emergency event and the time period in which the firefighting water is stored until final disposal (normally several days up to several weeks).

On-site waste water treatment plants may not be designed to treat contaminated firefighting water during the emergency event as:

- they usually also fail due to corrosion caused by acidic fire gases;
- the firefighting water has a more complex composition than the usually treated waste water so that environmentally sound treatment is not guaranteed;
- the treatment volume is too low as it is only designed to treat waste water from normal operation conditions.

The treatment or disposal is selected taking into account persistent or toxic contaminants that may also originate from firefighting foam materials (e.g. aqueous film-forming foams containing perfluorinated chemicals). As a precautionary measure, firefighting materials are assessed to select the most suitable option with the least impact on the environment.

Considering firefighting strategies and possible methods to reduce the amount of hazardous firefighting water run-off generated, e.g. by the use of sprays rather than jets, controlled burn down and the possible recycling of firefighting water, where safe and practicable, also supports the implementation of this technique.

Firefighting water bulkheads or other mechanical shut-off barriers can serve a double function, as they can be used to retain firefighting water as well as to prevent the production areas from flooding, e.g. in th eevent of heavy rain events.

Cross-media effects

None.

Technical considerations relevant to applicability

Generally applicable. In existing installations, retention volume can be created by the use of firefighting water bulkheads or other mechanical shut-off barriers.

Economics

The investment costs are dependent on the firefighting water retention system and vary widely. Annual costs for maintaining firefighting water retention systems are in the range of 5% of the construction costs.

Driving force for implementation

- Reduction of costs in the event of a fire.
- Legal requirement.

Example plants

The majority of plants reported the use of retention and handling of waste fire-extinguishing material.

Reference literature

[167, TWG, 2023], [168, TWG, 2023].

~~Specific EMS issues for surface treatment activities~~

[This technique has been included in Section 4.2.1.4.]

~~Specific EMS issues that may be relevant are:~~

- ~~installing valves and numbering them for all pipes. The numbers are then used in instructions for shutdown sequences, both long and short term shutdown~~
- ~~checking all tanks and pipework regularly for leakage. This requires tank bottoms and pipes to be visible, with no accrual of dirt, rubbish, old jigs, anode ends, etc. in contained areas and around tanks or pipes~~
- ~~using fixed and temporary pumps, hydraulic fluid systems and filters over mobile tanks or drip trays with sufficient capacity to retain leakage and spills. Pipe ends are kept over the process tank or drip trays. This enables liquid residues to be collected and returned to the correct process solutions or dealt with as a waste or waste water~~
- ~~keeping all process areas clean and painted to allow chronic leakage to be readily identified~~
- ~~the use of high level alarms in both process vats and waste water treatment where over flow is possible [125, Ireland, 2003]~~
- ~~the management of the chemicals and proprietary products for their correct use, and especially the identification of risks associated with the storage and use of incompatible materials [125, Ireland, 2003]~~
- ~~the identification of the use of priority pollutants in the installation (used currently and in the past). This may also be required for compliance with legislation controlling priority pollutants, see Annex 8.1 in the Water Framework Directive (2000/60/EG) [113, Austria, 2003]. Priority pollutants are also identified by PARCOM [12, PARCOM, 1992]. Key examples for this sector are:~~
    - ~~polychlorinated biphenyls, e.g. in capacitors and other electrical equipment~~
    - ~~cadmium~~
    - ~~other materials that do not or are slow to degrade, such as other metals in soluble form (such as nickel, chromium, zinc, copper, lead)~~
    - ~~VOCs used for degreasing (including C10–C13 chloralkanes)~~
    - ~~cyanides~~
    - ~~acids and alkalis~~
- ~~the establishment of the use of the land and buildings of the installation prior to the existing installation and/or activities and if the activities carried out could be confused with the activities of the surface treatment installation~~
- ~~the self-monitoring of indicators for environmental performance as well as those affecting individual processes. Examples are:~~
    - ~~effluent discharged and quality, see Annex 8.4.2 [56, France, 2003, 121, France, 2003]~~
    - ~~raw material consumption by type~~
    - ~~energy consumption~~
    - ~~water consumption~~
    - ~~waste produced and type.~~

~~These figures are most meaningful when related to other relevant production parameters, such as area of workpiece or substrate throughput, number of barrels or flight bars processed, weight of workpieces or substrate processed, etc.~~

~~4.2.1.7~~ Reduction in reworking ~~by process specification and quality control~~

Description

The right process specifications are defined and followed (e.g. according to quality and environmental management systems), to ensure that the production quality is as stable as possible. This is complemented by appropriate process control to achieve optimal production quality and avoid reworking.

Technical description

Workpieces or substrate surface treated incorrectly, to the wrong or inappropriate specification, or a specification incorrectly applied can lead to significant amounts of metal stripping and rectification (in barrel and jig work) ~~as described in Section 2.3, metal stripping~~. Workpieces and/or substrate may also have to be scrapped, predominantly large scale coils and printed circuit boards, although some jig and barrel processed workpieces may be damaged irrecoverably.

Reduction in reworking and scrap can be achieved in a variety of ways, such as using formal quality management systems, QMS. As with environmental management tools, described in Section 4.2.1.1, to achieve success within the installation, it is good practice to ensure these systems are formally recorded and disseminated to the workforce. While many such systems are externally accredited (and this may be a customer requirement) it may not be essential. However, it is usual to have the system externally audited, to provide unbiased input to validate and update the system, as well as giving customer confidence. These systems usually include statistical process control (SPC).

QMS and EMS systems like ISO 9001 and ISO 14001 are standard in the industry today; certifications are required by the customers. Unstable production quality has severe economic consequences and results in overconsumption of resources.

For special applications, e.g. for anodising and powder coating of workpieces used in the architectural field, specific quality labels like QUALICOAT, GSB International, Qualimarine and QUALANOD carrying out unannounced audits of the coating plants have proven to be a very effective means of ensuring the continuous quality of surface treatment in this demanding sector, where corrosion resistance and longevity of the coated workpiece are key requirements [175, ESTAL, 2024].

Attention to the appropriate process specification and its quality control is also an important factor. In surface treatment activities a ‘right first time approach’ is normally anticipated and is often part of a formal system. To achieve this, it is common practice to ensure the correct process is applied in the correct manner to achieve the desired effect. This requires a proper understanding of the properties given by the surface treatment and the subsequent operations to be performed on the workpiece or substrate such as pressing, forming, bending, crimping, drilling, welding, soldering, etc. Other techniques that form part of achieving the correct specification are discussed in EMS (Section 4.2.1.1) and in production management systems, such as ISO 9000.

To match the treatment to the required objective, environmental and/or quality management systems (as appropriate) can make sufficient provision for dialogue and agreement between the operator and the customer about the correct process specification, engineering design drawings and the quality control measurement points for the workpieces and/or substrates (see Applicability, below). The following are examples of areas that can be addressed:

- S~~s~~urface treatments can alter the dimensions of a workpiece by the thickness of layer added (e.g. changing the size of threaded components), the characteristics of the substrate (e.g. hydrogen embrittlement with acid zinc plating) or be inappropriate for subsequent manipulation (e.g. some finishes may be brittle and may flake when a treated workpiece is subsequently bent or crimped).
- I~~i~~n electrolytic processes where the applied material is current-carrying, the deposits build preferentially at edges and corners of the workpiece and/or substrate, where the charge density is greatest. The method of measurement and the points to be measured for quality control of the finish may be agreed taking account of the differences of thickness at different parts of the workpiece or substrate to be finished. Some measurement methods require flat surfaces and to meet performance requirements attention may need to be given the coating thickness being significantly thinner in flat areas than at the edges (a ratio of centre thickness to edge thickness of approximately 1:3 or 1:4). Also, while specifications may be met in the flat, measured areas, edge build-up can result in flaking if the edges are subsequently manipulated, such as by crimping.
- P~~p~~erformance specifications (such as to achieve a specified level of corrosion resistance) are preferable to total reliance on prescriptive specifications. The more usual and readily applied thickness measurements are best used in conjunction with performance specifications, when thicknesses at agreed points that meet the specified performance can be established (see also the discussion on Substitution, Section 4.9).
- A~~a~~lterations to the manufacturing process prior to surface treatment. For example, change in pressing oils (to a type which may become pressed into the substrate micro-structure and does not respond to normal degreasing processes), type of substrate, pressing workpieces in place of machining, hardening prior to surface treatment, etc.
- A~~a~~lterations to end use specification.
- B~~b~~arrel treatment instead of jig (possibly because of cost constraints).
- ~~Mmajor~~ organisations or industry sectors requiring large amounts of surface treatment may write their own specifications (such as automotive or aerospace organisations). Smaller organisations often use these publicly available specifications. To meet specifications, take care to ensure the latest versions are referred to, and the specifications are suitable for other products, their subsequent processing and end use.
- S~~s~~ome customers may request the highest quality specifications available, such as military and aerospace specifications involving cadmium for other products. However, military and aerospace applications are exempt from marketing and use legislation applying to cadmium.

There are many ways in which processes can be improved for stability and consistency over time and many techniques described in Chapter 4 have this advantage as well as improving environmental performance. Where this occurs, it is highlighted in the section ‘Driving force for implementation’. Examples are the use of insoluble anodes with external make-up (see Section 4.8.2), process solution agitation (Section 4.3.4) and control of concentration of process chemicals (Section 4.8.1).

Process specifications are strictly defined and followed in printed circuit boards manufacturing and semiconductors manufacturing, due to the very high quality of final products expected.

Achieved environmental benefits

Avoiding reworking minimises losses in raw material, energy and water inputs, as well as minimising waste water treatment and the generation of sludge and liquid acid wastes.

Metal stripping with strong acids is often carried out as a batch process. Reduction in this activity can result in reductions in:

- spillage which can attack concrete floors and can pollute surface and groundwaters
- exceeding waste water treatment plant capacity leading to breach of permit discharge conditions
- acid fumes and mists leading to problems with local air quality, health and safety and deterioration of plant and equipment.

Reduction in surface treated scrap can reduce emissions to air from other installations such as furnaces and foundries. In these, some non-ferrous metals may be vaporised and organic coatings burnt off with unknown breakdown products.

Environmental performance and operational data
If specification or processing is incorrect, a significant proportion of production capacity may be affected. The surface treatment subcontractor is not often contacted during the design phase.

In some cases, workpieces and/or substrates are damaged in the reworking, or cannot be reworked and are scrapped.

Cross-media effects
There are no negative cross-media effects.

Technical considerations relevant to applicability
Generally applicable to all installations. ~~However, note that the provisions of the IED IPPC Directive applies to the installation and its management systems. It does not apply to the supply chain and products.~~

Economics
There is significant economic justification for ensuring the specification is correct and is met, thus preventing reworking. Avoiding reworking is a positive action towards sustainable manufacturing and increases process throughput efficiency, as well as increasing customer confidence. There are cost savings in raw materials, hazardous waste disposal, energy and water, as well as labour. For sub-contract installations, the cost of stripping and reworking is usually borne by the sub-contractor.

Conversely, there are costs associated with introducing and maintaining process management systems and SPC.

Driving force for implementation
Business economics and sustainability.
Customer requirements for quality management systems.

Example plants
~~All sites visited have quality management systems; some accredited, but all externally assessed. Examples are: SIKEL N.V., Genk, Belgium; Exhall Plating, Coventry, UK; SGI, Plaisir, France; Corus, Llanelli, UK; Cropu SA, Burgos, Spain.~~

Reference literature
[11, Tempany, 2002, 18, Tempany, 2002]
[176, CETS, 2024] [168, TWG, 2023].

4.2.2 Monitoring

4.2.2.1 Monitoring of environmental performance

Description
Monitoring preferentially includes direct measurements. Calculations or recording, e.g. using suitable meters or invoices, can also be used. The monitoring is broken down to the most

appropriate level (e.g. to process or plant level) and considers any significant changes in the process or plant.

Technical description
Real data are required on the precise effects of the activities of the industrial site on the environment. It is thus necessary to conduct a planned, regular sampling and monitoring programme. The parameters monitored include:

- the consumption of water (e.g. groundwater, water supply network, surface water), energy and materials used, including process chemicals, expressed as a yearly average;
- the generation of waste water, expressed as a yearly average;
- the amount of each type of material recovered, recycled and/or reused, expressed as a yearly average;
- the amount of each type of residue generated and of each type of waste sent for disposal, expressed as a yearly average.

Achieved environmental benefits
Monitoring the parameters mentioned above (see Description) helps to maintain the proper operation of the facility and to detect instances of malfunctioning and thus helps to prevent any possible adverse environmental effects.

Environmental performance and operational data
Monitoring of consumption and waste figures is the basis for a more optimised production. As such, it is certain to deliver reductions in energy and resource consumption.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Economics
The costs associated with monitoring relate to the personnel involved and equipment used.

Driving force for implementation
- To ensure the proper operation of the installation.
- Indirect savings in utilities costs and handling of waste generated

Example plants
The majority of plants reported monitoring of the parameters mentioned above.

Reference literature
[168, TWG, 2023]

4.2.2.2 Monitoring of emissions to air

Description
Regular monitoring of emissions to air.

Technical description
Monitoring of the relevant parameters can be accomplished by online measurements (which facilitate rapid intervention and control) or analytical results derived from air samples. Parameters to be monitored and the frequency of monitoring depend *inter alia* on the activities responsible for generating the emissions to air.

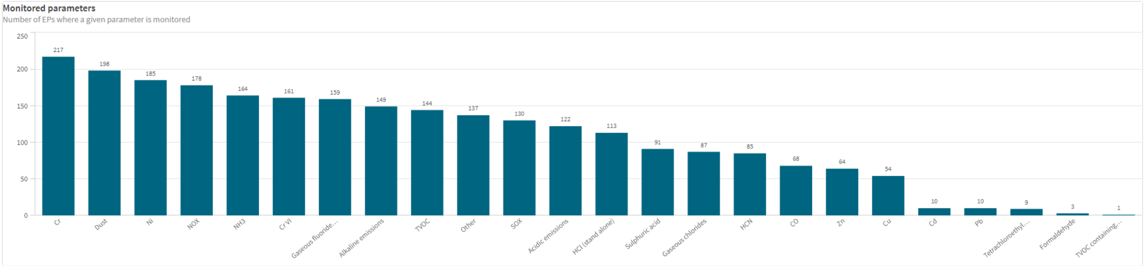
The monitoring of channelled emissions/waste gases is carried out in accordance with EN standards or, if EN standards are not available, ISO, national or other international standards which ensure the provision of data of an equivalent scientific quality.

For more information on the monitoring of emissions to air, see also the Reference Report on Monitoring of Emissions to Air and Water from IED Installations (ROM).

Achieved environmental benefits

Monitoring the waste gas helps to maintain the proper operation of the plant and to detect accidental releases and thus helps to prevent any possible adverse environmental effects when the waste gas is emitted.

Environmental performance and operational data



Source: [168, TWG, 2023]

Figure 4-4: Number of emission points for emissions to air that monitor a given parameter

Cross-media effects

Some equipment, ancillary materials and energy are required for carrying out monitoring.

Technical considerations relevant to applicability

Generally applicable to all foundries where there are channelled emissions to air.

Economics

The costs associated with monitoring the waste gas of a foundry plant relate to the personnel and equipment used for sampling and the measurement frequency.

Driving force for implementation

- Legal requirements.
- Local conditions.

Example plants

See examples in Chapter 3.

Reference literature

[168, TWG, 2023]

4.2.2.3 Monitoring of emissions to water

Description

Regular monitoring of emissions to water.

Technical description

Monitoring of the relevant parameters can be accomplished by online measurements (that facilitate rapid intervention and control of the waste water treatment plant (WWTP) or analytical results derived from waste water samples. Parameters to be monitored and the frequency of monitoring depend on the activities which generate the waste water, the type of waste water treatment and the destination of the effluent (direct discharge or indirect discharge after treatment in an industrial or municipal WWTP).

The monitoring of emissions is carried out in accordance with EN standards or, if EN standards are not available, in accordance with ISO, national or other international standards which ensure the provision of data of an equivalent scientific quality.

For more information on the monitoring of emissions to water, see also the Reference Report on Monitoring of Emissions to Air and Water from IED Installations (ROM).

Achieved environmental benefits
Monitoring the waste water parameters helps to maintain the proper operation of the waste water treatment plant and to detect accidental releases and thus helps to prevent any possible adverse environmental effects when the waste waters are discharged.

Environmental performance and operational data
See Chapter 3.

Cross-media effects
Some equipment, ancillary materials and energy are required for carrying out monitoring. The COD measurement relies on the use of very toxic compounds (i.e. mercury and chromate).

Technical considerations relevant to applicability
Generally applicable to all plants from where there are emissions to water.

Economics
The costs associated with monitoring the effluent waste water of a waste water treatment plant relate to the personnel and equipment used for sampling and the measurement frequency.

Driving force for implementation
- Legal requirements.
- Local conditions.

Example plants
See examples in Chapter 3.

Reference literature
[168, TWG, 2023]

4.2.2.3.1 Monitoring of PFAS emissions to water

Description
Monitoring of PFAS emissions to water.

Technical description
To get a better understanding of PFAS emissions to water, it is imperative that the inventory of inputs and outputs maps out, to the maximum extent possible, all the types of PFAS that are used, formed and emitted. This should take into account the PFAS degradation products and precursors, including both long-chain and short-chain PFAS. To obtain this information, a combination of untargeted and targeted analysis should be used.

This inventory has to be done for the whole plant or at different points in the installation, for instance after the surface treatment baths, before and after the physico-chemical waste water treatment and at the point of discharge.

Based on the inventory of inputs and outputs, all measurable PFAS have to be monitored frequently.

Several monitoring standards exist for measuring PFAS emissions to water, either as a sum of certain PFAS or as individual parameters:

- ISO 21675:2019 (30 PFAS);
- DIN 38407-42 (individual assessment of: PFBA, PFBS, PFPeS, PFHxA, PFHxS, PFHpA, 7H-PFHpA, PFHpS, PFOA, PFOS, PFNA, PFNS, PFDA, PFDS, PFUnDA, PFUnDS, PFDoDA, PFTrDA, PFTrDS, PFTeDA);
- WAC/IV/A/025 (individual assessment of: PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFUnDA, PFDoDA, PFTeDA, PFHxDA, PFBS, PFPeS, PFHxS, PFHpS, PFOS, PFNS, PFDS, 4:2 FTS, 6:2 FTS, 8:2 FTS, PFOSA, MePFOS A, EtPFOSA, MePFOS AA, EtPFOSA A, 8:2 diPAP, HFPO-DA, DONA, PFECHS, PFBSA, PFTrDA, PFODA, PFDoDS, PFUnDS, PFTrDS, 10:2 FTS, 6:2 diPAP, 6:2/8:2 diPAP) Reporting limit in waste water: 20 – 50ng/L;
- WAC/IV/A/026 (individual assessment of: TFA, PFPrA, PFPrS, PFBS, TFMS, PFEtS, 2,3,3,3-TFPA, 2,2,3,3-TFPA).

Achieved environmental benefits

In order to be able to tackle PFAS emissions to water effectively, the occurrence of certain PFAS emissions to water needs to be understood first. Monitoring then enables the quantification of set measures or techniques (process-integrated or end-of-pipe) to avoid or reduce PFAS emissions to water.

The information gathered can be used in light of the REACH Regulation and is of utmost importance for local competent authorities.

Environmental performance and operational data

Plant-specific monitoring data show that more types of PFAS are usually present in the waste water than identified via the inventory of inputs (due to break-down products, impurities, etc.) Thus a broad analysis of PFAS emissions to water is necessary to tackle the issue adequately. Plant-specific monitoring data are available in the Flemish BAT study for the abatement of PFAS emissions to water (Goelen, T., Lescrauwaet, A., Van der Aa, S., & Janssens, G. (2023)).

Cross-media effects

There are no cross-media effects with monitoring.

Technical considerations relevant to applicability

It should be noted that PFAS is only relevant in specific sub-sectors/processes of the STM sector.

Mainly the use of mist suppressants in Cr(VI) plating results in the intentional usage of PFAS. Most commonly 6:2-FTS is used in this case as PFOS is no longer to be used for this application. Leaching out effects of PFOS emissions can, nevertheless, still occur. Another process where PFAS are used intentionally is autocatalytic nickel plating in connection with Teflon (PTFE).

Accidental fires can be an issue for the STM industry and are a relevant safety issue. Firefighting foams can contain PFAS.

Economics

The costs for analyses are determined by the number of parameters that need to be measured and the required reporting limit at which the samples must be measured. The costs can vary slightly between different accredited laboratories. Generally, the costs are estimated at EUR 150–260 per sample for measuring 42–44 PFAS parameters from the WAC/IV/A/025 (Flemish standard) list with a reporting limit of 20 ng/l. However, the typical price for analyses is EUR 230–260 per sample. For companies that sign annual contracts or supply large numbers of samples, lower costs are charged, approximately EUR 150–170 per sample.

Driving force for implementation

This information is needed to estimate the magnitude of the PFAS issue within the installation and to subsequently determine the most adequate abatement technique(s) for the removal of PFAS if necessary.

Example plants

Example plants from the data collection that have successfully implemented this technique are: BE_003, BE_004, BE_005, BE_009, BE_011, BE_015, BE_020, AT_003, AT_005, DE_037 and DE_060.

Reference literature

[168, TWG, 2023], [167, BE contribution, 2024].

~~General operational issues~~

[Note to the TWG: This section has been completely reordered and rewritten compared to the 2006 existing BREF]

~~4.2.3~~ Energy efficiency

~~Utility inputs and their management~~

[Note to the TWG: This section corresponds to Sections 4.4.1 to 4.4.4 of the existing BREF]

~~This section discusses the general usage of utilities and individual measures are described by their specific activities, for example the optimisation of energy in air extraction systems is discussed in air emissions, Section 4.18.2 and water-saving measures for rinsing in Section 4.7 In this section, energy inputs are discussed separately as electricity and heating. The reduction of heating losses are discussed as a part of the heating section. Cooling is also discussed as it uses water and/or energy. Water inputs are also considered.~~

Energy saving measures and systems involve the use of operating tools or equipment capable of:

- maximising the use of energy consumed by the installation, e.g. management of incoming electrical supply;
- minimising the energy used to heat process solutions;
- minimising the energy (current) losses in electrochemical processes;
- minimising the energy used to cool process solutions;
- maximising the efficiency of other uses, such as air extraction and other electric drive motors, and the operation of peripheral and recycling plants;
- optimising air extraction and space heating.

All ~~utility~~ inputs can be recorded on an actual basis, and split according to type and major end-use on a specified basis, such as monthly, daily, hourly, etc. Inputs can also be benchmarked and optimised against other production measures (see Section 4.1.3), such as surface area or tonnage throughput, number of barrels, processing costs, etc. Action can be taken as described in these sections where there are variations from the benchmarks.

4.2.3.1 Energy efficiency plan and audits

Description

An energy efficiency plan is part of the EMS (see Section 4.2.1) and entails defining and monitoring the specific energy consumption of the activities/processes (e.g. kWh/m^3 or kWh/t of workpieces treated), setting objectives in terms of energy efficiency and implementing actions to achieve these objectives.

Audits (also part of the EMS, see Section 4.2.1) are carried out at least once every year to ensure that the objectives of the energy plan are met and the audits' recommendations are followed up and implemented.

Technical description

Extensive information about energy efficiency can be found in the ENE BREF. Some techniques applicable to increase the energy efficiency of surface treatment of metals and plastics installations are as follows:

(a) Appraising the costs and benefits of different energy options and energy saving opportunities.
(b) Monitoring energy flows (consumption and generation by source) and targeting areas for reductions.
(c) Defining and calculating the specific energy consumption of the activity (or activities), and setting key performance indicators on an annual basis (e.g. kWh/m^3 or kWh/t of workpieces treated).
(d) Carrying out an energy survey to identify the opportunities for further energy savings.
(e) Using combined heat and power (see Section 4.2.3.5.1).
(f) Applying operating, maintenance and housekeeping measures to the most relevant energy-consuming systems, such as:
    - air conditioning and cooling systems (leaks, seals, temperature control, evaporator/condenser maintenance);
    - operation of motors and drives (e.g. high-efficiency motors);
    - compressed gas systems (leaks, procedures for use);
    - steam distribution systems (leaks, traps, insulation);
    - room heating and hot water systems;
    - lubrication to avoid high friction losses (e.g. mist lubrication);
    - burner maintenance and control;
    - boiler maintenance, e.g. optimising excess air;
    - other maintenance relevant to the activities within the installation;
    - reviewing equipment requirements on a regular basis.
(g) Using techniques that reduce energy consumption and thereby reduce both direct (heat and emissions from on-site generation) and indirect (emissions from a remote power station) emissions. For example:
    - building insulation;
    - use of energy-efficient site lighting;
    - vehicle maintenance;
    - efficient plant layout to reduce pumping distances;
    - phase optimisation of electric motors;
    - heat recovery;
    - ensuring equipment is switched off, if safe to do so, when not in use;
    - ensuring on-site vehicle movements are minimised and engines are switched off when not in use.
(h) Applying basic, low-cost, physical techniques to avoid gross inefficiencies; including insulation, containment methods (for example seals and self-closing doors) and avoiding unnecessary discharges of heated air (for example by fitting simple control systems).
(i) Applying energy efficiency techniques to building services.

Energy audits are carried out at least once a year to ensure that the objectives of the energy management plan are met. Audits may be carried out using elements of international standards which have been developed to support the implementation of energy audits under the Energy Efficiency Directive, e.g.:

- EN ISO 50001 on energy management systems which provides a framework of requirements for large installations.
- EN ISO 50005:2022 on energy management systems – Guidelines for a phased implementation. This standard provides guidance for organisations to establish a phased approach to implement an energy management system. This phased approach is intended to support and simplify the implementation of an energy management system in particular for small and medium-size installations.
- EN 16247-1:2012 on energy audits – Parts 1 and 3.
- EN ISO 50002:2014 on energy audits – Requirements with guidance for use.

Achieved environmental benefits

- Reduction of energy consumption.
- Reduction of emissions.
- Decarbonisation.

Environmental performance and operational data

Energy management systems are set up to suit local conditions and must be individually adapted to each business. Energy management software can often assist in recording energy demand, but requires metering infrastructure and the utilisation of specific software. Peak load management systems often help to reduce energy costs. By identifying the main energy consumers in the surface treatment of metals and plastics activities, energy efficiency measures can be implemented in a targeted manner. Nevertheless, an energy management system shall also include the possibility not to implement uneconomical energy efficiency measures. An important element of energy management systems is the training of the energy team as well as all employees in the plant.

Cross-media effects

None identified.

Technical considerations relevant to applicability

The level of detail of the energy efficiency plan and of the energy audits will generally be related to the nature, scale and complexity of the installation and the types of energy sources used.

Economics

Associated personnel cost.

Driving force for implementation

Energy savings.

Example plants

Widely used.

Reference literature

[168, TWG, 2023]

4.2.3.2 Energy balance record

Description

The technique involves drawing up an energy balance record once every year which provides a breakdown of the energy consumption and generation (including energy export) by the type of energy source, for example:

- energy consumption: electricity, natural gas, renewable energy, imported heat and/or cooling;

- energy generation: electricity and/or steam.

Technical description
This includes:
- definition of the energy boundaries of the processes;
- information on energy consumption in terms of delivered energy;
- information on energy exported from the plant;
- energy flow information (e.g. Sankey diagrams or energy balances) showing how the energy is used throughout the processes.

Achieved environmental benefits
Reduction of energy consumption.

Environmental performance and operational data
The reduction of emissions from the energy system can only be evaluated with a proper calculation of the actual emissions generated. The breakdown between generation and consumption can help to optimise the balance between them and hence to optimise the use of energy resources.

Cross-media effects
None identified.

Technical considerations relevant to applicability
The level of detail and the degree of formalisation of the energy balance record will generally be related to the nature, scale and complexity of the installation and the type of energy sources used.

Economics
The requirements are basic and cost little.

Driving force for implementation
Reduction of energy costs.

Example plants
Widely used.

Reference literature
[168, TWG, 2023]

4.2.3.3 Use of general energy-saving techniques

[Note to the TWG: Please provide information to complete the 10-heading template below]

Description
This includes techniques such as:

- burner maintenance and control;
- use of energy-efficient equipment (e.g. motors, lights);
- use of optimised steam and compressed air distribution systems;
- regular inspection and maintenance of the steam distribution systems and of equipment in the electrical supply system;
- use of process control systems and optimisation of process solutions;
- use of variable speed drives;
- use of optimised air conditioning and building heating;

- minimisation of heat losses, e.g. thermal insulation of heated process treatment vats, pipe insulation, use of double-walled or pre-insulated containers, temperature control of heating treatment vats;
- reduction of heat losses from the surface of process treatment vats using floating spheres or lids for example.

Technical description

Energy can also be reduced by optimising utilities such as air compressors, fans, motors, pumps and lights.

General energy-saving techniques are applied by process and equipment selection and optimisation.

Energy-efficient motors

Measures include creating a motor management plan, selecting and purchasing motors strategically, performing ongoing maintenance, using properly sized motors, automating motors, using adjustable speed drives, using the correct power factor, minimising voltage imbalances and using soft starters.

Energy-efficient lighting

This can be achieved by turning off lights in unoccupied areas, using occupancy sensors and other lighting controls, upgrading exit signs, replacing magnetic ballasts with electronic ballasts, replacing T-12 tubes with T-8 tubes, reducing the lighting system voltage, replacing mercury lights with metal halide or high-pressure sodium lights, replacing metal halide HID with high-intensity fluorescent lights, using daylighting and using LED lighting (see also the ENE BREF [60, COM 2009]).

Achieved environmental benefits

- Reduction of energy consumption.
- Decarbonisation.

Environmental performance and operational data

Cross-media effects

None identified.

Technical considerations relevant to applicability

Generally applicable.

Economics

Driving force for implementation

Reduction of energy costs.

Example plants

Widely used.

Reference literature

[168, TWG, 2023]

4.2.3.3.1 Process line optimisation

For a description of the technique see Section 4.2.6.2.1.

4.2.3.3.2 Optimisation of process solution agitation, conductivity and composition

Description

This includes:

- reducing the surface treatment duration by process solution agitation using, for example, hydraulic turbulence;
- reducing the heating temperature by substituting chemicals, e.g. galvanic chemicals;
- increasing the conductivity of the process solution by using additives or by process solution maintenance.

Technical description

Implementation of various techniques can optimise the treatment process and therefore lead to energy savings.

Achieved environmental benefits

Energy savings.

Environmental performance and operational data

Cross-media effects

None.

Technical considerations relevant to applicability

Generally applicable.

Economics

Driving force for implementation

Energy savings and cost savings.

Example plants

20 plants from data collection have successfully implemented this technique.

Reference literature

[168, TWG, 2023]

~~4.2.3.3.3 Energy-efficient equipment~~

[This technique has been merge with Section 4.2.3.3]

~~**Description**~~

~~It is good practice to install energy-efficient equipment, such as energy-efficient motors, see Section 4.3.3.3.1.~~

~~**Achieved environmental benefits**~~

~~Power saving.~~

~~**Cross-media effects**~~

~~None~~

~~**Applicability**~~

~~Depending on the size of the unit and energy consumption, the use of energy-efficient motors is good practice for large applications. They can be specified for new installations, for the replacement for defective motors or for cost savings.~~

~~**Economics**~~
~~For large scale applications, see Section 4.3.3.3.1.~~

~~**Driving force for implementation**~~
~~Cost saving.~~

~~**Reference literature**~~
~~[19, Eurofer, 2003]~~

~~4.2.3.3.3.1 Compressed air system optimisation~~

~~4.2.3.3.3.2 Energy-efficient motors~~

[This technique corresponds to Section 4.14.3.1 of the existing BREF and has been merge with Section 4.2.3.3]

~~**Description**~~
~~See Section . the application of energy-efficient motors where motors are used in the process.~~

~~**Achieved environmental benefits**~~
~~Reduction in energy consumption on the line.~~

~~**Cross-media effects**~~
~~None~~

~~**Applicability**~~
~~Can be used in new plant or as replacement parts~~

~~**Economics**~~
~~The initial investment is medium: EUR 0.015 – 0.8/t installed.~~
~~Operating costs are low EUR 0.001 to 0.15/t.~~

~~**Driving force for implementation**~~
~~Process efficiency.~~

~~**Example plants**~~
~~Many continuous electroplating lines in EU-15.~~

~~**Reference literature**~~
~~[19, Eurofer, 2003]~~

4.2.3.4 Electricity

4.2.3.4.1 Incoming high voltage supplies and large current demands

[Note to the TWG: Please provide information to complete the 10-heading template below]

Description
Incoming supply should be managed to match phases, minimise reactive energy losses on stepping down from high voltage and supply large current demand, etc.

Technical description

~~Incoming supply should be managed to match phases, minimise reactive energy losses on step down from high voltage and supply large current demand, etc.~~

On a large site, the energy is supplied at 150 kV and is rectified to 0.033 kV for use in the galvanic cells. Typical rectifying operations involve the following steps:

- step 1: two high tension transformers drop the voltage from 150 kV to 15 kV
- step 2: 15 feeding cells drop the voltage for the rectifiers from 15 kV to 525 V
- step 3: 60 rectifiers (one per anode, four per galvanic cell) drop the voltage from 525 V to 33 V. Rectification is through thyristor bridges, transformers and diode bridges
- step 4: supply to 15 galvanic cells. The length of the copper bus bars are short and water cooled to minimise the resistance losses. This is achieved through:
  - a very short distance between the rectifiers and the conductor rolls and anodes
  - the connection of the conductor rolls and anodes through one (the same) side of the cells
  - the individual anode feeding allows an optimal current setting
- step 5: compensation for the reactive energy.

Any AC electrical equipment such as transformers, motors etc., absorbs a total energy called the apparent energy. This is made up of active energy (in the form of work or heat) and reactive energy which is unproductive. The reactive energy increases if the current is out of phase in relation to the voltage, and is the difference between the voltage and the current wave peaks. The power factor (cos φ) of an electrical device is the ratio of the active power P (kW) over the apparent power S (kVA) and is the cosine of the angle between the peaks of the sine curves of voltage and current. The closer cos φ is to unity (1), the more efficient the use of power; the lower cos φ value, the less effectively the energy is used. When cos φ lies permanently above 0.95, the reactive energy losses at 15 kV and 150 kV levels are limited.

Achieved environmental benefits

Minimises energy losses.

Environmental performance and operational data

Cross-media effects

None

Technical considerations relevant to applicability

All installations using a three-phase supply. Power correction and reduction of reactive energy requires skilled review of power demands and correction.

~~All installations using electrolytic processes can ensure reduction of resistance losses in power supplies.~~

Economics

Energy losses as unwanted heating, reactive energy, etc. increase power consumption and cause higher costs.

Driving force for implementation

Cost saving.

Example plants

Sikel N.V., Genk, NL.

Reference literature

[19, Eurofer, 2003], (Personal communication, Fernando Dorado Nevas, Escuela Superior de Ingenieros, University of Sevilla).
[168, TWG, 2023]

4.2.3.4.2 Optimised design and handling of voltage supply and current demands DC supply

[Note to the TWG: Please provide information to complete the 10-heading template below]

Description
Effective management of incoming supplies to ensure that they align with the production phases, minimising reactive energy losses during voltage reduction and efficiently meeting the current demand required in the process.

Technical description
Energy savings can be attained through:

- reduction of voltage drop in conductors and connectors
- regular maintenance of rectifiers and contacts (bus bars) in the electrical supply system
- installation of modern rectifiers having a better conversion factor than older types, when run at maximum power
- increasing conductivity of process solutions through additives, e.g. sulphuric acid in acid copper baths, and by maintenance of solutions, such as lowering the iron and the trivalent chromium content in hard chromium baths
- modified wave forms (e.g. pulse, reverse) which may improve metal deposits. This is widely used in PCB plating and is described in Section 6.2.

Achieved environmental benefits
In total, an energy saving in DC supply of 10 – 20 % may be expected.

Environmental performance and operational data
Risk of corrosion of rectifiers.

Cross-media effects
Higher concentrations in solutions means higher drag-out of materials.

Technical considerations relevant for applicability
Generally applicable.

Economics
Lower power consumption and therefore lower costs.

Driving force for implementation
Cost savings associated with saving 10 – 20 % of DC supply.

Reference literature
[3, CETS, 2002, 159, TWG, 2004] [176, CETS, 2024], [168, TWG, 2023]

~~4.2.3.4.3~~ Adjustment of electroplating current ~~Optimising process electrical efficiency~~

[Note to the TWG: Please provide information to complete the 10-heading template below]

Description

Each workstation is equipped with its own current rectifier to regulate the electroplating current and adjust it to the process specifications.

Technical description
Addition of conducting chemical compounds to the electrolyte to increase the electrical conductivity.

Achieved environmental benefits
Reduces electrical power consumption. Environmental benefit is high compared with cost.

Cross-media effects
None

Technical considerations relevant to applicability
To new and existing lines.
This requires technical support, either in-house or from the supplier.

Economics
For coil plating, the initial investment is EUR 0.001 to 0.15/t installed, with operating and maintenance costs of EUR 0.001 to 0.15/t installed.

Driving force for implementation
Process efficiency and cost.

Example plants
Many continuous electroplating plants

Reference literature
[19, Eurofer, 2003] [168, TWG, 2023]

4.2.3.5 Heating

4.2.3.5.1 Combined heat and power generation

Description
Combined generation of heat and electricity where the heat (mainly from the steam that leaves the turbine) is used for producing hot water/steam to be used in industrial processes/activities or in a district heating/cooling network.

Applicability
Applicability may be limited by the availability of a consistent and adequate heat demand.

Example plants
AT008, AT009, BE017, BG006, CZ007, CZ014, DE001, DE002, DE005, DE006, DE009, DE023, DE031, DE033, DE038, DE040, DE045, DE059, DE060, DE066, DE072, DE073, DE077, ES012, IT009, IT030, IT031.

Reference literature
[168, TWG, 2023]

4.2.3.5.2 Heating of process solutions

Description
There are four main ways of heating process solutions, and they are by indirect heating coils using:

- high pressure hot water
- unpressurised hot water
- thermal fluids- oils
- direct heating of individual tanks by electric (immersion) heaters or burners directly installed at the surface treatment vats. Immersion heaters are often used to supplement indirect systems.

Information from site visits revealed the following information:

- high pressure hot water can be expensive to run and maintain
- unpressurised hot water and thermal fluids may be cheaper to run
- thermal fluid leakage may damage process solutions irrecoverably
- hot water system leakage may dilute process solutions irrecoverably, although solution may be recovered if leakage is corrected before dilution is significant.

Achieved environmental benefits
Improved heating efficiency.

Cross-media effects
All process solutions may be damaged by leakages from heating coils, either by contamination of non-aqueous thermal fluids (oils) or by dilution from water leaks.

Where immersion heaters or direct heating are used, it is advisable to monitor the level of liquid in the tank. Heating a tank in this way as been known to dry the tank out and cause fire.

Operational data
High pressure hot water systems require specialist maintenance.
Other systems require monitoring of process solutions to ensure no leaks are occurring into the solutions.

Economics
One installation claimed a payback period of 11 weeks for a EUR 96000 investment when switching from high pressure hot water to a thermal fluid boiler. This figure is based on savings following a period of exceptionally high expenditure for maintenance of the high pressure system before the change over.

Driving force for implementation
Cost savings.

Example plants
Exhall Plating Ltd, Coventry, UK.

Reference literature
[18, Tempany, 2002] [125, Ireland, 2003, 128, Portugal, 2003].

4.2.3.5.3 Energy recovery ~~from extracted air~~

[Note to the TWG: This section corresponds to the Section 4.18.6 of the original STM BREF]

Description
The exhaust air is passed through a heat exchanger. The capital investment and operating costs are very high. Savings from energy recovery are only a fraction of these costs, a feasibility study prior to installation including economic considerations is essential to ensure sound investment. More information is given in the BREFs on Waste Water and Waste Gas Management Systems and Surface Treatments using Solvents.

Achieved environmental benefits

Energy recovery.

Environmental performance and operational data

Attention needs to be paid to energy efficiency in all installations using air extraction.

Technical considerations relevant to applicability

This energy saving measure is limited to installations of large size and/or with large volumes of warm air being extracted.

Reference literature

[3, CETS, 2002, 87, EIPPCB, , 90, COM 2020]

4.2.3.5.4 Reducing heating losses from process solutions

~~It is normal practice to minimise heating losses from process solutions but actual techniques used may depend on the options to re-use heat, the availability of renewable energy supplies and local climatic conditions.~~

~~This section briefly describes heating losses in the surface treatment industries. More information on cooling is available in the BREF on industrial cooling systems.~~

Description

Temperatures of heated processes can be monitored manually or automatically (according to the size and energy demand of the vat being heated), with automatic and/or lockable controls. Record and benchmark information and optimise heating according to Section 4.2.6.2.2.

Technical description

~~Energy losses from the surface area of heated process solutions related to processing temperatures are shown in~~ Table 3.1~~. It demonstrates that t~~The highest energy loss occurs from the solution surface with air extraction and with liquid agitation. Air extraction above the surface of process solutions enhances evaporation and thus the energy loss~~, see Section 1.1.1.1~~. Techniques to reduce the volume of warm air extracted and reduce energy losses by evaporation as long as this is safety-compatible are described in Section 4.2.8.2.2.

Where there is a temperature range for a process, the temperature can be controlled to minimise the energy input:

- operating temperature of process solutions that require heating may be reduced,
- processes that require cooling may be operated at higher temperatures.

Heated process tanks can be insulated to reduce heating losses by:

- using double skinned tanks
- using pre-insulated tanks
- applying insulation.

Floating spheres are widely used to insulate the solution surface without restricting the access of workpieces or substrates. They allow jigs, barrels, coils or individual components to pass between them. However, agglomerations and precipitations on the spheres may be a source of contamination of the workpieces. Holes in spheres may encourage liquid transfer between tanks. It is possible to overcome this situation with maintenance and replacement of sets of potentially defective spheres. The use of lids and covers instead of spheres should be examined carefully [175, ESTAL 2024].

Process solutions may be heated by energy coming from process steps generating energy. Water from the cooling circuit of various process solutions may be used to heat lower temperature solutions, incoming air, etc. Alternatively, the hot cooling water is collected in a central tank and cooled through a suitable heat pump. The gain in energy may be used to heat process solutions with process temperatures up to 65 °C, or to heat up water for other purposes.

Achieved environmental benefits
Energy saving.

Cross-media effects
None

Environmental performance and operational data
See Description~~,~~ above.
Seek technical support when changing operating temperatures changes to processes.

Technical considerations relevant to applicability
To all heated solutions.

Reducing the operating temperature of solutions will depend on support from the proprietary process suppliers or in-house expertise in developing solutions or processes that are viable at lower or higher temperature ranges. It may also be a factor in choice of process solution chemistry (see Section 4.9).

Many solutions have a narrow operating range, and cannot be operated outside of these. Other optimal operating factors may have to be considered, such as processing time.

In anodising, the heat of spent seal solutions can be used to heat the water used for a new sealing process, using a heat exchanger or piping the incoming cold water through the hot seal solution.

In automatic lines, floating spheres may be carried to the rinsing tanks by barrels or by components. The spheres may block pipes and cause malfunctions for pumps and transport tubes. This can be limited to some extent by the choice of size of spheres and installing simple coarse screens to critical pipework and equipment. The spheres can cause tidiness problems in the workplace by being carried outside of the tanks. The system can be used in manual lines, and in automatic plants.

Economics
Applicable to all heated solutions.
Floating spheres are cheap.
Capital investment for sophisticated heat-exchange systems may be high.

Driving force for implementation
Cost saving and process quality control.

Example plants
Exhall Plating Ltd, Coventry, UK; SGI, Plaisir, France, Sikel N.V., Genk, Belgium

Reference literature
[3, CETS, 2002, 18, Tempany, 2002, 165, Tempany, 2004] [85, EIPPCB,] [124, Germany, 2003] [118, ESTAL, 2003] [129, Spain, 2003]. [168, TWG, 2023] [175, ESTAL 2024].

4.2.3.6 Cooling of process solutions

4.2.3.6.1 ~~Water cooling systems~~ Use of passive cooling systems

Description

This includes:

- ambient cooling using outside air in cold weather conditions (e.g. below 7 °C);
- cooling using the thermal capacity of ground water.

Technical description

Once-through cooling systems pass cold water through the cooling system once, and then discharge the water. Water sources are described in Section 4.4.5.1. Open cooling systems recycle the water through an open cooling tower. Closed systems use a secondary system, such as refrigeration, for cooling the recirculating coolant in the primary system. These are described in Section 2.12.1.3 and more information is given in the BREF on industrial cooling systems

Water from once-through cooling systems may be re-used to utilise the heat gained, for instance in rinsing prior to drying. The water may also be used in processes, with treatment as required, see Section 4.4.5.1. Also, water used in the processes for rinsing may be used for cooling prior to discharge.

Achieved environmental benefits

~~Using closed cooling systems saves water.~~

Closed-loop cooling systems reduce water usage by recirculating it, minimising the need for fresh water. This results in less stress on local water resources and lower environmental impact. Additionally, they help to control water quality and reduce contamination risks.

When water is sufficiently available in the surroundings of a plant, once-through cooling systems are beneficial because they reduce energy consumption and hence CO_2 emissions by utilising the natural thermal capacity of water sources. Reusing heated cooling water in processes such as rinsing further improves energy efficiency [175, ESTAL, 2024].

Environmental performance and operational data

~~It is not good practice to use:~~

- ~~discharge cooling water through waste water treatment plant, unless treatment is necessary (such as to remove anti-corrosion additives)~~
- ~~use cooling water to dilute process waste waters.~~

Cross-media effects

There may be energy associated with pumping the water in any system, and increased energy consumption for refrigerated systems.

Once-through systems may deplete limited local resources, may become contaminated by chemicals and the heat content may have an impact on local ecosystems.

Open cooling systems can be the source of legionella infections. Proper design, cleaning maintenance and water treatment combined can generally minimise legionella counts but cannot be expected to eliminate them entirely in every system. Therefore, the location and design of cooling systems must also aim at minimising the distribution and transmission of legionella.

Technical considerations relevant to applicability

Applicability may be limited due to the prevailing climatic conditions.

~~Closed recirculatory systems are widely used. The type of cooling system may be dependent on water availability and local climatic conditions.~~

~~Where water resources locally allow, once-through systems may be used, particularly where the water can be returned to the source.~~

Economics
~~Once-through water systems are only likely to be economic where the cost of the incoming water is very low, including any charges or taxes for extraction, etc. However, they may be cost-effective where the water is re-cycled or re-used elsewhere in the installation, see Section 4.4.5.1.~~ Water used in the processes for rinsing may be used for cooling prior to discharge, although for most situations and if other water saving techniques are in use, there is insufficient water from such sources to provide sufficient cooling.

Driving force for implementation
Closed systems can offer cost savings in water usage for once-through systems and the cost of maintenance of open cooling systems.

Example plants
Sikel N.V., Genk, Belgium, Exhall Plating, Coventry, UK, Industria Galvanica Dalla Torre Ermanno e Figli SpA, Fontane di Villorba, Italy (re-use of heated water).

Reference literature
[18, Tempany, 2002, 85, EIPPCB, , 159, TWG, 2004] [121, France, 2003] [159, TWG, 2004](personal communication, RIZA and Infomil NL).
[168, TWG, 2023], [175, ESTAL, 2024].

4.2.3.6.2 Evaporation

Description
Evaporation is widely used to remove excessive energy from vats by evaporating water from the process solution and maintaining the process temperature at the desired level. It can be optimised by using an air agitation (see Section 4.3.4), an evaporation system or evaporator, and may be used with cascade rinsing systems to conserve materials, minimise discharges, and can assist with closing loops for materials ~~(see Sections 2.7.4, 2.7.5, 4.7.11.2, 4.7.11.3 and 4.16.12)~~.

Achieved environmental benefits
Evaporation combines process cooling with drag-out recovery and usually forms part of any closed loop or zero discharge systems.

Environmental performance and operational data
Normally run as an integrated system with countercurrent rinsing to maximise drag-out recovery and minimise process solution losses and therefore waste treatment. With sufficient countercurrent rinsing stages and/or additional heating in the evaporator, loops can be closed for certain materials.

For electrolytic processes, evaporators have less power input and costs are lower if the processing temperature is as high as necessary to remove any electrolytic energy input by natural evaporation from the solution surface ~~(see Annexes 8.5 and 8.11)~~.

Cross-media effects
May require higher process bath temperatures with increased energy use and/or for drag-out recovery.
May require energy input into the evaporator to evaporate sufficient water.
Condensed water may be re-used.

Technical considerations relevant to applicability
Can be used with solutions running at ambient temperatures.

Economics

Each kWh removed by evaporation is equivalent to 1.4 litres of water which can be balanced by drag-out recovery containing process chemicals and reduced rinse-water. ~~See Annex 8.11 and for example calculations and sites for cost savings.~~

Driving force for implementation
If direct evaporation is used, then no capital investment is required. See Section 4.7.11 for driving for solution recovery and minimum discharge processes.

Example plants
~~Merry Polishing and Plating, Wednesbury, West Midlands, UK, Frost Electroplating Birmingham, UK, most plants in Annex 8.5 use evaporation but plants K and L (Annexes 8.5.8 and 8.5.9) specifically use evaporators.~~
According to the data collection [50, TWG 2019], Plants CZ016, DE022 and FR133 use evaporation.

Reference literature
[3, CETS, 2002, 18, Tempany, 2002, 26, Envirowise, 2003] [104, UBA, 2003] [168, TWG, 2023]

4.2.4 Techniques contributing to decarbonisation

4.2.4.1 Greenhouse gas emissions record

Description
The technique involves drawing up once every year a CO_2 equivalent emissions record which provides a breakdown of the sources and generation such as:

- fossil energy consumption (including electricity from fossil sources);
- raw material used.

The methodology used may follow the EU Emissions Trading System, ISO14064 and/or the GHG protocol.

Technical description
A CO_2 equivalent emissions record measures the plant's carbon footprint by quantifying the total amount of CO_2 equivalent missions produced, whether directly or indirectly. The information provides a basis for understanding and managing climate change impacts and may be used as a business tool.

Achieved environmental benefits
Provides a basis for understanding and managing climate change impacts and may be used as a business tool.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Economics
Additional cost for implementation, data collection and regular updates if not carried out under another legislative framework.

Driving force for implementation
Decarbonisation of the surface treatment of metals and plastics activities.

Example plants

Example plants from the data collection that have successfully implemented this technique are: AT_001, AT_002, DE_054, ES_031, FR_007, IT_002 and IT_010.

Reference literature

[168, TWG, 2023].

4.2.4.2 Use of electricity and heat from fossil-free energy sources

Description

Use of electricity and heat generated from fossil-free energy sources (e.g. hydroelectric, solar, wind, alternative fossil-free fuels).

Technical description

Using electricity/heat from fossil-free energy sources (e.g. for thermal processes, mechanical processes, transport and transfer) on site. Green energy certificates and/or a Guarantee of Origin as specified in Directive 2018/2001 on the promotion of the use of energy from renewable sources (e.g. hydroelectric, solar, wind, alternative fossil-free fuels) can provide information to the operator on the source of the energy supply.

Electricity and heat from fossil-free energy sources may be full or partly purchased on global markets, or may be generated on site (e.g. solar panels, windmills, cogeneration using fossil-free fuels). For more details on the sharing of energy production see Section 4.2.12.

Achieved environmental benefits

- Decarbonisation.
- Prevention or limitation of negative impacts on the environment as a whole, e.g. emissions to air from combustion for thermal processes, water and soil as well as use of resources and waste generation (integrated approach).

Cross-media effects

- Energy generation from fossil-free energy sources may have other environmental impacts such as emissions to air (e.g. dust, SO_X, NO_X) depending on the type of alternative fossil-free fuel used, land use or noise emissions from wind turbines.
- Reinforcement of factory roofs may be necessary to support the weight of solar panels.

Technical considerations relevant to applicability

The applicability may be restricted by the following:

- *Availability of electricity from fossil-free energy sources:* The current energy policy of the European Union promotes decarbonisation of electricity generation. Accordingly, the share of fossil-free electricity in the European electricity mix is expected to rise drastically in the short to medium term. However, there are still significant differences between Member States in terms of the sources of electricity production.
- *Availability of electrical power output:* The use of electricity is dependent on the available electrical power output that can be delivered from the nearby electrical grid in the event that it is not sufficiently generated on site. In some cases, the available power output from the electrical grid may be insufficient to supply the high power input required. In this case, strong power lines as well as transformers are required. Peak load management is important to coordinate the thermal processes with the power of the grid.
- *Availability of heat from fossil-free energy sources:* The sources of fossil-free heat may differ from region to region (e.g. geothermal) and by the availability of alternative fossil-free fuels (e.g. biogas, renewable hydrogen).

Economics

Cost will depend on technical and economic factors. The costs of fossil-free energy in comparison to fossil energy is a key economic factor, with sizeable differences across the EU.

Driving force for implementation

- Reduction of the dependence from fossil energy and the global markets.
- Decarbonisation of the surface treatment of metals and plastics activities.

Example plants

Widely used; 34 plants reported the use of electricity produced exclusively from non-fossil fuels and 28 plants reported on-site photovoltaic energy production.

Reference literature

[168, TWG, 2023].

4.2.4.3 Raw materials with reduced carbon footprint

Description

Sourcing and use of raw materials, e.g. metals, plastics and packagings that are produced and delivered with a reduced carbon footprint.

Technical description

Selection of raw materials that have been produced and transported with a reduced carbon footprint, such as metals and plastics made from recycled or bio-based materials. The raw materials should be transported and stored according to low footprint standards and practices. The need for additional energy input is therefore reduced, as are greenhouse gas emissions.

Achieved environmental benefits

- Reduced greenhouse gas emissions.
- Improved resource conservation by promoting the use of sustainable materials.
- Decreased energy consumption.

Cross-media effects

None reported.

Technical considerations relevant to applicability

Applicability may be restricted by product specifications.

Driving force for implementation

- Green procurement policies.
- Carbon pricing.

Example plants

Plant SE_004 from the data collection.

Reference literature

[168, TWG, 2023]

4.2.4.4 Workspace temperature optimisation

Description

Optimisation of workspace temperature, e.g. lower temperature during winter period and higher during summer period.

Technical description

Installation of temperature control systems for the ventilation and air conditioning to maintain optimal temperatures within a facility. The systems are designed to minimise energy consumption and greenhouse gas emissions.

Achieved environmental benefits

- Reduced energy consumption.
- Decreased greenhouse gas emissions.

Environmental performance and operational data

May vary depending on the specific systems installed and the efficiency of temperature control.

Cross-media effects

None reported.

Technical considerations relevant to applicability

Applicability may be restricted by product specifications.

Economics

Cost savings by reducing energy consumption.

Driving force for implementation

Energy efficiency and green building standards.

Example plants

Plant IT_029 from the data collection.

Reference literature

[168, TWG, 2023]

4.2.4.5 Use of electric vehicles

Description

Use of electric vehicles for on-site material transportation and handling, e.g. forklifts, trucks. Such equipment should be powered by electricity generated from fossil-free energy sources, if available.

Technical description

Installation of charging stations on site to provide clean energy for electric or hybrid vehicles. Additionnaly, on-site solar panels can be used for the charging of vehicles. Electric vehicles are used for on-site (and off-site where possible) transportation and material handling.

Achieved environmental benefits

Reduced energy consumption and greenhouse gas emissions.

Cross-media effects

None reported.

Technical considerations relevant to applicability

Generally applicable, especially for new fleets of vehicles.

Economics

Costs for the replacement of the vehicle fleet.

Driving force for implementation

- Decarbonisation
- Renewable energy targets

Example plants

Example plants from the data collection that have successfully implemented this technique are: AT_006 and FI_005.

Reference literature

[168, TWG, 2023]

4.2.5 Water consumption and waste water discharge

[Note to the TWG: This section corresponds to Section 4.4.5 of the existing BREF. Please provide information to complete the 10-heading template below, e.g. on operational data and technical description]

4.2.5.1 Water management plan and audits

Description

A water management plan is part of the EMS (see Section 4.2.1) and includes:

- flow diagrams of processes and water mass balances of the plant as part of the inventory of inputs and outputs mentioned in Section 4.2.2;
- establishment of water efficiency objectives;
- implementation of water optimisation techniques (e.g. control of water usage, reuse/recycling, detection and repair of leaks).

Audits (also part of the EMS, see Section 4.2.1) are carried out at least once every year to ensure that the objectives of the water management plan are met and the audit recommendations are followed up and implemented.

Technical description

The flow diagrams and mass balances are based on the monitoring data and input/output streams inventory. Guidance on water management plans and audits is provided in ISO 46001 ‘Water efficiency management systems – Requirements with guidance for use’.

Achieved environmental benefits

Reduction of water consumption and waste water discharge, including reduced leaks, spillages and emissions to soil and groundwater.

Environmental performance and operational data

Cross-media effects

None identified.

Technical considerations relevant to applicability

The level of detail and the degree of formalisation of the water management plan and audits will generally be related to the nature, scale and complexity of the ~~installation~~ plant.

Economics

- Staff time.
- Cost of any metering required.

Driving force for implementation

- Legal requirements.
- Reducing cost depending on the pricing and availability of water.

Example plants

Widely used.

Reference literature
[168, TWG, 2023]

~~4.2.5.2~~ Use of general water-saving techniques ~~Minimisation of water consumption~~

[Note to the TWG: This section corresponds to Section 4.4.5 of the existing BREF. Please provide information to complete the 10-heading template below, e.g. on operational data and technical description]

Description
This includes techniques such as:

- automatic valves to prevent leaks;
- use of high-pressure water cleaning systems;
- recycling/reuse of spent process water;
- advanced process monitoring and control systems;
- automatic systems for the preparation and dosing of process chemicals;
- process line optimisation.

Achieved environmental benefits
Reduction of water consumption and waste water discharge.

Environmental performance and operational data

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Economics
This depends on the particular individual measure/task, but minimising water consumption in general leads to reduced fresh water costs.

Driving force for implementation

- Legal requirements.
- Reduction of water costs.

Example plants
Widely used.

Reference literature
[168, TWG, 2023]

4.2.5.3 Segregation of ~~polluted and unpolluted~~ waste water streams

[Note to the TWG: Please provide information to complete the 10-heading template below, e.g. on operational data and economics]

Description
Water streams (e.g. surface run-off water, process water, cleaning water) are collected separately, based on the pollutant content and on the required treatment techniques. Water

streams that can be recycled without treatment are segregated (e.g. cooling water) from water streams that require treatment.

Technical description

A detailed technical description of a water collection and segregation system can be found in the CWW BREF [87, COM 2016].

Achieved environmental benefits

Reduction of water consumption and waste water discharge.

Environmental performance and operational data

Cross-media effects

None.

Technical considerations relevant to applicability

Applicability to existing plants may be limited by the layout of the water collection system.

Economics

Driving force for implementation

- Legal requirements.
- Reducing cost depending on the pricing and availability of water.

Example plants

Widely used.

Reference literature

[168, TWG, 2023]

4.2.5.4 Water reuse and/or recycling~~Water supply, treatment and recycling/re-use~~

[Note to the TWG: Please provide information to complete the 10-heading template below, e.g. on operational data and economics]

Description

Water streams (e.g. process water, effluents from wet scrubbing and spray drying, cooling water, cleaning water) are reused and/or recycled in closed or semi-closed circuits, if necessary after treatment (see Section 4.2.10).

This may include:

- recirculating rinsing water from etching and surface treatment to treatment vats (see Sections 4.3.2.2.2 and 4.3.3.4.3);
- reusing purified water from evaporation;
- returning the rinsing water from the first rinse to the process solution;
- recycling of degreasing solutions for pH adjustment in rinsing;
- use of spent treatment solutions with high acidity or alkalinity for on-site physico-chemical waste water neutralisation;
- use of etching solution from the main etching tank for pre-etching.

Technical description

Water is commonly from the municipal supply, although it may also come from boreholes or surface waters such as rivers or lakes, depending on local resources and regulations. The types of processes and customer specifications will require a minimum quality of water used.

Water may also be re-used from cooling, rinsing or after waste water treatment, see Section 4.2.6.8.8.

It is important when considering the re-use/recycling of water to have an overall approach for the installation that considers the saving of water and raw materials, as well as waste water treatment, see Section 4.2.6.8 ~~(particularly Sections 4.2.6.8.8, 4.2.6.8.11, 4.2.6.8.12 and 4.2.6.8.13) and Section 4.3.5~~. Options may include combining compatible streams from different processes for purification/recovery. This could include use of single fixed location recovery systems (e.g., centralized reverse osmosis/ion exchange for recycling rinse-waters from several process lines). Combined strategies may be more cost-effective, due to economy of scale, unless there are substantially increased plant interface requirements. Point source systems may offer more flexibility, redundancy, and reliability.

For basic uses such as cooling and floor and plant cleaning, only the suspended and/or (total dissolved solids - TDS) content may be of importance and recycled water may be adequate; but depending on the source, filtering may be required. For many process solutions and rinses, water similar in quality to drinking water is satisfactory, again possibly with filtering. For high quality work or to improve process and product quality water sources will require treatment to lower TDS to demineralised or deionised water quality:

- where the staining from TDS left from drying is critical, such as decorative finishes or printed circuit boards, or
- where there is interference in the process, such as anodising annealing.

Where incoming water is treated to reduce TDS, it may be more effective to treat and recycle the waste rinse-waters, as the amount of dissolved salts added during the process rinsing may be less than the amount in the incoming water.

Treatment options include (see Section 4.2.6):

- filtration
- deionisation/demineralisation
- ultrafiltration
- reverse osmosis.

The residues of these treatments will contain the retained solids and any saline solutions from regeneration (deionisation/demineralisation). They may be discharged to the treatment plant of the installation or directly to foul sewers, according to local environmental considerations.

Achieved environmental benefits
Reduction of water consumption and waste water discharge.

Technical considerations relevant to applicability
The degree of water reuse and/or recycling is limited by the water mass balance of the plant, the content of impurities and/or the characteristics of the water streams.

Cross-media effects
Increased dissolved salts in waste waters from treatments such as reverse osmosis, deionisation, Use of chemicals in deionisation.

Driving force for implementation

- Legal requirements.
- Reduction of water costs.

Example plants

Widely used.

~~See German plants in Annex 8.5; BGT, Eindhoven, NL.~~

Reference literature

~~[166, RIZA, 2004]~~

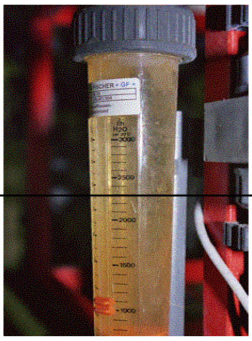
[168, TWG, 2023].

~~4.2.5.5 Control of water usage~~

[Note to the TWG: see new Section 4.2.2.1]

~~**Description**~~

~~Recording all water inputs on an actual basis, irrespective of the source costs enables usage control (including internally treated supplies, see Section 1.1.1.1.1). This is achieved by metering all usage points throughout the installation: on rinses, solution top-up, even in areas such as washrooms, etc. This identifies areas of high water usage for appropriate corrective action.~~



~~*Source :* ***Menoni SA, France and Agence de l'eau Seine-Normandie***~~

Figure 4-5: Example of locking flow valve

~~The usage can be monitored according to type and major end use on a specified basis, such as monthly, daily, hourly, etc. Inputs can also be benchmarked and optimised against other production measures (see Section 4.1.3.1) such as surface area or tonnage throughput, number of barrels, processing costs, etc. Where consumption is seen to be higher than external and/or internal benchmarks, action can be taken in the areas to examine the cause(s).~~

~~When optimum water usage is established, flow can be maintained at an optimum usage rate level by a variety of measures controlled by an authorised person, such as:~~

- ~~flow valves- it is good practice to use locking valves~~
- ~~conductivity, pH temperature or other process control measurements- this may be automated, and can also be used to control static fill and dump systems, either manually or automatically (see Section 4.7).~~

~~**Achieved environmental benefits**~~

~~Water consumption in one case has been reduced over seven years by 83 %, from 263636 m^3 to 31818 m^3 per year by installing about 70 water meters (usually 20 – 30 mm). Other installations confirm significant savings can be made.~~

~~**Cross-media effects**~~

~~None reported.~~

~~**Operational data**~~

~~Maximum effect is gained when used in conjunction with locking flow valves set at optimum usage rate and with other monitoring data, such as water usage per flight bar or per square metre treated.~~

~~**Applicability**~~

~~To all installations.~~

~~**Economics**~~

~~Installations with direct raw water abstractions from resources that are fully and continually replenished may not have a financial payback for the investment. Note that reduced water consumption also means reduced water volume discharged, and this may reflect in lower cost for discharge to municipal or third party water treatment plants.~~

~~**Driving force for implementation**~~

~~Rapid payback period where water costs are significant.~~

~~**Example plants**~~

~~Exhall Plating Ltd., Coventry, UK; Frost Electroplating Ltd., Birmingham, UK.~~

~~**Reference literature**~~

~~[18, Tempany, 2002]~~

4.2.5.6 Rinsing optimisation ~~stages using recycled water~~

[Note to the TWG: Please provide information to complete the 10-heading template below, e.g. on operational data and economics]

Description

This includes:

- using multiple rinsing with rinsing water recirculation (see Section 5.3.2);
- using eco-rinse (pre-dip) (see Section 5.3.3); eco-rinse can be combined with other rinse stages to increase the effectiveness of the multiple rinsing system;
- using spray rinsing;
- using vacuum evaporation;
- regenerating and reusing/recycling rinsing water.

Technical description

~~The technique may be regarded as an extension of the integrated treatment system (widely known as the Lancy system).~~ Water from a rinsing stage is re-used in another rinsing stage, where the chemical or physical characteristics acquired in the first stage can be exploited in the second stage without requiring any additional treatment.

As an example, in a nickel electroplating installation water from the rinsing stage after the nickel plating process may be used again in a sequence of several rinsing stages:

1st: after cool electrolytic degreasing, then

2nd: after pickling, and eventually
3rd: after heated chemical pre-degreasing

Achieved environmental benefits
Reduction of water consumption up to 40 %.
Reduction of chemicals used to modify the pH of water after the rinsing stages.
Reduction of chemicals used to neutralise the water before to channel it into the treatment plant.

Environmental performance and operational data
~~The technique applies only to processes free of cyanides. It requires the laying of an appropriate network of pipes and pumps.~~

Cross-media effects
None.

Technical considerations relevant to applicability
~~The technique may apply to new plants. It can be applied to existing plants, depending on local circumstances.~~
Generally applicable.

Economics
~~No data available~~

Driving force for implementation
Saving of water and chemicals.

Example plants
~~Coletto Danilo Srl, Padova, Italy. Industria Galvanica Dalla Torre Ermanno e Figli SpA, Fontane di Villorba, Italy.~~
Widely used.

Reference literature
~~Lancy Laboratories Inc., Zelienople, Pa (US) quoted in Bertorelle E. (1974) – Trattato di Galvanotecnica. 4th Edition, Vol. II, Hoepli Ed. Milano, pp. 693–697.~~
[168, TWG, 2023]

4.2.5.7 Prevention of contamination of surface run-off water

See Section 4.2.1.4.3 on prevention of contamination of surface run-off water.

4.2.5.8 Structuring and management of process areas and raw material storage areas

See Section 4.2.1.4.2 on structuring and management of process areas and raw material storage areas.

4.2.5.9 Drag-in reduction and drag-out reduction

See Section 4.2.6.6 on drag-in reduction. See Section 4.2.6.7 on drag-out reduction.

4.2.5.10 Closing the loop

[Note to the TWG: Please provide information to complete the 10-heading template below, e.g. on operational data and economics]

Description
Closing the loop by applying at process/line level:

- reduction of drag-out;
- optimising rinsing;
- concentrating the returning drag-out or receiving solutions (using, for example, ion exchange, membrane filtration, evaporation).

Technical description
See Section 4.2.6.7 on drag-out reduction. See Section 4.2.5.6 on optimised rinsing. See Section 4.2.10 on treatment techniques.

Achieved environmental benefits
Reduction of consumption.

Environmental performance and operational data

Cross-media effects
None.

Technical considerations relevant to applicability
Applicability may be restricted by the chemical composition of the process water.

Economics

Driving force for implementation
Cost savings.

Example plants

Reference literature
[168, TWG, 2023]

4.2.6 Materials efficiency

4.2.6.1 Installation design, construction and operation

[Note to the TWG: This section corresponds to Section 4.2 of the existing BREF]

4.2.6.1.1 Pollution prevention from unplanned releases – planning, design, construction and other systems

Description
Section 1.4.2 identifies the sector as still having the potential to cause environmental accidents, or unplanned releases. A planned, integrated approach can decrease this, starting with the identification of those aspects of an installation that may have significant impacts on the environment. The identified risks are then tackled by careful design and construction, as well as by management systems that address the prevention, mitigation and management of accidents and emergencies, and the breaches of permit conditions.

Regulatory and/or good practice systems for pollution prevention are in use in some countries, for example, see Reference literature, below. Many installations in the sector have benefited from the introduction of such techniques. The following activities are key examples where these techniques reduce the frequency and impacts of acute and chronic pollution of surface and groundwaters and soil, and make the operations more cost effective:

- routine and non-routine maintenance including maintenance of solutions, see Section 4.2.6.5.
- delivery and storage of raw materials, see Section 2.1.1.
- process control, process and environmental monitoring, see Section 4.2.6.4.

Key issues for delivery and storage of consumable raw materials are identified in Section 2.1.1.2 and environmental or health effects from chemicals are identified in Section 1.4.4. The BREF on emission from the storage of chemicals also discusses these issues [23, EIPPCB, 2002]. In surface treatment activities, the process solutions are usually kept in open tanks with connecting pipework in situations analogous to the storage of chemicals and many of the same techniques can be applied, such as double skinned tanks or contained areas.

Some key aspects of preventing pollution given in the Reference literature are:

- the identification of hazards and pathways
- a simple ranking of hazard potential
- a three step implementation of actions for pollution prevention:
  - primary measures (structural)
    - sufficient plant dimensions
    - selection of sealing materials where chemicals are stored or handled, e.g. for flooring, contained areas
    - stability of the process line and components (including temporary and infrequently used equipment, such as pumps and tanks used for occasional maintenance operations)
  - secondary measures (plant or equipment)
    - containment (or secondary containment) refers to additional protection against storage tank releases over and above the inherent protection provided by the tank container itself (in this sector, the tanks may be for storage or production). There are two major types of secondary containment for leakages, namely those that are part of the tank construction, such as, double tank bottoms (only for aboveground tanks), double skinned and double walled tanks and impervious barriers which are placed upon the soil surface below the tanks
    - correct specification of size and strength of tanks to receive pumped-out liquors (see also stability, in primary measures, above)
    - leak identification systems
  - tertiary measures (management systems)
    - inspections, external experts and internal including regular maintenance emergency plans for potential accidents (see Section 4.2.1.1)
    - test programmes.

The identification of pathways and targets for the environmental effects can determine the choice of site, plant and equipment as well as design and construction of the infrastructure and plant.

Achieved environmental benefits
Particularly useful in minimising contamination of soil and groundwater by routes that are not readily visible and are difficult to identify.

Facilitates site decommissioning.

Minimisation of unplanned chronic and acute discharges to surface waters as well as municipal waste water treatment systems.

Cross-media effects
No adverse implications.

Operational data
Careful planning and design utilising operational experience can make routine operation, maintenance and monitoring easier, cheaper and environmentally safer.

Single skinned tanks within a contained area are as secure as a double skinned tank; and any leakage is easy to find earlier than within a double skinned tank. Containment and capacity are discussed in the Reference literature (below): to fulfil its intended function the contained area must be able to contain an expected spillage or leak and. as an example, the contained or bunded volume is often 110 % of the volume of the largest tank contained within it. The contained area can be a sealed area draining to either a big vat under the process tanks or a floor with a chemical-resistant coat (within raised walls or drains or the floor is sloped to drains). During cleaning or maintenance the contents (of the contained area) may be connected to (or, pumped to) the appropriate waste water stream, but to ensure operational control of any spillages, the connection should be operated under supervision, see Section 4.2.1.1.

Applicability
These measures can be considered for all installations; however they are best implemented at the proposal and initial design and build stages. Many changes can be incorporated in major upgrades, while some improvements can be made to existing installations during normal maintenance periods, although retrospective improvement may be more difficult, and may not be as effective. Various standards and guidance can also form part of longer term planning for plant improvements.

Economics
These are part of the investment costs with initial investments or upgrades. Some techniques may be no-cost options at a new build or upgrade stage. Often costs can be recovered by more efficient working, maintenance, and the avoidance of costs for dealing with accidents and breaches of permit.

Driving force for implementation
Business duty of care and possible liability for any environmental damage arising.

Example plants
Widely used in many countries.

Reference literature
[16, RIZA, 1999, 19, Eurofer, 2003, EIPPCB, 2002 #23, 23, EIPPCB, 2002, 42, SEA, 2001, 81, INRS, 1998]

4.2.6.1.2 Oil-tight trays

Description
Leakage of oil from hydraulic systems to soils, surface and groundwater is prevented through ~~is a specific pollution prevention problem controlled by~~the use of oil-tight trays.

Achieved environmental benefits
~~Environmental benefit is medium, by minimising~~ Minimises the possible release of oil to ~~soil,~~ surface water, groundwater and soil.

Cross-media effects
None.

Environmental performance and operational data

The trays require checking and emptying as part of a maintenance programme.
Significant and/or repeated amounts of oil accumulating indicate maintenance problems with the hydraulic system.

Applicability
Generally applicable in new and existing plants ~~with significant hydraulic systems~~.

Economics
Installation costs for large scale coil plants are EUR 0.001- 0.15/t and operating costs are EUR 0.001- 0.15/t (2003 data).

Driving force for implementation
Efficient, clean and safer working environment (prevents slips by workforce).

Example plants
Many continuous electroplating lines in Europe.

Reference literature
[19, Eurofer, 2003]

4.2.6.1.3 Storage of chemicals

Description
See Section 2.1.1.2, and for more detailed information and the Storage BREF [23, EIPPCB, 2002]. Many other documents also advise on good practice (for examples, see Reference literature, below).

The key issues are to:

- avoid generating free cyanide gas by storing acids and cyanides separately
- store acids and alkalis separately
- reduce the risk of fires by storing flammables and oxidising agents chemicals separately
- reduce the risk of fire by storing in dry conditions, and separately to oxidising agents, chemicals which are spontaneously combustible when damp. Mark the storage area of these chemicals to avoid the use of water in fire-fighting
- avoid the contamination of soil and water environments from spillages and leakages of chemicals
- avoid or prevent the corrosion of storage vessels, pipework, delivery systems and control systems by corrosive chemicals and fumes from their handling.

Achieved environmental benefits
Reduction of unplanned releases to the environment, particularly from fire-fighting.

Cross-media effects
None reported.

Operational data
Requires management of chemicals as they are delivered and used.

Applicability
All sites.

Economics
Construction costs of separate and/or contained storage areas.

Driving force for implementation

Occupational health legislation, EMS and other management systems, Seveso Directive [142, EC, 1996] and water legislation, as well as PARCOM [12, PARCOM, 1992].

Example plants
CROPU S.A., Burgos, Spain

Reference literature
[16, RIZA, 1999, 19, Eurofer, 2003 October, 23, EIPPCB, 2002, VITO, 1998 #20, Agences de l'Eau, 1996 #82, 42, SEA, 2001, 79, Loire-Bretagne, 1985, 81, INRS, 1998]

4.2.6.1.4 Process line type and construction

Description
Process line type is generally prescribed by various factors (see the introduction to Section 2).

The use of horizontal in-line production lines is ideal for PCB production, with the exception of the generation of the primary images and etch resists. These lines often contain modules that can be integrated.

Coils also lend themselves to integrated production lines, on both small and large scale.

In some installations it is possible to produce an encapsulated integrated surface treatment line (see), or integrate the surface treatment into the overall production (see Section).

Achieved environmental benefits
No fugitive air emissions in the installation.
High process control reduces chemical and water usage.

Cross-media effects
None.

Operational data
The precision automatic movement of components and high accuracy plating reduces process time and improves quality.

[140, Atotech, 2003]

Figure 4-6: Encapsulated integrated chromium plating line

Applicability
For new build installation and lines. Most applicable where the parts have a high consistency of shape and size, such as shock absorber (automotive damper) piston rods, PCBs, and coils of steel and aluminium, etc.

Economics
High capital cost.

Driving force for implementation
Improved workplace environment.
Low production labour costs.
High precision and quality.

Example plants
Monroe, ZF-Sachs, Arvin in US and Europe.
Sikel N.V., Genk, Belgium

Reference literature
[122, UBA, 2003]

4.2.6.1.5 Handling of workpieces

4.2.6.1.5.1 Jigging

Description
See Section 2.1.2. The correct jigging, whether using jigs with spring clips to retain the workpieces, or wiring with copper wire, is important for several reasons:

- correct current/area loading in the electrolytic process
- minimising of drag-out, see Section 4.2.6.7
- prevention of loss of workpieces:
    - the dissolving substrates contaminates the process solution
    - reflects badly on customer quality.

Achieved environmental benefits
Optimises metal usage.
Minimises material losses.
Reduces solution maintenance requirements.

Cross-media effects
None.

Operational data
Requires skilled labour.
Can be labour-intensive.

Applicability
All jig plants.

Driving force for implementation
Process quality.

4.2.6.1.6 Maintenance – plant and equipment

Maintenance of all plant and equipment is an essential part of an EMS, see Section 4.2.1.1 viii.

4.2.6.2 Overall process optimisation

4.2.6.2.1 Process line optimisation

Description
Calculating the theoretical inputs and outputs required for selected options, such as those given in Sections 4.2.6.7 and 4.2.6.8 is useful to benchmark the installation's environmental and economical performance. While this can be carried out manually, it is tedious and time consuming. Software modelling tools can be used to help optimise performance of process lines by making recalculations easier and quicker. They can be written for processes by external contractors or in-house, and may be general or bespoke for a specific installation.

One software tool is based on an Excel spreadsheet and has a series of parameters for rack and barrel zinc electroplating. The calculations used in the spreadsheet are the same as, or similar to, the ones quoted in this BREF, and other similar information, including standard financial calculations. ~~An example calculation is given in Annex~~. One data set is held for a 'good practice' plant (the SE2000 model plant) and the other set initially to a UK industry average plant called the 'benchmark'(this is not 'benchmark as used in this BREF, but means the current level of practice).The example given shows the costs of changing from an industry average to a 'good practice' plant using several improvement options described in Chapter 4 of this BREF.

As an example, ~~using the software shown in Annex~~ the difference in a typical zinc and passivation barrel line and one optimised using various BAT techniquesis:

- Typical line: 11500 m^3 water usage per year
- Optimised line: 2951 m^3 water usage per year, a saving of 74 %

The input data for the ‘industry average’(benchmark) plant can be adjusted to an actual plant for benchmarking, or used to examine the effects of various options, such as adding rinsing stages, evaporators, or changing processes, etc.

While the software is set for zinc plating, all the variables, such as chemical make-up type, and all input and output costs can be varied, so the software can be used for other processes, either complete lines such as for copper plating, or to judge the effects of changing one activity.

Achieved environmental benefits
Enables a process line to be optimised theoretically for consumption of water, energy and conservation of raw materials, as well as minimising emissions to water.

Cross-media effects
Enables optimisation of inputs (raw materials and utilities) and emissions to water at the same time.

Operational data
Can use existing data and can be used to benchmark performance as well as plan improvements.

Applicability
For this example, the ‘front-end’(visible page in the software) shows zinc electroplating, but the same calculations can readily be adapted by the user to other surface treatment activities, by entering simple, appropriate data in the model. It can therefore be used for all multistage process lines, or individual sub-processes.

While financial data is shown in GBP this is purely symbolic, all financial data can be entered as if in other currencies for calculation.

The programme does not optimise the whole installation.

Other manual or software packages can be used or built, sometimes for a specific plant, see example, below.

Economics
The software referred to is free of charge.
Trialling options using software can assist with process management and investment decisions before commitment.
As an example, ~~Annex shows~~ a payback time for optimising a zinc and passivation barrel line, (without infrastructure work) = 0.6 years, based on savings in water, raw materials and reject reworking.

Driving force for implementation
Environmental optimisation can optimise the plant’s process and economic performance.

Example plants
A general example ~~is shown in Annex~~ of a non-optimised installation and an installation using various potential BAT techniques agreed with British industry is used as a comparison in the software.

For optimisation by bespoke software, Sikel N.V. Genk, Belgium

Reference literature
[26, Envirowise, 2003]

4.2.6.2.2 Benchmarking

Description

Benchmarking is the systematic recording of inputs (raw materials, energy and water) and outputs (emissions to air, water and as waste), and the regular comparisons of these with previous data for the installation, with its sector, national or regional benchmarks. Appropriate benchmarking requires comparable data – a "like for like" comparison. For surface treatment activities this would be best achieved on a surface area treated basis or other consumption or throughout basis. For instance, kg of zinc used per 10000 m^2 of surface, kg zinc discharged per 10000 m^2 of surface, kWh per 10000 m^2 of surface.

The surface area for stamped or pressed parts, or parts fabricated from the same thickness of substrate can be calculated [145, LeCarre, 2004] as follows:

$$S = \frac{\text{weight (kg)}}{\text{density (kg/m}^3\text{)} \times \text{e (m)}}$$

Where: S = surface area , e = thickness and m = metres

The IED gives a formula for calculating the surface area for the vehicle coating industry and other coated parts made from sheets (note the factor '2x' for coating both sides):

$$\frac{2 \times \text{total weight of product shell}}{\text{average thickness of metal sheet} \times \text{density of metal sheet}}$$

Variables can make such data difficult to acquire accurately: for instance, workpieces have irregular shapes and varying thicknesses so estimations of surface area can vary in accuracy, and thickness of deposited coatings can vary widely [124, Germany, 2003]. However, these difficulties do not prevent the gathering of data to be used as Section 4.1.1(j) describes (see Table 3-5). Designs produced electronically by CAD can also a be a source of deriving areas.

When data is benchmarked in an installation, it is good practice to maintain a system to action the data, including:

- identifying a person or persons responsible for evaluating and taking action on the data
- informing those responsible for plant performance, including alerting operators, rapidly and effectively to variations from normal performance
- other investigations to ascertain why performance has varied or is out of line with external benchmarks.

Examples of benchmarking methods and applications are given below. Where sector, national or regional data is gathered, it can be made public while keeping individual site identities confidential:

Installation

One company electroplating or phosphating complex-shaped parts uses five barrel lines, all with barrels of the same size. Water inputs are metered at every input point. Barrel movements are recorded per flight bar. All data, such as raw material consumption, water and power consumption etc are then related to flight bar movements, and tracked and compared on a regular basis to monitor plant performance and costs.

Sector
In the UK, the Surface Engineering Association conducts a national survey of members to benchmark costs, etc.

Regional
Data envelope analysis (DEA) is a method of analysis that has been developed to compare the efficiency of organisational units when it is difficult to make the inputs or outputs comparable with unambiguous quantities. It can be applied in situations in which there are observations from many relatively homogeneous production units. In this context, homogeneity refers to the inputs and outputs that the units produce. They do not need to be organised in the same way or use the same types of production technology.

An example of DEA applied to surface treatment is given in Data variables from a survey of 15 electroplating companies were analysed in four groups:

- quantity of workpiece/substrate outputs
- labour and capital invested in equipment
- energy and water consumption
- emissions.

The DEA results were calculated using a varying combination of input factors. The efficiency score (productive efficiency) was calculated for inputs in capital and man-hours, water and energy with various outputs to the environment. The only output quantifier was the annual revenue earned by treatment. The data was modelled using linear programming methods with weighting factors.

Examples are also given for steel coil coating in Section 0

Achieved environmental benefits
Assists individual installations to assess their environmental performance with other installations. Assists in identifying techniques used by the best performing installations.
Cross-media effects
None.

Operational data
Provides benchmarks and assessment of operational environmental performance for installations and techniques.

Applicability
Data must be available for several installations with homogeneity of inputs and outputs before an individual installation can be benchmarked. The breadth of data and installations needs to be sufficiently wide to be challenging; for example, [8, Nordic-Council, 2002] benchmarks water usage at 50 litres per m^2. The UK industry median is about 44 litres per m^2 (verbal information from TWG) and the French regulatory maximum is 8 litres per m^2 per rinsing operation which equates to 40 litres per m^2 for a 5-process line) [58, France, 2003].

Weighting factors need to be determined. Knowledge of DEA and its application with linear programming is required. This approach may be useful for a group of companies or a trade association. The technique does not readily take account of cross-media effects.

Economics
DEA may need expert assistance for application.

Optimisation of the plant environmental performance will usually achieve economic optimisation.

Driving force for implementation

Benchmarking is also commensurate with good economic performance. Benchmarking and optimising environmental performance (such as raw material, water and power inputs, as well as material losses) will achieve economic optimisation at the same time.

Example plants

Unnamed examples are given by, [8, Nordic-Council, 2002] Oekepol and Eurofer.
Regional/sector schemes: Ford-BOS (e.g. Frost Electroplating Ltd., Birmingham, UK)
Installations: Exhall Plating Ltd., Coventry, UK e.g. m^3 per barrel line per shift,
Metal Colours Ltd., Slough, UK: e.g. kWh/kg Zn
SIKEL N.V., Genk, Belgium: e.g. efficiency of zinc utilisation (>95 %).

Reference literature

Installation and national sector: [18, Tempany, 2002], [127, Oekopol, 2003],
Regional: [8, Nordic-Council, 2002], [19, Eurofer, 2003]

4.2.6.2.2.1 Benchmarking water consumption

Description

In France, a benchmark value for water usage of 8 l/m^2/rinse stage was introduced in 1985 in legislation applying to all surface treatment installations with a total volume of treatment tanks of more than $10m^3$.

Achieved environmental benefits

This benchmark reduces the water usage and the waste water treatment requirements, prevents dilution of effluents and reduces the flux (weight per day) of materials lost.

Cross-media effects

These depend on the water-reduction techniques used.

Operational data

Once determined, it need only be checked periodically. It is not a routine limit value, and that some key measures to achieve this value, such as number of rinses in a cascade, can only be changed periodically, see Section 4.2.6.8. Other measures can be used to control variables, such as conductivity meters on rinse tanks as well as flow-meters and restrictor valves on each point of water use: these are important factors in achieving the range, and maintaining the values., see Section .

Only the volume of water leaving the plant is measured, therefore avoiding problems with calculating evaporation, added liquid solutions, how much water is recycled, etc. This discharge figure accounts for all water used, except for domestic-type usage (toilets, canteens, etc.).

The values for individual rinsing stages (or the component steps) are not calculated, only the total volume against the total number of rinse stages for the installation. This allows for some rinsing stages to use more water than others, according to operational needs.

There is difficulty in calculating the surface area, see Section 4.2.6.2.1, but in 80 – 90 % of cases the operator knows this for commercial reasons, or can determine this. In some cases, operators can determine and use a surrogate measure; for example, by running the process for a set period using the most geometrically simple components and measuring the water discharged, at the same time measuring another consumption or throughput factor (e.g. power usage, number of jigs or barrels, number or weight of parts, chemicals or anode consumption, etc). The amount of water discharged is then related to this secondary throughput or consumption factor. This secondary factor can subsequently be used to re-check the benchmark value against more geometrically intricate components.

The surface area is the simple geometric wetted surface. It includes all surfaces of the supports moving through the rinses, i.e. barrels (inside and outside surfaces) and jigs.

A stage is all the tanks in one rinsing operation after a process or associated activity. It may be one or multiple tanks, and multiple tanks used in cascade rinsing significantly reduce water usage (as described in Section 4.2.6.8), see Figure 4-7.

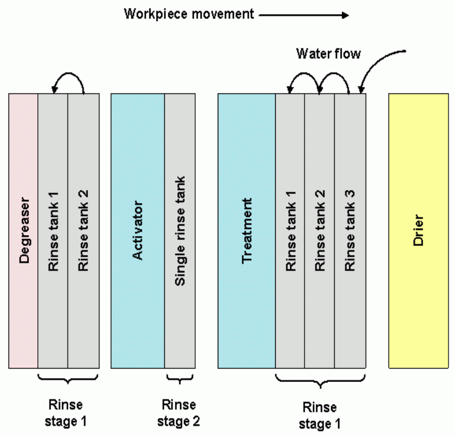


Figure 4-7: Definition of rinse stage

Applicability
This has been successfully used in 80 % of French installations since 1985. Water usage may be higher in very high specification activities such as PCB production (see Section).

Economics
This benchmark can reduce investment costs (particularly for raw water and waste water treatment) and running costs (particularly for raw materials and water).

Driving force for implementation
Reducing water flow through the process is crucial, not only for water saving, but can be used with drag-out controls to reduce raw material usage and increase materials efficiency. This also reduces the size of waste water treatment plant needed and the treatment chemicals and energy used in treatment.

Example plants
80 % of French surface treatment installations.

Reference literature
[58, France, 2003], [121, France, 2003], [165, Tempany, 2004]

4.2.6.3 Protection of workpieces and substrates- before and after treatment

Corrosion can take place on metal substrates prior to surface treatment and on treated surfaces of metals and plastics after surface treatment and prior to dispatch. Corrosion may cause poor adhesion of the surface treatment or damage decorative finishes and therefore require stripping and reworking or scrapping. Corroded products are likely to require additional processing to remove corrosion prior to surface treatment. Corrosion prevention can reduce the environmental impacts associated with stripping and reworking (see Sections 0).

Most metal surfaces oxidise or corrode when exposed to oxygen or other factors in the atmosphere. Corrosion time is dependent on the type of material and the conditions under which the material is stored, for instance, steel components do not corrode in an atmosphere with less than 50 % humidity. Humidity, temperature and acid atmospheres are factors determining how quickly corrosion takes place. All these factors are present in surface treatment installations, so controlling the exposure of stored products is important.

Protection of surfaces from mechanical damage is also important.

4.2.6.3.1 Shortening storage time

[Note to the TWG: this technique is proposed for deletion by CETS (CETS INPUT input in 176, TWG, 2024]), please provide further consideration]

Description
Eliminating or shortening storage between operations, e.g. between manufacture and surface treatment, or between surface treatment and dispatch, can avoid the need for other corrosion prevention treatment. This may be as part of a formal JIT (just in time) system or as part of good production planning.

Achieved environmental benefits
Prevention of stripping and reworking.

Applicability
Most applicable for in-house installations and where transport links are short and frequent. However, this may not be applicable where customers are distant and economic transport batch sizes require storage before and after processing.

Economics
The only foreseen costs are labour costs for planning and supervision of production and delivery timing. Reduced capital and running costs for storage, as well as production costs for stripping and reworking reject products.

Driving force for implementation
See Economics, above.

Example plants
Reference literature
[3, CETS, 2002] [118, ESTAL, 2003].
[176, CETS, 2024]

4.2.6.3.2 Storage and transport conditions

[Note to the TWG: this technique is proposed for deletion by CETS (CETS INPUT input in 176, TWG, 2024]), please provide further consideration]

Description
It is usual to store components both awaiting treatment and treated away from humid and acid air associated with many surface treatment installations. Good ventilation of the workplace will assist, as will ensuring the vented moist, and often acid, exhaust air does not come into contact with products in storage or awaiting transport. Ventilation of the storage areas may also be used provided that it reduces moisture and does not draw in moist and acid air. Moisture condenses

on components which become chilled during transport or storage and are subsequently delivered to a warm, humid location. Keeping products warm in transport and storage in a low humidity environment can eliminate these problems.

Achieved environmental benefits
Reduced stripping and reworking.

Cross-media effects
Increased energy usage for dehumidification or ventilation may be offset by environmental benefits from decreased reworking.

Applicability
All locations. However, detailed application will vary with regional climatic conditions such as normal humidity levels and daily mean temperatures.

Economics
Increased costs of energy usage for dehumidification or ventilation may be offset by savings from reworking. The discounted capital cost of segregating storage may need to be balanced with add-on measures such as improved dehumidification or ventilation.

Driving force for implementation
Economic and environmental savings from reduced stripping and reworking.

Example plants
SIKEL N.V., Genk, Belgium.

Reference literature
[3, CETS, 2002], [176, CETS, 2024]

4.2.6.3.3 Packaging

Description
Workpieces or substrates may be packed with absorbent or corrosion preventing materials such as specialist papers or woodchips. Such materials can both prevent corrosion and prevent surface damage in transit and are often specified by the customer, particularly for high value components, such as printed circuit boards and aerospace components. Coils are usually protected by the outer layers, with a protective strip providing immediate contact with flooring and cradles preventing unwanted movement.

Achieved environmental benefits
Reduced stripping and reworking.

Cross-media effects
Increased consumption of raw materials. This can be offset by selecting and using recyclable packaging systems.

Applicability
Can be considered in all applications, but costs will be limiting for low added value components.

Use of corrosion-preventing packaging may be restricted in the case of high-volume production.

Economics
Increased costs of packaging materials and labour may be offset by savings from reworking.

Driving force for implementation
See Economics, above.

Customer quality requirements.

Example plants
Sikel N.V., Genk, Belgium; Corus, Trostre Works, Llanelli, UK; SGI, Plaisir, France.

Reference literature
Site visits to example plants [176, CETS, 2024].

4.2.6.3.4 Corrosion prevention coating with oil or grease

Description
Oil and/or grease may be used for corrosion prevention during storage. The disadvantage is that items have to be cleaned. When choosing the type of oil or grease, the degree of protection required needs to be considered. However, this must be balanced with Section 4.2.6.3.5, below.

Achieved environmental benefits
Prevention of reworking and scrapping.

Cross-media effects
Increased chemical, energy and water usage to remove oil and/or grease.
Increased disposal to waste water and waste routes.

Operational data
Greases are often used for military applications when components are left in storage for long periods prior to use. The duration of coating becomes significant when cleaning the components at a later date. Long storage times especially during warm weather complicate cleaning.

Pure mineral oils are generally easier to remove compared with emulsions and vegetable-based products. Vegetable-based oils and greases are often promoted as environmentally friendly products, however these can be very difficult to remove especially if the product has been stored during a warm weather period. This may be a more important factor in warmer regions.

Applicability
Suitable in some applications and often associated with minimising tool wear in pressing, etc.

Use of corrosion preventing coating may be restricted in the case of high-volume production.

Economics
The environmental and economic savings from the avoidance of stripping, reworking or scrapping may offset or exceed the costs of avoiding corrosion.

Driving force for implementation
Economics, see above.
Customer requirements.

Reference literature
[3, CETS, 2002], [176, CETS, 2024]

4.2.6.3.5 Minimisation and optimisation of coatings from previous mechanical treatments- oil and grease

Description
Oil or grease is used to minimise tool wear, e.g. pressing sheet steel, drilling or drawing operations, or for corrosion prevention prior to surface treatment and therefore the choice of cleaning method begins early in the production process. Degreasing operations prior to surface treatment can often be simplified by manufacturing and storing components in the correct way

rather than using excessive oil or grease. Some oils used in pressing can be ground into the metal surface and are resistant to cleaning.

Any changes to remove or minimise oily coatings often take place at the mechanical production stage. This may involve discussion with the customer (see Section 4.2.3, Specifications). By changing the production method the use of oil can be minimised or eliminated. Oil usage can be minimised by regularly assessing the application methods, type and quantity of oil used. Oil that is compatible with the subsequent cleaning system should be used. Possibilities for reduction of oil and grease applied in the mechanical production areas are included:

- use of volatile lubricants
- employment of minimal quantity cool lubrication
- dripping off and/or centrifuging the workpieces
- pre-cleaning the workpieces at the point of production
- shortening the storage time, see Section 4.2.6.3.4
- drilling with compressed air cooling
- use of applied plastic film lubricants in pressing.

Achieved environmental benefits
Reduction in degreasing processing requirements including chemicals and energy consumption, as well as wastes produced.

Cross-media effects
Consumption of energy and/or materials for alternative techniques, such as dry lubricant films and air-cooled drilling.
Volatile lubricants contain VOC (volatile organic compounds), which are released to the air.

Operational data
Can be considered for all oiled workpieces/substrates.

Applicability
Case dependent. The use and type of oils and greases can be critically and constructively discussed with all customers.

Economics
Case dependent: one installation quotes savings of EUR 25000 per year in oil applied by one of their customers (year 2000 costs), plus uncosted savings in degreasing chemicals and energy, labour and impacts on process quality.

Driving force for implementation
Subsequent process control improved; reworking reduced.

Example plants
Exhall Plating, Coventry, UK.

Reference literature
[18, Tempany, 2002]; [104, UBA, 2003],[3, CETS, 2002]. [113, Austria, 2003].

4.2.6.4 Process optimisation

4.2.6.4.1 ~~Real time~~ Advanced process monitoring and control systems

Description
The regular monitoring and control of processes by collecting and analysing key process parameters to reach optimal process conditions (e.g. optimal uptake of process chemicals,

electrolytic cleaning with pH control). This is carried out with, for example, on-line automated systems equipped with sensors and controllers and/or sampling and laboratory analysis.

Key process parameters include:

- level, pH, temperature and conductivity of the treatment vats;
- chemical composition of the treatment vats.

Technical description
Digital process control systems collect data and react to maintain predetermined process values in real time.

Environmental performance data
Flexible installations may be less productive and more resource-intensive [176, CETS, 2024].

Achieved environmental benefits
Improved plant efficiency and product quality as well as lowering the emissions.

Cross-media effects
None.

Applicability
Many continuous electroplating lines

Economics
For coil coating, the initial investment is EUR>0.8/t installed with operating and maintenance costs of EUR>0.8/t installed (2003 data).

Driving force for implementation
Process efficiency and quality requirements.

Example plants
CROPU S.A., Burgos, Spain, SIKEL N.V., Genk, Belgium.

Reference literature
[19, Eurofer, 2003], [73, BSTSA,] [176, CETS, 2024]

4.2.6.4.2 Agitation of process solutions

Description
It is good practice for process solutions to be agitated to keep a consistent solution concentration throughout the vat. This replaces depleted solution at the surfaces and prevents the build-up of gas bubbles and contaminants at the workpiece or substrate surface, giving uneven finishes, pitting, etc. In barrel treatments, sufficient agitation is usually achieved by the turning of the barrels and movement of the workpieces within.

Agitation of anodising solutions is essential to maintain a constant temperature in the bath and remove heat from the surface of the aluminium.

The options are:

- compressed air through nozzles
- low pressure air is the standard [175, ESTAl, 2024]
- hydraulic turbulence
- agitation of the workpieces by moving the flight bars or rods by cams or motors

- vibrating anode frame to improve anodes repartition.

The use of compressed air gives high evaporative heat losses, especially when used in conjunction with air extraction, as well as energy consumption by the compressor. However, the energy losses may be negligible when used in very small tanks.

Hydraulic turbulence is by a pumped system with eductor nozzles placed at the bottom of the tank. Although the energy required is greater than that needed for traditional air or cathode rod agitation, the energy loss through evaporation of water in air agitated tanks offsets the higher energy usage of hydraulic turbulence.

Hydraulic agitation with pumps and eductor nozzles may not be suitable for certain workpieces (small parts and delicate jigging). The use of this technology should be assessed according to the workpieces treated [175, ESTAl, 2024].

The positive effect is higher if recycling of rinses is allowed (upgrading of the heated bath by water washing or by the introduction of pre-rinsing over the bath).

Achieved environmental benefits
The energy consumption when using air agitated systems is considerable.

Cross-media effect
Air agitation may create or exacerbate sprays, mists or fumes of airborne particles or droplets. These may contain chemicals harmful in the workplace and/or in the environment, if removed by extraction systems.

Compressors for air agitation may be a source of noise.

Air agitation can be the source of large energy losses.

Operational data
Hydraulic turbulence provides greater agitation than air systems. This results in improved plating quality, reduction of rejects, and optimisation of proprietary additives consumption.

All systems need to be operated at a level that is effective in moving the solution, but does not cause displacement of workpieces from jigs. Displaced parts left in the solution often cause contamination problems.

Applicability
All process tanks requiring agitation.

Driving force for implementation
Costs saved in energy consumption, improved process quality, improved workplace health and safety.

Example plants
Bodycote, Uxbridge, UK (formally West Middlesex Plating)

Reference literature
[3, CETS, 2002], [18, Tempany, 2002] [118, ESTAL, 2003], [176, CETS, 2024]

4.2.6.4.3 Other techniques to optimise raw material usage

[Note to the TWG: This section corresponds to Section 4.8 of the existing BREF]

4.2.6.4.3.1 Control of concentration of process chemicals

Description
Process solutions become increasingly ineffective when the working concentration of certain process chemicals drops below specification. By topping up of the consumed process chemicals the service lifetime of a solution can be extended, see Section 4.2.3. SPC controls are often used and/or other production management systems A key problem remains that some production operators tendency to add more material than is necessary.

Where possible, automated dosing is the best option for accuracy and reliability, and allows regular additions and avoids swings in concentration. This may be actuated on a time, temperature, flowrate, or other control basis, such as pH or rH, etc.
Existing processes can be optimised by suppliers and/or in-house expertise to reduce the concentration of chemicals, particularly those with significant environmental or health effects.

There are two cases to differentiate between:

- Metals: the balance of the metal ions in electroplating is theoretically constant between the amount dissolved from the anode and the amount deposited at the cathode, but this is not true in practice, see Section 1.1.1.1.1. In the electroless deposition of a metal or with the use of inert anodes, the metal ions must be replaced in the solution according to their deposition rate and their drag-out.

- Process chemicals: the concentration of other remaining chemicals in the process solution, such as acids, alkalis, salts, gloss additives/brighteners or buffer substances is reduced automatically by drag out of electrolyte or by degradation in the process.

Achieved environmental benefits
Extension of service life of solutions.

Reduction in over-use of chemicals through uncontrolled additions.
Cross-media effects
None

Operational data
Measurement of key process solution components at preset intervals is necessary to monitor consumption, breakdown rates and additions made.

The consumption of the individual ingredients of the process solutions does not happen uniformly. Selected ingredients which are subject to a higher consumption need to be topped up separately. The selected dosage of components can be problematic where the individual material components are not known to the operator and not always available on the market. Chemical suppliers can assist with advising on control parameters and provide concentrates for topping up. The top up may have to be based on empirical investigations (operational experience) and can often only be automated with difficulty.

Applicability
All process solutions. The top-up of process chemicals to the original composition is general process technology and in practice found everywhere

Economics
Extends working life of most process solutions.
Improved process quality and consistency.

Driving force for implementation
See Economics, above. This is frequently required by customers.

Example plants

All sites visited; for example, SGI, Plaisir, France; Sikel N.V. Genk, Belgium; Corus, Llanelli, UK.

Reference literature
[18, Tempany, 2002], [104, UBA, 2003], [177, TWG, 2020]

4.2.6.4.3.2 Different electrode yields

Description
The simple concept of electrolytic metal deposition is that the concentration of the metal ions in the solution remains constant because the metal anode dissolves at the same rate as deposition. However, in reality, there are frequently different electrode efficiencies at the anode and cathode. A higher anodic yield leads to an increase of the metal ion concentration. This can be found with certain electrolytes, such as nickel and zinc solutions.

There are options for dealing with this problem, which may be used alone or together. Problems are discussed under Applicability, below:

- where solution electrochemistry allows, use insoluble anodes with external dissolution of the metal and controlled solution strength (see introduction to Chapter 2, Electrolytic cells and reactions)
- replace some of the soluble anodes by membrane anodes with an extra current circuit
- special insoluble anodes that allow the concentration of the solution to balanced
- run workpieces or substrates requiring higher thickness coatings
- ‘plating out’ on steel sheet
- removing anodes.

Achieved environmental benefits
Minimisation of energy usage and waste of process metal in drag-over.
Reduction of plating over the required specification thickness.
Reduction in environmental effects from reworking due to problems with over-plating.

Cross-media effects
Additional equipment is required where external dissolution tanks are used, or membrane circuits and/or separately controlled additional circuits.

Use of insoluble anodes requires the use of additional metal salts, which must be produced and transported.

Operational data
All techniques may improve process control, but see Applicability. Use of external make-up tanks or process additions requires increased process quality control and maintenance.

Applicability
Many electrolytic processes, including zinc, can utilise insoluble electrodes and use external make-up tanks, or separate solution additions. An inert anode system with external make up requires additional investment but addresses the problem consistently over time.

Running workpieces or substrates requiring higher thickness coatings and ‘plating out’ on steel sheet, only works with soluble anodes. ‘Current efficiency’ may then become too high. The right balance of specifications for workpieces (i.e. combination of thicker and thinner coating thickness requirements) may not coincide with the need to remove excess dissolved metal, especially for jobbing shops.

Removing anodes: the anodic current density must be considered. This can lead to anode passivation and/or increased electrolytic decomposition of process solution constituents. The reduced current density reduces throughput and takes more time to reduce the process solution metal concentration.

Plating out does not recover anode metal. However, electrolytic selective plating using low current densities can be used to remove unwanted contaminating metals, for example from nickel baths with soluble Ni anodes.

In practice, nickel processes cannot utilise insoluble electrodes (see Section 2.2.1.2)

Membrane anodes are breakable, and it may not be possible to use this technique in sub-contract plating, where the shapes and sizes of parts to be plated vary continuously (and may make contact with and break membranes). Membrane anodes are also limited by current density.

Economics
Investment in an inert anode system with external make-up or using membrane anodes with a separate circuit is usually self-financing through materials saving and improved process quality. Other options are cheaper in the short term, but lack long-term consistency and savings, and if relied on regularly, may give more quality problems (and hence cost) than they resolve.

Driving force for implementation
Process economics.
Process uniformity over time and reduction in reworking.

Example plants
Metal Colours, Slough, UK.; SIKEL N.V. Genk, Belgium.

Reference literature
[18, Tempany, 2002](verbal discussions with TWG members) [60, Hemsley, 2003], [73, BSTSA,]. [119, Eurofer, 2003] [73, BSTSA,], [113, Austria, 2003], [165, Tempany, 2004], [176 CETS 2024].

4.2.6.4.3.3 Switching the polarisation of the electrodes in the electrolytic processes

Description
The polarisation of electrodes in electrolytic degreasing and in electrolytic pickling processes is switched at regular time intervals.

Achieved environmental benefits
Reduction of raw material consumption as the plating efficiency is higher.

Cross-media effects
None.

Applicability
Only applicable in plants with bipolar electrodes.
New and existing coil coating plants with bipolar electrodes.
For jig and barrel plants, the solutions become contaminated by the substrate metals and would require two tanks.
Where the substrate is suitable, e.g. hydrogen production may occur.

Economics
For coil coating, the initial investment is EUR 0.015 to 0.8/t to EUR >0.8/t installed, with maintenance costs of EUR 0.001 to 0.15/t (2003 data).

Driving force for implementation
Process efficiency and product quality.

Example plants
Many continuous coil electroplating lines.

Reference literature
[19, Eurofer, 2003]

4.2.6.5 Process solution maintenance

[Note to the TWG: This section corresponds to Section 4.11 of the existing BREF]

Proper control of bath operating parameters will result in more consistent workpiece/substrate quality as well as longer bath life. This requires determining critical operating parameters and maintaining them within the established acceptable limits [67, IAMS, 2003].

Contaminants which affect the quality of treatment accumulate in process solutions as conversion or decomposition products during processing or drag-in from preceding solutions with the workpieces/substrates. Batch or continuous maintenance and regeneration are therefore necessary especially when the renewing function of drag-out is eliminated through drag-out recovery.

Particularly when carrying out solution maintenance on a batch or ad hoc basis, care must be taken to prevent spillages when pumping concentrated solutions from tank to tank, by ensuring all tanks are properly and evenly supported inside contained areas, pump drips and spillages are collected and pipework is secure.

In principle, there is a difference between electrochemical and chemical process solutions.

Electrochemical procedures with dissolving anodes are based on metal ions migrating to the cathode in the applied electrical field and are reduced to the metal. In electroplating, the workpiece or substrate is connected as a cathode, while the anode usually consists of the metal to be deposited. Within the electrical field ideally the same quantity of metal dissolves from the anode, as it is cathodically deposited, so that the composition of the process solution remains essentially constant. That means that the service life of the process solution of electrochemical processes is theoretically infinite. However in practice the process solutions suffer quality losses by the entry of impurities and formation of interfering substances by different causes, such as:

- introduction of interfering substances from preceding process solutions due to insufficient rinsing
- dissolving of base metal (in particular with acid working process solutions)
- chemical change of the process solutions (reduction of Cr(VI) to Cr(III) with the chromium plating, carbonate formation by reaction of CO_2 from air in alkaline cyanide process solutions)
- higher dissolution of anode metal than separation at the cathode
- decomposition of organic compounds in the process solutions.

In other processes, chemicals are also consumed, such as the reduction of metal ions to metal by chemical reducing agents at activated sites on the basic material in autocatalytic plating, or other chemical reactions take place (such as layer conversion). Metal ions, reducing agents and other chemicals must be added in salt form constantly, so in principle the service life of these solutions is limited.

Because of these degradation processes, the quality of a process solution can deteriorate to the extent that it must be discarded, unless it is possible to keep the quality of the process solutions constant by the application of a regeneration technique, such as those described in this section.

The procedures described this section are not limited exclusively to electrolytes. They include the care of pickling and etching solutions, degreasing solutions, etc. The remarks are limited to the technical description of the individual procedures for avoidance and decrease of environmental nuisance.

The following table shows the most significant disturbing solution pollutants for many processes.

Some are dealt with elsewhere and are cross-referenced:

Table 4-2: Examples of techniques applied for maintenance of process solutions

Process Solution	Disturbing pollutants	Remarks	Maintenance technique
Soak cleaner	Sludge of oil, liquid grease, metal slivers, dirt etc.	Removed from the work	Described in detail in Section 4.2.7.17.2
Pickling of metals	Dissolved metal	Large volumes only	Retardation
Pickling of plastics	Dissolved resin reduced oxidising agent	Balance situation	Reoxidation through ceramic membrane
Desmear of multilayers	Dissolved resin Cr(VI) and O^{4-}		Electrolytic reoxidation
Electrolytic cleaner	Dissolved metal, oil, grease	Use overflow compartment	Skimmer
Cyanide copper	Redundant copper	May be used in an extra tank for cyanide oxidation for waste water treatment and/or Cu recycling. In the plating bath, it will oxidise cyanide to ammonia and carbonate, which are unwanted decomposition products.	Insoluble anodes with individual DC supply
	Decomposition products of organic additives, carbonates		Active carbon treatment Dilution of solution
Acid copper	Redundant copper		Dilution of solution
	Decomposition products of organic additives		Active carbon treatment
Electroless copper	Decomposition products		Feed and bleed
Dull nickel, Watt’s type	Redundant nickel		Membrane anodes with individual DC supply
	By-metals		Selective plating cathode at low current densities
			Electrodialysis can be used to remove breakdown products
Bright nickel, Watt's Type	Redundant nickel		Dilution of solution
	Decomposition products of organic additives		Active carbon treatment Electrodialysis Adsorber resin treatment
	By-metals as Zn, Cu, Fe		Elective plating cathode at low current densities
			Electrodialysis can be used to remove breakdown products
Sulphamate nickel	Decomposition products of surfactants		Active carbon treatment Electrodialysis can be used to remove breakdown products
Electroless nickel for plastics	Orthophosphite, sulphate, sodium palladium		Replace after lifetime Electrodialysis can be used to remove breakdown products
Electroless nickel for metals	Orthophosphite, sulphate, sodium		Replace after lifetime Electrodialysis can be used to remove breakdown products

Bright chromium and hard chromium	Cr(III), by-metals, dissolved from plated items		Static rinse-water recirculated over cation exchanger prior to balance evaporation losses of treatment solution
Alkaline zinc	Carbonates		Crystallisation of carbonate by low temperature treatment, batch and/or continuously
Cyanide Zinc	Redundant zinc		Insoluble anodes
	Decomposition products carbonates		Crystallisation of carbonate by low temperature treatment, batch and/or continuously
Acid Zinc	Redundant zinc		Membrane anodes with individual DC supply
	Decomposition products of organic additives		Active carbon treatment H_2O_2 treatment with lots of air
	By-metal (iron)	Oxidise FeII to insoluble Fe III	High pH H_2O_2 treatment and filter
Zinc-nickel (alkaline)	Carbonates		Crystallisation of carbonate by low temperature
Zinc –iron	Carbonate		Crystallisation of carbonate by low temperature
Passivation	Conversion products of passivated zinc and zinc alloys, sulphate, by-metals		Feed and bleed
Aluminium etching~~pickling~~ Caustic etch recovery	Dissolved aluminium, $Al(OH)_3$		Removal of $Al(OH)_3$ NaOH
Aluminium anodising (sulphuric)	Dissolved aluminium	Usually more economic to replace solutions, and use old solution to neutralise waste waters [113, Austria, 2003]	Retardation (see comments)
Aluminium anodising (chromic acid)	Dissolved aluminium, Cr^{3+}	Filtration not appropriated	Feed and bleed Correct anode-cathode ratio
Electrolytic colouring	Sn^{4+} Aluminium enrichment		Feed and bleed
Inorganic colouring	Drag in of sulphate and phosphate Iron hydroxide	Affects colour	Feed and bleed based on colour Filtration
	Free ferri-ammonium oxalate		Reaction with H_2O_2
Organic colouring	Numerous pollutants		Regeneration difficult
Silver	Decomposition products, potassium carbonate	Based on potassium	Feed and bleed
Static rinses	Metal hydroxides, depending on pH, surfactants and algae		Filtration
Phosphating baths	Metals, pH		adjust metals concentration and pH Filter

4.2.6.5.1 Filtration of process solutions

Description
Particles suspended in electrolytes can generate negative effects on the layer quality (in particular by inclusion of the particles into the layer). The filtration of process solutions is used to remove particles (e.g. splinters or dirt), which were introduced by the workpieces/substrate, anode mud, dust from the air or the insoluble compounds developed during the process (such as metal hydroxides). In order to guarantee a continuous removal of the solids, the filter is operated in a bypass to the process tank.

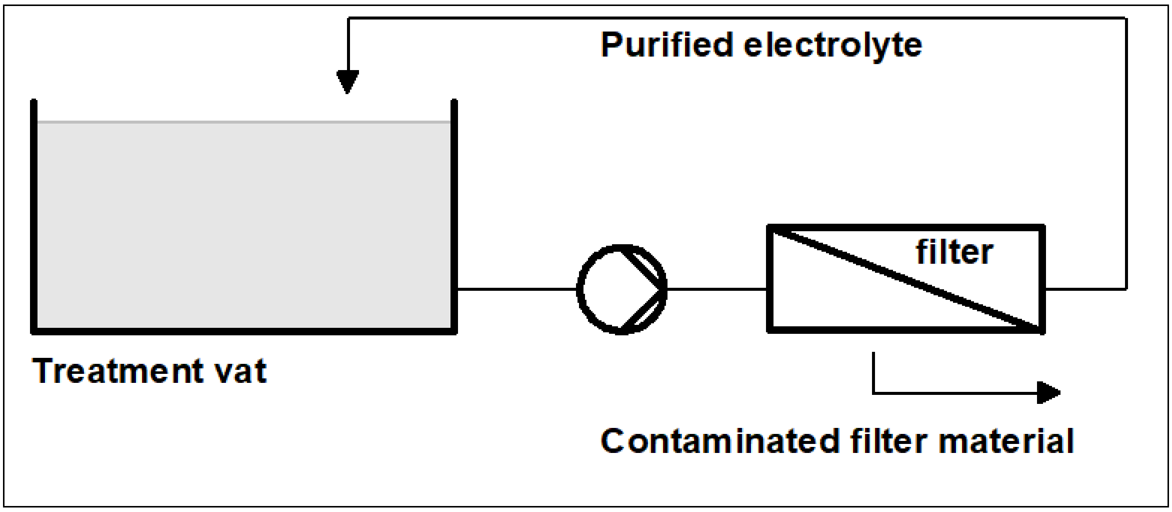


Figure 4-8: Filtration of process solutions

Achieved environmental benefits
Extension of the process solution life.

Cross-media effects
Energy consumption for pumping.

Renewable materials are preferred as a filtration medium, since increased waste results from disposable filters.

Filters which cannot be used any more despite back flushing are usually contaminated with hazardous solution remainders and need to be disposed of as hazardous waste.

Applicability
Many solutions can benefit. The filtration of process solutions in surface treatment is part of the normal practice to extend process solution life.

Economics
The investment required for filtration is small with costs of a few hundred to thousands of euros. They are usually economically viable, as insufficient filtration causes surface quality problems and the process solution must be rejected earlier than it otherwise need be, as well as the cost of reworking reject work.

Driving force for implementation
Reduction in frequency of replacing solution.
See Economics, above.

Example plants
Widely used in many installations.

Reference literature

[104, UBA, 2003].

4.2.6.5.2 Electrodialysis

Description

See also pickling Section 4.2.6.5.14. Maintenance by electrodialysis, for example, removes organic decomposition products from nickel electrolytes and preserves the ductility of the nickel deposits. It is also used to extend the lifetime of electroless nickel plating solutions.

Achieved environmental benefits

Extension of bath quality and lifetime.

Cross-media effects

See Section 4.2.6.5.14.

Operational data

See Section 4.2.6.5.14.

Driving force for implementation

Example plants

Small installation: Siemens AG in Speyer (Germany)
Large installation: Otto Kynast in Quakenbrück (Germany)

Reference literature

[3, CETS, 2002]

4.2.6.5.3 Retardation (acid resin sorption)

Description

Retardation (or acid resin sorption) is an ion exchange separation technique used primarily for the regeneration of acids (e.g. pickling acids and etchants such as in anodising).

A high concentration solution containing metal (or acid salt) is pumped upstream through an ion exchange resin, where the major proportion of the acid anions penetrate into the resin of an anion exchanger while the metal cations are excluded by electrostatic repulsion, and pass through. In the second step, water is pumped downstream through the resin; the acid is set free again. The recovered acid can be re-used. A depletion rate of between 40 and 60 % can be achieved, depending on the type of acid and metal (see figure below).

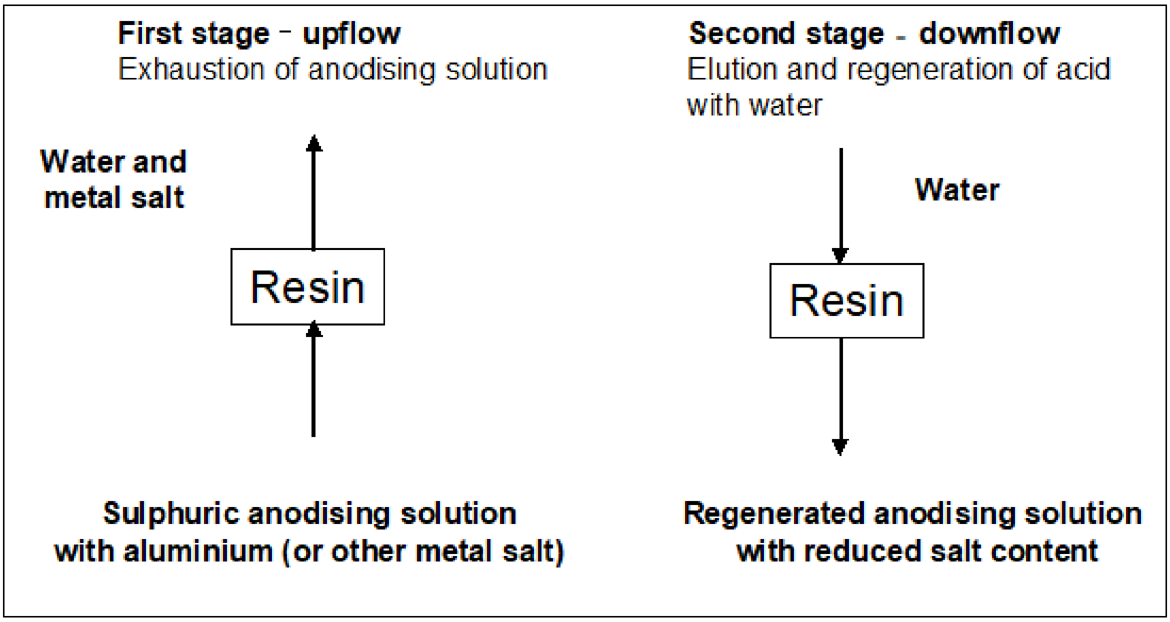


Figure 4-9: Retardation process

Achieved environmental benefits
Recovery of used acids.

Cross-media effects
The acid sorption process recovers only a portion of the free or unused acid. It does not recover any of the combined acid (salt). As a result, approximately 35 to 70 % of the total acid used is incorporated into a waste stream from the process and will require treatment. Depending on the metal involved, treatment will range from conventional neutralisation (pH adjustment with caustic) to metals removal (e.g. precipitation).

Operational data
Not applicable for some highly concentrated acids.

Should not be used on acids with anionic complexes that sorb to the resin, thus reducing acid recovery.

Application-specific temperature limitations should not be exceeded (e.g., approximately 32 °C for nitric acid, and up to 70 °C for sulphuric or hydrochloric acid).

Applicability
Can be used on

- sulphuric acid anodising baths for aluminium
- sulphuric or nitric acid pickling, etching, or brightening baths for copper or brass
- nitric/hydrofluoric acid pickling baths used for processing stainless steel
- phosphoric and/or sulphuric acid baths for stainless steel or aluminium electropolishing
- cation ion exchange acid regenerated solutions
- sulphuric or hydrochloric acid pickling baths for steel and galvanized steel.

Economics
See Section 4.2.6.5.3.1.

Driving force for implementation
Recovery of used acid, particularly to provide a constant acid quality to ensure process stability See Section 4.2.6.5.3.1)

Example plants
See Section 4.2.6.5.3.1.

Reference literature
[3, CETS, 2002, 53, France, 2003, [86, COM, 2022], [162, USEPA, 2000]

4.2.6.5.3.1 Retardation regeneration of sulphuric acid anodising solution

Description
The dissolved aluminium levels in the sulphuric acid anodising operation must be kept low. When the aluminium level in the acid reaches 15- 20 g/l, the anodising bath is decanted or dumped. Continuous purification can eliminate waste and enhance the uniformity of the anodised film.

Operating an anodising bath presents a number of potential problems. There is a delicate balance within an anodising bath between the electrical resistance (caused by the oxide coating being created) the anodising solution conductivity, the applied voltage, and the controlled constant current condition. The electrical resistance increases according to the thickness of the oxide coating and decreases when aluminium concentration rises in the anodising solution. To compensate this increased resistance, the rectified voltage must be increased so that the current remains stable. Other variables such as bath temperature, degree of solution agitation, and sulphuric acid concentration cause a decline in product quality. Maintaining a stable low aluminium concentration removes or lowers a variable affecting the balance between resistance, voltage, and current.
An anodising bath containing 200 g/l H_2SO_4 and 5- 10 g/l Al is passed over an anion exchange resin bed (preferentially upstream) until the sulphuric acid appears in the bed effluent and the whole resin becomes saturated with sulphuric acid.

When the resin is rinsed with demineralised water, the aluminium sulphate which is not absorbed by the resin beads appears first in the eluate, followed by the sulphuric acid, which has to be replaced by demineralised water from inside the resin beads.

Achieved environmental benefits
Extension of process solution life.
The whole pickling solution is recovered.

Cross-media effects
Retardation generates a high volume of waste water.
Alternatively, waste acids can be used in waste water treatment, replacing fresh acids for this purpose. This will depend on waste acid generation and waste water requirements.

Operational data
For optimum performance, it is essential that the acid concentration of the process bath exceeds 10 %.

Applicability
The efficiency of retardation decreases in the following sequence:
$HCl > HNO_3 > HClO_4 > H_2SO_4 > (HF)_n > H_3PO_4 >$ tartaric acid.

Controlling the aluminium concentration and recovery of sulphuric acid for a continued process in the aluminium finishing industry has been carried out for years.

Economics
The cost of a regeneration unit system for sulphuric acid anodising is between EUR 30000 and 60000.

Driving force for implementation

The end result is ensuring a stable, predictable bath operation leading to cost savings and improved product quality.

Example plants

LRB Roulie, Nanterre, France

Reference literature

[53, France, 2003] [121, France, 2003] [3, CETS, 2002, 118, ESTAL, 2003]

4.2.6.5.4 Crystallisation of carbonates and metal sulphates

Description

Cold crystallisation is a technology by which interfering salts can be separated selectively from a process solution. These salts are formed by the dissolving of metals or metal oxides (pickling) or by unwanted reactions (oxidation of cyanide to carbonate). By cooling down a solution to <5 °C, the solubility of most of the salts is reduced. Only certain salts in the selected salt mixture crystallise with the cooling down of a solution, while the remaining salts stay in the solution, see figure below.

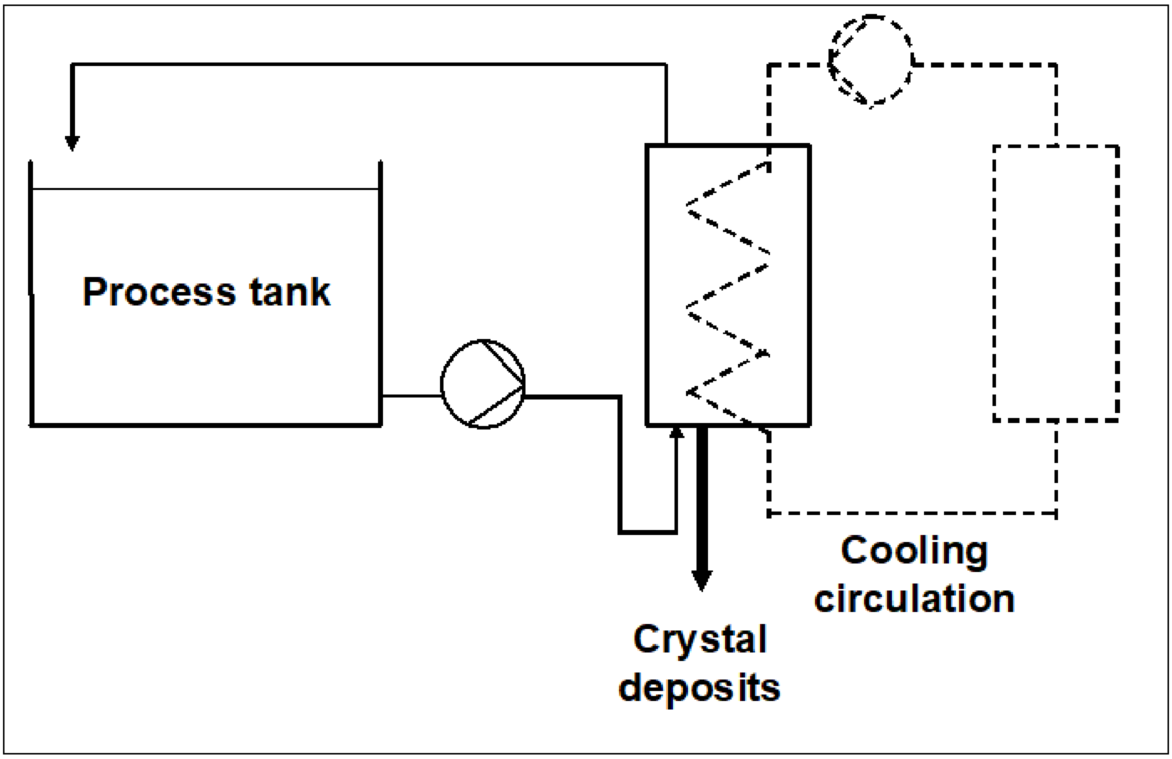


Figure 4-10: Operating principle of cold crystallisation

Simple systems can be utilised, where the solution is pumped to a tank that can be cooled naturally during a winter shut-down period. This also enables other maintenance to be carried such as checking tank liner integrity, removing broken jigs and dropped workpieces.

Achieved environmental benefits

Extension of the process solution life.

Cross-media effects

Additional energy will be required for cooling, where this is applied. This may be necessary in warmer countries.

For anodising, the additional energy requirements for cooling outweigh the benefits from crystallisation.

For cyanide solutions, the precipitated carbonate will contain cyanide.

The wastes produced will require management as hazardous wastes, unless the metal content is sufficiently high for recovery.

Simple pumping out systems increase the risk of spillages.

Operational data
The service lifetime extension attainable by cold crystallisation depends on:

- the type of salts to be frozen out of the electrolyte
- the process of salt formation
- the time necessary for the process.

In many cases, this is carried out in winter, especially during shut down periods, such as Christmas, when the solution can be cooled naturally.

Applicability
Due to the diversity of each application, an individual examination of each case is recommended.

Economics
For electroplating, the investment is in the order of EUR 15000 to 20000 for a cooling system.

Simpler systems using winter temperatures for cooling require only a tank and pump.

Example plants
In Germany, approximately 10 % of installations have this technique installed.

Reference literature
[104, UBA, 2003] [[118, ESTAL, 2003, 124, Germany, 2003]

4.2.6.5.5 Anodising caustic etch recovery

TWG please note that ESTAL proposes to delete this technique considering that it is not proven, not functional and therefore not sustainable

Description
A hot solution of sodium hydroxide creates a decorative matt surface finish by removing a thin layer of aluminium. This etching process is caused by a reaction between the aluminium and caustic soda that produces sodium aluminate and hydrogen gas:

Etching reaction: $2Al + 2NaOH \rightarrow 2NaAlO_2 + 3H_2$ (gas)

The etching process is typically responsible for 80- 90 % of the aluminium in the waste treatment system.

Chemical stabilisers (complexing agents) are added to prevent the aluminium from precipitating out in the etch tank. Water is used to rinse the etching solution off the parts. The rinse-water carries dissolved aluminium and caustic to the plant waste treatment system.

If stabilisers are not used, the sodium aluminate concentration becomes too high and it will hydrolyse to produce alumina trihydrate ($Al_2O_3 (H_2O)_3$), liberating free caustic soda.

Hydrolysis reaction: $2NaAlO_2 + 4H_2O \rightarrow 2NaOH + Al_2O_3(H_2O)_3$

This reaction, known as the Bayer process, is used in the primary aluminium industry to make alumina. If not properly controlled, it leads to an accumulation of a rock-hard aluminium hydroxide scale in the etch tank.
A regeneration system recirculates the etch solution continuously between the etch tank and a separate crystalliser tank, where the etch solution is seeded with alumina crystals in a separate crystalliser tank. It is then possible to regenerate the etch solution without scale building up.

The hydrated alumina crystals formed in the crystalliser settle out in a settlement section. Regenerated etch solution, with reduced aluminium and increased free caustic levels, feeds back to the etch bath directly from the top of the crystalliser. Alumina crystals are withdrawn periodically from the bottom of the crystalliser and dewatered in a vacuum filter.

Achieved environmental benefits
Regeneration can reduce a plant's solid waste by over 80 % while lowering caustic chemical (and neutralisation) costs by over 70 %.

The removed alumina crystals may be used in a variety of alumina substitutes (however, this is dependant on quality, see Cross-media effects, below).

Cross-media effects
In some installations, to achieve a specific quality for specified products, additives may be added to the etching baths which generate impurities in the recovered alumina. The alumina is then impure and is not directly usable.

Operational data
The use of some additives may inhibit precipitation of alumina.
The process is difficult to control.

Applicability
Where the use of additives to achieve a specific surface specification does not interfere with the process or prevents the re-use of the alumina

Economics
Although these systems are relatively expensive to install, larger plants can recover their costs within two or three years.

Driving force for implementation
Economic and waste reduction.

Reference literature
[62, France, 2003, 152, ESTAL, 2004, 165, Tempany, 2004]

4.2.6.5.6 Activated carbon treatment

Description
Activated carbon filtration is an absorption technique (or adsorption, in the case of activated carbon) and used with filtration. Organic decomposition products in electrolytic solutions tend to disturb electrolytic metal deposition or the properties of the metal deposit itself. The major proportion of such products can be extracted from electrolytes through activated carbon treatment. The quantity of active carbon needed depends on the quantity of the products to be removed: up to 10 g/l may be necessary.

Activated carbon is mixed into the electrolyte and removed by filtration after a suitable reaction time. A combination of normal filtration and active carbon cartridges in by-pass is used to continuously remove both solid contaminants and soluble organic decomposition products from the electrolytes.

Achieved environmental benefits
Extension of process solution life.
Theoretically, contaminated activated carbon can be regenerated, but this is usually not economical or has associated limiting cross-media effects.

Cross-media effects
Additional energy in pumping. Used carbon filters may need to be disposed of as hazardous waste.

Operational data
The process is non-specific and also removes active process substances. Compensating additions need to be made to the process solution.

Applicability
The process is widely used, and frequently for bright nickel electrolytes.

Reference literature
[3, CETS, 2002, 104, UBA, 2003]

4.2.6.5.7 Ion exchange purification of metallic contamination

Description
The technique can be used to selectively remove unwanted metal ions (cations) from aqueous solutions and cation exchange resins with special properties, such as resistance to strong oxidants, are used. An example for chromic acid regeneration is shown in the figure below.

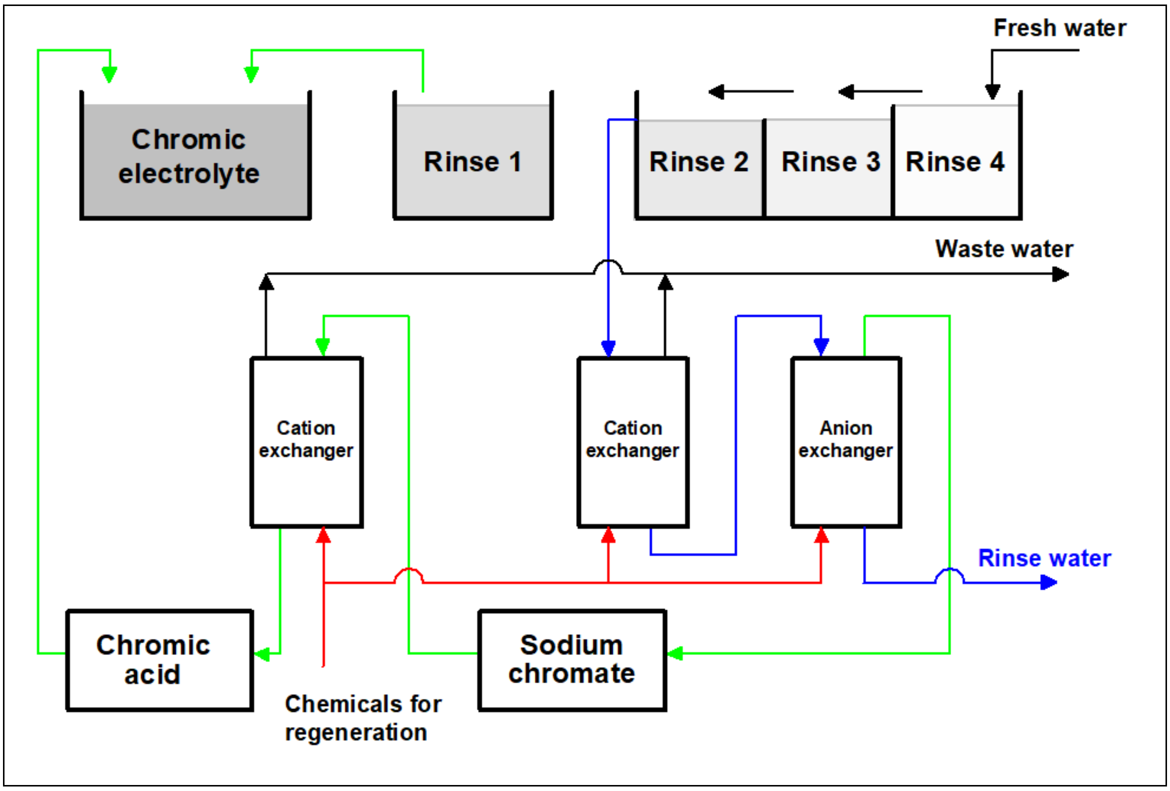


Figure 4-11: Chromic acid electrolyte regeneration by ion exchange

Achieved environmental benefits
Extension of the process solution life.

Cross-media effects
Eluates arising from ion exchange column regeneration have to be treated in waste water plants.

Applicability
This technique is applied in by-pass for the regeneration of process solutions, such as phosphoric acid pickling and chromium plating electrolytes. It is essential when using Cr(III) electrolytes (see Section 2.2.1.3) although control may be more difficult than for other ions. Selection of the correct resin is essential.

Metal pollution in process baths can be removed by using acid cation exchangers, e.g. chromium electrolyte: removal of Fe(III), Cr(III), Ni(II), Cu(II), Zn(II).

Example: Chromic acid passivation after zinc plating. After weeks of working, the bath contains Zn(II) which must be removed to increase the solution life. When the bath contains more than 15 mg/l of zinc it must be changed. Zn(II) can be removed using a cationic ion exchanger.

Economics
The technology is expensive and may not give payback for small installations.
Na_2CrO_4 regeneration from passivation may not be economic.

Driving force for implementation
The technique is easy to integrate into the production process.

Example plants
In a Spanish installation, a cation exchange resin is used to treat a hexavalent chromium solution. The recovered chromium solution is then concentrated in an evaporator and returned to the solution..

Reference literature
[3, CETS, 2002] [120, Finland, 2003] [114, Belgium, 2003] [113, Austria, 2003] [114, Belgium, 2003] [129, Spain, 2003]

4.2.6.5.8 Electrolysis – purification of process solutions

Description
Some metallic contaminants can be removed selectively from electrolytes at low current densities from 0.05 to 0.3 A/dm². The efficiency of this selective cleaning can be enhanced with increased electrolyte throughput.

Achieved environmental benefits
Extension of process solution life.

Cross-media effects

Operational data
Not only unwanted metals, but also unused organic additives can be removed. Therefore electrolytic purification may be reduced to a minimum or compensatory additions of organic process materials may be necessary.

Reference literature
[3, CETS, 2002]

4.2.6.5.9 Electrolysis – removal of surplus metal from process solutions

Description

Metal process solutions where there is a higher anode yield than required in solution (such as zinc and nickel) suffer from increasing metal concentration leading to over-plating. The concentration can be lowered by electrolysis – usually called plating out, see Section 1.1.1.1.1. A typical system for maintaining nickel solution is shown in the figure below, with activated carbon to remove organic contaminants as well as electrolysis.

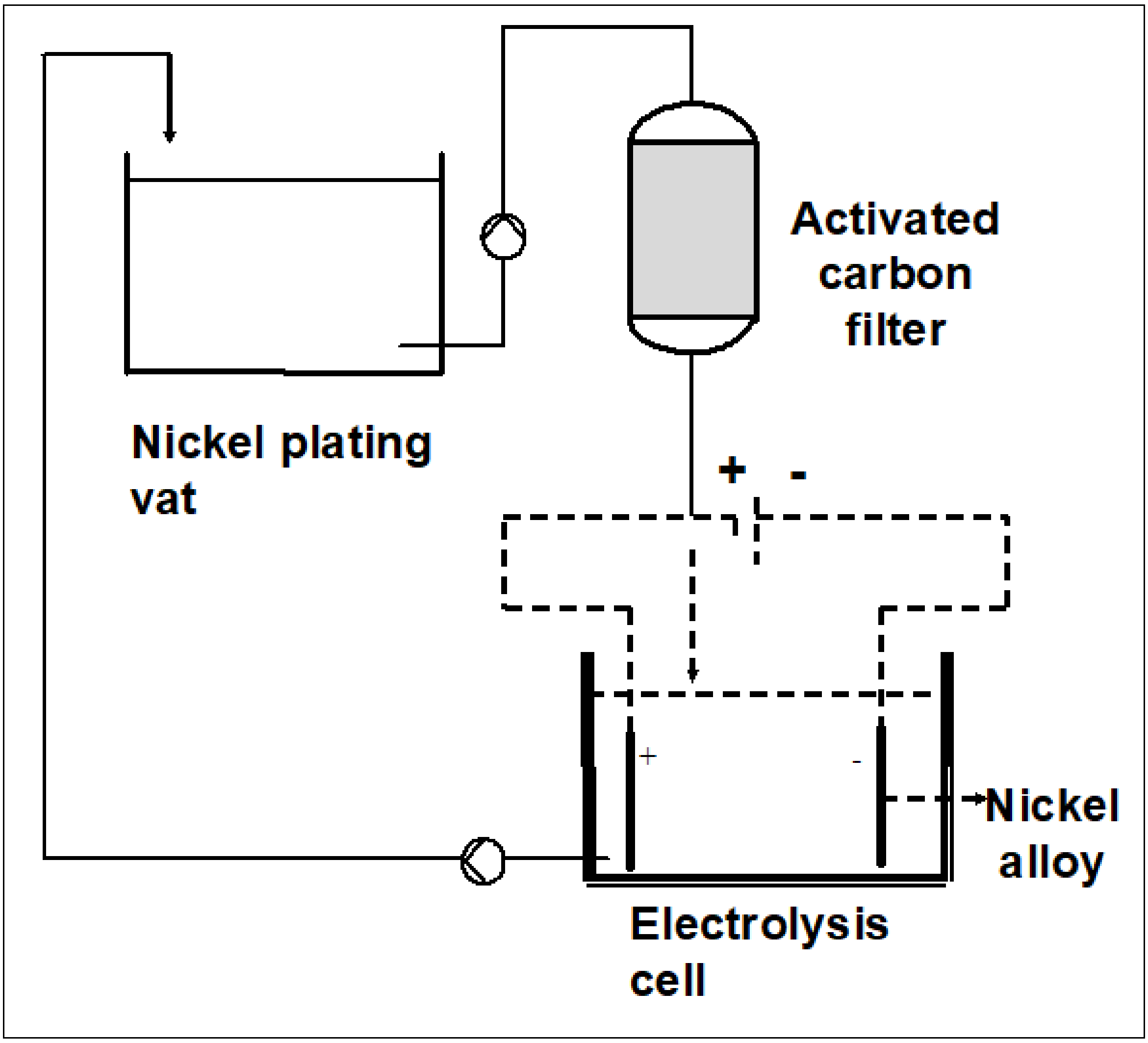


Figure 4-12: Electrolytic removal of surplus and contaminating metals

Achieved environmental benefits

Reduction of reworking.

Minimising dissolved metal drag-over into rinses.

Cross-media effects

Unwanted metal in solution increases dragged-out quantities.

Operational data

High anode yield can be better controlled by using insoluble anodes and external metal dissolution, see Section 4.2.6.4.3.2.

Applicability

Zinc and nickel electroplating with soluble anodes.

Driving force for implementation
Process control and minimisation of reworking.

Reference literature
[104, UBA, 2003]

4.2.6.5.10 Electrolysis – reoxidation of breakdown products

Description
Chromium/sulphuric acid pickling of ABS plastic items oxidises and dissolves the butadiene component of the substrate, simultaneously generating trivalent chromium. Both the organic decomposition product and the trivalent chromium will disturb the process if a tolerable concentration level is exceeded.

It is possible to oxidise trivalent chromium without a membrane but with adequate anodic and cathodic density conditions.

Ceramic membrane electrolysis is the more reliable means to continuously regenerate process solutions.

Achieved environmental benefits
Extension of the process solution life.

Applicability
Chromium/sulphuric acid pickling of ABS plastic items.

Driving force for implementation
Product and process quality.

Reference literature
[3, CETS, 2002] [129, Spain, 2003]

4.2.6.5.11 Membrane electrolysis for chromium solution maintenance

Description
Membrane electrolysis uses one or more ion-selective membranes to separate electrolyte solutions within an electrolysis cell. The membranes are ion-permeable and selective. Cation membranes pass cations such as Cu and Al, but reject anions. Anion membranes pass anions, such as sulphates and chlorides, but reject cations.

Membrane electrolysis can regenerate process solutions through two primary mechanisms:

> (1) Selective transfer of ions from the process solution, across the membrane, into an electrolyte solution and
> (2) Regenerating oxidation states/ionic forms of key constituents in the process solution through electrode electrochemical reactions.

A common configuration for removing cation contaminants from surface finishing process solutions uses a cation specific membrane coupled with a two-cell compartment drawing an electrical potential applied across the membrane. One cell contains an anode with the anolyte solution; the other contains a cathode with the catholyte solution.

The anolyte solution is typically the spent process solution requiring regeneration. Contaminant cations are removed from the anolyte solution and transferred into the catholyte solution. Anode and cathode reactions occur based on the relative electro-negativity and concentration of specific ions in each solution, as water decomposes.

An electrolytic cell technique with fluidised bed technology and used in conjunction with semi-permeable membranes extends the life of a hexavalent solution by 300 to 400 %.

Achieved environmental benefits
Reduces chemical usage.
Extends solution life.

Cross-media effects
Low power consumption.
Hazardous fumes may be emitted depending on solution (see Operational data, below).

Operational data
The membrane life depends on the conditions but can be more than a year.

Limitations of membrane electrolysis:

- special materials of construction and cell configurations may be required for processing
- highly corrosive fluids
- fume collection and treatment may be required if hazardous gases are generated in electrode reactions
- anionic metal complexes require pretreatment prior to removal across a cation exchange membrane
- operating temperatures are typically limited from 15°c to 60°c
- oil, grease and solvents can adversely affect membranes
- suspended solids and precipitates can clog membranes.

Membrane electrolysis systems can be configured as multi-cell systems to enhance capacity. Three compartment cells are used for special applications where the electrodes must be isolated from the feed stream. A range of selective and custom-made electrodes are available for removal of special and noble metals.

Applicability
Membrane electrolysis has been used with chromic acid based solutions, including chromium plating, chromic acid anodising, etchants and chromating solutions. Trivalent chromium can be beneficially deoxidised at anodes to hexavalent chrome. Contaminant metals are transported into the catholyte. Membrane electrolysis has also been applied to various acid-based etchants, stripping and pickling solutions to remove contaminant metals. Multi-cell systems with special anolyte and/or catholyte solutions have been used with highly corrosive acids, such as nitric and hydrofluoric, to isolate the electrodes. Membrane electrolysis can be used on a batch or continuous basis, and is often configured as a mobile unit for smaller point source applications.

Economics
Typical plant costs are EUR 15000 for the unit with annual operating costs of EUR 300.

Driving force for implementation
Materials and cost saving.
Process and quality reliability.

Example plants
BAe Systems plc, Balderstone, Lancs, UK

Reference literature
[110, BEWT, 2003]

4.2.6.5.12 Cleaning and regeneration of phosphate solutions

Description

See Section 2.4.8.9.
Spent phosphate solution is filtered; the concentrations in metallic ions and the pH are adjusted. The regenerated phosphate solution is re-used.

Achieved environmental benefits

Environmental benefit is high. Reduces the consumption of chemicals, reduces water and sludge releases.

Cross-media effects

None.

Applicability

New and existing plant, provided space is available.

Economics

Investment costs are EUR 0.015 to 0.8/t installed and operating costs are EUR 0.001 to 0.15/t (2003 data).

Driving force for implementation

Process efficiency primarily.

Example plants

In several continuous electroplating lines in EU-15.

Reference literature

[19, Eurofer, 2003]

4.2.6.5.13 Maintenance of degreasing solutions

Table belowsummarises the techniques described in this section that may be used to maintain and extend the lives of degreasing solutions.

Table 4-3: Techniques for degreasing solution maintenance

Technique	Uses and comments
Simple methods:	Low cost for low volumes, widely applicable
Filtration with cellulose filters	
Mechanical separation	Higher cost, but still widely applicable.
Gravity separation	
Breaking emulsion by chemical addition	
Static separator	Reduction in COD of effluent up to 50 % Extends solution life 50- 70 % Simple in use and monitoring High cost: only applicable to high volumes of oil
Biological degreasing/regeneration	Used for weak alkali and/or unstable emulsions. Cheap and effective. May not work for all oils/greases.
Centrifuging degreasing baths	98 % removal of oil Low servicing Use in restricted space High cost: only applicable to high volumes of oil

Membrane filtration	COD load in effluent reduced 30- 70 % Up to 10-fold increase in bath life High cost: only applicable to high volumes of oil
Multistage	Cost varies according to options combined
Electrolytic degreasing	Any of the same techniques as above
Cascading or re-using	Re-use or cascade the electrolytic cleaner to the soak clean vat.

4.2.6.5.13.1 Cascade (multiple) use of degreasing solutions

Description
One technique for extending the working life of degreasing solutions is to re-use the solution, or use it in a cascade fashion. The solution from the electrolytic degreasing section is re-used once a certain oil level is reached, either in the spray section of coil lines, or in the first degreasing section of other lines. The spent degreasing solution of the spray section can be regenerated.

Achieved environmental benefits
Significant reduction in electrolytes and water consumptions within the processes and hence a reduction in the quantity of waste water volumes.

Applicability
New and existing plant, provided space is available.
Not applicable where specific solutions are used for the electrochemical degreasing (e.g. highly alkaline with high conductivity) and the precleaning (e.g. good oil solubility).

Economics
For coil systems, investments costs are EUR 0.015 to 0.8/t installed and operating costs are EUR 0.001 to 0.15/t (2003 data).

Driving force for implementation
Process efficiency primarily.

Example plants
In several continuous electroplating lines in the EU~~-15~~

Reference literature
[19, Eurofer, 2003]

4.2.6.5.13.2 Simple methods

Descriptions of typical simple methods
Simple filtration with cellulose filters~~, see Section~~.

Mechanical separation by skimmers.

Gravity oil separators working in by-pass separate oil/grease by allowing agglomeration of small droplets of oil to larger globules which float to the surface and are then removed. This may be enhanced by dissolved air flotation.

Separating emulsified oil by breaking down the emulsion. The easiest route is by chemical addition which splits the wetting agent system and releases the oil, at the same time destroying the degreasing effect.

Achieved environmental benefits
All methods remove oil and extend the working life of degreasing solutions.

Cross-media effects
Energy consumption for skimmers and for dissolved air flotation.
Chemicals used for demulsifying.
Cellulose filters have to be discarded periodically, increasing waste.

Environmental performance and operational data
Gravity separation is the lowest maintenance system.
Cellulose filter: retains particles but not oils and fats.

Applicability
Applicable to all degreasing solutions, depending on solution life, and investment costs.

Economics
Mechanical separation by skimmers is the simplest and cheapest method of removing floating oil from the cleaner surface.

Driving force for implementation
Improved cleaning results in improved performance and reliability of subsequent surface treatments. This in turn decreases rejects and reworking.

Reference literature
[129, Spain, 2003], [176, CETS, 2024]

4.2.6.5.13.3 Static separator for degreasing baths

Description
Using a static separator (where the used degreasing bath is pumped by batch or continuously) is a simple technique to increase the bath life, although baths may need active ingredients adjusting to keep their efficiency. Physical separation by the difference in density between two phases allows the separation of the oil-water mixture. This separation is made by natural decantation of the separated oil in a separate tank off-line or by a mechanical system using a scraper or oleophilic drum or belt skimmers on the surface.

Achieved environmental benefits
Large fall of the COD in the effluents, by 50 % in some cases.

Significant reduction in dumping of used solutions: in most cases reduction of between 50 and 70 %.

Reduction of detergent purchases by 50 %.

Cross-media effects
This process is less selective and also less expensive than techniques using membranes. The recuperated oils are usually polluted and therefore destroyed.

There is only elimination of the floating layer, with just a small fraction of the emulsions discarded.

Operational data
This technique is very simple (there is no membrane). Monitoring is very simple.

The pollution in the degreasing bath is maintained at a constant low level, reducing the level of drag-out and minimising the use and pollution of rinsing water.

Eliminates the floating oils which represent the main pollution of a bath.

Decreases problems with waste water treatment by decreasing flocs and sludges coming from hydrocarbons, and batch discharge of high pHs.

Very fine dispersions (emulsions, micro emulsions, COD) and soluble oils are not readily separated. The polluted species concentration will increase in the bath and it will be necessary to discard the solution or make additions of surface active agent.

Applicability
Best used with weak emulsion degreasing solutions.

Economics
This is an inexpensive technology, depending on the size and sophistication of the technique applied. At its most basic, it will comprise a separate tank, with pump, and pipework. Costs can be up to EUR 50000 for a more complex system (2003 data).

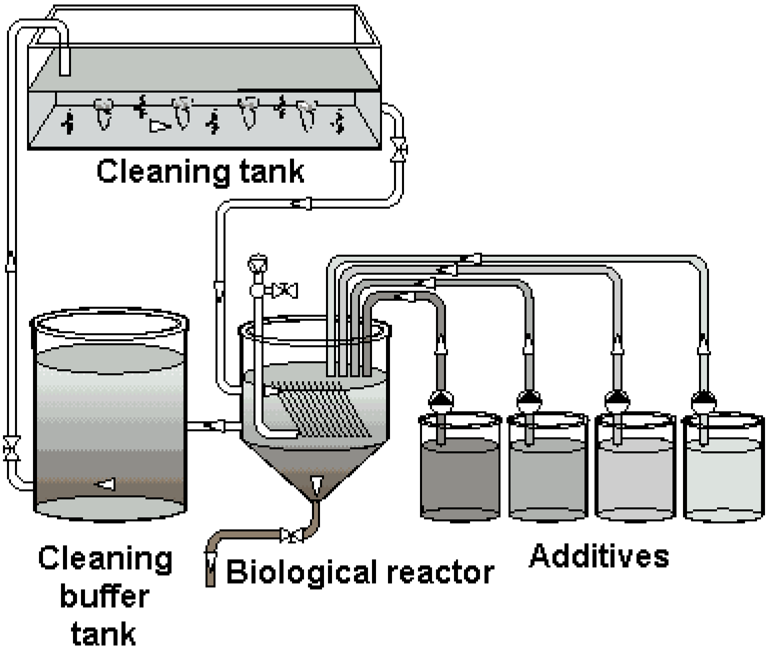
Driving force for implementation
High throughput through degreasing process.
Strong demand for high quality and consistent degreasing.
High cost of rejection and reworking.

Example plants
In France: Berezecki (Beauvais), Kerbério (Gretz Armainvilliers), Berthollet (Montreuil)

Reference literature
[57, France, 2003]

4.2.6.5.13.4 Biological degreasing regeneration

Description
Although often referred to as a degreasing system, it is a maintenance system for weak alkali degreasing baths. Its constant bypass regeneration of the bath by degrading the oil biologically overcomes the limitation of the weak alkali bath: the accelerated exhaustion of its dissolution capacity compared with strong alkali/stable emulsion systems. A typical layout is shown in the following figure, although simple systems with manual additional of additives also work well.



[3, CETS, 2002]

Figure 4-13: Biological aqueous degreasing process

Workpieces/substrates are placed in the process solution consisting of mildly alkaline emulsifying cleaners. In this case, the operating temperature is lower (approximately 45 °C). The ingredients include a surfactant to lift and emulsify dirt and oil from the surfaces, naturally occurring micro-organisms to degrade the oils to carbon dioxide and water, and nutrients for the micro-organisms. Air is bubbled into the solution at a low rate to ensure the system stays aerobic. The solution is continuously circulated through a side tank, containing the micro-organisms, where additions of nutrients and other process chemicals are made and the solution continuously regenerates itself, with the occasional removal of small amounts of sludge from the side tank.

There are several variants of this general type of biological degreasing process. In some applications, the degreasing bath itself is used as a bioreactor and the workpieces to be degreased are immersed into this solution-containing biomass. It can be operated as a two-stage process with normal alkaline aqueous degreasing as a pre-degreasing stage followed by a combined biological degreasing/rinsing stage where the bath itself is also the bioreactor.

Achieved environmental benefits
Runs at more neutral pH, with lower operating temperatures of around 45 °.
Reduced use of process chemicals as the solution rarely needs replacement.
Reduction in use of hazardous chemicals in the workplace.
Reduced usage of neutralising chemicals when discharging used process solution and lower impact of surfactants on effluent treatment.
Lower evaporation losses therefore less need to extract water vapour.

Cross-media effects
Possible growth of legionella bacteria and regular testing may be required.

Operational data
Reduces downtime of production line to replace spent solutions.

Ensures consistent quality of degreasing versus changing quality of chemical degreasing with a short service life
Some operators report the process may not be suitable for all oils and greases (possible problems with oils containing sulphur compounds).

In some applications, the biomass in the degreasing solution can be partially carried over into the following process stages, causing quality problems to the following surface treatments. Processes which combine a bioreactor with membrane separation are currently under investigation to overcome the problem of the limited efficiency of lamella separators [124, Germany, 2003].

The biological system can break down if only small amounts of biotoxic substances like cyanide, copper, AOX, etc. are dragged into the solution. The system does not work with some polishing pastes, which may also be biotoxic.

The right choice of surfactants is important. They need to be – at least partially – resistant against microbial degradation.

The system requires a continuous supply of oil, or extra feeding if downtime is more than three days.

The system does not give good cleaning quality if soaking in high temperatures is needed (for example, with polished pieces).

Applicability

See Operational data, above. It is advisable to test all the likely applications (types of work piece, types of oil/grease coating etc) before using on a full scale. Sufficient installations are using this technique commercially for it to be considered.

Economics
One operator reports chemical savings of EUR 6000 – 7000 per year (2002) on two 50 kg barrel lines.

Another operator reported chemical savings of EUR 3400 per electroplating line first year savings and EUR 3800 per year per line thereafter (1999).

A medium sized contract electroplating company reported a 15- 25 % reduction of specific treatment costs for the degreasing/rinsing/pickling stage when substituting a conventional aqueous hot alkaline degreasing process by a biological degreasing process.

None of these figures include savings in water, energy, labour in reduced solution make-up time, increased efficiency (line downtime) and improved process performance (with less rejects).

Driving force for implementation
Reduces process line downtime for degreasing solutions to be changed.
Reduces the amounts of hazardous chemicals in use in the workplace (replaces strong caustic and surface active solutions).
Reduces sludges from the waste water treatment from cleaning by 80 %.
Reduced costs.

Example plants
Dundee Electroplating Ltd, Dundee, UK; Exhall Plating Ltd, Coventry, UK; Merrydale Industries Ltd, Wednesbury, UK; Metal Colours Ltd, Slough, UK, Sessler Galvanotechnics, GmbH, Germany, See Annex 7.1

Reference literature
[18, Tempany, 2002, 31, Biowise, 2001] [124, Germany, 2003] [115, CETS, 2003] [113, Austria, 2003]German Federal Ministry of Education and Research report 01RW0189

4.2.6.5.13.5 Centrifuging of degreasing baths

Description
Centrifuging cleans the degreasing baths by separating oils. The polluted degreasing solution is pumped to a centrifugal separator. The oil is removed and collected for recovery separately to the solids and sludge produced. The clean degreasing solution is then returned to the degreasing bath.

Achieved environmental benefits
This process reduces the discarding of used baths contaminated with oil and solids.
The pollution in the degreasing bath is maintained at a constant low level, reducing the level of drag-out and minimising the use and pollution of rinsing water.

Oil is recovered and concentrated at the output of the separator for possible recovery.
Sludges are collected separately.

Reduction of the draining frequencies (between 30 and 80 %) according to the size, the production and many other parameters relative to the installation, with less heating and downtime required.

There is no loss of surface active agent.

Cross-media effects
Electrical power for pumping and operating the centrifuge.

Operational data
The bath purification is higher than 98 %. According to a supplier, the residual oil concentration is less than 2.5 g/l.

Drag-out is reduced; the following rinsings are less polluted so the treatment quality increases.

Limited servicing and maintenance (once every 2000 hours for automatic machines).

Centrifuging makes it possible to eliminate a large amount of oil in a restricted space.

The machines used can be mobile and can be used to treat baths of different origins.

It is very useful when the sedimentation speed of particles is very low.

Manual machines are sensitive to fouling by sludges and must be reserved for baths with a relatively low sludge content. The maintenance of manual machines which have not been sufficiently protected from sludges can be tedious.

Sometimes surface active agents must be added to maintain the bath efficiency because oil in the micro-emulsion is not separated from the aqueous phase.

Applicability
The chemistry of the surface active agents must be adapted. Centrifuges cannot treat very acid baths (pH <2).

Economics
It is a very expensive form of technology which costs at least EUR 50000 and can reach over EUR 150000 when installation, the storage and collection of baths is included.

Driving force for implementation
High throughput through degreasing process.
Strong demand for high quality and consistent degreasing.
High cost of rejection and reworking. The effcectivness of this technique may vary.

Example plants
In France: Renault (Flingues, Cléon) Chan-t'eou et Maury (Lucé) Freudienne (Langres) Noiraud (Laon), Ronéo (Noyon).

Reference literature
[46, France, 2003] [176 CETS, 2024]

4.2.6.5.13.6 Membrane filtration of emulsifying degreasers (micro- or ultrafiltration)

Description
This technique can be used where, for technical reasons, the use of strongly emulsifying degreasing systems are necessary, and the regeneration of the cleaning solution by other methods may become expensive or even impossible.

Membrane filtration technology, particularly micro or ultrafiltration is a process of physical separation using membranes for the separation of particles from 0.005 to 0.1 micrometers (the separation of smaller particles is by nanofiltration or reverse osmosis). There is a small difference in pressure so that the liquid moves from one side of the membrane to the other.

Filtration is tangential, so that the fluid circulates in parallel with the membrane, rather than the traditional filtration which is perpendicular or frontal (therefore loading particles onto the filter). Tangential filtration allows the accumulation of fouling particles without fouling the filtration surface. The liquid crossing the membrane is the filtrate or permeate and is a clean solution containing purified detergent solution that is fed back in the degreasing bath. The solution unable to cross the membrane is the retentate, containing oil and suspended material. A typical system is shown in the figure below.

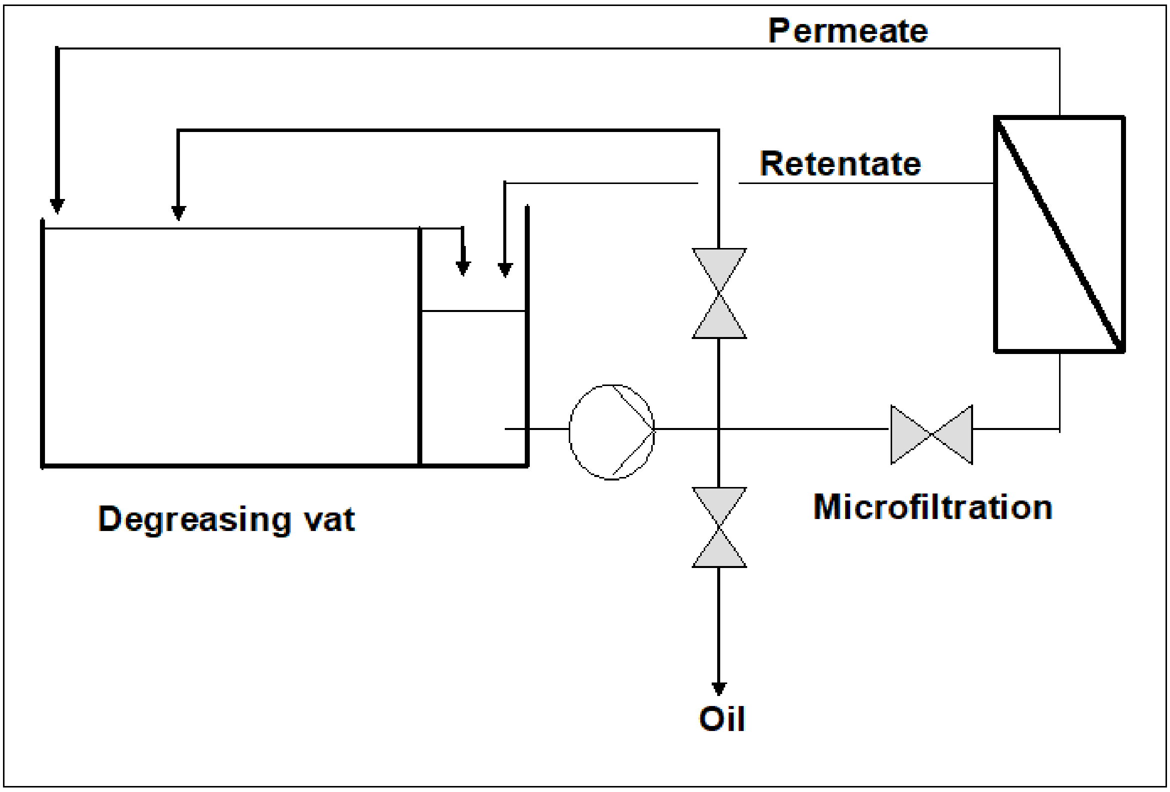


Figure 4-14: Bypass microfiltration for extending the service lifetime extension of a degreasing solution

Achieved environmental benefits

Reduced chemical and energy consumption in degreasing heavily contaminated workpieces or substrates. Increase of the degreasing bath lifetime (up to 10 times). Reduction of detergent consumption by 50 %

High reduction in pollution, reducing COD between 30 and 70 % according to water agency data. There is less discarding of the used baths (usually with oil levels between 10 and 15 g/l).

Cross-media effects

Power consumption of pumping to microfiltration, although with tangential filtration the costs will be lower than for a perpendicular system.

Operational data

The surfactant components may also be lost by permeating through the membranes, and for the successful use of microfiltration, the composition of the chemicals in the cleaner must be maintained.

The oil concentration in the bath decreases to 2 or 3 g/l and is held constant depending on the filtering rate. The bath is filtered continuously, and with the constant efficiency of the degreasing bath (between 500 and 800 microns), there are fewer problems of fouling when used with spraying systems.

The choice of membranes ha~~ve~~s to be determined by tests, as there is a possibility of fouling during use. This technique is interesting for high-volume baths (> 10 m^3).

Applicability

Only a few operators have successfully retained the cleaning quality in practice over longer periods. For this reason, the successful employment of the diaphragm cleaning system for degreasing solutions requires the close co-operation of operators, equipment manufacturers and chemical suppliers.

The cost-effectiveness success of this technique is based on using the membrane best suited to the wide range of pollutants encountered in a degreasing bath. Most of the equipment is installed in in-house shops where the composition of oils to be removed is more constant.

Economics

Energy cost: electric consumption between 0.10 and 0.20 kWh per m^3 treated.
No draining down of hot used baths so less waste of heating energy.
No need to stop production to change degreasing baths.

The investment is relatively expensive. The cost of the ultrafiltration installation depends on the particular situation of the company (volume vats, degreasing quality, quantity of oil to eliminate, etc.). This cost is estimated between EUR 40000 and 200000 including the total price of the ultrafiltration unit (membranes, storage of the ultrafiltrate and, in some cases, installation of connection).

Driving force for implementation

Where heavily oiled/greased components require a strongly emulsifying degreasing system.
High throughput through degreasing process.
Strong demand for high quality and consistent degreasing.
High cost of rejection and reworking.

Example plants

In France: Renault (Sandoval, Clean), Renault Trucks (Plainville), Sausage Production Service (Pont Saint Maxine), STILL (Minatare), Sachs Aliquant (Mousy), Ago France (Beavers).

Reference literature

[3, CETS, 2002, 104, UBA, 2003] [19, Eurofer, 2003] [59, France, 2003] [121, France, 2003], [176 CETS, 2024].

4.2.6.5.13.7 Multistage maintenance of degreasing solutions

Description

Multistage systems use a simple method removing the majority of oil and/or grease followed by diaphragm filtration. For example, gravity filtration followed by ultrafiltration.

Achieved environmental benefits

All remove oil and extend the working life of degreasing solutions.

Cross-media effects

Energy consumption for skimmers, dissolved air flotation or any other primary treatment, as well as in pumping for subsequent diaphragm filtration.
Chemicals used for demulsifying.

Operational data

Improved process reliability both of cleaning and subsequent treatments.
Gravity separation is a simple system requiring low maintenance.

Applicability

Where large amounts of oil and grease are present on incoming workpieces or substrates, where process line throughput is high, and/or where the quality of degreasing is highly critical to the following treatments.

Economics

The size of subsequent (and possibly expensive) stages, such as ultrafiltration or mechanical separation by skimmers can be reduced by pretreatment by simple techniques such as gravity separation (the simplest and cheapest simple method).

Driving force for implementation

Improved cleaning results in improved performance and reliability of subsequent surface treatments. This, in turn, decreases rejects and reworking.

Reference literature

[104, UBA, 2003]

4.2.6.5.13.8 Maintenance of electrolytic degreasing processes

The same processes used for alkaline cleaners can be applied for electrolytic cleaners, taking into account that the quantity of oil removed is small compared with that removed in soak cleaning.

4.2.6.5.14 Pickling

Pickling solutions lose activity by the dissolution of metals [124, Germany, 2003] as well as the constant entry of rinsing water from the previous process stage, so they must be renewed at relatively short intervals. At present, no techniques exist in practice to extend the service life of pickling solutions, although two-stage or drag-in through a used picking solution may be considered (see Section 2.1.4.6).

The prevention of over-pickling is important. Over-pickling is the attack of the pickling solution on the basis metal, and in surface technology is an unwanted side effect, as it:

- leads to increased acid consumption with increased metal erosion and thus also increasing waste generation (from the dissolved metal being precipitated in waste water treatment and the increased amount of waste acid generated)
- causes substantial quality losses in the base material (hydrogen brittleness)
- can degrade the quality of the workpiece surface and/or change the geometrical measurements of the workpiece adversely.

Over-pickling can be prevented by the addition of so-called pickling inhibitors which are widely used [104, UBA, 2003].

~~4.2.6.5.14.1 Measures for decreasing pickling acid consumption~~

[Note to the TWG: this technique is proposed for deletion by CETS (CETS INPUT input in 176, TWG, 2024]), as it is not suitable for ST industry due to the variety of substrates treated, with various alloys, and on-site recycling solutions involve heavy installations, which are more the domain of the chemical industry than that of STM]

~~**Description**~~

~~A three-stage cascade hydrochloric acid system running at 0.5 l/min is being used successfully to remove hardening scale from parts prior to plating The system is identical to a cascade water rinse system, but uses 32 % hydrochloric pickling acid instead of water.~~

~~Achieved environmental benefits~~
~~Extending chemical process life. A three-stage cascade system has reduced chemical usage by 50 % (the Example plant, see below, reported a drop from two tonnes to one tonne per day of 32 % hydrochloric acid).~~

~~A smaller, continuous flow of hydrochloric acid is more readily treated in a typical waste water treatment plant, removing the problems caused by batch discharges of acid to treatment~~

~~Operational data~~
~~Substantial reduction in rejects, as the strength of the acid through the cascade system remains constant and effective, unlike 'batch treat and dump' systems, where acid strength decreases constantly until replaced.~~

~~May require more process stages in line, and these will be in the most corrosive part of the line.~~

~~Applicability~~
~~This is applicable where some or all of the following apply:~~

- ~~pickling acid consumption is considerable~~
- ~~pickling of parts is on a large scale~~
- ~~quality of pickling is a problem, such as surfaces to be treated are resistant to pickling (e.g. hardening scale, which require a constant supply of fresh acid)~~
- ~~batch acid discharges from pickling to waste water treatment adversely affect the treatment.~~

~~Economics~~
~~Cost savings in materials offset the increased amount of plant required for multistage pickling.~~
~~Reduced rejects, see Operational data, above.~~

~~An example calculation for changing from three-stage static pickling to cascade rinsing is given in Annex.~~

~~Driving force for implementation~~
~~For multistage pickling, increased process stability, decreased rejects and cost savings.~~

~~Example plants~~
~~Metal Colours Ltd, Slough, UK~~

~~Reference literature~~
~~[18, Tempany, 2002, 104, UBA, 2003] [124, Germany, 2003]~~

~~4.2.6.5.14.2 Extension of the service life of pickling solutions by diffusion dialysis~~

[Note to the TWG: this technique is proposed for deletion by CETS (CETS INPUT input in 176, TWG, 2024]), as it is not encountered industrially and cannot be considered as BAT for subcontracting workshops]

~~Description~~
~~If the concentration of the metal salts in the pickling solution, formed by dissolution, becomes too high, no more pickling effect can be achieved even with further addition of acid. At this~~

~~point, the pickling bath is useless and is usually discarded. Further use of the pickling solution is possible only by selective separation of the dissolved metal salts.~~

~~Diffusion dialysis separates acid from its metal contaminants via an acid concentration gradient between two solution compartments (contaminated acid and deionised water) that are divided by an anion exchange membrane. Acid is diffused across the membrane into the deionised water whereas metals are blocked due to their charge and the selectivity of the membrane. A key difference between diffusion dialysis and other membrane technologies such as electrodialysis or reverse osmosis is that diffusion dialysis does not employ an electrical potential or pressure across the membrane. Rather, the transport of acid is caused by the difference in acid concentration on either side of the membrane. As such, the energy requirements for this technology are low.~~

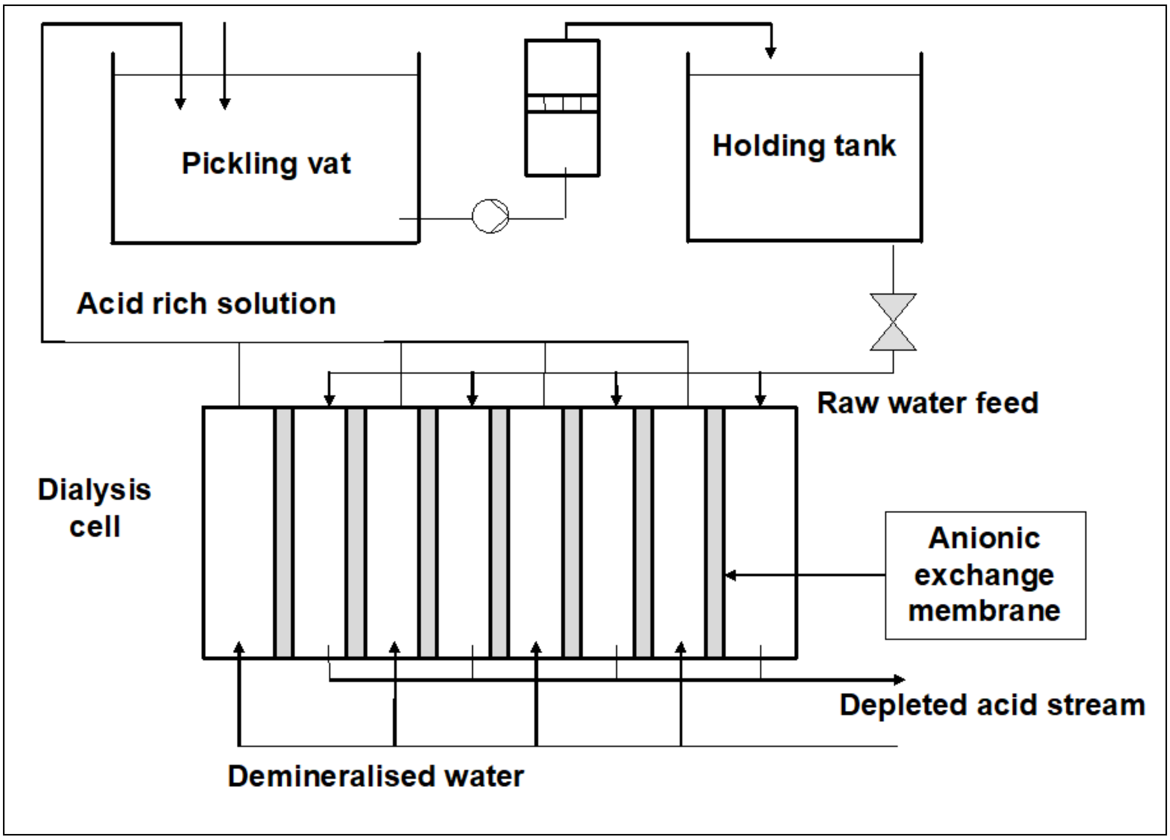


Figure 4-15: Regeneration of pickling solutions by dialysis

Table 4-4: Results of the dialysis treatment on etching solutions

~~**Separating integral parts**~~	~~**Parameters**~~	~~**Feed**~~		~~**Emissions**~~	
		~~**Etching solution**~~	~~**Water**~~	~~**Diffusate**~~	~~**Concentrate**~~
	~~Flowrate (l/h)~~	~~830~~	~~830~~	~~700~~	~~960~~
~~HCl, $AlCl_3$~~	~~HCl (g/l)~~	~~100~~		~~85~~	~~25~~
	~~$AlCl_3$ (g/l)~~	~~30~~		~~0.7~~	~~26~~
	~~Flowrate (l/h)~~	~~20~~	~~20~~	~~14~~	~~26~~
~~H_2SO_4, $NiSO_4$~~	~~H_2SO_4 (g/l)~~	~~32~~		~~27~~	~~12~~
	~~Ni (g/l)~~	~~1.7~~		~~<0.04~~	~~1.6~~

~~Achieved environmental benefits~~
~~Extension of service life of the chemical process solution. Achieved concentrations are shown in.~~
~~Lower power consumption than techniques using pressure~~

~~Cross-media effects~~

~~The concentration of recovered acid will normally be lower than that of the feed acid, and make-up acid must be added to bring the concentration up to the process level. When the feed has a significant salt concentration, the concentration of recovered acid can exceed the concentration of the feed acid.~~

~~The depleted acid waste stream (after diffusion dialysis processing) is approximately equal in volumetric flow to the waste acid influent. Depending on the application-specific acid removal and metals rejection rates, the depleted acid waste stream (retentate) typically contains 5 to 20 % of the acid and 60 to 95 % of the metals from the influent waste acid stream. This stream is usually sent to waste water treatment.~~

~~Operational data~~

~~To prevent mechanical blocking, pickling acids must be pre-filtered before using dialysis.~~

~~For diffusion dialysis processing, an increase in membrane area per unit of acid flow increases the acid recovery rate. If the flowrate of DI water increases, the acid recycling rate increases and the recycled acid concentration decreases.~~

~~Diffusion dialysis systems can be used for batch or continuous flow applications. Small systems are often configured as mobile units.~~

~~Limitations in using diffusion dialysis to recover surface finishing process acids include:~~

- ~~acids not highly dissociated (e.g., phosphoric acid) will not diffuse across the membrane~~
- ~~complexed metal anions (e.g., fluorotitanium anions) can readily diffuse across the anion exchange membrane and are not efficiently separated from the acid.~~

~~Cooling is typically needed if influent waste acid temperature exceeds 50 °C.~~

~~Heating may be needed for low temperature influent waste acid. A temperature drop of 2 °C reduces the acid recycling rate by approximately 1.5 %.~~

~~Solvents can cause membrane swelling.~~

~~Strong oxidising substances (e.g., chromic acid) can cause membrane deterioration.~~

~~Applicability~~

~~Diffusion dialysis is a purification/recycling technology that can be used to maintain or reclaim spent or contaminated acids where acid concentrations are greater than 3 % by weight. Diffusion dialysis is most typically used where contaminant metals concentrations are less than 1 gram per litre. Surface finishing process solutions amenable to the use of diffusion dialysis include:~~

- ~~hydrochloric acid (HCl) pickle and strip solutions~~
- ~~sulphuric acid (H_2SO_4) anodising solutions~~
- ~~sulphuric acid pickle and strip solutions~~
- ~~nitric acid (HNO_3) pickle and strip solutions~~
- ~~nitric acid/hydrofluoric acid (HNO_3/HF) stainless steel pickling solutions~~
- ~~hydrochloric acid/sulphuric acid (HCl/H_2SO_4) aluminium etch solutions~~
- ~~methane sulphonic acid (MSA) solutions.~~

~~Economics~~

~~Diffusion dialysis may be expensive in capital and running costs for simple applications, and complex to run. The most cost-effective use for it may be, for example:~~

- ~~where there is significant use of the more expensive and/or concentrated acids (e.g. phosphoric)~~
- ~~in expensive etching techniques such as methyl sulphonic acid used with tin and tin/lead.~~

~~**Driving force for implementation**~~
~~Process consistency and quality.~~
~~Reduction in fresh acid, waste acid treatment or disposal costs.~~

~~**Reference literature**~~
~~[104, UBA, 2003], [154, NMFRC,] [129, Spain, 2003, 159, TWG, 2004, 162, USEPA, 2000]~~

~~4.2.6.5.14.3 Recovery of copper from pickling baths~~

~~**Description**~~
~~In pickling baths for copper (non-ferrous metals), copper can be recycled by simple electrolysis [113, Austria, 2003]~~

4.2.6.5.15 Recovery of process metals

[Note to the TWG: This section corresponds to Section 4.12 of the existing BREF]

This refers to recovery systems within installations, not to external processes.

4.2.6.5.15.1 Electrolytic recovery of metals

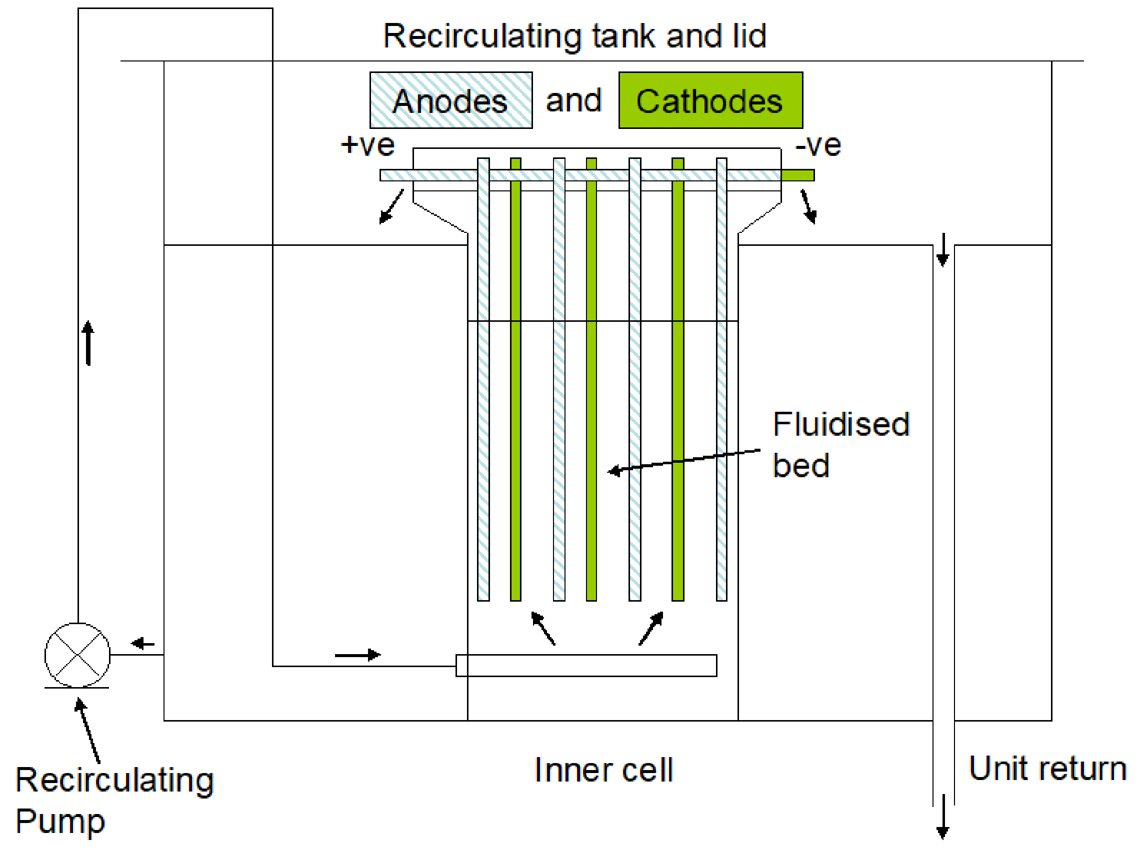
Description
Metals may be recovered by electrolysis. The system is widely used for precious metal recovery, but can also be used to recover other metals such as nickel and chromium from drag-outs. Suitable electrolysis cells are marketed in different sizes and can operate down to metal contents of less than 100 mg/l.

May be operated in conjunction with other techniques to achieve low emission levels for water, or recycling of rinse-waters, etc, see Section 4.2.6.8.12

Achieved environmental benefits
Recovery of metals for re-use.
Reduction of metals in drag-out and their consequent decrease in effluent concentrations.
In the electrolytic separation of metal solutions containing cyanide, the anodically oxidative destruction of the cyanide takes place in parallel to the metal winning.

Cross-media effects
Power consumption at low current efficiencies.

Operational data
Precious metals electrolytic recovery requires the electrolytic reactor to be able to reduce the metal concentration down to a very low concentration (1 ppm or less). The current efficiency at this level is very low. In all cases, a simple flat plate cathode would be sufficient in theory, but when high current efficiencies are required (for both precious and transition metals) sophisticated cathode design is needed (rotating tube cell, graphite fibre cathode), or a fluidised bed to overcome cathode surface depletion. In all cases (including anodic oxidation) the anode must be of the ‘insoluble’ type.



Chemelec cell, BEWT Environmental Services Ltd.

Figure 4-16: Optimised cell using fluidised bed technology

Cathodes are usually sheets, foil or particles, generally made of the same metal to be recovered, but also of stainless steel or other metals, which allow either a mechanical parting of the deposit from the cathode blank, or its removal by anodic dissolution. Iron, stainless steel, porous carbon, graphite particles, glass or plastic metallised beads and metallised fabrics are all examples of common materials used. Cathode material selection is largely determined by the nature of the treatment, which follows the metal deposition. In any case, maximising both the cathode surface area and the diffusion process are the most important means to enhance the efficiency of the electrolytic reactor.

Anodic material includes: graphite, lead, lead alloys with antimony, silver or tin, stainless steel, cast iron, ferro-silicon and the valve metals (titanium, tantalum, tungsten, niobium) coated with noble metals (platinum iridium) or with noble metal oxides (iridium, ruthenium oxides).

Anodic material selection is usually a compromise based on:

- over-voltage behaviour for the particular reaction on a given material
- anode corrosion, mechanical properties and the form in which the material is available
- price.

Operating conditions vary as a function of the metal to be recovered; for gold the recommended conditions are: pH minimum of 10, cell voltage 8 V, current density 20 A/dm^2, temperature >60 °C, and an anode-cathode gap from 8 to 16 cm.

Further advantages of the electrolytic recovery over the ion exchange method are:

- it does not produce any increase in the dissolved salt concentration

- the presence of other metals in similar concentrations does not affect the rate of removal of the desired species
- may also oxidise unwanted species, such as cyanide

Noble metals, because of their electropositive character, are more readily electrodeposited than non-noble ones.

For electrolytic metal recovery, the following streams are particularly suitable:

- rinsing (drag-out) concentrates from electroplating metal
- rinsing (drag-out) concentrates and used process solutions from chemical metal plating excluding solutions-containing phosphate
- sulphuric acid regenerates of cation exchangers from the treatment of rinsing waters: these contain non-ferrous metals.

The purity of the generated metals may permit a direct in-house use as an anode material, otherwise re-use is via the scrap metal trade.

Applicability
Gold and silver have been recovered electrolytically for well over 50 years.
Electrolytic recovery has wider applicability than precious metals: it can also be used for transition metals, see reference plants in Annex 7.1 and Example plants, below.
Fluidised bed cells increase the process efficiency.

Economics
Cost-effective for precious metals.
Can be cost-effective for transition metals, for example, where it reduces the waste water treatment costs (capital and running costs).

In-house electrolysis has costs in investments and personnel (both time and skills) as well as a substantial energy expenditure because of the low electricity yield (kg/amp hour). This may be offset for cyanide solutions where the cyanide is destroyed in parallel.

For a- fluidised bed cell: although the technique can be utilised on most metals, economic considerations limit the application to either valuable or easily re-usable metals. Units can recover from 1 kg/week to 150 kg/week of electrolytically pure metal from solution. The solutions can be very dilute, typically containing 100 – 500 parts per million (0.1 – 0.5 gm/l). Typical costs are shown in the table below.

Table 4-5: Typical capital and operating costs for a fluidised bed electrolytic cell

Nominal capacity	Capital cost GBP	Typical operating cost/yr GBP
<1.5 kg/week	6500	<10
<5 kg/week	14000	115
<30 kg/week	24000	300
<150 kg/week	68000	800

Driving force for implementation
See Economics, above.
Water pollution protection legislation and PARCOM.

Example plants
For nickel and chromium: Townrow (Hi-Tech Plating) Ltd, Sheffield, UK.

Gold, silver, rhodium, nickel, copper recovery; cyanide destruction; and water re-use:

Marigot Jewellery (Thailand), Samutprakarn 10280, Thailand.

Copper Recovery (Printed Circuit Manufacturer): P.W. Circuits Ltd. South Wigton, UK.

Silver recovery from waste photographic solutions: Shannon Environmental Services Ltd., Shannon, Republic of Ireland.

Reference literature
[3, CETS, 2002, 18, Tempany, 2002] [110, BEWT, 2003] [12, PARCOM, 1992]

4.2.6.5.15.2 Ion exchange – recovery of precious metals from rinses

Description
Precious metals in concentrated solutions are usually recovered electrolytically, while more dilute solutions, sometimes of no more than a few mg/litre, are treated by adsorption of the metal content on ion exchange resins.

Ion exchange provides only a concentration of the metal in the resin, the subsequent recovery being possible by incineration of the resin or by releasing the metal in dissolved form, but at higher concentration. The final metal recovery by incineration is in an oxygen-rich atmosphere at 500 – 600 °C; metals are found with the residual ash. Recovery is about 95 % efficient.

Achieved environmental benefits
Recovery of precious metals.

Cross-media effects
Emissions from incineration of the resin.
Increased salt concentrations in resin regeneration.

Operational data
For gold and precious metals, the principle of the method is based on treating the rinse-water with a strong basic type of anionic ion exchange resins, in the OH^- or in the Cl^- form. This does not work well for alkaline cyanide or chloride-based rinses. Ion exchange resins are quoted as having a useful capacity of 100 g of gold per litre of resin.

Typically the equipment consists of two ion exchange resin columns in series, with the first unit taking the main load, while the downstream column takes any excess. Each resin column needs to contain around four litres or more of ion exchange resin to be effective.

When very large volumes of rinse-water are used, an option is the treatment of the static rinse which workpieces pass through after the precious metal plating tank. The treatment is through a closed loop resin column. This ensures such a low gold concentration in the static rinse that further drag-out losses into the following cascade rinses may be neglected.

Silver recovery requires using weak basic anionic ion exchange resins, followed by regeneration and subsequent electrolytic recovery of the regenerate. Typically the resin capacity is in the range of 50 – 75 g of Ag/litre (silver per litre) of resin. A further option is the use of ion exchange units built into a recirculation rinse loop with periodical regeneration. Precious metal is then recovered by electrolysis from the concentrate. This has been successfully used for silver.

Palladium used in the PCB industry is recovered from acid solutions containing chloride (pH about 2), where it is present as a chloro-complex, using strongly basic ion exchange resins. The same process readily allows its separation from copper. The typical resin capacity (the same type of resin as used for gold) varies from 30 to 50 g of Pd per litre of resin.

Driving force for implementation
Cost recovery.

Reference literature
[3, CETS, 2002]

4.2.6.5.15.3 Chromating

Description
The hexavalent chromium in chromating solutions is exhausted after a certain time. The solutions also dissolve and accumulate zinc and other metals and eventually lose their workability, and must then be rejected and renewed.

Numerous attempts have been made to regenerate chromating solutions, predominantly via ion exchangers or via diaphragm technology, e.g. purifying the hard chromating surface treatment baths of pollutants using ion exchangers and evaporators.

Achieved environmental benefits
Extended bath life and recovery of metal.

Cross-media effects
Energy and chemicals used in regeneration techniques.

Economics
Regeneration is usually only cost-effective with relatively concentrated and expensive solutions~~, for example, black chromating solutions containing silver.~~

New yellow chromating process solutions for zinc only costs EUR 3 to 4/100 litre (2002). This makes it difficult to recover the costs of capital, the energy expenditure and maintenance for the recovery measures.

Reference literature
[104, UBA, 2003], [176 CETS 2024] [177, TWG, 2020]

4.2.6.5.15.4 Precipitation

See Section 4.2.10.11.1.3.2.

4.2.6.5.15.5 Common techniques for treating waters and aqueous solutions: feed-water, rinses, waste water treatment, process solutions, and materials recovery

[Note to the TWG: This section corresponds to Section 4.10 of the existing BREF]

Many techniques can be used with waters and aqueous solutions, to:

- remove unwanted materials, such as:
    - cleaning incoming water for rinsing
    - recycling rinse-waters
    - removing breakdown products or tramp metals in process solutions
    - treating waste water prior to discharge
- remove the water to concentrate the materials, such as to recover drag-out, recovery of materials from waste waters

Table below lists the sections which discuss the application of treatment techniques.

Table 4-6: Sections discussing the application of treatment techniques

Section	Subject or techniques
4.2.11	Water supply, treatment and recycling/re-use
4.2.6.8	Rinsing techniques and drag-out recovery
4.2.6.8.8	Regeneration and re-use/recycling of rinsing waters
4.2.6.8.11	Increasing drag-out rate and closing the loop
4.2.6.8.12	Combining techniques and installation-wide approaches
4.2.6.5	Process solution maintenance
4.2.6.5.13	Maintenance of degreasing solution
4.2.6.5.14	Pickling
4.2.6.5.15	Recovery of process metals
4.2.10	Waste water emission abatement techniques
4.2.10.18	Zero discharge techniques

A list of the current common techniques used singly or in combination to achieve a variety of objectives is given in the following table.

Table 4-2 in Section 4.2.6.5 lists common process solutions, their disturbing pollutants and their treatment techniques.

Table 4-7: **Common techniques for treating aqueous systems**

Technique	Applicability: references to sections with examples of uses (Key process descriptions are marked *)	Limitations	Cross-media effects
Filtration	Widely used for: • incoming water supplies • process solution maintenance **(*)** • waste water treatment	Limited to the removal of solids except when used in conjunction with an absorption technique.	Generation of waste solids, used filter media, etc. Energy used in pumping.
Absorption techniques	Activated carbon to remove organic breakdown products form solutions **(*).** Granulated polypropylene felt, or other lypophilic media are used to absorb oils in filter housings or as ropes, clothes etc. used **(*).** Polymer filtration is used to selectively bind target metals.	Activated carbon can also indiscriminately remove active organic additives.	Generation of waste solids, absorption media, etc. Energy used in pumping.
Crystallisation	Some etching or pickling baths with relatively high concentrations where controlled metals removal and recovery can be beneficial, e.g. copper from peroxide-sulphuric acid solutions. Removal of carbonates to maintain alkaline and cyanide plating solutions **(*).** Also for acid pickling, and aluminium etchant **(*)**	See Applicability.	Energy used for cooling and pumping.
Atmospheric evaporation: natural and assisted (evaporators, etc.)	Used to concentrate process solutions or rinses. (4.2.6.8.2, **4.2.6.8.11.2*, 4.2.6.8.11.3***) In some cases, the distillate can be re-used in rinsing in the process. The distillate may trap spray from the process (such as in Cr(VI) plating.	In some applications there is a risk of over-concentration and fouling of the evaporator due to salting out. Surfactants can cause foaming problems Some bath constituents may be heat degraded or oxidised. Aeration can cause build up of carbonates. Recovery results vary depending on changing process and air stream conditions.	When the feed streams and/or air streams need to be heated, atmospheric evaporators have a high energy use. The discharged air may contain hazardous substances. If the distillate traps process spray and is not returned to the solution, it may require treatment.
Vacuum evaporation	Used to concentrate process solutions or rinse-waters **(*)** where: • air pollution is potential problem • relatively low evaporation temperatures are needed to avoid problems with solutions sensitive to temperature and/or oxidation • alkaline cyanide solutions that build up carbonates easily • energy costs are high for atmospheric evaporation. Produce high-quality condensate that can be re-used and a concentrate that that may be re-used, recycled or is managed as waste.	High capital cost. Application-specific potential for fouling and separation limitations.	Periodic waste streams form clean out if there is fouling. Some concentrated wastes may be difficult to dispose of if not recycled or re-used.

Electrolysis – Recovery of metals	Widely used to recover precious metals, copper, zinc, tin, tin/lead. The more noble the metal, the easier plating out is **(*).** Best carried out from concentrated solutions, such as a static rinses, and in combination with other techniques e.g. ion exchange regenerates and reverse osmosis concentrates (4.2.6.8.12). There are options to improve efficiency and overcome electrode polarisation and low ion diffusion rates.	Chromium is the only common metal not usually recovered (but see *). Minimum practical concentrations vary, but plating from low concentrations difficult (see Applicability). Metals recovery can be difficult for solutions that contain chelated or complexed metals, reducing agents or stabilisers.	High current use if concentration is very low.
Electrolysis – plating out	Removal of metallic impurities (at low current densities, LCD) which accumulate with time, e.g.: • nickel strikes, and plating nickel, copper, cadmium, and trivalent chromium **(*)** • removing excess metals • purifying acids (e.g. sulphuric from copper wire pickling).		
Electrolysis – oxidation	Oxidation of cyanide solutions High-current density (HCD) to oxidise Cr(III) to Cr(VI) and organic by-products **(*)**.		
Ion exchange – resin	1. Used to remove ions to increase of water: • improving incoming water quality in deionisation water softening applications • rinse-water recovery (4.2.6.8.8.1) • waste water treatment applications 2. Concentration of ions onto resin, and recovery of concentrated metals solution	Ion exchange may become impractical for use with total dissolved solids concentrations above 500 ppm, due to the need for frequent regeneration. Different resins have different effective pH ranges. Oxidants, solvents, organics, oil and grease, and strong acids or alkalis (with the inappropriate resins) can degrade resins. Suspended solids can clog resin columns.	Chemicals used in regeneration. Impacts of waste solutions from regeneration. Energy consumption used for pumping.
Electro-deionisation	Effective for relatively high purity water purification/recovery applications, such as polishing treatment of reverse osmosis permeate (no example).		No chemical usage in resin regeneration.
Acid (resin) sorption or retardation	Regeneration of acids, particularly for pickling and etching **(*)** including anodising **(*)**	Not applicable for some highly concentrated acids. Should not be used on acids with anionic complexes that sorb to the resin, thus reducing acid recovery. Application-specific temperature limitations should not be exceeded	Only a part of the free or unused acid is recovered. 33 – 70 % of the acid may end up in the waste stream and require treatment.
Ion exchange – liquid/liquid	Currently only one application: in PCB manufacture, recycling of alkali (ammonia) etchants with copper recovery **(*)**	High capital cost.	Some power consumption.

Membrane filtration **microfiltration (MF)** **ultrafiltration (UF)** **nanofiltration (NF)**	Input water purification (MF and UF) Removal of oils and greases from degreasing baths (MF and UF) and in coil coating Waste water treatment: increases amount of solids removed, and hence lower metals levels achieved, e.g. replace clarification and polishing applications, zero discharge techniques, etc For PCBs, filtration of stripped resist from effluents	Cleaning agents removed along with oils/greases. Cleaners with high silicate concentrations less amenable to treatment. Aluminium cleaning solutions not recycled due to build up of dissolved aluminium.	Waste oil/grease or solids to dispose of: Power consumption for pumping. Clogging of membranes, depending on solutions treated.
Reverse osmosis (RO)	Purifying input water for generating high-quality deionised water Separation and recovery of rinse-waters and chemical for: In general **(4.2.6.8.8.2*)** nickel electroplating (4.2.6.8.11, 4.2.6.8.11.5 copper (acid and cyanide) acid zinc chromate Large-scale waste water recycling. In combination with other techniques: (4.2.6.8.12)	Membrane performance deteriorates with time. Membranes subject to fouling by organics, water hardness, suspended solids (may require pre-filtering, prior pH control and control of ionic concentration). Some ions such as borates show poor rejection. Oxidising agents can damage membranes, as well as acid or alkali solutions >0.25 molar. Osmotic pressure limits RO to <5000 ppm TDS.	Energy for pumping to overcome osmotic pressure of solution.
Diffusion dialysis	Maintain or reclaim spent or contaminated acids where acid concentrations are >3 % w/w, such as: For HCl, H_2SO_4 HNO_3 pickle and strip solutions **(*)** anodising solutions HNO_3/HF stainless steel pickling solutions HCl/H_2SO_4 aluminium etch solutions methane sulphonic acid (MSA) solutions	Acids not highly dissociated (e.g. H_3PO_4) will not diffuse across the membrane. Complexed metal anions (e.g., fluorotitanium) can readily diffuse and are not well separated. Cooling may be needed if influent >50C or heating if cold.	The recovered acid is not full strength and fresh acid is still needed. Depleted acid waste stream contains 5 – 20 acid and 60 – 95 % of metals from influent, which require treatment. Requires deionised water supply.
Membrane electrolysis	Extends bath life for chromic acid solutions and other acid based etchants (including for plastics), pickling and stripping solutions. Removes contaminants. Oxidises Cr(III) to Cr(VI) **(*)** Multi-cell systems can be used with highly corrosive acids. Extending life of autocatalytic nickel solutions (in 0)	Special materials may required for construction. Anionic metal complexes require pretreatment. Operating temperatures limited between 15 – 60 °C. Oil, grease and solvents can damage membranes. Suspended solids and precipitates can clog membranes.	Hazardous fumes may be generated.
Electrodialysis	Maintain nickel electrolytes by removing organic decomposition products (preserves ductility of the nickel deposit). Maintain and extends life of electroless nickel solutions. Extends life of pickling acids and etching solutions (such as for tin. tin/lead) **(*)** Recovery of metals from rinse-waters, e.g. nickel **(4.2.6.8.11.4*).**	To prevent blocking of the membrane, pickling acids must be pre-filtered.	Power consumption.

4.2.6.6 Drag-in reduction

[Note to the TWG: This section corresponds to Section 4.5 of the existing BREF]

Description

Techniques to reduce drag-in include the use of:

- the eco-rinse (or pre-dip) technique;
- air knives or wiper rollers to remove as much rinsing water as possible for sheet and coil substrates.

Technical description

Drag-in can contaminate a process solution if is there is insufficient rinsing after the previous processes. Drag-in of clean rinse-water can significantly dilute a process solution. Drag in can be minimised by using an eco-rinse (or pre-dip), see Section 4.2.6.8.4, or by removing as much rinse-water as possible, such as by air knives or wiper rollers for sheet or coil substrates. The effects can also be minimised by using compatible chemical systems, see Section 4.2.6.7.5.

Achieved environmental benefits

Extends the life of process solutions.

Cross-media effects

Spray from using air knives or blowers.

Operational data

See Description and Section 4.2.6.8.4.

Applicability

Eco-rinse cannot be used in all situations, see Section 4.2.6.8.4.

Economics

See Overall economics, Section 4.2.6.8.1

Driving force for implementation

Extending process solution life, improving process quality and reducing material costs in make up chemicals.

Reference literature

[159, TWG, 2004, 165, Tempany, 2004]

4.2.6.7 Drag-out reduction

[Note to the TWG: This section corresponds to Section 4.6 of the existing BREF]

~~Preliminary remarks~~

~~Drag-out is described in Section 2.1.5.~~

A reduction of drag-out is an effective primary measure for:

- minimising losses of chemicals in rinses
- reducing the amount of rinsing required
- reducing raw material costs
- reducing quality and maintenance problems with subsequent processes
- reducing environmental problems associated with rinsing waters.

Techniques to reduce losses of chemicals resulting from drag-out are outlined in this section These are also applicable to other process specific sections e.g. coil coating, PCBs, etc.

However, elimination of drag-out is impossible.

Drag-out depends on a large variety of parameters and a reduction of this key step with many impacts on the environment and the process can only be achieved by close co-operation of all personnel involved. For this reason a thorough understanding of the complex interrelations of many parameters is needed by the operational staff to improve the situation successfully, see issues such as training in environmental management systems, Section 4.2.1.1

4.2.6.7.1 Eco-rinse (or pre-dip)

See Section 4.2.6.8.4.

4.2.6.7.2 Evaporation using surplus internal energy

See Section 4.2.6.8.11.2.

4.2.6.7.3 Evaporation using additional energy with an evaporator

See Section 4.2.6.8.11.3.

4.2.6.7.4 Electrodialysis

See Section 4.2.6.8.11.4.

4.2.6.7.5 Use of compatible chemicals

Description
The use of compatible chemicals (e.g. the use of the same acid in pickling or activating the surface prior to an acid-based plating process) reduces the consequences of chemical drag-over to the subsequent process.

Technical description
As an example, in aluminium anodising, spent anodising electrolyte with approximately 5 g of aluminium per litre acting as an inhibitor can be used for desmutting. Desmutting additives may be necessary to increase the oxidising effect. In some individual cases, however, where for example special alloys are treated or the anodising process specialises in high gloss surfaces, the use of nitric acid for desmutting is necessary [175, ESTAL, 2024].

Achieved environmental benefits
Minimises loss of chemicals as they are used in the next process.
Minimises water use in intermediate rinsing.

Cross-media effects
May increase the need to top up the chemicals in the first stage that would otherwise be recovered from counter-flow rinsing, etc. (see Section 4.2.6.8).

Operational data
May increase maintenance requirements on the subsequent solution, e.g. removal of dissolved contaminating metals.
Reduces the number of stages required in a process line by removing/reducing rinse steps.

Applicability
Applicable to all types of processing, but limited to where processes having compatible chemistry can be used.

Economics
Low cost, depending on choice of chemical systems.

Driving force for implementation
Cost savings.

Reference literature
[CETS, 2002 #3; [104, UBA, 2003].

4.2.6.7.6 Properties of process solutions – effect on drag-out

Description
The drag-out also depends on the properties of the process solutions.

Drag-out can be reduced by raising the temperature of the process solution which normally lowers the viscosity of the solution.

Lowering the concentrations of the process solutions will effectively reduce the drag-out, by lowering the amount of material contained in the dragged-out solution, as well as reducing surface tension and viscosity of normal ionic solutions.

The addition of wetting agents to the process solution reduces the drag-out by reducing surface tension.

To avoid excessively increased concentrations, the process solution may be controlled to a constant composition during regeneration and maintenance. This, and the selection of appropriate process solutions, is an important step in the reduction of drag-out.

Achieved environmental benefits
This is a key step in reducing the loss of soluble chemicals from process vats to the environment via rinsing.

Cross-media effects
Increasing the temperature of process solutions uses extra energy and may lead to quality risks due to drying of the surface during transfer into the first rinse, conflicting with the general principle of avoiding rework. Increasing the bath temperature in baths containing nitric acid may lead to the formation of toxic vapour and risks for work safety [175, ESTAL, 2024].

The addition of wetting agents increases in the amount of chemicals used.

Not all wetting agents can be treated by waste water treatment plants. All environmental risks must be taken into consideration. The consequences are usually worse from a water quality point of view if wetting agents are used.

Operational data
Reducing the concentrations of chemicals in solutions below prescribed levels will need technical expertise in-house or from suppliers.
Ensuring constant compositions of process solutions is a part of SPC,
Temperature sensitive brighteners may be affected by increased temperatures.

Applicability

All process solutions.

Driving force for implementation
Improved process control and costs.

Reference literature
[CETS, 2002 #3; UBA, 2003 #104, [124, Germany, 2003], [176, CETS, 2024]

4.2.6.7.7 Transition from drag-out draining to rinsing

Description
There is a close connection between minimising drag-out and the following rinsing steps. In barrel plating, sucking off or blowing off a considerable part of the drag-out above the process tank is a successful measure to reduce losses of process solutions.

A key measure for high drag-out reduction for uniform cross section workpieces or substrate are squeeze or wiper rollers. They are used in coil processing and for PCB manufacture see Section 4.3.4.1.4.

When jigs (racks) or barrels are being removed from a tank of heated solution, it is good practice to drench it with a fog spray while it is still over the processing tank. This achieves a reduction in drag-out loss, and the water used compensates for evaporation. This treatment can be combined with a pre-rinse, returning water from the first static rinse to the process solution. For removing solution adhering to, or trapped in, recesses, combined water and air jets may be used above the process tank and within an empty tank, respectively.

Sloping drain boards of plastic material can be provided at the exit end of each tank. In effect, these extend the draining period for the workpieces and return as much of the drippings as possible to the tank of origin.

Achieved environmental benefits
This is a key step in reducing the loss of soluble chemicals from process vats to the environment via rinsing.

Cross-media effects
Energy usage in compressed air for blowing drag-out off workpieces.

Blowing off or spraying can distribute aerosols of bath solutions within the workplace and via extraction systems to the environment. Other processes can be contaminated.

Operational data
Blowing off or spraying jigs or barrels is difficult practice, and can be technically elaborate

Applicability
To all jig and barrel installations.

Economics
Costs in energy consumption and pumping may be offset by savings in chemicals and waste water treatment

Reference literature
[3, CETS, 2002] [113, Austria, 2003].

4.2.6.8 Rinsing techniques and drag-out recovery

[Note to the TWG: This section corresponds to Section 4.7 of the existing BREF]

4.2.6.8.1 Introduction

This section must be considered in conjunction with Section 4.2.6.7 above, which highlights the reasons for controlling drag-out and drag-in. This section discusses techniques for two connected purposes [3, CETS, 2002]:

- how drag-out (and drag-in) can be reduced by different means
- how rinsing water consumption can be reduced.

Section 2.1.5 describes the need for rinsing to reduce cross-contamination and/or deterioration in the appearance of the workpiece by chemical attack or dried-on salts.

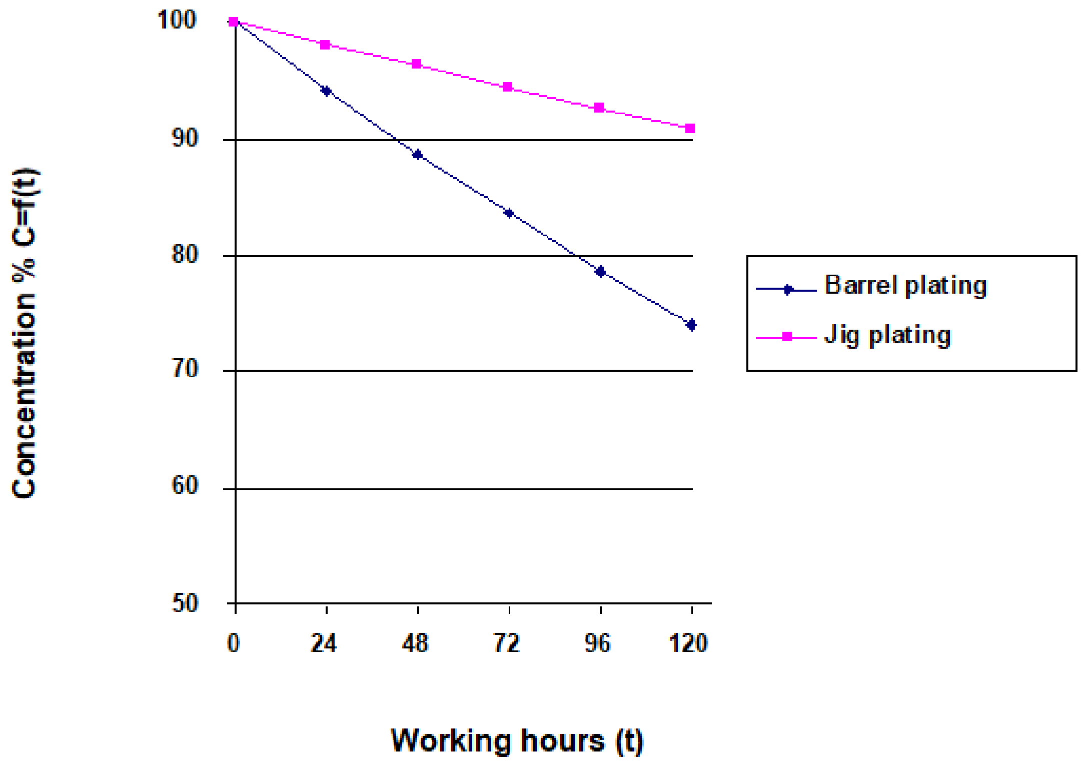
Some recommended rinsing ratios are given in Table 4-8:

Table 4-8: Some recommended rinse ratios

Process		Ratio
Post alkaline cleaner rinse		2000
Post acid pickle rinse	Pre-cyanide process	5000
	Pre non-cyanide process	2000
Post plating rinse	Cadmium, silver, zinc (alkaline)	2000
	Zinc (acid)	3000
	Electrolytic nickel	5000
	Autocatalytic nickel	10000
	Chromium VI	15000
Post passivate rinse		5000
[29, EA, 2001-3]		

Drag-out of process solution and drag-in of rinse-water leads to continuous dilution and drop of chemical concentration in process solutions. This is shown in Figure 4-17.

Note: *The theoretical formulas have been used, as little operational data have been provided. All formulas mentioned in this section provide exact theoretical results which do not concur with practical experience. This is caused by (but not limited to) simple parameters such as varying quantities of drag-out for different workloads, different rinsing efficiencies due to differing shapes of processed components or changing concentrations of wetting agents in process solutions.*



Note: C=f(t) is concentration of process solution at time (t)

Figure 4-17: Drop of chemical concentration in process solution due to drag-in of rinse-water and drag-out of process solution without replenishing

The concentration left in the process solution can be calculated:

$$C_0n = C_0\{V/(V+D)\}^n$$

C_0n = concentration of chemicals in process solution after n work loads
C_0 = concentration of chemicals in process solution at start of operation
V = volume of process solution
D = quantity of drag-in/drag-out per work load (barrel or flight bar)
n = number of workloads processed.

Reference data for Figure 4-17:

Barrel plating:

- throughput: 10 barrels per hour
- drag-in/-out: 1.5 litres per barrel, 15 litres per hour
- process solution: medium cyanide zinc
- total volume: 6 m^3
- processing temperature: ambient.

Jig plating:

- throughput: 15 flight bars per hour (25 m^2 of surface area to be plated)
- drag-in/-out: 0.4 litres per flight bar, 6 litres per hour
- process solution: bright nickel, air agitated
- total volume: 7.5 m^3
- processing temperature: 60 °C.

General cross-media and operational effects
Drag-out can be used as a means for regeneration of process solution, as it continuously removes process-disturbing residues of degradation products from brighteners and other organic additives. This ignores the simultaneous loss of valuable undegraded components. However, the use of drag-out minimisation and recovery techniques are likely to increase the need for properly designed techniques to reduce or remove contaminants *in situ*.

Overall economics
The economics for the recovery of materials and the reduction of water usage, vs. the cost of increasing the number of rinse tanks in a rinsing stage, amendments to plant, etc. can be calculated using the data in this section, with specific plant data. It can also be calculated using software tools for plant optimisation, ~~shows examples of rinsing after cleaning, after pickling, after electrocleaning, after plating and in conjunction with forced evaporation, as well as after passivation~~.

4.2.6.8.2 Evaporation as a requirement for drag-out recovery

Evaporation is described in Sections .Increased recovery of drag-out is made feasible by using the used rinse-water to equalise the evaporation losses from process solutions. Techniques for using and increasing evaporation are discussed in Sections 4.2.6.8.11.2 and 4.2.6.8.11.3.

4.2.6.8.3 Benchmarking for rinsing

Benchmarks for rinsing are given in Section 0 and the method for calculating the rinse volume of water per square metre per rinse stage is given in Section 4.2.6.2.1

4.2.6.8.4 Eco-rinse or pre-dipping

Description
Some drag-out from process solutions working at (but not limited to) ambient temperature can be recovered through a single rinse station in which the workload is dipped before and after being processed. Figure 4-18 shows the sequence of workload transport schematically.

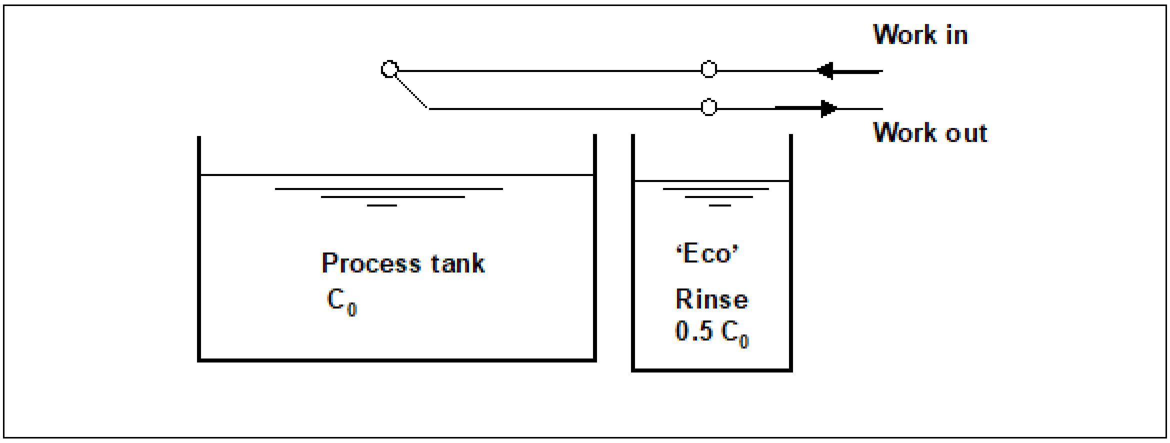


Figure 4-18: Drag-out recovery through eco-rinse

The eco-rinse station (or pre-dip) can be made up with diluted process solution from the very beginning or filled with deionised water only. In this case it will take some time until the final equilibrium concentration of 0.5 C_0 (50 %) will be reached. The solution only has to be changed when the tank itself and/or the tank walls have to be cleaned.

An eco-rinse tank can also be used in conjunction with other options to reduce water usage, see Section 4.2.6.8.

Achieved environmental benefits
During normal operation, no water has to be added assuming that drag-in is equivalent to drag-out. Drag-out recovery rate (jig and barrel plating) is approximately 50 %.

Cross-media effects
None reported.

Applicability
Can be used for minimising chemical usage for metal plating baths, where the concentration of metal and other ions must be increased by salts to maintain a certain level. For some processes, pre-dip can cause problems, for example copper plating on dye-cast causes adhesion problems because of partial premature chemical plating. Pre-dipping in eco-rinses with solid particles can also cause roughness in the following layer.

This may be considered where other alternatives are not achievable or as part of several rinse steps.

This cannot be achieved for:

- where problems are caused with subsequent processes (such as partial chemical pre-plating)
- carousel, coil coating or reel-to-reel lines because work cannot be returned through the pre-dip tank. A second tank could be installed after and coupled by a pumped system, but this is not known in practice and would require the creation of another tank in the line, which may be impossible with existing plant
- etching or degreasing
- nickel lines because of increased quality problems.

Eco-rinse or pre-dipping is not widely used in etching and anodising processes. Instead a warm rinse (without constant water replenishment) especially after etching and brightening is regarded as a practicable technology. The purpose of the first rinse after any active bath is to stop the reaction of the active bath on the surface [175, ESTAL, 2024].

Economics
See ~~Overall~~ economics, Section 4.2.6.8.1.
An increase in the number of steps causes loss of machine capacity.

Driving force for implementation
Where the process solution is running at ambient temperatures and/or there is little evaporation taking place.

Reference literature
[3, CETS, 2002] [113, Austria, 2003].

4.2.6.8.5 Spray rinsing

Description
Spray rinsing may be carried out in two ways: over the process solution (as in Figure 4-19) or in a separate empty tank.

Spraying prior to rinsing (or pre-rinse) above the process bath is an effective method of rinsing. The rinsing water is sprayed onto the workpieces while they are still above the bath surface. This may be manually for small process lines, or automatically. For the pre-rinse, the amount of water to be used should equal that dragged-out from the process tank to maintain the water balance. The pre-rinse causes a direct feedback of process solution into the process tank.

Spray rinsing in a separate tank acts as a first rinse. The solution can then be recycled back to the process solution in amounts equal to evaporative and drag-out losses.

Producmetal S.A., France

Figure 4-19: Manual spray rinsing

Achieved environmental benefits

This is a key step in reducing the loss of soluble chemicals from process vats to the environment via rinsing.

Cross-media effects

There is a risk of legionella bacteria infecting in the pipe ends of spray systems and being spread in the spray aerosols.

Operational data

Spraying above the bath recovers the process solution directly back into the tank. No additional tank is required. However, overspray may cause problems, but can be controlled in various ways, for example:

- in anodising, spraying is used at low pressure, referred to as ‘splash rinsing’, which avoids the creation of aerosols and over-spraying
- spraying in a tank reduces over-spray.

Legionella infection can be prevented by design of the spray systems or regularly cleaning. Testing may be required.

Applicability

Can be considered for all installations, but may be limited where there is a risk of drying and residues being left on workpieces or substrate prior to further rinsing or processing.

Example plants
SGI, Plaisir, France.
See reference plants in Annex 7.1.

Reference literature
[104, UBA, 2003] (Personal communication from ESTAL)

4.2.6.8.6 Manual or semi-automatic lines

Description
Manual or semi-automatic lines are used for small production throughput, or for development work. Controlling water usage, drag-in and drag-out may appear more difficult. To achieve adequate draining time on a manual line, the jig or barrel should be supported on a static rack over the preceding bath.

This enables spray rinsing (see Section 4.2.6.8.5) to be carried out directly above the treatment tank to return the drag-out and/or allows draining to be properly timed before immersion in a rinse.

In semi-automatic lines, spray rinsing can be also carried manually, see Section 4.2.6.8.5 and Figure 4-19

Achieved environmental benefits
As for drag-in and drag-out control, see Sections 4.2.6.4 and 4.2.6.7

Cross-media effects
None

Operational data
Ensures better reliability and repeatability of rinsing and draining for automatic and semi-automatic lines.

The amount of spraying above a treatment process needs top be controlled to avoid exceeding the drag-out and evaporative losses.

Applicability
All manual and semi-automatic lines.

Economics
Cheap and easy to install.

Driving force for implementation
Health and safety of staff using manual lines.

Example plants
Bodycote West Middlesex Plating Co. Ltd., Uxbridge, UK.

Reference literature
[18, Tempany, 2002, 165, Tempany, 2004]

4.2.6.8.7 Chemical rinses

Description

An accelerated technique to achieve the required cleaning efficiency is obtained by means of chemical rinses called the Lancy process. Here the dragged-out process solution is reacted chemically with the rinsing liquid at the same time.

Achieved environmental benefits
Reduces the effluent treatment capacity required by reducing or eliminating the primary waste water treatment stages.

Cross-media effects
The main use of the Lancy process, the oxidation of dragged-out cyanides by rinsing in chlorine bleaching caustic solution, is now reduced because of concerns about the associated AOX generation.
The processes make recovery of dragged-out solution impossible.

Operational data
Technically simple to operate.

Incorporation of chemical rinsing can reduce the number of rinse stations with a consequent increase in contaminated rinsing.

Can lead to large sludge build up in the rinsing tanks. There is a danger of gas build up if the automatic dosing fails.

Applicability
Requires a suitable chemical reaction that can readily take place in the conditions of the first drag-out tank. The main uses are:

- oxidation of cyanide
- reduction of hexavalent chromium.

Limited contact time may not eliminate the target chemical, especially cyanide. This limits the usefulness to the reduction of Cr(VI), particularly where workpieces have complex geometry and retain Cr(VI) solution. The usual system is a vat after the chromium bath with sulphuric acid and sodium bisulphite.

Driving force for implementation
Can be used where waste water treatment capacity is limited.

Reference literature
[IHOBE, 1997 #6; UBA, 2003 #104[3, CETS, 2002, 6, IHOBE, 1997] [124, Germany, 2003]
Lancy Laboratories Inc., Zelienople, Pa (US)

4.2.6.8.8 Regeneration and re-use/recycling of rinsing water

Section 4.2.5.4 highlights how water can be regenerated and re-used, and that this should be considered in the context of the water usage for the whole installation.

Spent rinse-water can be regenerated, such as by one of the techniques described below (for other possibilities, see Section 4.2.10). This can lead to savings in water consumption and will reduce to amount of waste water to be treated, reducing the waste water treatment costs for capital investment, energy usage and chemicals. However, this has to be offset by the cost of the regeneration equipment and the power and chemicals that this may incur. Where incoming water is treated, it is often easier and cheaper (in terms of capital deployed, chemicals and power) to recover the rinse-water than to treat fresh incoming water, as the ionic concentration or TDS in the incoming water may be higher than that of the rinse-water.

The cross-media effects for one application have been investigated, see Section 4.2.6.8.8.2 [159, TWG, 2004, 166, RIZA, 2004].

4.2.6.8.8.1 Regeneration by ion exchange

Description
By feeding the rinsing water through cation and/or anion exchangers, the cations become exchanged for H^+, and the anions for OH, and water of a quality approaching demineralised water is achieved. This is fed back to the rinsing system.

Achieved environmental benefits
Minimised water usage.

Cross-media effects
Construction and operation of the ion exchanger with consumption of energy and regeneration chemicals.

Operational data
A filter is used before the ion exchanger for protection against blocking by solid particles.

Applicability
An ion exchanger to regenerate rinsing water is not usable if strong oxidants, high concentrations of organic material, and metal cyanide complexes are present. To regenerate highly concentrated rinsing waters, large scale installations and frequent regeneration of the system are needed, e.g. with HCl or H_2SO_4 and NaOH.

The resins do not usually remove organics, which will accumulate in the rinsing water. This may require additional treatment. If not, in a system with a central ion exchange plant, the organics may be spread to all processes and might interfere with other processes, such as the rinse recovery, unless additional cleaning processes are added, such as activated carbon filtration, or the use of the recycled water is limited to selected uses.

Ion exchange may become impractical for use with total dissolved solids concentrations above 500 ppm, due to the need for frequent regeneration.
Resins have different effective pH ranges. For example, iminodiacetate chelating resin works best in a slightly acidic range; selectivity is lower at higher pH and below a pH of approximately 2.0.

Oxidants, solvents, organics, oil and grease can degrade resins and suspended solids can clog resin columns.

Economics
Capital cost of equipment versus savings in water usage will be site-specifc.

Example plants
Richard (Argenteuil), SATEC (Buchelet), SEAM (les Mureaux), France

Reference literature
[104, UBA, 2003], [114, Belgium, 2003, 124, Germany, 2003, 162, USEPA, 2000]

4.2.6.8.8.2 Regeneration by reverse osmosis

Description
Rinsing water can, in some cases, be regenerated by reverse osmosis (this process is described in Section 4.2.6.8.11.5).

Achieved environmental benefits
The achieved environmental benefits are more than just a reduction in water usage and extend to energy savings and a significant reduction in chemical use in waste water treatment.

Cross-media effects
Construction and operation of the ion exchanger with consumption of energy and regeneration chemicals. The salt content of the residual water is high and may be difficult to treat in a typical waste water treatment plant. The membranes also need rinsing with fresh water.

Applicability
The water to be treated may not be suitable or may need pretreatment because of solids or undissolved particles, organics, calcium, aluminium and heavy metals, see Section 4.2.6.8.11.5

Example plants
BGT Eindhoven, Netherlands

Reference literature
[126, Netherlands, 2003].

4.2.6.8.9 Single rinsing techniques

Description
In certain situations, single rinsing operations are necessary. This may be where there is a loss in quality if there is too much rinsing of the surface, for example, black passivation zinc, thick film passivations or rinsing between nickel and bright chromium

In other cases, the stopping of the surface reaction succeeds only when there is quick dilution in the first rinsing stage, which requires the use of high quantities of water. In such cases, the concentration of the reacting chemicals in the first rinsing stage must kept low.

Other examples are manual or semi-automatic lines with small production throughput, or used for development work, see Section 4.2.6.8.6 above.

To minimise environmental impacts:

- water used here may be regenerated and recycled within the process, e.g. by a deioniser, or water regenerated from elsewhere may be used
- where technically possible, having compatible chemistry for the preceding and subsequent solutions can minimise the need for rinsing (e.g. same acid base), see Section 4.2.6.7.5.

Achieved environmental benefits
Steps to minimise impacts are described in Description, above.

Cross-media effects
High water consumption and material losses.

Operational data
Multi-stage rinsing may damage surface treatment, such as reducing corrosion resistance.

Applicability
See Description, above.

Reference literature
[3, CETS, 2002, 104, UBA, 2003],[113, Austria, 2003, Germany, 2003 #124]

4.2.6.8.10 Multiple rinse techniques

General description

Multiple stage rinsing is particularly suitable to achieve a high rinsing rate with a small amount of rinsing water.

For example, in cascade rinsing, the water flows in the opposite direction to the workpieces, as shown in Figure 4-20. This results in a rinsing water requirement of constant rinsing quality (the rinsing ratio), and is mathematically expressed in the term:

$$Q/t = \sqrt[n]{Sk}\ (V/t)$$

Q/t = rinsing water amount (in l/h) required to reach the rinsing ratio
n = rinsing stage number
Sk = rinsing ratio
V/t = drag-out (in l/h)

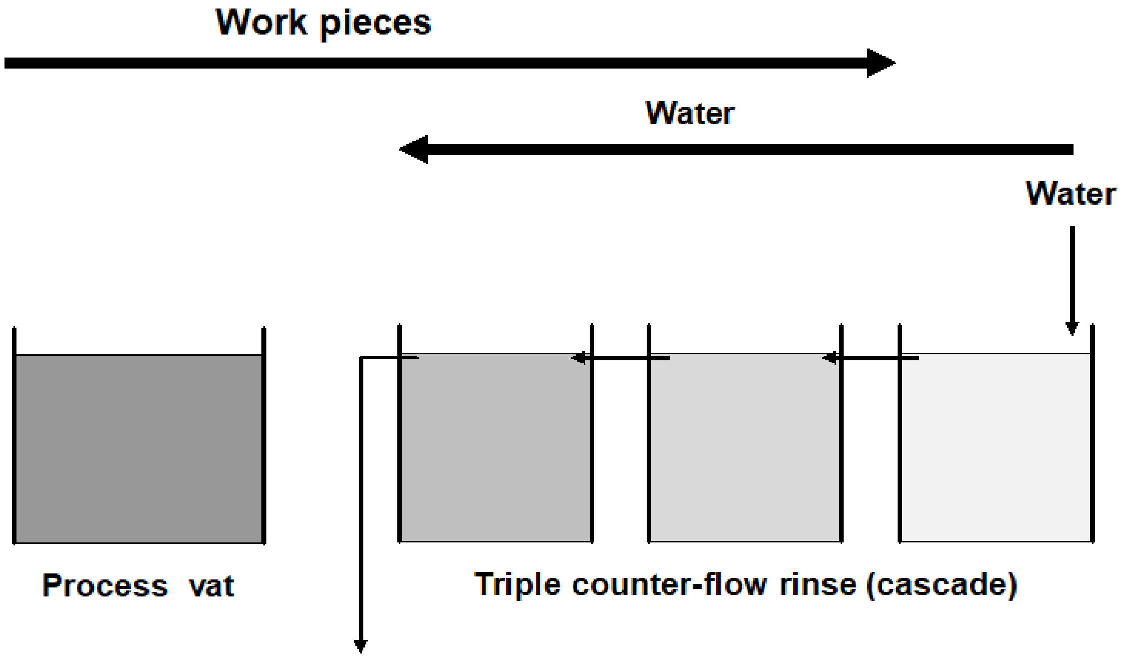
The main effect of saving is reached with the transition from the first into the second stage. As Table 4-9 shows, a smaller rinsing quantity of water can be achieved by the selection of the correct rinsing system. The effect of water saving decreases with an increasing number of rinsing stages. However, the volume of water required decreases to the point where direct make up for water losses from process solutions at ambient temperatures can be considered. The achievable recovery rate is, at a given volume of evaporation, directly related to the concentration of process chemicals in the first rinse station.

Table 4-9: The rinsing ratio is a function of a specific rinsing quantity of water (expressed as litres of rinsing water per litre of dragged-out electrolyte) given and the number of cascades

Rinsing ratio(x:1)	**10000**	**5000**	**1000**	**200**
Number of stages	Necessary rinsing quantity of water in l/h			
Single stage	10000	5000	1000	200
Two stages	100	71	32	14
Three stages	22	17	10	6
Four stages	10	8	6	4
Five stages	6	5	4	3
[3, CETS, 2002]				

Some options and variations are outlined in Sections 4.2.6.8.10.1, 4.2.6.8.10.2, 4.2.6.8.10.3 and 4.2.6.8.10.4. They may be used in conjunction with other techniques, such as those described in Sections 4.2.6.8.1, 4.2.6.8.4, 4.2.6.8.5, 4.2.6.8.7, and 4.2.6.8.8.

Only a description of each option is given, other factors are described in this general section.



[104, UBA, 2003]

Figure 4-20: Multi-level rinsing technology (cascade technology)

Overall achieved environmental benefits for all options described

Multiple rinsing techniques play an important role in reducing water usage and materials recovery. The zero discharge (or squared water balance) is often seen as the ultimate criterion of the rinsing technology for a surface treatment process low in emissions and requires additional techniques to prevent all water discharges, However, closing the loop for materials for specific process chemistries within a process line is more readily achievable, see Section 4.2.6.8.11.

Closing the loop for a process requires the water returned to the process solution from the first rinse station to be brought into balance with the water lost in evaporation and drag-out. Process solutions operated at higher temperatures and with multi-stage rinsing offer possibilities for this (see Sections 4.2.6.8.11.2 and 4.2.6.8.11.3). By the introduction of multistage rinsing systems partly combined with a rinsing water recycling system and other techniques (see Section 4.2.6.8.11) and decreases of waste water of up to 90 % can be obtained. One coil coating plant reports a reduction of 30 m^3 per hour.

Table 4-10 shows drag-out recovery rates achievable with different multiple rinse techniques, taking the respective values of the reference lines as basis. Good practice for the rinse criterion after both main processing steps is a minimum R =1000,for the examples given here: medium cyanide zinc barrel plating and bright nickel jig plating (see Table 4-9).

Table 4-10: Achievable recovery rates for some multiple rinse techniques

Rinse technique	Recovery rates Medium cyanide zinc barrel	Recovery rates Bright nickel, jig
Triple counter flow rinse	<24 %	<57 %
This technique does not provide satisfactory recovery rates in a barrel plant since WD>3WR (see formulas, 4.2.6.8.10.1). If no major additional investment is necessary, a rate of 57 % in jig plant seems attractive.		
Triple static rinse	>40 %	>95 %
The necessity of changing rinse-water already after less than eight hours operation in barrel plating plant makes this technique difficult to apply, whereas in jig plant the rinse-water has to be changed no earlier than 56 hours operation and the recovery rate		

of>95 % can be attained again without major additional investment		
Dual static rinse plus flow rinse	>90 %	>98 %
When a high drag-out recovery is required, this technique should be used in barrel plating. Changing of rinse-water is required after 24 hours operation. The installation of an appropriate ion exchanger plant or a counter-flow rinse system will minimise the use of water.		

Overall cross-media effects for all options described
There are none for multiple rinsing on its own.
If used in conjunction with other techniques, there may be increased energy if evaporation or other concentration techniques are used (see Section 4.2.6.8.11) and chemicals for regeneration if deionisation is used

Overall operational data for all options described
A combination of spray rinsing, particularly if carried out over the process solution, as part of a multiple rinsing system may combine the advantages of multiple stage water usage reduction with minimum extra space requirement. It may also reduce water usage further.

Overall applicability of all options described
There are options and combinations suitable for most types of installations. In some cases, this may be limited by the need for single rinsing, see Section 4.2.6.8.9.

A build-up of breakdown materials which may reduce process quality is likely unless other solution maintenance measures are taken.

Overall economics for all options described
Generally the installation of multistage rinsing techniques is associated with higher space requirement and higher investments (costs for additional tanks, workpiece transport equipment and control). The decrease of the water consumption, recovery of process chemicals and the smaller effluent discharge, which requires a smaller waste water processing facility and less treatment chemicals, reduces the total costs.

The economics for the recovery of materials and the reduction of water usage, vs. the cost of increasing the number of rinse tanks in a rinsing stage, amendments to plant, etc. can be calculated using the data in this section, with specific plant data. It can also be calculated using software tools for plant optimisation, for examples of rinsing after cleaning, after pickling, after electrocleaning, after plating and in conjunction with forced evaporation, as well as after passivation.

One example plant avoided the need to construct a waste water treatment plant by using multistage cascade rinsing combined with process solution evaporation, see Section 4.2.6.8.11.3.

Overall driving force for implementation for all options described
See Overall economics for all options, above.

Example plants
SGI, Plaisir, France, Sikel N.V., Genk, Belgium, Exhall Plating Ltd, Coventry, UK. Frost Electroplating Ltd., Birmingham, Merrydale Ltd, Wednesbury, UK; Bodycote Metallurgical Coatings, Uxbridge, UK, Germany

Reference literature
[3, CETS, 2002, 18, Tempany, 2002, 104, UBA, 2003], [159, TWG, 2004]

4.2.6.8.10.1 Multiple stage counterflow rinse

Description

This is shown in Figure 4-21, with drag out recovery. The rinse ratio R achievable with counter flow rinsing can be calculated as

$$R = C_0/Cn = (q^{(n+1)-}1)/(q-1)$$

where $q = W/D$

R = rinse ratio
C_0 = concentration of chemicals in process solution
C_n = concentration of process chemicals in last nth rinse station
D = quantity of drag-out,
n = number of counterflow rinses

W = quantity of rinse-water to achieve R at a given D,

A triple counter flow recovery rinse is shown in Figure 4-21, below.

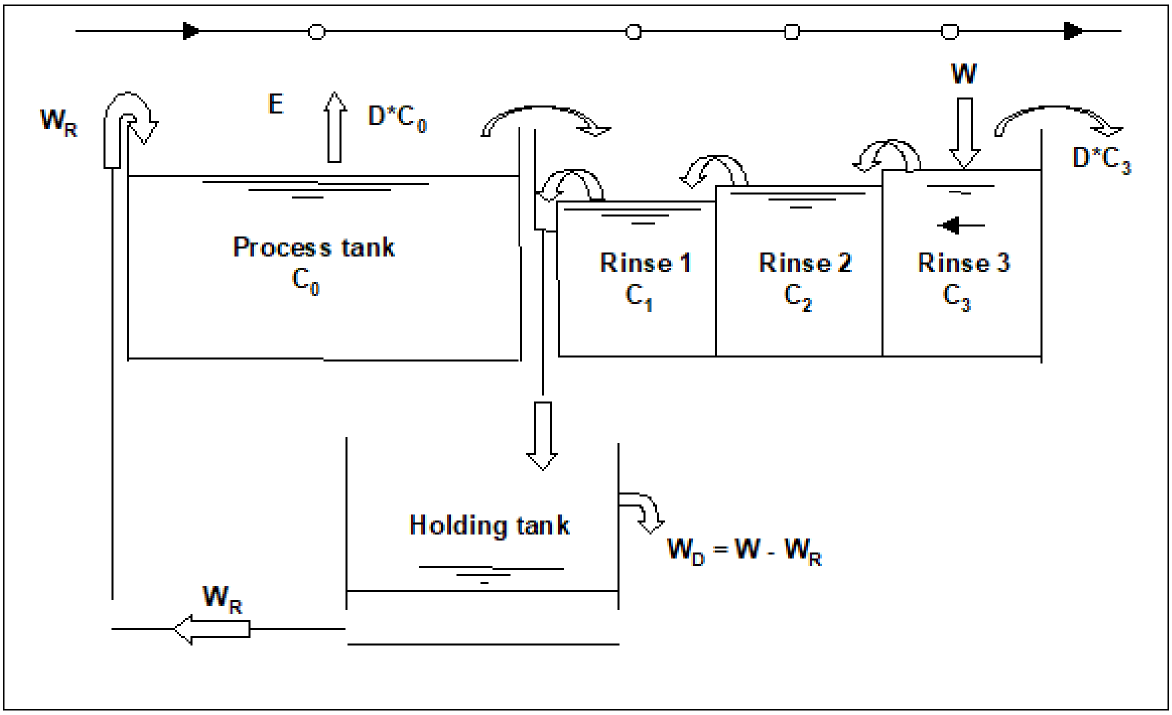


Figure 4-21: Recovery of drag-out with a triple counter flow rinse

In cases where $E \geq W$, the drag-out recovery rate is:

$$Rc_R = 1 - C_3/C_0$$

In cases where E = WR <W, drag-out recovery rate is reduced to:

$$Rc_R = (1 - C_3) * W_R/W$$

C_0 = concentration of chemicals in process solution
C_3 = concentration of process chemicals in rinse station 3
E = evaporation losses
Rc_R = recovery rate of drag-out

W = quantity of rinse-water used
W_D = quantity of rinse-water to be discharged
W_R = quantity of rinse-water available for drag-out recovery.

Figure 4.6 shows the specific water consumption of triple and quadruple counter flow rinses in litres per litre drag-out.

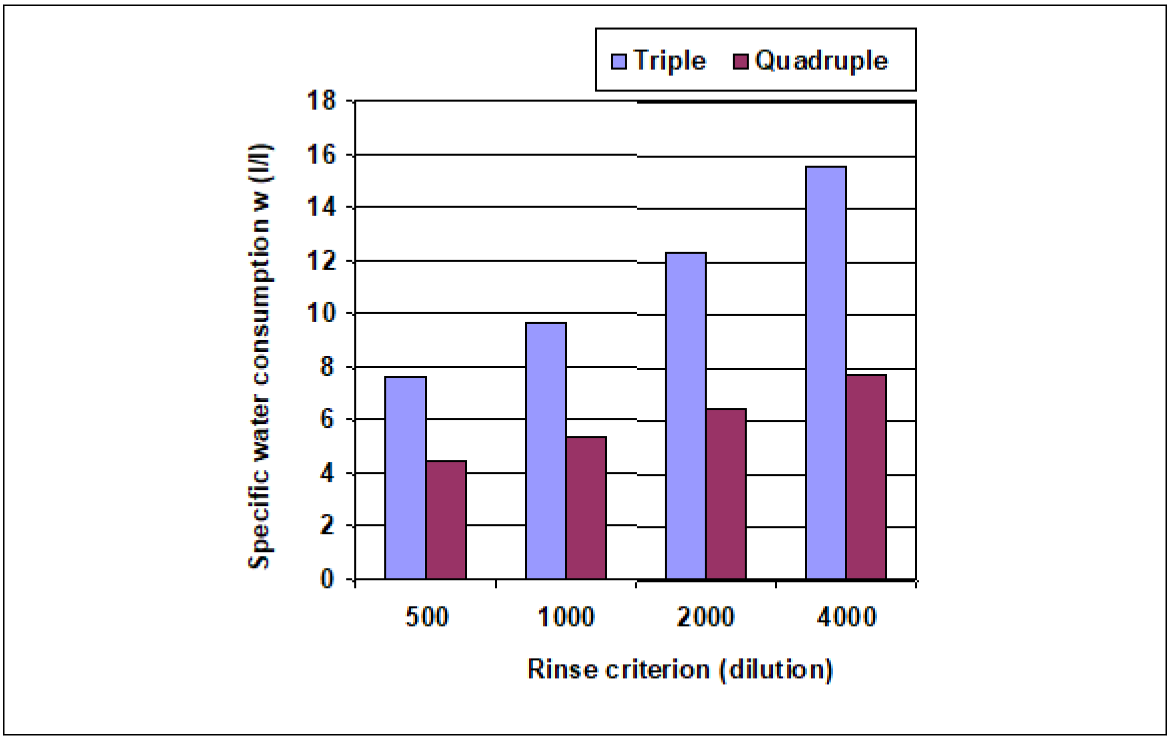


Figure 4-22: Specific water consumption ‘w’ of triple and quadruple counterflow rinses

4.2.6.8.10.2 Multiple static rinse

Description
Multiple static rinsing instead of counter flow rinsing allows for reduced water consumption [3, CETS, 2002].

Figure 4-23 shows the arrangement of tanks and the process sequence of a triple static rinse.

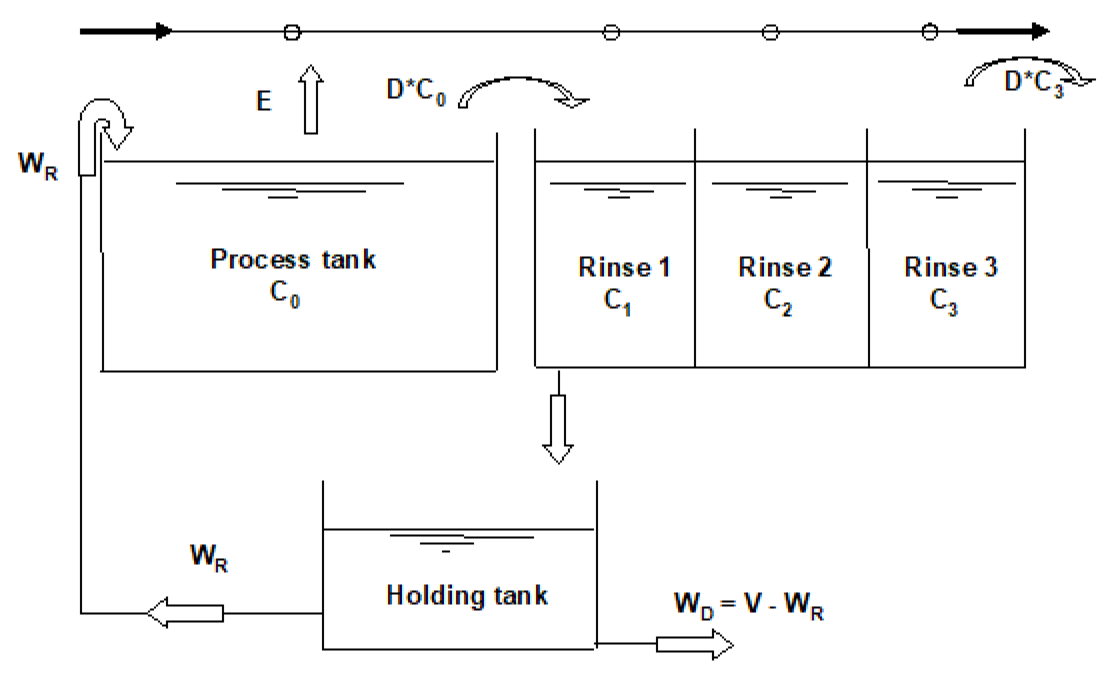
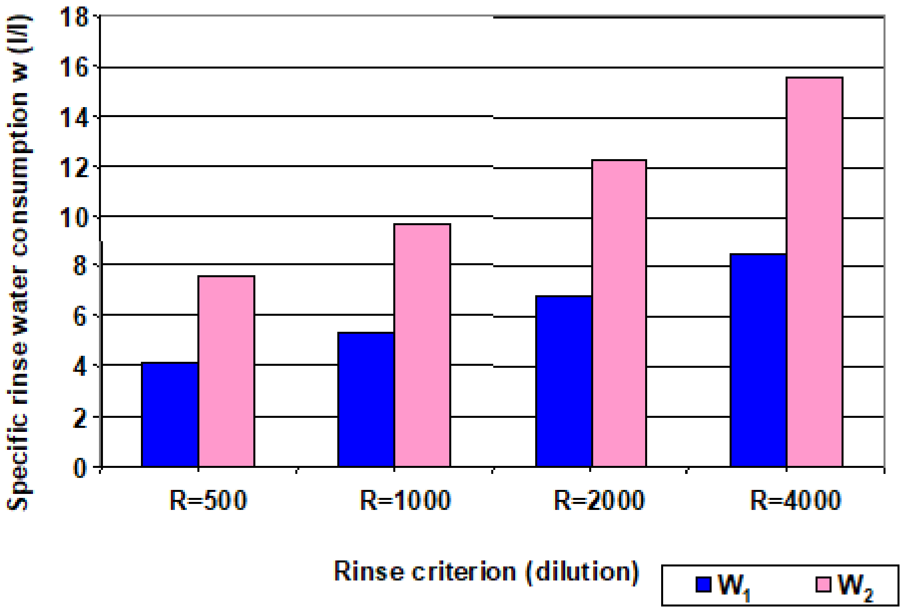


Figure 4-23: Recovery of drag-out with triple static rinse

Instead of continuous inflow and overflow, rinse 1 is discharged into holding tank only when C_3 has reached its set value. Rinse-water from tank 2 than is pumped into tank 1 and water from tank 3 into tank 2. After tank 3 has been filled with fresh water, processing can be continued.



(Values for W_1 valid when all three tanks are filled with fresh water)

Figure 4-24: Specific water consumption in litre per litre of drag-out W_1 triple static vs. W_2 triple counter flow rinse

As Figure 4-24 shows, savings of water compared with counter-flow rinsing are substantial: savings of approximately 45 %, when all rinse tanks are filled with fresh water, and approximately. 40 %, when water from tank 2 has been filled into tank 1 and tank from tank 2, as it is done at normal operation.

The concentration of process chemicals in static rinses 1, 2, 3 can be calculated with the following equations:

$$C_1n = C_0\,(1-q^n)$$

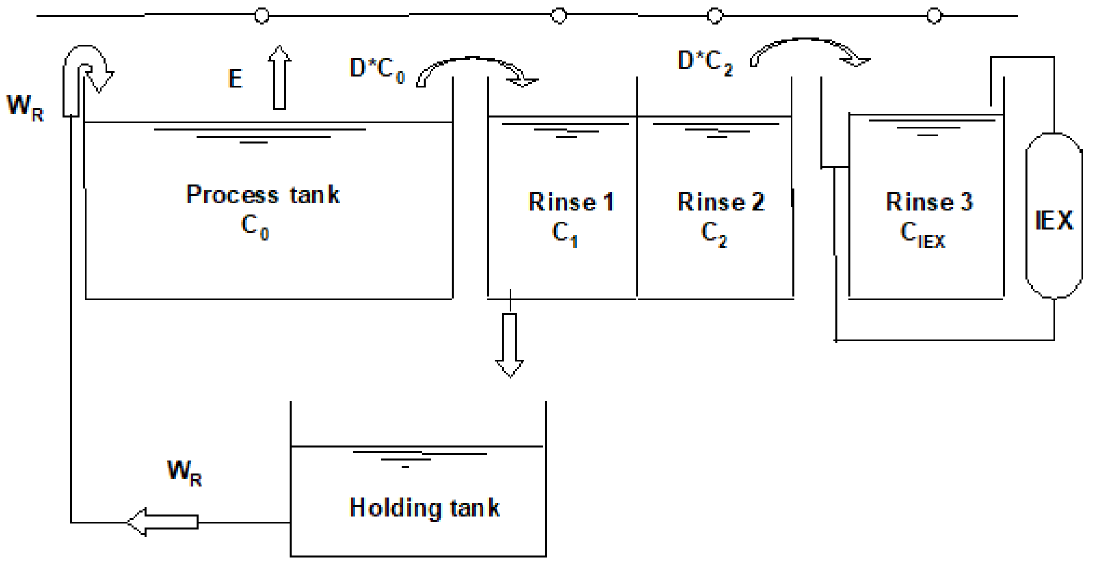
$$C_2n = C_0\{1-(n+1) * q^n + n * q^{(n+1)}\}$$

$$C_3n = C_0\,\{1-(1/2) * (n+1)(n+2) * q^n + n * (n+2) * q^{(n+1)} - (n/2)(n+1) * q^{(n+2)}\}$$

C_0 = concentration of chemicals in process solution
$C_{1,2,3}n$ = concentration of process chemicals in rinse station 1, 2, 3, etc. after n workloads rinsed
D = quantity of drag-out
n = number of workloads rinsed
V = volume of water per rinse station.
q = $V/(V+D)$

4.2.6.8.10.3 Dual static rinse followed by final flow rinse with recirculated water

At comparatively high drag-out rates, even triple counter flow or static rinses might not be sufficient for satisfactory drag-out recovery. A modified triple rinse is shown in Figure 4-25.



[104, UBA, 2003]

Figure 4-25: Dual static rinse followed by single flow rinse with recirculated water, continuously purified in ion exchangers (IEX)

Description

Rinse 1 is discharged into a holding tank after a period of time depending on the mode of operation of the line. In this example, this would be after three shifts or 240 rinsed barrels (Figure 4-25).

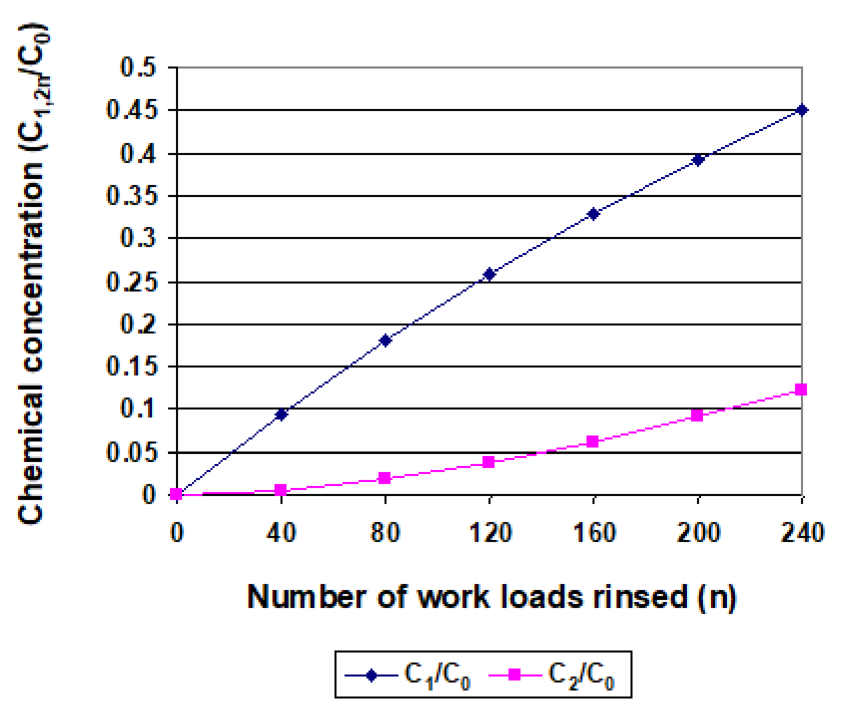


Figure 4-26: Increase of chemical concentration C_1 and C_2 related to number of rinsed barrels

This technique allows for concentrations $C_2 \leq 0.2\ C_0$, equalling an average value of approximately $0.095\ C_0$, starting from 0 and ending at $0.2\ C_0$. The area below curve C_2/C_0 is equivalent to the quantity of chemicals loaded on the ion exchangers. The design flowrate of recirculated water has to be high as the ion concentration must not exceed 2 mVal per litre.

The final rinse in recirculated water provides a sufficiently high rinse rate (or criterion) at low water consumption (approximately 5 % of flowrate).

Reference Literature
[3, CETS, 2002]

4.2.6.8.10.4 Multi-cascade rinsing with limited process line space

Description
In the case of existing plants, the use of a larger number of tanks is often not possible within the plant because of reasons of space. In such cases, the employment of so-called external cascades (where the cascades are external to the process line) may be possible. In the treatment line there is only one rinsing tank per process step. Each rinse tank is connected to several external tanks which work as rinsing stages according to the cascade principle. The workpieces or substrates are brought into the rinsing tank and rinsed successively with the water from the individual rinsing stage tanks, becoming progressively cleaner. Rinsing can be by sprays or filling the tank to immerse the workpieces or substrates. Figure 4-27 shows a spray rinsing system with the first rinse holding tank being concentrated. The concentrate is returned to the process solution and the cleaned water returned to the final rinse holding tank. Concentration techniques are described in 4.2.6.8.11.

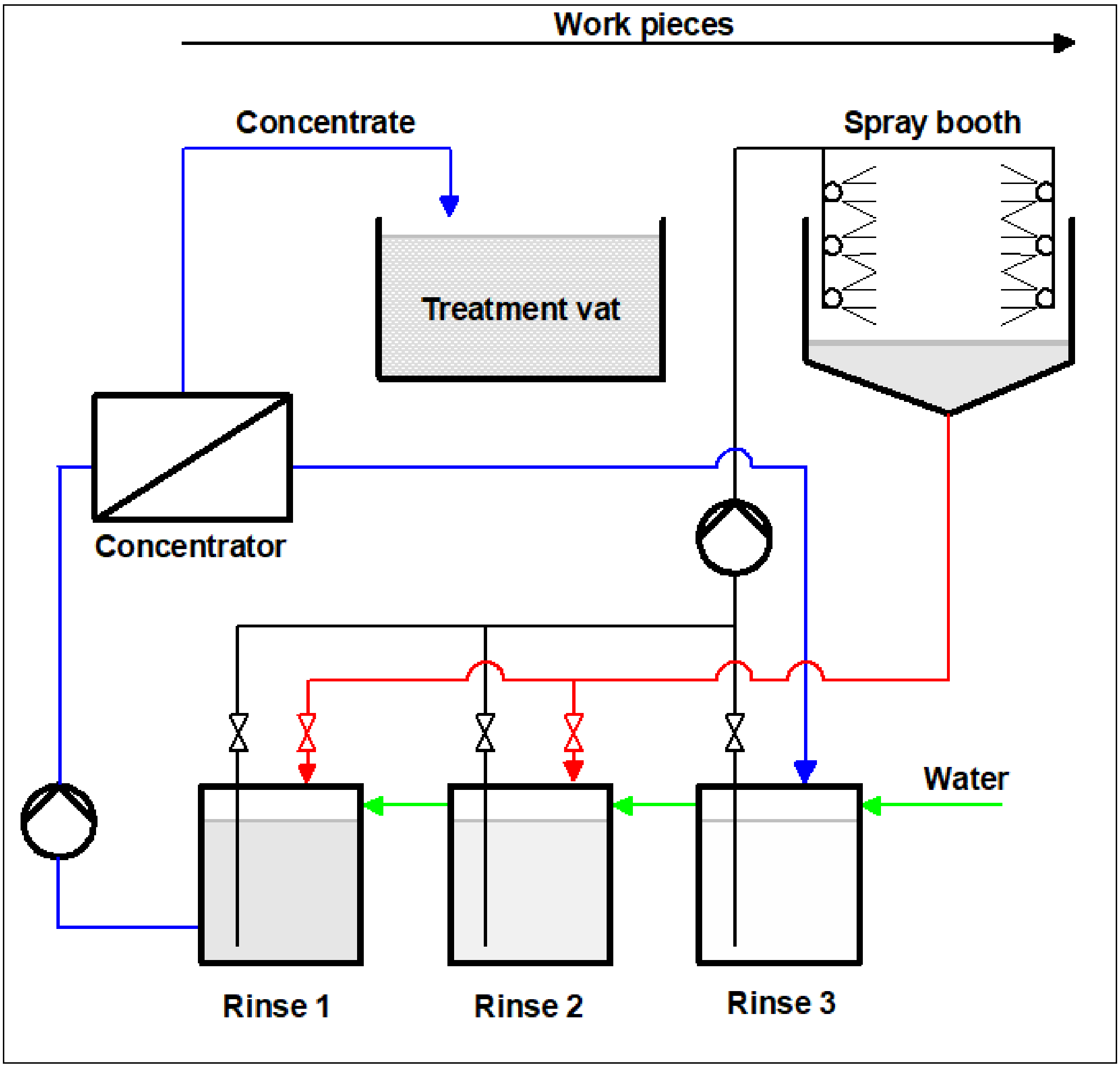


Figure 4-27: External cascade system: Single spray compartment with external cascade and concentrate recycling

Operational data
Gives quality problems if rinse-water contains solid particles, especially with alkaline water

Reference Literature
[104, UBA, 2003], [113, Austria, 2003].

4.2.6.8.11 Increasing drag-out recovery rate and closing the loop

Where the quantity of water needed for appropriate rinsing (to achieve process control and product quality) exceeds evaporation losses, and recovery rates>90 % are expected, the amount of water in the drag-out recovery system has to be decreased. This is achieved by a combination of techniques.

In some cases, drag-out can be recovered until the loop can be closed for process chemicals by applying a suitable combination of techniques. Closing the loop refers to one process chemistry within a process line, not to entire lines or installations,

Closed loop is not zero discharge: there may be small discharges from the treatment processes applied to the process solution and process water circuits (such as from ion exchange regeneration). It may not be possible to keep the loop closed during maintenance periods. Wastes and exhaust gases/vapours will also be produced. There are also likely to be discharges from other parts of the process line, such as rising after degreasing or etching.

Increasing drag-out recovery can best be considered with other processes and activities, such as recycling and re-using water and an overall approach derived for the installation, see Operational data, below.

Increasing drag-out recovery and closing the loop require techniques to:

- reduce drag-out, see Section 4.2.6.7
- reduce rinse-water (such as by cascade rinsing and/or sprays) with drag-out recovery, see Section 4.2.6.8
- concentrate the returning drag-out or receiving solutions, such as by ion exchange, membrane techniques, or evaporation. The water removed during concentration (such as from evaporation) can often be recycled back into the rinse.

Examples of techniques for this purpose are, for example:

- addition of an eco rinse tank
- evaporation using surplus internal energy
- evaporation using additional energy (and in some cases, low pressure)
- electrodialysis
- reverse osmosis.

The principle of rinse-water removal and chemical concentration is shown in Figure 4-28. The concentrate is used to replenish the process solution whilst the condensate can be reutilised as rinse-water.

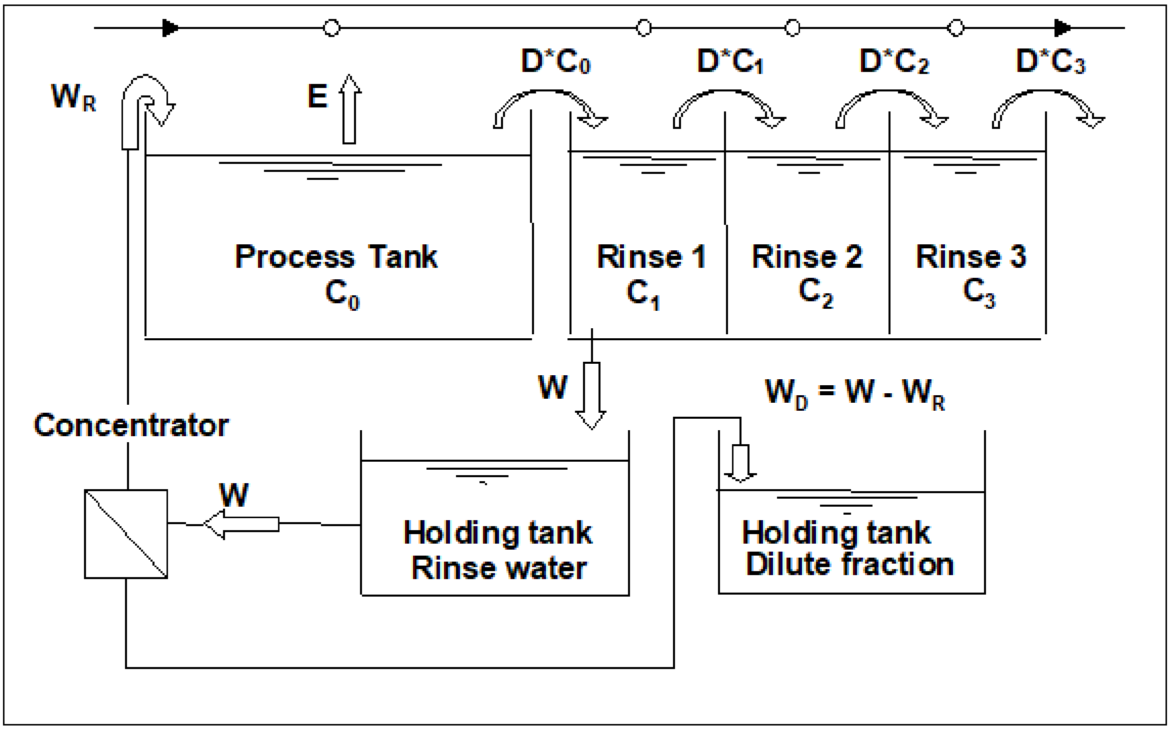


Figure 4-28: Rinse-water and chemical recovery through concentration

Achieved environmental benefits
See Overall achieved environmental benefits, Section 4.2.6.8.10.

Closing the loop achieves a high raw material utilisation rate and in particular can:

- reduce the use (and therefore cost) of raw materials and water
- as a point-source treatment technique, achieve low emission limit values
- reduce the need for end-of-pipe waste water treatment (e.g. removing nickel from contact with effluent containing cyanide)
- reduce overall energy usage when used in conjunction with evaporation to replace cooling systems
- reduce the use of chemicals for treating the recovered materials that would otherwise be discharged in the waste water
- ~~reduce the loss of conservative materials such as PFOS where used.~~

Cross-media effects
See Overall applicability, Section 4.2.6.8.10.
The lifetime of the process baths may be affected by the recycling of contaminants, and may require additional maintenance.
Energy is used for concentration techniques, although this is less for processes that gain heat from the electrochemical reactions, such as hexavalent Cr(VI). Energy is also used for pumping and pressure filtration techniques.
Chemicals are used in some concentration techniques, such as ion exchange.

Operational data
See individual techniques, Section 4.2.6.8.10.1 to Section 4.2.6.8.10.4.

It is good practice to consider increased drag-out recovery with other options for the whole installation. These can include combining compatible streams from different processes for purification/recovery,

Applicability
Increasing drag-out recovery is widely practised. Some techniques require additional energy, which means cost, which may be offset by savings in cooling energy and drag-out recovery. The chemical content of the rinse-water to be processed also affects the appropriate choice.

Closing the loop has been successfully achieved on some substrates for:

- precious metals
- ~~cadmium~~
- ~~barrel nickel plating~~
- copper, nickel and hexavalent chromium for decorative rack plating
- hexavalent decorative chromium
- ~~hexavalent hard chromium~~
- etching copper from PCBs.

The type of system installed will depend on the existing infrastructure, and plant as well as the process type.

Economics
See Overall applicability, Section 4.2.6.8.10. These will be site-specifc.
Capital and running costs of the techniques may be offset by increased recovery of process chemicals, which can be >95 %. Also, these techniques can reduce running costs and/or investment in a waste water treatment plant. Extra steps cause a loss in process line capacity (an increase in the number of cycles).

Planning calculations can be assisted by software tools.

Driving forces for implementation
See Overall economics, Section 4.2.6.8.10.

Reduced costs.

Example plants

See individual techniques, Section 4.2.6.8.10.1 to Sections 4.2.6.8.10.4 and 4.2.6.8.11.5, and Reference Plants K and L.
Bodycote, Uxbridge, UK (formally West Middlesex Plating)
Merrydale, Wednesbury, UK

Reference literature

[3, CETS, 2002, 104, UBA, 2003], [18, Tempany, 2002, 48, France, 2003, 49, France, 2003, 55, France, 2003, 113, Austria, 2003, 162, USEPA, 2000]
[176, CETS, 2024]

4.2.6.8.11.1 Addition of an eco rinse tank

Description

The operation of an eco tank is described in Section 4.2.6.8.4. This alone can recover 50 % of drag-out; and can assist in achieving rates of above 50 %. The total rate can be calculated when 50 % of the values in Table 4-10 are taken, for instance, triple static rinse in barrel plating:

$$Rc_R \text{ total} = 50\ \% + 0.5(40)\ \% = 70\ \%,$$

equivalent to an increase of 75 % and a reduction of rinse-water by >20 %.

Achieved environmental benefits

May be considered where other alternatives are not achievable or as part of several rinses steps.

Cross-media effects

See Section 4.2.6.8.4

Operational data

See Section 4.2.6.8.4. Requires additional process line space as well as an additional process station programming into automatic lines.

Applicability

Adding an eco rinse tank requires additional space on the process line.
Can also be used for minimising chemical usage for metal plating baths, where the concentration of metal and other ions must be increased by salts to maintain a certain level. For some processes, pre-dip can cause problems, see Section 4.2.6.8.4.

Eco-rinse or pre-dipping is not widely used in etching and anodising processes. Instead a warm rinse (without constant water replenishment) especially after etching and brightening is regarded as a practicable technology. The purpose of the first rinse after any active bath is to stop the reaction of the active bath on the surface [175, ESTAL, 2024].

Economics

See ~~Overall~~ economics Section 4.2.6.8.1.

Driving force for implementation

See Overall economics Section 4.2.6.8.1.

Reference literature

[3, CETS, 2002] [113, Austria, 2003]

4.2.6.8.11.2 Evaporation using surplus internal energy

Description

Evaporation is atmospheric and achieved here by using the surplus heat energy in the process generated because of the poor electrical efficiency of the solution. The amount of energy necessary for evaporating corresponds roughly to the energy which is released in the process tank as heat energy thus the system is energetically self-sufficient. The rate of evaporation can be increased by using air agitation, or an evaporator. In this case, the process solution is pumped through the evaporator where it meets an air stream blown through the evaporator to the atmosphere. The evaporator chamber is usually filled with packing material to increase the water evaporation surface. Heated evaporators are described below in Section 4.2.6.8.11.3

Evaporation from the process can be due to:

- an elevated processing temperature, such as >80 °C for electroless nickel and >55 °C for electrolytic nickel and phosphating at >90 °C (see Figure 4-29)
- cooling of the process solution by evaporation to maintain a constant processing temperature, such as in cyanide zinc barrel plating at <25 °C, bright chromium at 40 °C and hard chromium at 60 °C.

The evaporation of 1 litre of water requires approximately 1.4 kWh.

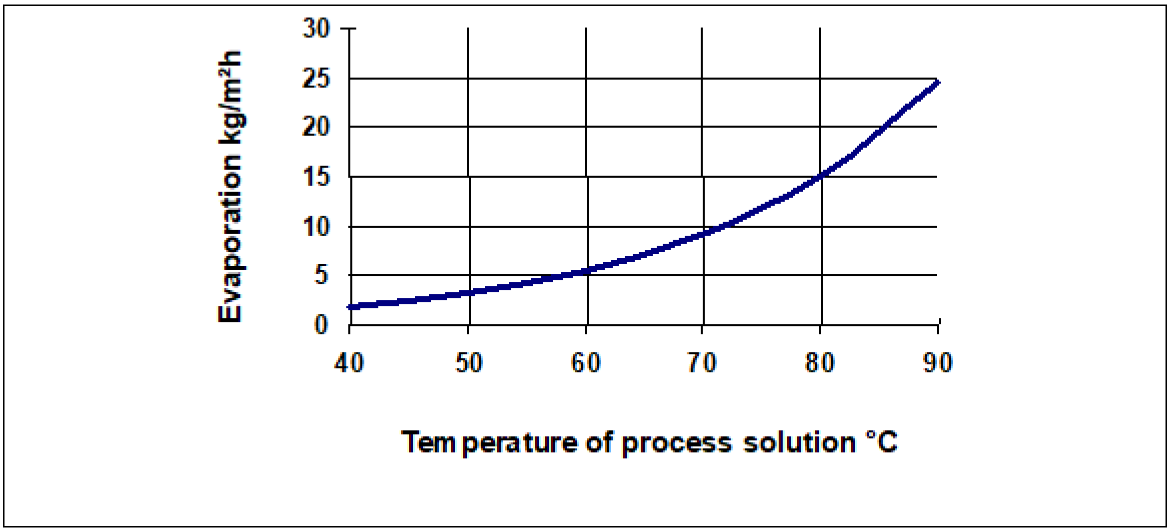


Figure 4-29: Specific water evaporation from process solutions, with fume extraction at the process tank

The evaporation losses in operating parameters in the previous example can be calculated as follows:

Jig plating

surface area of plating solution	6	m^2
water evaporation at 60 °	5.5	litres/m^2h
water evaporation	33	litres/h.

Barrel plating

plating energy/barrel	2.5	kWh
plating energy total	25	kWh
water evaporation equivalent	35	litres/h.

~~An example calculation is given in for zinc barrel plating and examples are shown in Annex 7.1.~~

Equivalent quantities of rinse-water with diluted process solution can be added back into the process tank. The recovery rate is directly related to the concentration of process chemicals in rinse-water, and this again depends on the chosen rinse technique. A choice of appropriate technique is outlined below.

Even if there is no significant evaporation, a technique for drag-out recovery is shown in Section 4.2.6.8.4.

Achieved environmental benefits
Higher recovery of drag-out.
Can be part of closing the loop for specific process steps.

Cross-media effects
Reduction in the need for cooling systems.

Possible aggressive fume formation at higher operating temperatures in some processes.
Extraction of the vapours from the process is part of the evaporation. The extracted air may need scrubbing. Scrubbing liquors may be treated in a typical waste water treatment plant.
Decomposition products are concentrated, so additional solution maintenance is required

Operational data
Evaporation is most readily used with process solutions working at elevated temperatures, in particular chromium electrolytes. In connection with multistage rinsing technology (in practice up to five rinsing stages), the procedure can be operated almost waste water free. Sufficient evaporation can occur at an ambient temperature. In hexavalent chromium plating, chromic acid dragged out from the process bath into the rinses is virtually completely recovered to the solution. Minimum chromium acid losses are to be expected through the exhaust air and with the regeneration of the electrolytes.

Evaporation can be increased by using air agitation and/or an evaporator to increase the surface area (see Sections 0, 0 and 4.2.6.8.11.3).

Applicability
All process solutions, particularly those with poor electrical efficiency where the process solution heats and is often cooled by evaporation. Hexavalent chromium electrolytes are particularly suitable for this technique.

May also be used with chemical solutions with a high heat of reaction.

Regional weather patterns may also affect applicability.

Economics
Requires little or no capital installation.

Driving force for implementation
See Overall economics, see Section 4.2.6.8.10.

Example plants
See reference plants in Annex 7.1

Reference literature
[18, Tempany, 2002, 104, UBA, 2003], [124, Germany, 2003] [113, Austria, 2003].

4.2.6.8.11.3 Evaporation using additional energy with an evaporator

Description
In electrochemical installations, atmospheric evaporators are used for the concentration of rinsing water, which are fed back into the process tank. Industrially used evaporators usually work at temperatures between 20 and 200 °C and at operating pressures between 0.1 and 1 bar. Usually the evaporators used in electroplating shops are equipped with energy recovery (vacuum evaporators with vapour consolidating or heat pump) and need approximately 150 – 200 kWh per cubic metre of evaporated water.

The principles of (natural process) evaporation (see Section 4.2.6.8.11.2) and evaporators are approximately the same, yet the evaporator is more universally applicable in practice, since its performance is adjustable independently of the process conditions, (see Sections 0 and 0)

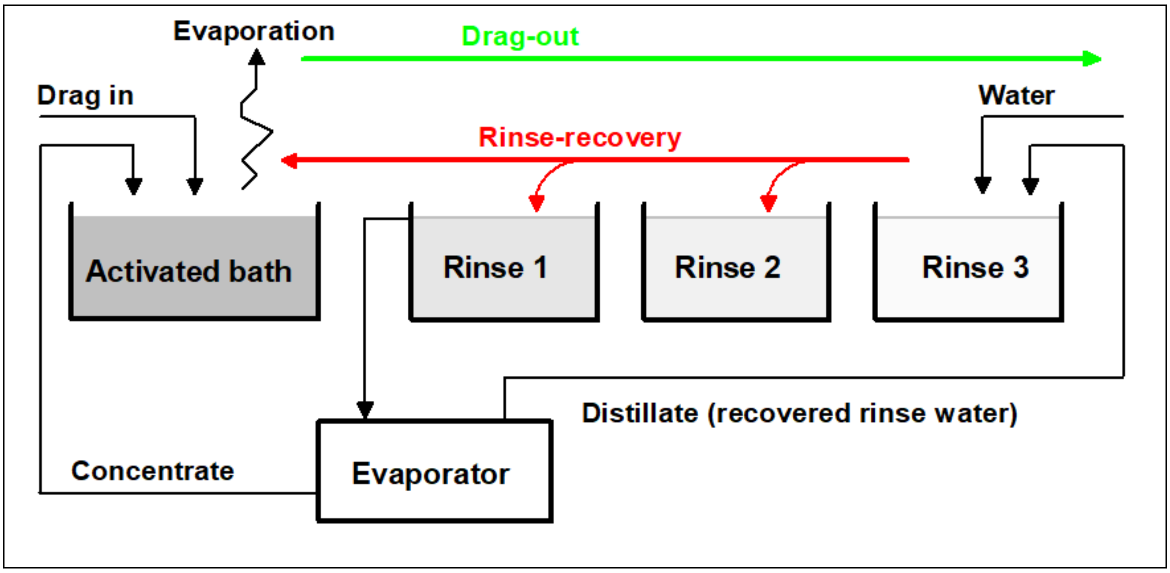


Figure 4-30: Schematic diagram of the evaporator

Achieved environmental benefits
See Overall achieved environmental benefits, see Section 4.2.6.8.10.

Cross-media effects
Additional energy in the order of 150 – 200 kWh/m^3 of water may be used in evaporators, either as heat input and/or reducing pressure.

To prevent contaminated water droplets being emitted to the air, the evaporation tank can be equipped with a mist eliminator at the outlet side. The performance of the evaporation tank depends on the air temperature and humidity, and there are likely to be significant regional variations

Operational data
With the evaporation of diluted electrolytes at normal boiling temperature of the water, organic additives of the electrolytes can be destroyed. Vacuum evaporator systems have therefore been developed which work at much lower pressures and low temperatures. Due to high demands on the materials in such systems, they are more expensive than simpler systems.

Applicability
All process solutions that are heat stable.

Although not dependent on surplus energy in the process bath (see Section 4.2.6.8.11.2), the process will work most effectively with hot solutions, or those with poor electrical efficiency where the process solution heats and is often cooled by evaporation.

Regional weather patterns may also affect applicability.

To ensure appropriate investment all process chemicals contained in the process solution must be tested for their application in an evaporation system before introduction of the technique.

In addition to the evaporation of chromium electrolytes, evaporators are also used for concentration of rinsing waters from the acid or cyanide zinc, nickel and cadmium electroplating. With zinc solutions, there is a tendency for the electrolytes to form foam which requires additional treatment.

Evaporators are increasingly used for electrolyte feedback from rinsing waters. The complete closing of material cycles with an evaporator enabling the complete feed back of rinse-water for certain process stages is achievable.

Economics
See Overall economics, Section 4.2.6.8.10.

There is a capital cost for installation of the evaporator (with or without vacuum), usually with a storage tank. There are additional energy costs, although these may be marginal with hot solutions. Cost savings come from recovered materials, reduced use of effluent treatment materials and in some cases, reduced capital investment in a waste water treatment plant.

The economics for the recovery of materials and the reduction of water usage, vs. the cost of increasing the number of rinse tanks in a rinsing stage, amendments to plant, etc. can be calculated using the data in this section (with specific plant data). It can also be calculated using software tools for plant optimisation, ~~for examples for rinsing after cleaning, after pickling, after electrocleaning, after plating and in conjunction with forced evaporation, as well as after passivation.~~

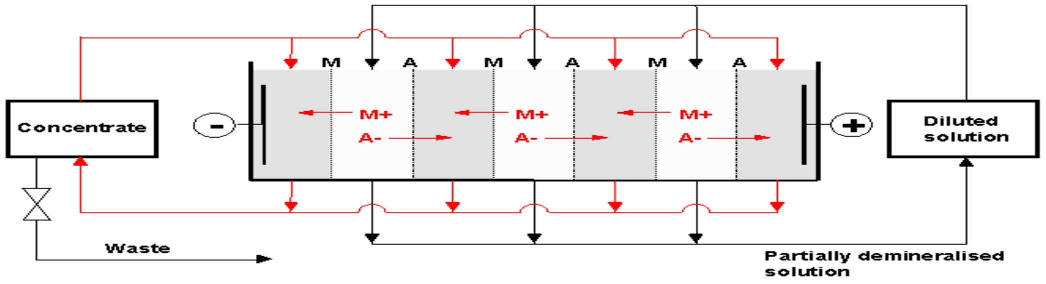
Driving force for implementation
See Overall economics, Section 4.2.6.8.10

Example plants
Frost Electroplating Ltd, Birmingham, UK; Merrydale, Wednesbury, UK, Sikel N.V. Genk, Belgium, Disflex France (Breuil le sec), TMN (Notre Dame de Gravenchon), France, ACRODUR (Carrière sur Seine), France (see Section 4.2.6.8.11.6).

Reference literature
[18, Tempany, 2002, 104, UBA, 2003], [119, Eurofer, 2003], [124, Germany, 2003], [124, Germany, 2003], [119, Eurofer, 2003, Czech, 2003 #116].

4.2.6.8.11.4 Electrodialysis

Description
The electrical dialysis is a diaphragm procedure, in which an electrical field forces material transport. Anions and cations are removed from solutions with an applied electric field in cells with alternating anion- and cation-permeable membranes. It is used both for the concentration of diluted solutions and for the demineralisation of water.



Note: M^+ = cation, A^- = anion; [104, UBA, 2003]

Figure 4-31: Operational principle of the electrical dialysis

Achieved environmental benefits

Reduced water consumption.
Increased drag-out recovery.

Cross-media effects

Requires energy inputs.

Operational data

To achieve long service life of the diaphragms:

- the diaphragms must be protected by a pre-filtration stage against mechanical pollution
- the blocking of the diaphragms by organic materials (such as oils) must be prevented
- blocking at the diaphragm surface can be avoided by regular rinsing and polarity reversal (pole changes).

Applicability

Has been used in surface treatment to recover nickel salts from rinse-water.

Economics

Criteria for an economic application of electrical dialysis are the service lifetimes of the diaphragms, the efficiency of the plant in separating components and the yield per kWh.

Reference literature

[104, UBA, 2003], [113, Austria, 2003, 162, USEPA, 2000]

4.2.6.8.11.5 Reverse osmosis – closed loop electroplating

TWG please note that CETS considers that is not used industrially and the example presented is from a non-IED installation

Description

Reverse osmosis (RO) uses a hydrostatic pressure gradient across a semi-permeable membrane to separate water from a solution of salts. The pressure applied exceeds the osmotic pressure of the feed solution causing water to flow from the concentrated solution to the more dilute solution: the reverse of the natural osmotic diffusion. Dissolved solids are rejected by the membrane surface. Many multi-charged ions can be rejected at rates exceeding 99 %. Single-charged ions typically have rejection rates in the range of 90- 96 %.

Menoni S.A. and Agence de l'eau Seine-Normandie

Figure 4-32: Reverse osmosis plant

Achieved environmental benefits
Used to concentrate rinse-waters and recover materials, treat waste waters and incoming or recycled water.

Cross-media effects
Energy required for maintaining pressure.

Operational data
Reverse osmosis is used in the surface finishing industry for purifying rinse-water and for recovery of chemicals from rinse-waters. It has also been used to purify raw water for the generation of high-quality deionised water in rinsing and plating solutions. Figure 4-32 presents a reverse osmosis flow schematic for rinse-water applications. Reverse osmosis applications involving the separation of plating chemical drag-out from rinse-water have been applied mainly to nickel plating operations (sulphamate, fluoborate, Watts and bright nickel). Other common applications include copper (acid and cyanide) and acid zinc. Recently, RO has been applied successfully to chromate rinse-water. In the typical configuration, the RO unit is operated in a loop with the first rinse following plating. The concentrate stream is recycled to the plating bath and the permeate stream is recycled to the final rinse. Reverse osmosis is commonly used for water treatment(with and without ion exchange) applications requiring production of high-quality water from high total dissolved solids (TDS) sources. Large scale waste water recycling is evolving as an important application for RO in the surface finishing industry.

Membrane performance of all polymer-based membranes decreases over time and permeate flow (flux) and membrane rejection performance are reduced. RO membranes are susceptible to fouling by organics, water hardness, and suspended solids in the feed stream or materials that precipitate during processing. Installing prefilters can control solids in the feed stream. Changing operational parameters, such as pH, inhibits precipitation. Oxidising chemicals like peroxide, chlorine and chromic acid can also damage polymer membranes. Acid and alkaline solutions with concentrations greater than 0.025 molar can also deteriorate membranes. In most applications, the feed solution will have significant osmotic pressure that must be overcome by the hydrostatic pressure. This pressure requirement limits the practical application of this technology to solutions with total dissolved solids concentrations below approximately 5000 ppm (with the exception of disc tube applications). Specific ionic levels in the concentrate must be kept below the solubility product points to prevent precipitation and fouling. Ionic species differ with respect to rejection percentage. Some ions such as borates exhibit relatively poor rejection rates for conventional membranes.

Applicability
See Operational data, above.

Economics
See Example plant, below. Payback can be short (see Example Plants, BGT Eindhoven)

Driving force for implementation
Materials recovery, water recovery, reduced investment and running costs in a typical waste water treatment plant

Example plants
BGT Eindhoven, Netherlands
Disflex France, Breuil le Sec, France.

The following data are for: Disflex France
Nickel is deposited on a flexible support before decorative chromium plating.

Water from the first cascade rinsing is recovered. This water is rich in nickel because of the drag-out, and is passed through activated carbon and it is sent to a buffer tank. The solution is pumped at 20 bars pressure through the membranes of the reverse osmosis unit. The recovered nickel solution is returned to the treatment bath and the water is reintroduced in the first stage of the cascade rinsings.

The process conditions are:

- nickel bath temperature: 60 °C
- nickel bath volume: 6000 l
- nickel bath concentration: 80 g/l
- five cascade rinsing tanks, volume: five tanks at 400 litres
- buffer tank volume (after activated carbon and before reverse osmosis):300 litres

Nickel concentration of the different cascade rinsings to judge the system efficiency:

- nickel bath = 80g/l
- rinse 1 Ni = 6.3 g/l
- rinse 2 Ni = 1.6 g/l
- rinse 3 Ni = 0.54 g/l
- rinse 4 Ni = 0.250 g/l (250 mg/l)
- rinse 5 Ni = 0.065 g/l (65mg/l).

The size of the reverse osmosis unit is not large and comprises two blocks of membranes each one metre long.

Benefits
Recovery of nickel solution, both metal and other additives.
Reduced waste water treatment costs.
Reduced water consumption.

Economics
For this example:

- electric consumption of the pump: 2.5 kWh
- membrane maintenance costs (change and cleaning): EUR 2000 for 3 years
- monitoring of the system (in time and manpower), levels control and filters cleaning:
- 1 hour each day
- cost of a reverse osmosis unit: EUR 30 000.

Other driving forces for implementation

There is no loss of nickel to solid waste or water. All the nickel bought is deposited, so there is 100 % efficiency.

Better quality of the products because rinsing is more effective.

Reference literature

[55, France, 2003, 162, USEPA, 2000, 166, RIZA, 2004]

4.2.6.8.11.6 Electrolytic chromium plating- closed loop electroplating

Description

Design and operation of hexavalent Cr(VI) plating as a closed loop for chromium and PFAS recycling by using a combination of strong exhaust air systems, cascade rinsing, ion exchange and spray tower evaporators.

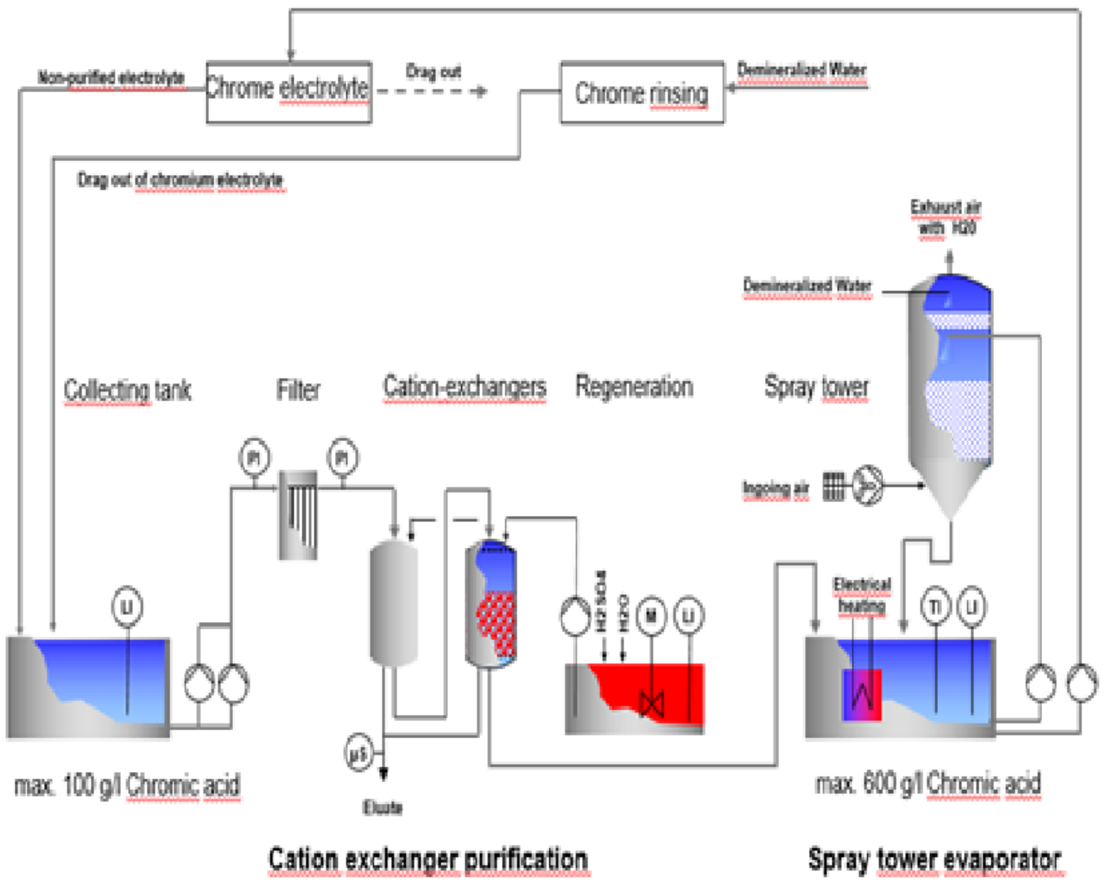
~~Hexavalent Cr(VI) plating can be operated as closed loop for chromium. This is achieved by a combination of cascade rinsing and an evaporator to ensure that the rinsing water is in equilibrium with the evaporation.~~

~~Ion exchange is used to remove accumulated impurities.~~

Technical description

The closed loop system consists of the combination of an effective exhaust air system, optimised cascade rinsing, an evaporator and ion exchange (see figure below).

- Utilise strong exhaust air systems for suction of Cr(VI) aerosols close to the bath surface (< 30 cm distance) and clean the exhaust air with a wet air scrubber to return the dragged out Cr(VI) and PFAS to the chromium bath.
- In order to prevent accumulation of ions in the solution, impurities such as Cr(III) and other metals, like iron and nickel from rinsing water are removed by cation exchanger purification. Care is taken to not expose ion exchange resins to concentrations of more than 100 g/l chromic acid in the rinsing water.
- Rinsing water is concentrated in a spray tower evaporator to regain chromic acid and PFAS and to ensure that the rinsing water is in equilibrium with the evaporation. Only demineralised water is used to refill the rinses and wash solution in the spray tower.
- Evaporators are used to concentrate the rinse solution to be recirculated into the plating bath. If higher evaporation rates are required, a heating medium, e.g. hot water instead of electric current, is used to heat the cleaned rinsing water. Heat required for evaporating has a considerable cross-media effect (energy consumption). Using excess heat from chromium plating (caused by low current efficiency) lowers energy consumption.
- In functional chromium plating of individual parts with low rinsing water usage and high electrolyte concentration, no additional evaporation by means of atmospheric evaporator or vacuum evaporator for a closed circuit is required.



Source: DE input in [167, TWG, 2023]

Figure 4-33: Typical closed loop system in functional chromium plating

Achieved environmental benefits

Discharges of Cr(VI) and PFAS from the chromium plating process in waste water and waste are significantly minimised. This reduces the capital cost of waste water treatment, and the use of chemicals and energy in waste water treatment.

Chromic acid and PFAS are, to a very large extent, recycled in the process.

~~There are no discharges of Cr (VI) or other materials from the process to waste water. This minimises the capital cost of treatment and the use of chemicals and energy in treatment.~~

~~Chromic acid and other components (such as foam suppressants, e.g. PFOS) are recycled in the process.~~

Cross-media effects

The baths of hexavalent Cr(VI) plating are polluted by inorganic cations from the treated metals and the reduction of the chromic acid. These impurities must be maintained at low concentration in order not to disturb the chromium plating operation.

The regeneration of the ion exchangers can be carried out on site followed by waste water treatment for Cr(VI) and PFAS, or in a hazardous waste treatment facility.

If an evaporator is used, energy is used. There is the possible problem of corrosion, depending on the quality of the evaporator alloy. Often titanium is used to avoid corrosion.

~~Energy is used to assist in evaporation~~

Operational data

If a vaporiser is used, instead of a spray tower evaporator, the distillate can be recycled in the rinsing step.

The equipment size depends on the pollution drag-out quantity. The evaporation flows are between generally 60 l/h and 200 l/h.

Ions exchangers collect the metal cations on the rinsing water before evaporation. The regeneration of the ion exchangers can be carried out on site or in an hazardous waste treatment centre.

Since in the long run no cycle can be run at 100% in a closed loop, remaining waste water will require treatment in order to minimise the release of Cr(VI) and PFAS.

~~The plating bath is followed by reversed cascade rinsing. The rinsing water is treated on cationic resin (to retain Cr(III) and other cations) and then concentrated on an evaporator to get a concentrate rich in chromic acid. This acid is sent back to the working bath. The distillate is recycled in the rinsing step.~~

~~The evaporator reduces the rinsings until a concentration of 250 – 280 g/l is obtained, or an intermediate concentration (120 g/l), which can be returned to the plating solution, where the natural evaporation of the bath contributing to the concentration.~~

~~There is an efficiency optimum which is a compromise between the necessary consumption of electricity for the evaporation and the consumption of used water for the rinsing refeeding.~~

~~The equipment size depends on the pollution drag-out quantity. The evaporation flows are between generally 60 and 200 l/h.~~

~~Ions exchangers collects the metal cations on the rinsings before evaporation. The regeneration of the ions exchangers is carried out in an hazardous waste treatment centre.~~

~~There is the possible problem of corrosion, depending on the alloy quality of the evaporator.~~

Applicability

Generally applicable in all Cr (VI) plating plants.

Economics

Capital costs are site-dependent on existing plants.

Regulatory pressure concerning the need to minimise Cr(VI) and PFAS discharges and increase waste water treatment plant capacity if open systems are used needs to be considered.

There are higher maintenance and energy costs of the closed loop system compared to open systems with subsequent waste water treatment.
~~Capital cost will be site dependant on existing plant and drivers, such as the need to reduce Cr(VI) discharges, increase waste water treatment plant capacity, etc. There are higher maintenance and energy costs.~~

Driving force for implementation

- Obligation to further reduce Cr(VI) and PFAS emissions by more and more ambitious legal requirements.
- Recovery of chromic acid and surfactants.

Example plants

Disflex France (Breuil le sec), TMN (Notre Dame de Gravenchon), ACRODUR (Carrière sur Seine)

Reference literature
[48, France, 2003], [176, CETS, 2024], DE input in [167, TWG, 2023]

4.2.6.8.12 Combining techniques and installation-wide approaches

General Description
Techniques can be used in combination more widely within the installation to achieve the overall environmental objectives for the installation (see 4.2.1.1 (a) and (b)).

The preceding sections (4.2.6.4, 4.2.6.7 and 4.2.6.8) describe point source techniques based on one process or process line to:

- reduce water consumption by recovering and re-using water
- reduce materials consumption by recovery and re-use.

These and other techniques can be used to further the objectives above for the whole installation as well as to minimise waste waters and waste water treatment. However, this needs an overall view taking into account, for example:

- the details of the objectives
- the existing equipment (including infrastructure such as existing waste water treatment plant), existing or planned changes in process
- the condition/suitability of the equipment for the current or planned tasks
- pressures for change, such as meeting environmental quality standards
- costs, including point in the depreciation curve for existing equipment.

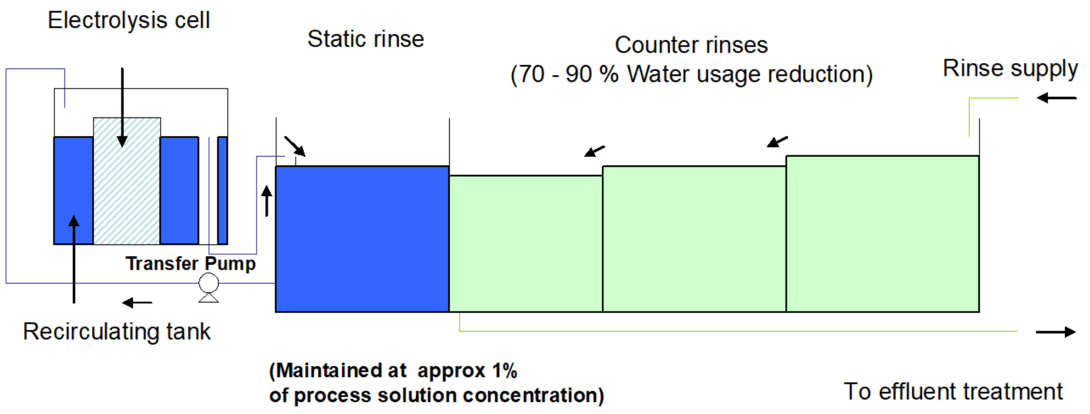
There are trade-offs between the point source options and centralised or combined systems for purification/recovery. For example, a single fixed location recovery systems (e.g., centralized reverse osmosis/ion exchange for recycling rinse-waters from several process lines). Another combined strategy would be to use a mobile system to perform intermittent purification/recovery of several point sources. For example, a single mobile diffusion dialysis system might be used to purify/recycle several different acid baths. Combined strategies may be more cost-effective, due to economy of scale, unless there are substantially increased plant interface requirements: for example, a typical waste water treatment plant is based on combining all the flows (see Sections 0 and 0). Point source systems, in part or completely, may offer more flexibility, redundancy, reliability and may be more cost-effective. In some cases, techniques can be combined to achieve zero, or close to zero, discharge.

Examples of combining techniques
There are several techniques that can be used to enable water to be re-used in processes and/or for the final cleaning of waste waters to meet low emission requirements, ~~see Annexes 7.1 and.~~

Description
The final cleaning of waste waters by using chelating cation exchange resin is more efficient when carried out after effective metal removal. This can be by prevention and retention of raw materials (for example, see Sections 4.2.6.7 and 4.2.6.8), electrolytes ~~(see Section)~~ and/or precipitation (see Section). The efficiency of chelating cation exchange resin depends also on the effluent pH. The optimum pH is different for each metal. [121, France, 2003].

The removal of the metal (for example, with electrolysis,) may be most easily achieved at the rinsing stages (see Figure 4-34 Section 4.2.6.8), where it most concentrated and prior to mixing with any other contaminants. High efficiency electrolytic cells increase the lifetime of the exchange resin.

A combination of electrolysis and fluid bed technologies can be used on their own or in combination with semi-permeable membranes and ion-exchange technologies for the recovery of metals from polluted aqueous solutions, (some of these are proprietary and patented).



Chemelec cell, BEWT Environmental Services Ltd

Figure 4-34: Removal of metal lost in rinsing prior to ion exchange

Achieved environmental benefits

Achieving low levels of metal discharged.
Potential to re-use rinse-waters.

Ion exchange systems require space, not only for the resin columns but also for the regeneration plant. They also require sufficient expertise to control the regeneration and the produced water quality. For small installations, commercial systems operate where the resin columns are exchanged with a supplier who regenerates the resins at a central facility.

Cross-media effects

Power consumption, especially at low concentrations, unless a high efficiency cell is used.

Operational data

~~See Section~~

Applicability

Wide applicability on precious and non-precious metals.

Economics

There are several parameters that can have a significant effect on the capital cost but the central ones are the sustained flow through the ion-exchange and the level of metal contamination. Introducing metal recovery in the process line can remove 95 % of the metal transferred to the ion exchange resulting in a 2000 % increase in the time before the resin needs to be ‘refreshed’ (or alternatively the amount of resin and therefore the size and cost of the equipment can be reduced significantly):

- nominal capacity:
    - <1 m^3/hr at 100 ppm GBP 25000 (June 2003)
    - <3 m3/hr at 100 ppm GBP 47000

Effluent treatment: The standalone units, which require minimal civil engineering works to install (i.e. pipe runs and level hard-standing) are modular in design and cater for a range of continuous flow of effluent from 0.5 to 9.0 cubic metres/hour of rinse solution. Capital costs vary dependant upon the number of stages of treatment prior to the final settlement tank and the level of process monitoring that has to be included and the method of off-site discharge. Operating costs are almost totally dependent upon the cost of the chemicals (acid, alkali, flocculent etc.) required for pretreatment.

- nominal capacity:

<0.5 m3/hr	GBP 11000
<3 m3/hr	GBP 23000
<9 m3/hr	GBP 38000

Driving force for implementation
Water protection policy and legislation.

Example plants
For cadmium recovery and water re-use:

- South West Metal Finishing Ltd, Exeter, UK
- Moores (Wallisdown) Ltd., Bournemouth, UK.

For effluent treatment:

- C-TEC Ltd., Leighton Buzzard, UK
- Ekkato Ltd. (Aluminium Thrakis), 19 300 Athens, Greece.

Deioniser exchange is used by over 1500 installations in Germany.

Reference literature
[104, UBA, 2003, 110, BEWT, 2003], [12, PARCOM, 1992].

4.2.6.8.13 Zero discharge

In some cases techniques can be combined to the achieve zero discharges to water.

4.2.6.9 Post-treatment activities – techniques relevant to the determination of BAT

[Note to the TWG: This section corresponds to Section 4.13 of the existing BREF]

4.2.6.9.1 Drying

Options exist such as hot water drying, hot air, air knives. (No further data given).

4.2.6.9.2 De-embrittlement

Description
De-embrittlement is heat treatment carried out after certain processes to avoid the unwanted embrittlement caused by hydrogen being trapped in the crystalline structure of metal substrates. This occurs in pickling, cathodic cleaning, or the electrodeposition of metal where the current efficiency is less than 100 %, or by chemical deposition (phosphating). The temperature and time of the embrittlement process depends on the substrate.

Achieved environmental benefits

Cross-media effects
High energy consumption in heating.

Driving force for implementation

Work piece or substrate finish specifications.

Reference literature
[159, TWG, 2004]

4.2.7 Chemicals substitution

[Note to the TWG: This section corresponds to Section 4.9 of the existing BREF]

~~Introduction Substitution – choice of raw materials and processes~~

~~**General description**~~
~~Surface treatment uses a wide range of chemicals in a wide range of processes. Section 1.4.4. Annex IV of the Directive requires the use of less hazardous substances to be considered [1, COM, 2024] and it is also a PARCOM recommendation.~~

~~There are also other operational and economic reasons for substitution, e.g.:~~

- ~~improved quality and reliability of the process~~
- ~~costs savings for decreased waste water treatment~~
- ~~cost savings for reducing air extraction and treatment~~
- ~~health and safety in the workplace.~~

~~Substitution can be achieved by:~~

- ~~substitution directly of one substance by a less harmful one. An example is the replacement of EDTA or NTA with derivatives of gluconic acid. There are limited opportunities for this in surface treatment~~
- ~~substitution by different process chemistries or methods. This is used where there is no direct replacement, for example, replacement of zinc cyanide by cyanide-free alkali or zinc acid solutions. Different coating process chemistries give treatments with different properties, even for the same materials~~
- ~~substitution by different surface treatments, such as substituting autocatalytic nickel or vapour deposition of chromium for hard chromium plating. If the substitution is for the core treatment, the final properties may be different.~~

~~Some key issues are discussed as substances, e.g. hexavalent chromium, and options include substitution of chemicals and processes. Others issues are discussed as process types, such as degreasing.~~

~~Substitution by alternative processes~~

~~**Description**~~
~~The manufacturing industry is moving towards performance standards, such as corrosion resistance achieved. This is being catalysed where the use of traditional coatings (such as zinc and hexavalent chromium passivation) are being challenged by recent Directives being implemented limiting the amount of hexavalent chromium in end-of-life products. This change is challenging traditional specifications.~~

~~To achieve modern high standards for corrosion prevention, multilayer systems are increasingly used. This enables the operator to offer alternative systems to customers that achieve the same performance criteria, and the potential to move away from more polluting processes. For example:~~

- ~~electroless nickel for some hard chromium applications~~
- ~~zinc alloys in place of zinc and chromium passivation, in conjunction with organic lacquers applied by dipping or electropainting~~

- ~~electropainting in conjunction with phosphating (see the STS BREFs [90, COM 2020]).~~

~~**Note**: As an example, substitution has already been widely achieved for cadmium electroplating as marketing and use regulations required many specifications to be changed to utilise alternative surface treatments.~~

~~**Alternative processes not in the scope of this document**~~
~~Metals can be applied by physical methods, such as vapour phase deposition. They are not within the scope of this document. However, an operator may wish to consider them as a clean technology option, as set out in IPPC Directive, Annex IV. While such techniques are 'clean technology' at the point of use, they may produce some cross-media effects, such as higher energy usage.~~

~~Examples of such techniques are:~~

- ~~vapour phase deposition of aluminium on plastic for automobile lighting reflectors;~~
- ~~vapour phase deposition of chromium as a decorative finish, such as bathroom fittings.~~

~~Hard chromium can be replaced in some applications by alloyed WC-Ni(Co)Cr/Cr_2O_3, or by high velocity oxy-fuel spraying or plasma spraying.~~
~~The US Defence Department is funding a study on alternatives for chromium conversion coatings, and USEPA have also researched the replacement of chromate conversion coatings on aluminium and zinc.~~

~~**Achieved environmental benefits**~~
~~Reduction of toxic emissions.~~

~~**Cross-media effects**~~
~~To be investigated for each application.~~

~~**Operational data**~~
~~To be determined for each application.~~

~~**Applicability**~~
~~To be determined for each application.~~
~~May be limited by existing specifications.~~

~~**Economics**~~
~~To be determined for each application.~~
~~Overall, regulation of mass customer sectors will drive a shift away from traditional standards for surface treatment.~~

~~**Driving force for implementation**~~
~~Health and safety and product regulations, such as automotive and electronics Directives.~~

~~**Reference literature**~~
~~[68, USEPA, 2003, 106, NCMS, 2003] [94, EC, 1999, 96, EC, 2003, 98, EC, 2003, 99, EC, 2000] [30, EC, 2003] [121, France, 2003] [106, NCMS, 2003] [66, PPRC, 2003, 68, USEPA, 2003]~~

~~However, there may be other environmental benefits to be gained, either in conjunction with using less harmful substances, or for the other gains in their own right, e.g.:~~

- ~~lower materials usage, both in process, in waste water and air emission treatment~~
- ~~energy saving~~
- ~~water saving~~

~~**Overall achieved environmental benefits**~~

~~Reduction in the use of harmful substances and the amounts subsequently entering the environment.~~
~~Other improvements in environmental performance, such as energy saving, production of less waste, emission of less noise or dust, etc.~~

~~**Overall cross-media effects**~~
~~These effects depend on the individual alternative technique. Some may have effects such as increased energy usage (vapour deposition techniques), increased waste production (acid zinc) or increased water or raw material consumption.~~

~~Failure to meet specific requirements (see Overall applicability, below) will lead to increased rejects and reworking, with consequent environmental impacts (see Section 4.2.3).~~

~~**Overall operational data**~~
~~See individual examples from Sections 4.9.1 to 4.9.16.~~

~~**Overall applicability**~~
~~In all cases, it is essential to discuss the changes with the customer in advance of making the substitution. It is good practice not to make changes without full knowledge of the final performance characteristics required. Failure to meet these characteristics, particularly without warning, can lead to loss of customer confidence and increased rejects. To ensure processes operate to the required standard, it is advisable for both operator and customer to monitor quality and performance to, and exchange information on, the required specification (see Section 4.2.1.7).~~

~~**Economics**~~
~~This will be on a case by case basis. In some cases, there will be economic incentives from energy saving, etc.~~

~~**Driving force for implementation**~~
~~Health and safety of employees is a major driver for substituting less harmful substances, e.g. substituting for hexavalent chromium other environmental legislation, such water legislation driven by OPSAR and PARCOM recommendations, the Water Framework, Seveso II, and Solvent Emissions Directives. Substitutes may be more cost effective .~~

~~**Example plants**~~
~~SGI, Plaisir, France; Sikel N.V., Genk, Belgium.~~

~~**Reference literature**~~
~~[11, Tempany, 2002, 18, Tempany, 2002](verbal discussions with TWG members industry at site meetings)[60, Hemsley, 2003] [12, PARCOM, 1992] [124, Germany, 2003]~~

4.2.7.1 Minimisation of the use of hazardous substances and metallic salts

Description
This includes:

- regularly reviewing the inventory of process chemicals (see Section 4.2.1.3) and optimising the formulation of chemicals used;
- substitution of chemicals containing hazardous substances with non- or less hazardous ones (based on the analysis in Section 4.2.1.3 d));
- optimisation of the quantity of chemicals used (see Section 4.2.6, in particular Section 4.2.6.4.3.1 and Section 4.2.6.5.15), e.g. the anode consumption is regularly monitored and the anode is promptly renewed in Cu-, Sn-, Ni- and Ag-containing solutions, to avoid the addition of metallic salts;
- use of a closed loop to recover/reuse chemicals.

Technical description

Surface treatment uses a wide range of chemicals in a wide range of processes. Therefore, there are ~~also other~~ operational and economic reasons for substitution, e.g.:

- improved quality and reliability of the process
- cost~~s~~ savings for decreased waste water treatment
- cost savings for reducing air extraction and treatment
- health and safety in the workplace.

Substitution can be achieved by:

- substitution directly of one substance by a less harmful one. An example is the replacement of EDTA or NTA with derivatives of gluconic acid. There are limited opportunities for this in surface treatment
- substitution by different process chemistries or methods. This is used where there is no direct replacement, for example, replacement of zinc cyanide by cyanide-free alkali or zinc acid solutions. Different coating process chemistries give treatments with different properties, even for the same materials
- substitution by different surface treatments, such as substituting autocatalytic nickel or vapour deposition of chromium for hard chromium plating. If the substitution is for the core treatment, the final properties may be different.

Some key issues are discussed as substances, e.g. hexavalent chromium, and options include substitution of chemicals and processes. Others issues are discussed as process types, such as degreasing.

To achieve modern high standards for corrosion prevention, multilayer systems are increasingly used. This enables the operator to offer alternative systems to customers that achieve the same performance criteria, and the potential to move away from more polluting processes. For example:

- electroless nickel for some hard chromium applications
- zinc alloys in place of zinc and chromium passivation, in conjunction with organic lacquers applied by dipping or electropainting
- electropainting in conjunction with phosphating (see the STS BREFs [90, COM 2020]).

~~**Note:**~~ As an example, substitution has already been widely achieved for cadmium electroplating as marketing and use regulations required many specifications to be changed to utilise alternative surface treatments.

~~**Alternative processes not in the scope of this document**~~

Metals can be applied by physical methods, such as vapour phase deposition. They are not within the scope of this document. However, an operator may wish to consider them as a clean technology option~~, as set out in IPPC Directive, Annex IV. While such techniques are ‘clean technology’ at the point of use, they may produce some cross-media effects, such as higher energy usage~~.

Examples of such techniques are:

- vapour phase deposition of aluminium on plastic for automobile lighting reflectors;
- vapour phase deposition of chromium as a decorative finish, such as bathroom fittings.

Hard chromium can be replaced in some applications by alloyed WC-Ni(Co)Cr/Cr_2O_3, or by high velocity oxy-fuel spraying or plasma spraying.

~~The US Defence Department is funding a study on alternatives for chromium conversion coatings, and USEPA have also researched the replacement of chromate conversion coatings on aluminium and zinc.~~

~~However~~Furthermore, there may be other environmental benefits to be gained, either in conjunction with using less harmful substances, or for the other gains in their own right, e.g.:

- lower materials usage, both in process, in waste water and air emission treatment
- energy saving
- water saving

~~Overall applicability~~
In all cases, it is essential to discuss the changes with the customer in advance of making the substitution. It is good practice not to make changes without full knowledge of the final performance characteristics required. Failure to meet these characteristics, particularly without warning, can lead to loss of customer confidence and increased rejects. To ensure processes operate to the required standard, it is advisable for both operator and customer to monitor quality and performance to, and exchange information on, the required specification (see Section 4.2.1.7).

~~Economics~~
~~This will be on a case by case basis. In some cases, there will be economic incentives from energy saving, etc.~~

~~Driving force for implementation~~
Health and safety of employees is a major driver for substituting less harmful substances, e.g. substituting for hexavalent chromium as well as other environmental legislation, such water legislation driven by OPSAR and PARCOM recommendations, the Water Framework, Seveso II, and Solvent Emissions Directives. Substitutes may be more cost effective too.

~~Example plants~~
~~SGI, Plaisir, France; Sikel N.V., Genk, Belgium.~~
~~Widely used.~~

~~Reference literature~~
~~[11, Tempany, 2002, 18, Tempany, 2002](verbal discussions with TWG members industry at site meetings)[60, Hemsley, 2003] [12, PARCOM, 1992] [124, Germany, 2003]~~

Achieved environmental benefits

- Reduction of the pollutant load in effluents.
- Reduction of hazardous waste.
- Reduction of the consumption of hazardous substances.

Cross-media effects
None reported.

Technical considerations relevant to applicability
The substitution of chemicals containing hazardous substances may be restricted by the availability of a suitable alternative.

Economics
It is possible that alternative chemicals have a different price compared to the original chemical.

Driving force for implementation

- Environmental and product safety regulation (e.g. Regulation EC No 66/2010 on the EU Ecolabel).

- Chemical regulation (e.g. Regulation EC No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals, REACH).

Example plants
A total of 64 installations in the data collection reported substituting the use of hazardous substances.

Reference literature
[168, TWG, 2023]

4.2.7.2 Use of PFAS-free surfactants

Description
This includes:

- use of Cr(VI)-free processes that make the use of PFAS unnecessary, e.g. replacing chromium layers with nickel-based layers, alternative hardening techniques on steel instead of plating with chromium(VI), and alternative plastic etching using for example manganese (III)-based compounds;
- use of fluorine-free alternatives to substitute the current mist/fume suppressant 6:2 fluorotelomer sulphonic acid (6:2 FTS).

Technical description
Substitution of PFAS as a mist suppressant or surfactant in decorative chrome plating and hard chrome plating of metals and plastic metallisation (including etching) by fluorine-free wetting agents or by an alternative process.

PFAS (Per- and polyfluoroalkyl substances) are a large group of substances, some of which are used as mist suppressants and surfactants. PFAS are used for preventing the formation of mists in hexavalent chromium electroplating and thus controlling the exposure of workers to aerosols of Cr(VI)-containing process solutions and as surfactants in plastic etching to lower the surface tension in order to improve the etching attack on the plastic surface). Currently, the main substitute for PFOS in the galvanising and hard chromium plating process sectors is 6:2 FTS CAS no 27619-97-2. This is because 6:2 FTS is structurally similar to PFOS with the difference that 6:2 FTS is not fully fluorinated.

Specific suppliers offer a PFAS-free alternative for the mist suppressant. According to the supplier, the alternative is PFAS-free, offers the same performance as the existing PFAS-based products and is suitable for all applications using hexavalent hard chromium plating.

However, care should be taken to prevent regrettable substitution when considering alternatives for 6:2 FTS. Some suppliers provide possibly misleading information when advertising their products. In some cases they advertise products as ‘PFOS-free’ but they still contain PFAS or in other cases they advertise them as ‘free of perfluoroalkyl substances’ but the products might still contain polyfluoroalkyl substances which are still PFAS.

There are several coating technologies with no use of PFAS, depending on the requirements:

- electroless plating;
- nickel and nickel alloy electroplating;
- case hardening: carburising, carbonitriding, cyaniding, nitriding, boronising;
- chemical vapour deposition (CVD);
- nanocrystalline cobalt phosphorus alloy coating;
- high velocity thermal process;
- physical vapour deposition (PVD);
- plasma spraying;

- stainless steel & high-speed steel (HSS);
- thermal spray coatings;
- high-speed flame spraying (HVOF process);
- Laser Metal Deposition (LMD).

Achieved environmental benefits
No or reduced PFAS emissions to water.

Environmental performance and operational data
6:2 FTS is less stable than PFOS during the hard chrome plating process, which means that a much higher amount of 6:2 FTS is needed relative to PFOS to achieve the same protective effect in chromium baths in the hard chromium plating process.

A continued emission of PFAS from the historical use of the PFAS-containing mist suppressant is possible (historical use of PFOS as a mist suppressant for hexavalent hard chromium plating activities).

Cross-media effects
If a higher amount of subsitute is needed to reach the same performance as the existing PFAS-based products then the substitution may lead to higher consumption of chemicals.

Technical considerations relevant to applicability
According to the supplier, the alternative is PFAS-free, offers the same performance as the existing PFAS-based products and is suitable for all applications using hexavalent hard chromium plating.

Economics
The alternatives to hard chrome plating available are sometimes economically feasible in one or few uses only, but sometimes in larger areas of application.

Driving force for implementation
To meet local environmental quality standards for emission and The European Water Framework Directive.

Example plants
In Germany, according to the data collected, a nationwide substitution of PFOS by 6:2 fluorotelomer sulphonic acid (6:2 FTS) took place in functional chromium plating and in plastic etching. In decorative chromium plating, PFOS was completely replaced by fluorine-free mist suppressants, 6:2 FTS, or by the use of chromium(III)-based processes that do not require fluorine-containing mist suppressants.

Reference literature
BE, DE and SE contributions to [167,TWG, 2024]
[168, TWG, 2023]

~~4.2.7.3~~ Substitution of ethylenediaminetetraacetic acid (EDTA) with non- or less hazardous subtances ~~Substitution for EDTA and other strong complexing agents (chelating agents)~~

Description
Use of gluconic-acid-based substances.

Technical description
~~The problems of s~~Strong chelating agents particularly EDTA are ~~described in Section 1.4.4.5. They are~~ widely used in process solutions such as degreasing and etchants used for printed

circuit board manufacture. They may be replaced by weaker and biodegradable ones, such as those based on gluconic acid. There are alternatives used in pickling and cleaning ~~in Germany~~. EDTA is also used to some extent in electroless copper in PCB manufacturing. However, there are many alternatives to substitute EDTA, including so-called direct plating methods (for example tartrate-complex in copper solution)~~, see Section 2.6.2.4~~.

Achieved environmental benefits
Reduction in solubilisation of metals in waste water treatment systems and in environment systems.

Environmental performance and operational data
EDTA can also be destroyed or eliminated.~~, see Section 0~~

Cross-media effects
Substituting or reducing the amount of EDTA released reduces the energy and chemicals required for destruction.

Technical considerations relevant to applicability
Applicability may be restricted by product specifications.~~Printed circuit board manufacture: specifications for the latest technology may require the return to using EDTA.~~

Example plants
Example plants from the data collection that have successfully implemented this technique are: [AT_014], [BE_004], [DE_048], and [IT_008].

Reference literature
[3, CETS, 2002], [12, PARCOM, 1992], [22, Fraunhofer, 2002] [124, Germany, 2003] [120, Finland, 2003], [176 CETS, 2024]
[168, TWG, 2023]

4.2.7.4 Substitution for, and reduction of, toxic surfactants (NPE ~~and PFOS~~)

Note to the TWG: references to PFOS are proposed to be deleted as PFOS have been widelyreplaced]

Description
~~There are two families of problem materials that are toxic and bio-accumulative:~~

NPE and nonylphenol are toxic and bio-accumulative and are two of the OSPAR chemicals for priority action and are banned for metal working, with effect from 17 January 2005, except for uses in "*controlled systems where the washing liquid is recycled or incinerated*"

- ~~PFOS (Perfluorooctane sulphonate) is widely used as a foam suppressant and surfactant, especially in preventing the formation of mists in hexavalent chromium electroplating and alkali non-cyanide baths. However, it is now under investigation (see Annex 8.2) and the OECD Task Force on Existing Chemicals has already agreed that it is persistent, bio-accumulative and toxic.~~

Technical description
~~No substitutes for NPE have been reported.~~ Substitutes are available and in use for anodising.

~~There are currently no substitutes for PFOS in Cr(VI) plating and pickling because of its strong resistance to oxidation. PFOS is also used in alkali cyanide-free zinc processes to reduce spray, as well as zonc alloy plating, some anodising and strong acid gold processes.~~

Achieved environmental benefits

Substitution by less harmful substances, or alternative processes will reduce the environmental and health effects.

Environmental performance and operational data

~~In situations where PFOS has been used, such as Cr(VI) plating, other measures may be taken to prevent Cr(VI) mist reaching MAC levels in the workplace, such as use of floating insulation (see Section 4.4.3), lids on tanks and/or redesigned and/or upgraded ventilation (see Section 4.18.2), substitution by a less harmful process (see the appropriate parts of this section), etc.~~

~~If PFOS has to be used, then it is best practice to use it in a closed loop process. Cr(VI) plating can be run on this basis.~~

~~Other processes can be run with drag-out reduction and rinsing techniques to conserve PFOS in the process tanks, see Sections 4.6 and 4.7~~

Cross-media effects

~~PFOS has important health and safety functions in controlling the spray from harmful solutions.~~
Increased extraction of Cr(VI) and other air pollutants due to cessation of use may require additional scrubbing and treatment.

Technical restrictions relevant to applicability

Cr(VI) plating can be run on a closed loop system. ~~Other processes can utilise drag-out and rinsing techniques to minimise the release of PFOS. Its use can also be minimised by controlling the addition of PFOS (or solutions containing PFOS) using surface tension measurements.~~
~~Originally, it was reported that no PFOS is used in France, but other reports suggest it is in use.~~

Economics

Cost of additional air extraction or control equipment.
Control measures, such as surface tension measurements, are minimal.
Drag-out measures also retain other materials.

Driving force for implementation

Occupational health legislation. For NPE, a ban is now in place

Example plants

Plant [CZ_012].

Reference literature

[73, BSTSA,] [30, EC, 2003] [109, DEFRA, 2004, 165, Tempany, 2004]
[176 CETS, 2024] [168, TWG, 2023]

4.2.7.5 Substitution of cyanide with non- or less hazardous subtances ~~Substitution for cyanide – overview~~

Note to the TWG: techniques related to Zinc have been merged]

Description

Use of cyanide-free solutions, e.g.:

- copper-based solutions in degreasing;
- alkaline silver-based solutions in plating.

~~Overall~~ Technical description

Cyanide has been widely used in many electrolytic processes such as zinc, copper, cadmium, silver and gold plating. It is also extensively used in other surface treatment processes, such as degreasing processes and nickel stripping.

Zinc electroplating has been one of the major uses for cyanide in the sector~~,~~; however, cyanide zinc solutions are no longer used. [176 CETS, 2024].

Zinc alloys are widely used and well-established.

~~Processes with alternatives to cyanide are discussed in Sections 4.9.4 and 4.9.5.~~

Table 4-11: Process solutions using cyanide

~~Chapter 2 description~~	**Process or chemical**	**~~Chapter 4 Reference~~**
~~2.3 Workpiece or substrate preparation~~		
	Cyanide degreasing	Thought to be obsolete except for removing traces of glue. [112, Assogalvanica, 2003] [176 CETS, 2024] Copper-based solutions are used.
~~2.5~~	**~~Core activities- plating~~**	
~~2.5.1~~	**Copper and copper alloy plating**	Copper cyanide is necessary for strike plating on steel and zinc die casts, and some barrel plating. Acid copper is the solution of choice in Germany. Pyrophosphate copper has limited applications. No alternatives to cyanide solutions for brass and bronze are reported.
	Copper cyanide	
	Acid copper	
	Pyrophosphate copper	
	Brass	
	Bronze	
~~2.5.4~~	**~~Zinc and zinc alloy plating~~**	~~See Section .~~
	~~Alkali cyanide zinc~~	
	~~Alkali cyanide free zinc~~	
	~~Acid zinc~~	
	~~Zinc alloys~~	
~~2.5.5~~	**Cadmium plating** Electrolytes may be based on cyanide, fluoroborate, sulphate or chloride For most other applications acceptable alternatives have been developed. Acid zinc plating lowers the risk for hydrogen embrittlement and tin can replace cadmium for giving a low and constant friction coefficient on fasteners. Mechanical zinc plating and zinc/aluminium flake coatings can also be viable alternatives for protecting high strength steels. [115, CETS, 2003]	
~~2.5.7~~	**Precious metal plating**	
	Silver	
	Gold	

~~Overall a~~Achieved environmental benefits

Substitution of cyanide leads to a reduction of use and emission of cyanide, as well as of ~~Reduction of AOX:~~ AOX that may be generated through chemical oxidation of cyanide in waste water treatment with sodium hypochlorite and chlorine.

~~Cyanide electrochemical baths have low current efficiency compared with acid zinc (70–85 % efficient), see Section 2.2.1.3.5.~~

~~The plating baths for cyanide-free plating of copper on iron and steel have a phosphonate complexing agent, which can only be removed by precipitation with lime. This leads to more waste produced when compared to cyanide plating.~~

~~Cyanide-free copper also needs twice the current than cyanide copper because of the two oxidation states of cyanide-free processes.~~

~~Overall cross-media effects~~
~~See specific applications for data on each application.~~

~~Overall operational data~~
~~Free cyanide is easy to manage and treat.~~

~~See specific applications for data on each application.~~

~~Applicability~~
~~There is no single chemical substitute for cyanide.~~

~~There is no successful substitute (chemical or process) for cyanide in the treatment of substrates such as zinc die-cast, magnesium die-cast and others. Zinc die-cast products are widely used in bathroom fittings, furniture, automotive and telecommunication products. A stable working substitute process is not known for serial, high volume production lines.~~

~~Other factors affecting substitution for cyanide are:~~

- ~~poorer degreasing ability of cyanide-free electrolytic degreasing electrolyte (cyanide solutions have inherently good cleaning properties and are tolerant of indifferent pre-cleaning)~~
- ~~increased maintenance and skill level required for alternative processes (bath control, bath analysis, etc.)~~
- ~~modification of the coating characteristics.~~

~~Economics~~
~~There may be increased costs with running non-cyanide systems. However, these may be offset by reduced effluent treatment.~~

~~Driving force for implementation~~
~~Decreased health and safety risk.~~
~~Public perception of the use of cyanide.~~
~~Improved compliance with environmental quality standards.~~
~~Decrease in the risk of environmental accidents.~~

~~Example plants~~
~~Metal Colours Ltd, Slough, UK; SIKEL N.V. Genk, Belgium.~~

~~Reference literature~~
~~[3, CETS, 2002, 18, Tempany, 2002, 124, Germany, 2003] [113, Austria, 2003]~~

~~Zinc electroplating~~

~~Zinc electroplating has been one of the major uses for cyanide in the sector.~~

~~Alkaline cyanide zinc~~

~~Description~~
~~See Section 2.5.4.~~

~~Achieved environmental benefits~~
~~Cyanide can be readily oxidised in waste water treatment plants~~

~~Cross-media effects~~

~~Requires waste water treatment.~~
~~May require fume extraction.~~
~~Poor process efficiency of 50 % power input, decreasing with current density.~~

~~Operational data~~
~~Does not require high standard degreasing because of self-cleaning capability~~
~~Easy to operate and maintain.~~
~~Has a lower consumption of brighteners Requires more space.~~
~~Highly suitable for barrel plating. Achieves guaranteed layer thickness on jig and barrel processing and has good throwing power into holes and blind spaces~~

~~Applicability~~
~~Ductile deposit with good throwing power.~~

~~Reference literature~~
~~[114, Belgium, 2003, 124, Germany, 2003].~~

~~Alkaline cyanide-free zinc~~

~~Description~~
~~See Section 2.5.4.~~

~~Technical description~~
~~E..G alkaline alkaline-sylver based plating.~~

~~Achieved environmental benefits~~

Alkaline cyanide-free zinc
No cyanide used.
Reduced waste water treatment requirements.

Acid zinc
High current efficiency, approaching 95 %.
No cyanide used.
Reduced waste water treatment requirements.
No special requirement for fume extraction.

Environmental performance and operational data

Alkaline cyanide-free zinc
Needs to be preceded by high quality degreasing systems.
Needs skilled process control and management.
Dispersion of coating thickness is better than cyanide processes.

Acid zinc
Needs to be preceded by high quality degreasing systems.
Needs skilled process control and management.
Soluble and insoluble anodes can be used instead of only soluble ones, giving better quality control, see Section 4.8.2

Cross-media effects
Alkaline cyanide-free zinc
With higher voltage because of insoluble anodes and poor current efficiency of 50 – 70 % decreasing with increasing current density, the process is at least twice as energy intensive as

other Zn processes. With potassium electrolytes, the current efficiency can be increased to 70 %. 70 – 85 % is achievable at 2 A/m^2 for well managed processes. See Section 2.5.4.

With poor current efficiency, more (possibly twice) the process capacity is needed compared with acid zinc systems.

Alkaline zinc needs more air extraction than the other Zn processes. It can be optimised by using wetting agents, which provide a foam covering to the bath. A further option is to cover the tank where the zinc is chemically dissolved externally to the solution, ~~although the foam suppressant may contain PFOS (see Section 4.9.2 and Annex 8.2).~~

Technical considerations relevant to applicability
~~Better metal distribution than cyanide processes.~~

~~Driving force for implementation~~
~~See Section 4.9.3, Overall driving forces for implementation.~~

~~Reference literature~~
~~[3, CETS, 2002, 18, Tempany, 2002, 124, Germany, 2003] [113, Austria, 2003] [129, Spain, 2003, CETS, 2003 #115]~~

~~Acid zinc~~

~~Description~~
~~See Section 2.5.4.~~

~~Achieved environmental benefits~~
~~High current efficiency, approaching 95 %.~~
~~No cyanide used.~~
~~Reduced waste water treatment requirements.~~
~~No special requirement for fume extraction.~~

~~Cross-media effects~~
~~Increased sludge production, from dissolution of some of steel substrates and with soluble anodes.~~

~~May require fume extraction for acid mists, but not necessary for chloride-based solutions. However, extraction is advisable.~~

~~Operational data~~
~~Needs to be preceded by high quality degreasing systems.~~
~~Needs skilled process control and management.~~
~~Soluble and insoluble anodes can be used instead of only soluble ones, giving better quality control, see Section 4.8.2~~

~~Applicability~~
The metal distribution in acid zinc is ~~poor to acceptable,~~ increasing with warm electrolytes.

Economics
Large savings in power consumption.

Driving force for implementation
~~See Section 4.9.3, Overall driving forces for implementation.~~

Example plants
~~Metal Colours Ltd, Slough, UK; Sikel N.V. Genk, Belgium.~~

Plants [DE_018], [DE_018], [ES_024], [ES_024], [FR_014], [FR_015], [FR_015], [FR_018], [IE_001], [IT_002], [IT_009], [PT_002] from the STM data collection.

Reference literature
~~[18, Tempany, 2002] [119, Eurofer, 2003]~~
[176, CETS, 2024] [168 TWG, 2024]

~~Zinc alloys~~

~~Zinc alloys are widely used and well-established, but no data has been provided on their use as substitutes for zinc processes.~~

~~Other cyanide- based solutions~~

~~More detail is given on these in the relevant sections in Chapter 2.~~

~~**Table 4-12: Process solutions using cyanide**~~

~~**Chapter 2 description**~~	~~**Process or chemical**~~	~~**Chapter 4 Reference**~~
~~**2.3 Workpiece or substrate preparation**~~		
	~~Cyanide degreasing~~	~~Thought to be obsolete except for removing traces of glue. [112, Assogalvanica, 2003] [176 CETS, 2024]~~ ~~Copper-based solutions are used.~~
~~**2.5**~~	~~**Core activities- plating**~~	
~~**2.5.1**~~	~~**Copper and copper alloy plating**~~	~~Copper cyanide is necessary for strike plating on steel and zinc die casts, and some barrel plating. Acid copper is the solution of choice in Germany. Pyrophosphate copper has limited applications. No alternatives to cyanide solutions for brass and bronze are reported.~~
	~~Copper cyanide~~	
	~~Acid copper~~	
	~~Pyrophosphate copper~~	
	~~Brass~~	
	~~Bronze~~	
~~**2.5.4**~~	~~**Zinc and zinc alloy plating**~~	~~See Section **Error! Reference source not found.**.~~
	~~Alkali cyanide zinc~~	
	~~Alkali cyanide free zinc~~	
	~~Acid zinc~~	
	~~Zinc alloys~~	
~~**2.5.5**~~	~~**Cadmium plating**~~ ~~Electrolytes may be based on cyanide, fluoroborate, sulphate or chloride~~ ~~For most other applications acceptable alternatives have been developed. Acid zinc plating lowers the risk for hydrogen embrittlement and tin can replace cadmium for giving a low and constant friction coefficient on fasteners. Mechanical zinc plating and zinc/aluminium flake coatings can also be viable alternatives for protecting high strength steels. [115, CETS, 2003]~~	
~~**2.5.7**~~	~~**Precious metal plating**~~	
	~~Silver~~	
	~~Gold~~	

4.2.7.6 Substitution of Cr(VI) with non- or less hazardous subtances and/or use of alternative processes ~~Substitution for, and minimisation of, hexavalent chromium~~

~~**Introduction**~~

Description
This includes:

- use of Cr(III)-salts-based solutions such as chloride-based or sulphate-based solutions in passivation and plating;
- use of Cr-free options, e.g.:
  - use of potassium permanganate and phosphoric acid for plastic etching;
  - zinc-based solution;
  - tin-cobalt alloy;
  - platinum-plated titanium anodes in pre-treatment, phosphating, passivation, plating, etching for example;
  - use of electroplated nickel-tungsten, electroless nickel or nickel alloy deposits (NiL35) in plating;
- use of alternative processes, e.g.:
  - High Velocity Oxygen Fuel (HVOF) process;
  - Physical Vapour Deposition (PVD);
  - plasma nitriding;
  - Laser Metal Deposition (LMD);
  - Extreme High-speed Laser metal deposition (EHLA).

Technical description

Historically, hexavalent chromium chemicals, such as chromic acid, ~~are~~ were frequently used in surface finishing. The main applications were~~are~~:

- decorative chromium plating;
- hard chromium plating;
- chromic acid anodising;
- chromate conversion coatings.

Nowdays, the use of chromate in the EU is limited to applications authorised by ECHA. Chromic anodising has been successfully replaced by tartaric/sulphuric acid anodising (TSA) for many applications. Other alternatives are also available.

~~See Annex 8.1 for details of chromium and its compounds in relevant legislation and agreements. Hexavalent chromium has been classified as carcinogenic by inhalation, and regulations apply to its use in processes. It is a priority substance for the US EPA to minimise use and release [148, HTMLA, 2003] [108, NEWMOA, 2003], as well as restrictions on the use of hexavalent chromium products [144, EC, 1976]. Chromium trioxide is being reviewed by the EU and is likely to be raised in status from toxic to very toxic. This may trigger the lower threshold requirements of the Seveso II Directive where over five tonnes are used [142, EC, 1996].~~

~~The health and environmental issues associated with hexavalent chromium are described in Section 1.4.4.1. In addition, only chromate films containing hexavalent chromium may release Cr(VI) during the handling and the usage of the finished product. There are no contact problems with metallic chromium on finished workpieces from any process (hexavalent or a trivalent) [124, Germany, 2003].~~

~~Any zinc-plated part is usually post-treated with a suitable chromate conversion process as well as many substrates (such as die-castings). The colour of the finishes of existing hexavalent chromium conversion processes and the level of their corrosion protection is directly in relation to their thickness and to their hexavalent chromium content.~~

~~Because of these environmental and health and safety concerns, European directives limit the amount of hexavalent chromium left in the product in the automotive, electrical and electronic industries [96, EC, 2003, 98, EC, 2003, 99, EC, 2000]. This is the driving force for innovative hexavalent chromium-free technologies. Various EU R&D projects are nearing conclusions on Cr(VI) management, [28, DG-RTD, 2002].~~

Achieved environmental benefits

- Reduction of the use of hazardous chemicals.
- Reduction of the pollutant load in effluents.
- Reduction of hazardous waste.
- Reduction of the consumption of hazardous substances.

Environmental performance and operational data

Cross-media effects

None reported.

Technical considerations relevant to applicability

Applicability may be restricted by product specifications.

Economics

It is possible that alternative chemicals or processes have a different price compared to the original Cr(VI)-containing chemical or process.

Driving force for implementation

Example plants

Example plants from the data collection that have successfully implemented this technique are:

Reference literature

[168, TWG, 2023]

~~Minimisation of release of hexavalent chromium from treated surfaces~~

~~Description~~

~~Topcoatings for chromium passivation systems are described in Section 2.5.17. or they can be provided by powder coating or any other topcoat From Table 4.10, it can be seen that an application of a suitable topcoating layer on the chromate conversion coating is sufficient to dramatically reduce release of chromium VI.~~

~~The chromium VI release is also a function of the quality and amount of the rinsing following the post treatment: rinses have to be designed to avoid any residue of the chromate conversion solution remain adsorbed on the surface of the treated parts. However, the corrosion protection of the more intense colours (yellow to black) can be severely diminished by excessive leaching from rinsing.~~

~~Table 4.10 shows the releases of Cr(VI) from different coloured passivations, based on several statistical industrial determinations.~~

~~Table 4-13: Release of chromium (VI) from treated substrate~~

~~Electroplated coating~~	~~Chromate conversion coating Finish colour process type~~	~~Cr(VI) release~~
~~Zinc and zinc alloys [124, Germany, 2003]~~	~~Clear blue Cr(VI)~~	~~0.05 – 0.1 µg/cm^2~~
	~~Clear blue Cr(III)~~	~~0.0 µg/cm^2~~
	~~Yellow-Tropical Cr(VI)~~	~~0.3 – 0.6 µg/cm^2~~
	~~Green Cr(VI)~~	~~0.7 – 0.9 µg/cm^2~~
	~~Black Cr(VI)~~	~~0.7 – 1.0 µg/cm^2~~
	~~Yellow-Tropical Cr(VI) Followed by a topcoat layer~~	~~0.1 – 0.2 µg/cm^2~~
	~~Black Cr(VI) Followed by a topcoat layer~~	~~0.02 – 0.1 µg/cm^2~~

~~Achieved environmental benefits~~

~~Reduced hexavalent chromium releases in subsequent handling and use.~~

~~Driving force for implementation~~

~~Increasing health and safety concerns for the use of Cr(VI) and various directives limiting its use.~~

~~**Example plants**~~

~~**Reference literature**~~

~~**[124, Germany, 2003]** [96, EC, 2003, 98, EC, 2003, 99, EC, 2000] [3, CETS, 2002] [118, ESTAL, 2003].~~

~~Chromium electroplating techniques~~

~~There are several options commercially available. Hexavalent chromium is the most widely used, but concern about its toxicity and use are increasing. The most widely used alternative is trivalent chromium. There has been a significant information exchange and validation of this issue by the technical working group The comments *[146, ZVO, 2003, CETS, 2004 #147]* and discussion are in Annex 8.10.~~

~~Hexavalent chromium plating~~

~~**Description**~~

~~See Section 2.5.3.~~

~~**Achieved environmental benefits**~~

~~Waste water s can be treated in a typical waste water treatment plant.~~

~~Because of poor current efficiency and the need to cool the solution, it can be run as a closed loop system, using multistage cascade rinsing and evaporation.~~

~~**Cross-media effects**~~

~~Very toxic to health in the workplace and the environment (see Section 4.9.6).~~

~~Treatment requires additional hazardous chemicals.~~

~~High solution concentrations have high viscosity and drag-out levels.~~

~~Air extraction requires scrubbing to remove the aerosol of Cr(VI).~~

~~High waste production from lead anodes.~~

~~Cr(VI) compounds are strong oxidising agents and it is advisable to store them separately. Dried Cr(VI) electrolytes have been known to cause fires~~

~~**Operational data**~~

~~Poor electrical efficiency caused by hydrogen evolution at the cathode (up to 85- 90 % of power consumption) and the solution requires cooling.~~

~~Hydrogen evolution causes a mist of Cr(VI) which, with handling of the solution and components, creates high profile workplace occupational health problems.~~

~~Mist suppression additives can be used, but these are based on PFOS, which has health and environmental risks (see Section 4.9.2).~~

~~Poor metal distribution and sensitivity to ripples in the power supply cause relatively high reject rates.~~

~~Self-passivation of unplated areas assists corrosion resistance.~~

~~**Applicability**~~

~~Widely applied in nearly 3000 installations worldwide.~~

~~Hard or functional chromium for engineering purposes can only be applied by this technique (but for an emerging alternative technique, see Section 6.2).~~

~~**Economics**~~

~~Solution costs are cheap.~~

~~High energy costs for power consumption, higher reject rates and waste water treatment plant costs.~~

~~Increasing insurance costs to cover heath and safety of workforce have been reported.~~

~~Driving force for implementation~~
~~Only large scale techniques for hard chromium plating, and some higher specification decorative finishes. Self-passivating in unplated areas.~~

~~Example plants~~
~~Widely applied in nearly 3000 installations worldwide.~~
~~Closed loop operation (with preceding closed loop nickel and copper) in Merrydale Industries Ltd, Wednesbury, UK.~~

~~Reference literature~~
~~[108, NEWMOA, 2003, 147, CETS, 2004] [125, Ireland, 2003, 147, CETS, 2004]~~

~~'Cold chromium' – hexavalent process~~

[Note to the TWG: this technique is proposed for deletion by CETS (CETS INPUT input in 176, TWG, 2024]), as it can't be used industrially]

~~Description~~
~~A new technique using 'cold chromium' has been put into production in 2000 in an Italian plant. The temperature of the processing bath with Cr(VI) is kept at about 18 – 19 °C by a refrigeration system (instead of 25 – 30 °C). At this temperature, the concentration of Cr(VI) in the process solution may be reduced by about 50 %. The quality of plating is the same.~~

~~Achieved environmental benefits~~
~~Minimisation of hexavalent chromium released.~~
~~Minimisation of evaporation of process solution evaporation.~~
~~Less energy used in the process.~~
~~Reduction of exposure to workers.~~
~~Reduction of water consumption.~~
~~Less waste water treatment required and less sludge produced.~~

~~Cross-media effects~~
~~Additional energy required for refrigeration. It is not clear how this compares with the energy savings in the process.~~

~~Operational data~~
~~Less concentrated solutions require a longer time for processing.~~
~~Better quality because of better throwing power.~~
~~No white edges.~~

~~Applicability~~
~~The technique may only be suitable for application in a new plant.~~

~~Driving forces for implementation~~
~~As introduction to Section 4.9.~~

~~Example plants~~
~~Industria Galvanica Dalla Torre Ermanno e Figli SpA, Fontane di Villorba, Italy.~~

~~Reference literature~~
~~[112, Assogalvanica, 2003]~~

4.2.7.6.1 Trivalent chromium chloride-based electroplating process

Description
~~See Section 2.2.1.3~~

Use of Cr(III) and chloride-based solution.

Technical description

The plating bath runs at a concentration of 20 g/l instead of 200 to 450g/l for hexavalent chromium. Reduced solution viscosity means less chromium dragged-out, and a reduction of chromium released: Cr(VI) is not released. Solutions can be chloride- or sulphate-based.

Achieved environmental benefits

In three case studies, the following were found:

- reduced or no hexavalent chromium compounds to store, handle or were in use
- in conjunction with electrolytic removal of chromium (as hydroxide), waste water treatment sludge reduced from 20 tonnes per year to 2 tonnes per year in one case, and there was thirty times less sludge in another
- about 30 % reduced power consumption
- no chemicals required for metals reduction
- no surfactants required to prevent mist formation
- the plating baths can be recovered using porous pots, membrane electrolysis or ion exchange
- air pollution treatment requirements reduced.

Lower health and environmental problems for Cr(III), reflected in TA-Luft values of 1 mg/m³ for Cr(III) to 0.05 mg/m³ for Cr(VI).

Environmental performance and operational data

The colour of the Cr(VI) deposit is described as blue-bright, the chloride trivalent deposit varyingly as grey-bright, yellow-bright or dark-bright. These historic problems with colour differences to deposits from hexavalent chromium and variations during processing compared with hexavalent chromium have largely been overcome by new solutions. These colour problems, and poor solution reliability and life, have long been overcome: it is crucial to use carbon filtration and ion exchange, or proprietary solution treatment processes, as well as minimising carry-over from previous processes.

Trivalent chromium solutions containing chloride can theoretically produce chlorine at the anode and hence AOX in the solutions, which could be dragged-out. In practice this has been controlled for 20 years by the addition of proprietary chemicals.

Requires training of staff and increased process control, which is similar to that required for bright nickel, which is used for the preceding layers.

Thicknesses can be measured by the same equipment (e.g. Couloscope, X-ray diffraction).

Higher current efficiency means higher loading of racks and 15 % increase in throughput has been reported.

Lower current density requires lighter, less expensive racks and wiring.

Reject rate reduced from 5- 10 % to 0.5 % due to Cr(III)’s better throwing power, higher current capacity and less susceptibility to ripples in supply, reducing rough deposits (i.e. burning in high current density areas) and reduced ‘whitewashing’ from plating interruption.

Cross-media effects

~~Problems have been reported in waste water treatment plant caused by complexing agents used in Cr (III) solutions. However, these have not been confirmed on site visits or in the case studies.~~

Trivalent chromium electroplating electrolytes may contain boric acid EC 234-343-4. The overall impact of substitution may be difficult to evaluate without a comparative risk assessment.

Technical considerations relevant to applicability
Applicability may be restricted by product specifications.

It ~~cannot~~ may not replace hard chromium plating.

It ~~cannot~~ may not replace certain corrosion resistance applications, such as where the CASS requirement is greater than 16 h. Trivalent chromium does not passivate unplated surfaces. Lower corrosion resistance has been reported, which is likely to be due to areas of no or low nickel thickness. Where hollow or recessed components (such as tubes) are plated, care is needed to prevent corrosion post-plating. This includes rapid and thorough rinsing of the acid bath, and possibly followed by passivation in a proprietary organic solution (validation from industry practitioners internationally) or a light Cr(VI) passivation (this mitigates some of the advantages of a Cr(VI)-free system).

The colour is a slightly yellow hue when compared directly to parts plated by hexavalent chromium. Cases have been reported of this being a problem to specific customers.

Colour and corrosion resistance has been accepted in major retail uses, such as cookers, on components subject to high temperatures and abrasive cleaners with strong caustic and acid components.

This has successfully been used with no loss of customer confidence (see Section 4.1.2).

Economics
One-off costs include disposal of old hexavalent chromium solution, replacing lead vat lining with PVDF and replacing lead/antimony anodes with carbon. An ion exchange system is required for controlling metal contamination, and the resin requires changing at approximately three year intervals. The base chemicals are more expensive.

These are more than offset by:

- a 30 % saving in energy
- a reduction in solid waste produced and disposed of
- reduced effluent treatment costs (no Cr(VI) to reduce)
- reduced air monitoring
- reduced staff medical monitoring
- reduced reject rate
- a significantly reduced risk of employee ill health.

One case study reports an overall gross profit improvement of USD 182 per shift of 670 m^2 from a jig plating line (1995 costs).

Driving force for implementation
Reduced risk to employee health. Reduces health and safety requirements, as well as expenditure on aerosol suppression, air extraction, monitoring for hexavalent chromium in the workplace atmosphere, as well as medical monitoring of staff. Cost-effective overall.

Example plants
Townrow (Hi-Tech Plating) Ltd, Sheffield, UK (case study), Foss Plating, Santa Fe Springs, California.

Reference literature

[43, SEA, 2001] [108, NEWMOA, 2003, 115, CETS, 2003, 148, HTMLA, 2003] [168, TWG, 2023].

4.2.7.6.2 Trivalent chromium sulphate electroplating process

Description
Use of Cr(III) and sulphate-based solution.

Technical description
For decorative nickel-chromium process. The process is carried out using sulphate electrolyte with Cr (metal) concentration between 6 and 8 g/l.

Achieved environmental benefits
Reduced Cr concentration when compared with trivalent chromium chloride (up to 20 g/l) and with hexavalent chromium (up to 450 g/l) processes.

No complexing agents (unlike chloride process) that may give rise to problems in the waste water treatment plant.

In addition to the environmental benefits achieved with chromium chloride solutions this process is more safe because there is no production of chlorine at the anode.

The solution is less aggressive and last longer. The problem of iron dissolution in the inner, hollow parts of workpieces is dramatically reduced.

Environmental performance and operational data
Special insoluble anodes are used. They last much longer than graphite anodes used for trivalent chromium chloride solution (chlorine corrodes graphite anodes). Use of insoluble anodes requires the use of additional metal salts, which must be produced and transported.

The bath is operated at 55 °C. Evaporation reduces the level of solution in the vat and therefore the addition of recovered solution is made possible. When slowly withdrawn workpieces are rather dry and drag-out is reduced.

The colour difference to hexavalent chromium coating is further reduced when compared with the colour of coatings deposited from chloride solution.

Throwing power is excellent: it increases the overall resistance to corrosion and in particular of those places usually never reached even by Cr(VI) coating and where rust will first crop out. In addition, no “burning” like patch forms when the intensity of current is high.

Reduced drag-out thanks to the low viscosity of the solution.

Cross-media effects
~~No data available.~~
Trivalent chromium electroplating electrolytes may contain boric acid EC 234-343-4. In addition, depending on the type of Cr(III) plating, a Ni underlayer is needed, e.g. nickel salts such as nickel sulphate EC 232-104-9 or nickel dichloride EC 231-743-0. The overall impact of substitution may be difficult to evaluate without a comparative risk assessment.

Technical considerations relevant to applicability
~~The technique may apply to new and existing plants.~~ Applicability may be restricted by product specifications.

Economics
No data available.

The components of the solution are very expensive when compared with those of Cr(VI). These costs are only partially offset by the lower costs of waste water treatment and the smaller amount of sludge produced. However, other costs are also lower (see Cr(III) chloride case studies).

Driving forces for implementation
As for chromium (III) chloride process, see Section 4.9.8.3.

Example plants
Industria Galvanica Dalla Torre Ermanno e Figli SpA, Fontane di Villorba, Italy. About 12 more lines in Italy.

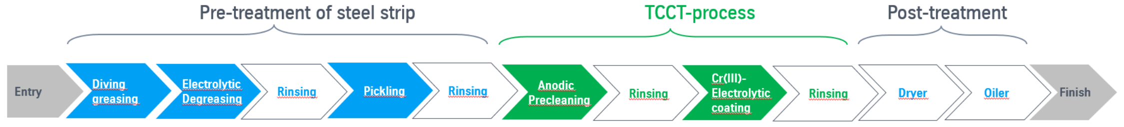
Reference literature
[161, Assogalvanica, 2004]
[176 CETS, 2024], [168, TWG, 2023].

4.2.7.6.3 Trivalent Chromium Coating Technology (TCCT) for packaging steel

Description
Trivalent Chromium Coating Technology (TCCT) for packaging steel is based on chromium(III)-electrolyte. It is an alternative to the hexavalent chromium(VI)-electrolyte conventionally used in the production process of Electrolytic Chromium Coated Steel (ECCS). TCCT can be used lacquered or with a polymer coating in the metal packaging industry. Applications are wide-ranging, e.g. food, paint or aerosol components.

Technical description
Cr(III) plating processes are generally based on the same principle as Cr(VI) processes and use the electrolytic depositions of chromium out of an electrolyte on a substrate. In general, the TCCT production process is following the former ECCS production process consisting of:

- pre-cleaning of steel plate;
- the chromium coating (TCCT-process); and
- post-treatment.



Source: (EUROFER submission in [167, TWG 2023]).

Figure 4-35: Process flow scheme of Trivalent Chromium Coating Technology (TCCT)

As usual in the production of packaging steel, the following pre-cleaning steps are installed:

- alkaline pre-cleaning of the steel strip;
- electrolytic alkaline cleaning using anodic current;
- rinsing with de-ionised water;
- pickling (activation of the surface in an acidic solution);
- rinsing with de-ionised water .

For the chromium coating, the strip undergoes the following process:

- It is again anodically pre-cleaned.
- It is then passed into a sequence of electroplating tanks containing the trivalent chromium-based electrolyte. The steel strip is switched as a cathode, so that in the tanks, an electrolytic deposition of a mixed layer of Cr-CrOx forms. The TCCT baths

comprise a mixture of a trivalent chromium salt and a complexing agent in a watery solution. The pH is adjusted to slightly acidic. In the oxidic bath there is no use of the complexing agent and a slightly different pH.

The electroplating tanks contain a set of suitable anodes to prevent the oxidation of trivalent chromium to its hexavalent state.

Post-treatment consists of the well-known steps:

- drying, and
- oiling.

Achieved environmental benefits

Comparing the environmental hazard of chromium trioxide and the trivalent chromium electrolyte regarding CLP classification, it reduces from H410 ‘very toxic to aquatic life with long lasting effects’ (Cr(VI)) to ‘no classification’ (Cr(III)).

The technology is much more environmentally friendly for the workers in the plant. It also eliminates the use of SVHC (chromium trioxide).

The temperatures in the process are slightly elevated, so relatively low-quality heat can be used for heating. Installing state-of-the-art rinsing will bring down the water consumption significantly. Although in conventional tin plate and ECCS production the hexavalent chromium is also reduced and acidic effluents are neutralised before being emitted to air or water, in the TCCT technology this potential risk does not exist: The emissions to air reduce in terms of amount and sources, because the official limit value of total chromium is up to one fifth lower than in the former permission for the hexavalent chromium process (amount) and the emissions of Cr(VI) are no longer applicable (source). Due to an integrated water preparation step for the electrolyte, the total water consumption during production is reduced. In comparison to the former hexavalent chromium coating process, the step of chromium reduction is no longer needed. This removes one process step in the waste water treatment, meaning elimination of the energy and raw materials used, as well as the waste produced from this step.

Environmental performance and operational data

- Reduction of water consumption.
- Reduction of emissions to air in amount and hazardouness.
- Reduction of raw materials.
- Reduction of energy use.

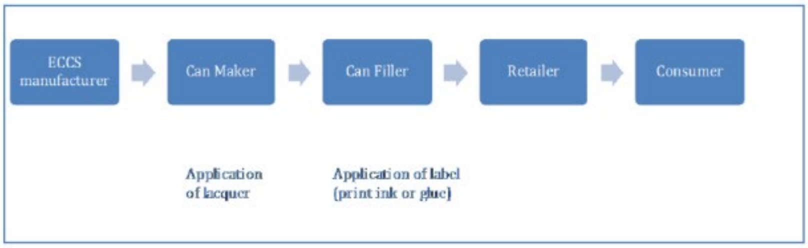
Cross-media effects

The cross-media effects are very complex for several reasons:

Electrolytic Chromium Coated Steel (ECCS) is a standardised product, used since the 1960s, available worldwide in exactly the same form, and using hexavalent chromium in the production process. ECCS is mainly used in the packaging of food and pet food. Therefore, it has to fulfil strict requirements related to food contact in order to be safe for consumers.

In Europe, due to the substitution push induced by the REACH authorisation requirement, the development of the alternative use of trivalent chromium for the production of TCCT removes the border for the worldwide standard of the product.

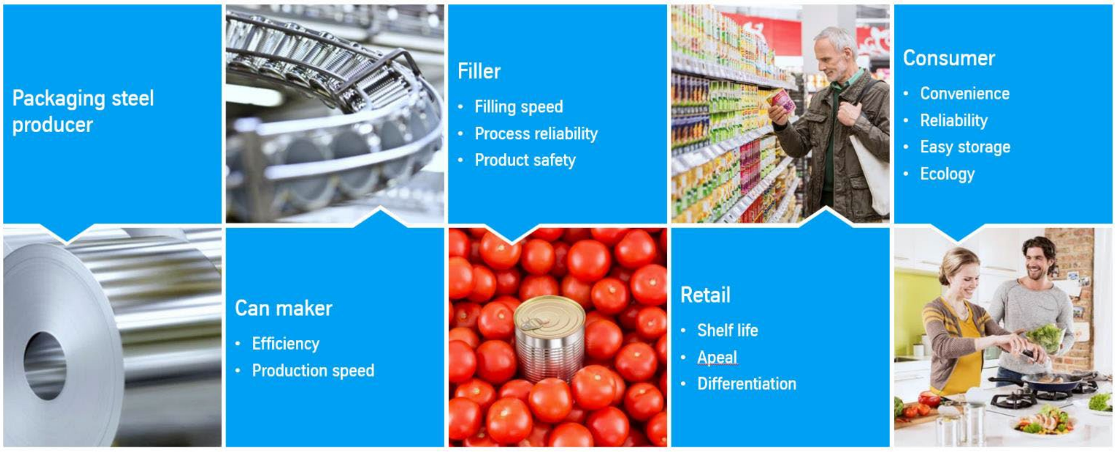
The production of the final product – the filled can ready for sale to the general public – requires many actors:



Source: (EUROFER submission in [167, TWG 2023])

Figure 4-36: ECCS supply chain

The complexity of the supply chain, with each actor having their own process requirements, limits how fast the new material can be introduced.



Source: (EUROFER submission in [167, TWG 2023])

Figure 4-37: Main requirements are different in the supply chain of ECCS

One of the main performance criteria is the adhesion of the organic coating (lacquer or laminate) to the metal packaging material. As there are different downstream users applying an organic coating, using different types of coatings, the combination of substrate and coating is complex. An additional constraint is the shelf life testing where food industry standards require that certain canned products have to be tested over a time span of up to 4 years.

Technical considerations relevant to applicability

Between the technical implementation of Cr(III)- compared to Cr(IV)-based processes, there are significant differences in the chemical composition of the electrolytes, the required additives, the operating parameters and the anodes. Because of these differences, some modifications need to be implemented in a Cr(VI)-based ECCS production line to use a Cr(III)-based technology. In case of limitations regarding space in existing lines, and taking into account the fact that during modification no normal production can take place, the decision to opt for a new line might be the best option.

Economics

A very rough estimate is that operational costs per tonne are similar to the production of ECCS for a line of equal capacity and location.

Driving forces for implementation

The search for an alternative to the use of Cr(VI) for the coating of packaging steel was driven by environmental improvement and better worker safety and started in 2006 by working on the RFCS-project ‘Innovative packaging Steel with enhanced adhesion to organic coatings based on nanostructured interphases’ (IPSA-Project). This was the joint work of Arcelor Mittal, Tata Steel and thyssenkrupp Rasselstein, representing the European producers of ECCS. In 2013, hexavalent chromium was included in Annex XIV to the REACH Regulation with a sunset date of 21 September 2017. For the purpose of phasing out Cr(VI) as soon as possible, the identification of an alternative chromium-free process was changed to Cr(III)-based solution, developed and patented by Tata Steel 2012, and in conjunction with a licensing agreement from thyssenkrupp Rasselstein in 2014.

Example plants
thyssenkrupp Rasselstein GmbH, Andernach, Germany Tata steel Europe, IJmuiden, The Netherlands.

Reference literature
Patent: https://patents.google.com/patent/WO2014079909A1
(EUROFER submission in [167, TWG 2023])

4.2.7.6.4 Low-Tin Steel (LTS) for packaging steel

Description
Low-tin Steel (LTS) is in fact chrome-free passivation tin plate, with very low tin gauge. It is a totally chrome-free alternative to Electrolytic Chromium Coated Steel (ECCS). It covers most of the ECCS applications in metal packaging industry.

Technical description
The process is the same as standard tin plate, with:

- low-tin gauge around 0.6 g/m²/face, which imposes specific electrolytic cells;
- chrome free passivation (CFPA – see related ET).

The main steps are:

- pretreatment;
- electrolytic tinning low gauge;
- quenching;
- optionally anodic oxidation (depend on applications)/rinsing/drying;
- CFPA passivation;
- drying.

Fundamentally, LTS as an alternative to ECCS is totally chromium-free in any form. It avoids any known issues associated with Cr(VI), whether considering Cr(VI) or Cr(III) as intrant substances. In the case of the replacement of ECCS, the reduction of Cr(VI) is much greater as the amount of chromium in ECCS is much more significant than in tin plate with chromic passivation (10 times more on average (5 to 40 times more)).

Environmental performance and operational data
Compared to standard tin plate for steel packaging applications, LTS has a coating rate on average five times lower.

It also eliminates the use of SVHC (chromium trioxide).

Raw material needs, energy consumption and emissions are reduced proportionally in the same range.

Cross-media effects
See cross-media effects in Section 4.2.7.10.5.

Technical considerations relevant to applicabilit

The technique can be applied by any tinning line equipped with chromium-free passivation (CFPA). The issue is that classical soluble anode technology quickly generates too high a dispersion in the very thin tin coating; this is due to the wear of the anodes.

Adapted electrolytic cells technology is necessary; no real constraints are identified, but investment can be consequential depending on the line layout.

Economics

A very rough estimate is that operational costs per tonne are similar to the production of ECCS for a line of equal capacity and location

Driving force for implementation

See Section 4.2.7.10.5.

Reference literature

(EUROFER submission in [167, TWG 2023])

4.2.7.6.5 Chromium free processes – other coating processes

Description

Options are given in Table 4.11~~,~~ below.

Other hard chromium plating substitutes such as nickel-tungsten-silicon carbide composite are still in the research phase. For specific applications, an alternative could be an electroless nickel coating [3, CETS, 2002]. Nickel- tungsten is only used in brush plating in applications [113, Austria, 2003].

Hard chromium can be replaced in some applications by alloyed WC-Ni(Co)Cr/Cr_2O_3, or by high velocity oxy-fuel spraying or plasma spraying [121, France, 2003].

Table 4-14: Summary of non-chromium substitutes for hard and decorative chromium baths

Possible Non-chromium replacement		Comments
Electroplated nickel	Nickel-tungsten-boron	Uses conventional plating equipment and operates similarly to a conventional nickel plating bath; may be more costly than Cr(VI)
	Nickel-tungsten-silicon-carbide	May provide higher plating rates and higher cathode current efficiencies; may provide better throwing power and better wear resistance; may be more costly than Cr(VI)
	Tin-nickel	Good corrosion resistance in strong acids, breaks down above 320 °C, less wear resistance than Cr(VI)
	Nickel-iron-cobalt	Vendor claims twice the wear resistance and 2.6 times the corrosion resistance of hex chrome; same colour can be obtained
	Nickel-tungsten-cobalt	Contains no chloride or strong chelators; can be used in rack and barrel plating; good corrosion resistance except in marine environments; may tarnish; contains ammonia
Non-nickel electroplate	Tin-cobalt	Three commercial options reported, with different attributes: • plate on nickel; decorative only • plate on decorative nickel and nickel alloy; may be used in racking; mildly alkaline • good colour, light blue cast; no ammonia; no fluorides; no chlorides
	Cobalt phosphorous	Nano-crystalline deposit produces extreme hardness; plating current waveform modification (electrically mediated deposition) used to produce nano-crystalline deposit.
Electroless	Electroless nickel: -nickel-tungsten -nickel-boron -nickel-diamond composite -nickel-phosphorous -nickel-polytetrafluoroethylene	Possibly less hardness and abrasion resistance than Cr(VI); no build up on corners
Other methods	HVOF (high velocity oxygenated fuel) thermal sprays	Hardness and wear resistance similar to Cr(VI); limited to line-of-sight applications.
	Physical vapour deposition (PVD) -titanium nitride	Greater hardness than Cr(VI) with a thinner coating; less corrosion resistance
	Ion beam-assisted PVD	Line-of-sight; thinner coatings give same properties as other thicker coatings
	Plasma spray -titanium carbide	Aluminium, steel, carbon steel, titanium substrates
	Chemical vapour deposition	Vacuum deposition; not limited to line-of-sight; resistant to acids; high deposition rate
	Ion implantation	Ions are implanted – no thickness; non-line-of-sight
	Powder coating	Vacuum metallisation (PVD) – has met OEM wheel industry testing requirements including ASTM B117, GM4472P, GM9508P, GM9682P, and GM6
	Laser cladding	Non-line-of-sight; nickel carbide coating

North East Waste Management Officers' Association, US [108, NEWMOA, 2003]Tin cobalt alloy electroplating

~~D~~Technical description

~~A chromeless technique using Sn/Co alloy (Co 5 – 10 %) has been tested and run in production lines for several years in Italian installations and in the Netherlands. This technique has a high penetration capacity (it can plate more complex shapes than hexavalent chromium) and provides top quality finishing. The finishing colour may be slightly darker than that obtained with Cr(VI).~~

A number of substituting processes are not requiring the use of Cr(VI) are available. They include physical as well as chemical processes. Most of them require a substantial change of the production process and may only be applied in new or substantially remodelled installations.

Chemical processes

Electroplated nickel-tungsten

This process leads to very wear- and corrosion-resistant surfaces replacing hard (functional) chromium as well as nickel-phosphorus coatings. The limitation of this process is that due to the high costs of tungsten, it can only be used economically in certain niche applications. With all nickel alloy deposits, problems can arise in waste water treatment due to complexing agents contained in the process solution. Due to nickel emissions, the process is not suitable for the food industry (e.g. separators) and the production of medicines.

Electroless nickel

In electroless nickel with dispersion layers, particles are incorporated into the nickel layer. The particles are in suspension in the electrolyte solution during metal deposition. For example, particles of diamond or boron nitride can be co-deposited, leading to wear-resistant coatings that can replace hard chromium coatings in individual cases. These coatings are used in the machinery industry and in mechanical engineering.

In electroless nickel coatings with embedded phosphorus or nanoparticles the ‘electroless nickel coating’ is deposited without an externally applied current in a chemical process. Functional chromium layers can be replaced by electroless nickel, especially when nanoparticles are incorporated into the layer. A total of 6-13% phosphorus is also incorporated into the coatings, which is why the coatings are also called nickel-phosphorus coatings, or NiP for short.

The process leads to high wear and corrosion resistance. It is applicable for complex geometries and for many applications, from the automotive industry to the electrical industry and mechanical engineering. The base materials range from steel, stainless steel and non-ferrous metals (brass, copper, etc.) to sintered metals and aluminium. NiP coatings are mainly used for small components and for increased corrosion protection requirements.

Nickel alloy deposits (NiL35)

This nickel alloy deposition is a combination layer of two alloys of the metals copper, tin and nickel. The layers are highly corrosion-resistant The maximum achievable hardness of about 600 HV is far below the hardness levels achievable by hard chromium coatings.

The coatings are resistant to sea salt and are, therefore, used in wind power offshore plants or for hydraulic cylinders of harbour cranes.

Physical processes

High-velocity oxygen fuel (HVOF) process

This is a high-speed flame-spraying method where a metal powder mixture is applied in a burning gas jet at supersonic speed. For example, tungsten carbide and chromium carbide are used in a cobalt or nickel/chromium matrix to replace hard chromium surfaces. The HVOF process has already been used by more than 100 facilities in Germany for products such as pressure rollers, aircraft landing gear, pistons and rollers, hydraulic pistons and piston rods, sliding surfaces of steam irons, rollers for the photographic industry, parts for petrochemical and chemical machines, e.g. pumps, slide valves, ball valves, mechanical seals, and to repair and increase in the service life of agricultural machines, etc.

Physical vapour deposition (PVD)

In physical vapour deposition, the later deposited material is converted into the gas phase in a vacuum by evaporation or by laser bombardment. It is then accelerated by electrical fields, as a stream of particles at 160-500 °C and precipitates again on the colder workpiece by condensation. The piece to be coated must be kept in rotation for full coating.

Hard material coatings based on titanium nitride (TiN), titanium carbonitride (TiCN), titanium aluminium nitrite (TiAlN) or diamond (DLC) are mainly used as coatings. For die-cast parts made of aluminium and magnesium, chromium-based coating systems such as chromium nitride (CrN), chromium vanadium nitride (CrVN) and chromium aluminium nitride (CrAlN) are mainly used.

Plasma nitriding

Plasma nitriding uses a nitrogen-hydrogen mixture, which is ionised in a closed vacuum furnace at negative pressure by applying a voltage between the container wall and the charge. The ionised gas atmosphere diffuses into the peripheral zone of the metal components, increasing the surface hardness and improving the corrosion behaviour of castings and low- to high-alloy steels. The surface temperatures are 350-600 °C.

Typical applications are transmissions, crankshafts, camshafts, cam followers, valve components, extruder screws, pressure die casting tools, forging dies, tools for cold forming, injection nozzles, plastic injection tools, long shafts, axles, clutches and engine parts.

The process is also suitable for very large parts.

Laser metal deposition (LMD)

In laser metal deposition, metal powders are applied to the surface of a base material and melted by laser. The laser beam causes a melting bath on the component surface and a powdery coating material is introduced into this melting bath with the aid of a nozzle. The filler material melts and metallurgically bonds with the base material leading to the formation of individual welding beads, which are placed next to each other for flat coatings.

The achievable coating thicknesses are 500 µm.

Extreme high-speed laser metal deposition (EHLA)

Extreme high-speed laser deposition welding is a further development of laser metal deposition (LMD). In laser deposition welding, metal powder is applied to the surface of a base material and melted by laser. In the EHLA process, the powdered filler material already hits the laser light above the melting bath, which heats it up to close to the melting point on its way to the component.

Depending on the requirements for the wear layer, tungsten carbide, titanium and chromium carbides, but also iron-, nickel- and cobalt-based powders are used. The deposition rate is up to 1 000 cm²/min, coating thicknesses are 10-250 µm and the feed rate is >100 m/min.

Possible fields of application are brake discs, valves, piston rings, shafts in the automotive industry, metering rollers, printing cylinders, plate cylinders in the printing industry, hydraulic cylinders, rollers, pistons, rods in mechanical engineering.

Plastic etching

Plastic etching with various chemical systems such as potassium permanganate and phosphoric acid, a manganese (III) base and microporous foaming are available and at different stages of application in installations. They all substitute Cr(VI).

Achieved environmental benefits

Minimisation of hexavalent chromium.

Treatment of rinsing water is easy and effective.

Cross-media effects

~~Some tin-cobalt baths contain chelating amines which cause problems with waste water treatment. However, this does not apply to all solutions.~~ The toxicity of alternative solutions must be taken into account, e.g. nickel and cobalt salts are CMR susbtances.

Environmental performance and operational data

~~The bath is rather unstable, a strict control of the operative conditions is required, in particular the pH.~~
~~A passivation stage with light Cr(VI) may be needed.~~
~~Barrels need to be made of acrylic.~~

~~A~~ Technical considerations relevant to applicability

~~It has been approved for certain automotive interior parts since the 1990s by General Motors.~~
~~It does not have high wear resistance.~~

High-velocity oxygen fuel (HVOF) process
The HVOF process is not suitable for complex geometries, workpieces with indentations and for internal coatings but can be used for coating rotationally symmetrical or flat components. Internal coatings are possible up to a diameter of 100 mm.
The process requires a sound insulation and is sometimes complex in terms of preparing the components. If the process parameters for high-temperature flame-spraying of chromium are not kept within the optimum range, the formation of chromium(VI) compounds is possible in conjunction with atmospheric oxygen.

PVD
The processes are only suitable for small parts in non-corrosion-sensitive installation areas. Large parts such as hydraulic rods in aircraft construction or rollers in the printing industry can usually not be coated in high vacuum. The surface temperature of the workpieces to be coated is approximately 250 °C, which may limit usability in individual cases.

Extreme high-speed laser metal deposition (EHLA)
The process can only be used for rotationally symmetrical workpieces. Complex geometries and workpieces with undercuts, blind holes, etc. cannot be coated.

Electroless nickel
Due to the nickel emissions from the surfaces, the deposited surfaces are not suitable for use in the food and pharmaceutical industries. As with all electroless nickel processes, problems can arise in waste water treatment due to complexing agents in the process solution.

Nickel alloy deposits (NiL35)
The repair of incorrectly coated surfaces is not successful with conventional methods. Due to the possible nickel emissions from the surfaces, the deposited surfaces are not used in the food and pharmaceutical industries. There are manufacturers who have withdrawn the process from their range of products due to quality problems in long-term use. As with all electroless nickel processes, problems can arise in waste water treatment due to complexing agents in the process solution.

Economics
No data available

Driving forces for implementation
~~As introduction to Section 4.9.~~ Legal requirements for substitution of Cr(VI).

Example plants
~~Cromotrevigiana Srl, Ponzano Veneto, Italy. Industria Galvanica Dalla Torre Ermanno e Figli SpA, Fontane di Villorba, Italy. Brandsma Metaalveredeling B.V., Hilversum The Netherlands.~~
BIA Solingen

Reference literature
[112, Assogalvanica, 2003] [165, Tempany, 2004] (Personal communication, Hank de Man, Brandsma Metaalveredeling BV.) [176 CETS, 2024]
[168 CETS, 2024] [177 FR, 2021], [167, DE contribution to TWG, 2024]

4.2.7.6.6 Chromium-Free Passivation Alternative (CFPA) for the tin layer of packaging steel

Description

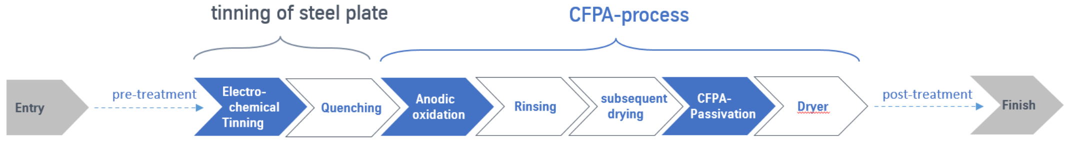
In the production of steel for packaging, the passivation of the tin layer is obligatory for protection against tin oxide growth. The Chromium-Free Passivation Alternative (CFPA) uses a titanium/zirconium (Ti/Zr) oxide film embedded in an organic polymer matrix which replaces the passivation that uses hexavalent chromium. It is applied through coil coating technology (i.e. by a roll coater or by a spraying-and-smoothing roll system).

Technical description

The production of electrolytic tin plate (ETP) as metal packaging material is described in Section 1.3.2 of the existing STM BREF. The surface of the tinned steel strip needs to be completely and effectively protected against corrosion and/or against reaction with sulphur because of food-contact requirements. Therefore, a thin passivation layer is applied on the tin layer which consists of titanium and zirconium. More details on Ti/Zr passivation are described in EN10202/2022, Chapter 6.4.2.

The biggest technical change is the application system for the Chromium-Free Passivation Alternative; it is done by spraying or roll coating (instead of dipping in a hexavalent chromium solution). In general, the tin plate production process follows the well-known ETP production process consisting of:

- pre-cleaning of steel plate;
- the electrochemical tinning process;
- the application of the passivation layer; and
- post-treatment.



Source: (EUROFER submission in [167, TWG 2023]).

Figure 4-38: Process flow scheme of Chromium Free Passivation Alternative (CFPA)

The application of CFPA on the tinned steel plate is described in detail below:

- The optional anodic oxidation of the tinned steel plate takes place in a sodium carbonate solution. This step can be optionally used because in some end-use conditions and with some can content, a chromium-free post-treatment agent alone does not protect the tinned steel strip surface enough against a reaction with sulphur. However, with this anodic oxidation before the application of a chromium-free post-treatment agent, the resistance of the tinned steel strip surface to reaction with sulphur is increased. An oxide layer with a layer thickness in the nanometer range is produced on the tinned steel strip surface by the anodic oxidation.
- Optional rinsing of the tinned and oxidised steel strip with water (preferably distilled or demineralised water).
- Subsequent optional drying before the chromium-free passivation application.
- The above-mentioned optional steps refer to passivation type 555. In the event that these steps are not used during the production process, the CFPA passivation type is 505.

- Now a thin layer of CFPA-solution agent can be deposited on the tin layer or on the optional tin oxide layer, and the surface of the tinned steel strip will become completely and effectively protected against corrosion and/or against reaction with sulphur. The Ti/Zr/polymer agent is applied by a roll coater or by a spraying-and-smoothing roll system on both sides of the metal strip.
- Final drying, after which a CFPA passivation film in the nanometer range remains on tinned steel surface.

This method was jointly developed and is pushed forward by all European producers of steel for packaging. Because of regulations forcing out the use of hexavalent chromium, this will be the European production standard as of the end 2027.

Achieved environmental benefits
The main optimisation of the new technology is the reduction of the risk to workers' health.

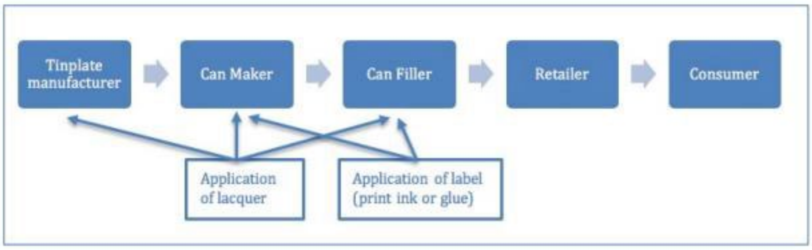
Environmental performance and operational data

- Reduction of water consumption.
- Reduction of emissions to air in amount and hazard.
- Reduction in raw materials use.
- Reduction in energy use.

Cross-media effects
The cross-media effects are very complex for several reasons:

Electrolytic tin plate (ETP) is a standardised product, available worldwide, using hexavalent chromium in the passivation process. ETP is mainly used in the packaging of food and pet food. Therefore, it has to fulfil strict requirements in order to be safe for consumers.

The production of the final product – the filled can ready for sale to the general public – requires many actors:



Source: (EUROFER submission in [167, TWG 2023]).

Figure 4-39: ETP supply chain

The supply chain (see above), with each actor having their own process requirements, limits how fast the new material can be introduced. One of the main performance criteria in the supply chain is the adhesion of the organic coating (lacquer or laminate) to the metal packaging material. As there are different downstream users applying an organic coating, using different types of coatings, the combination of substrate and coating is complex.

An additional constraint is the shelf life testing where food industry standards require that certain canned products have to be tested over a time span of up to 5 years. Therefore, a smooth transition and carefully controlled processes are needed to introduce the CFPA-passivation to the market step by step. In Europe, due to REACH authorisation issues, the development of a chromium-free alternative for the production opens the border for the worldwide standard of the product. This method has been developed and is put on the market by all European producers of steel for packaging together.

Technical considerations relevant to applicability
In existing passivation lines, the integration of the equipment for the passivation of the tin-plate strip with CFPA is mostly possible. There may be restrictions in existing lines due to space limitations.

Driving force for implementation
The search for an alternative to the use of Cr(VI) for the coating of packaging steel was driven by environmental improvement and better worker safety. It started intensively in 2006, with Arcelor Mittal, Tata Steel and thyssenkrupp Rasselstein working together on the RFCS project 'Innovative packaging Steel with enhanced adhesion to organic coatings based on nanostructured interphases' (IPSA-Project).

In 2013, hexavalent chromium was included in Annex XIV to the REACH Regulation with a sunset date of 21 September 2017. For the purpose of phasing out Cr(VI) as soon as possible, the identification of an chromium-free passivation process was pursued with even more urgency.

It is a common European alternative agreed on by all European producers of steel for packaging and was developed under the umbrella of their European association Steel for Packaging Europe (formerly APEAL).

Example plan
thyssenkrupp Rasselstein, Andernach, Germany.
Tata steel Europe, Ijmuiden, The Netherlands .
Arcelor Mittal, swing (also known as swing-out or swing-away) lines in several EU countries.
U.S.Steel Košice, s.r.o., Slovakia.

Reference literature
(EUROFER submission in [167, TWG 2023])

4.2.7.6.7 Chromium conversion coatings

~~The processes are widely used and described in Section 0. Due to the driving force of the ELV and ROHS Directives [98, EC, 2003, 99, EC, 2000], a large amount of work is being undertaken worldwide to develop alternatives to Cr(VI). Improvements and options are steadily being reported. Some reports indicate the future lies with alternative substrates, or alternative coating systems, such as replacing zinc plating with zinc alloys [149, PPT, 2004, 150, Rowan, 2003].~~

~~Phosphochromating exists with both hexavalent chromium (Cr(VI)) and trivalent chromium (Cr(III)) versions and is used in the treatment of aluminium prior to painting [90, COM 2020] [118, ESTAL, 2003].~~
The use of chromate in the EU is limited to applications authorised by ECHA.

Chromium trioxide is a substance of very high concern requiring authorisation before it is used, included in Annex XIV to REACH ('Authorisation List').

For this reason, phosphochromating with hexavalent chromium (Cr(VI)) is no longer used in the EU in the treatment of aluminium prior to commonly used painting processes like powder coating [175, ESTAL, 2024].

4.2.7.6.7.1 Hexavalent chromium

Description
A widely used technique, often in conjunction with zinc plating~~, as discussed in Section 0~~.

Used in passivating copper, brass and bronze in preference to bright dipping, as fewer fumes are evolved. It is also used for magnesium and its alloys.

The use of hexavalent chromium (Cr(VI)) in pretreatment prior to painting is limited to certain applications like aerospace and military.
~~It is widely used prior to power coating, although l~~Low Cr(VI) solutions are available, as well as the alternatives described in Sections 4.3.1.2.7.6.2 and 4.3.1.2.8.1.

Achieved environmental benefits

Low Cr(VI) solutions reduce negative impacts.
Cr(VI) solutions run at lower concentrations and lower temperatures than some of the alternatives.

Cr(VI) can readily be reduced and precipitated in a typical waste water treatment plant.

Environmental performance and operational data

Easy to use.

Technical considerations relevant to applicability

Economics

Very cheap.

Driving force for implementation

Cost, ease of use and corrosion resistance.

4.2.7.6.7.2 Trivalent chromium conversion processes

Description

~~Trivalent chromium passivation is described in Section 0.~~ The protection mechanism of the trivalent chromium conversion coatings is not yet fully understood. Their behaviour seems to indicate that the protection is mainly due to the physical barrier of the coating itself, since the coating is not sensible to any subsequent thermal shock. As can be seen from Table 4.10, there is no release of trivalent chromium from workpieces where it is used.

In some cases at least, the action of the Cr(III) is catalysed or assisted by other metals, such as cobalt

Certain Cr(III)-based conversion coatings have a higher performance and can match normal Cr(VI) conversion coatings when used with alloy plating and/or with additional coatings, see Sections 2.5.11, 2.5.17 and for emerging techniques, Section 6.3.

Achieved environmental benefits

No hexavalent chromium use and releases.

Cross-media effects

May involve the use and release of other metals such as cobalt.
Runs at ten times the concentration of Cr(VI) conversion layers, requiring more attention to minimisation of drag-out and possibly more waste water treatment.
Requires heated solutions with more energy input.

Technical considerations relevant to applicability

The corrosion protection achievable with these processes is currently limited to the protection level provided by the equivalent clear blue and yellow iridescent finishes achieved with hexavalent chromium. Although trivalent chromium can now exceed the equivalent hexavalent chromium performance for these colours, they are not capable of replacing brown, olive drab and black finishes. Their corrosion resistance is extended to match or exceed Cr(VI) performance by using additional coatings~~, see Section 2.5.11 and Section 2.5.17~~.

Economics

Savings in reduced effluent treatment costs, and health and safety management including scrubbing any extracted air.

Driving force for implementation

The ELV and ROHS Directives.

Also reduces health and safety requirements, as well as expenditure on aerosol suppression, air extraction and monitoring for hexavalent chromium in the workplace atmosphere.

Reference literature

[3, CETS, 2002] (Personal communication, Berthold Sessler, CETS) [98, EC, 2003, 99, EC, 2000].

4.2.7.6.7.3 Chromium-free conversion processes

Description

Chromium-free processes are based on treatments with a composite organic-zirconium fluoride solution, treatments with titanium fluoride, or treatments with organic silicon derivatives (silanes). They may require a subsequent polymer layer, such as electrophoretic lacquer, to achieve required corrosion resistance~~, see Section 2.5.11.~~.

There are black dyeing methods, which must be supplemented by sealing or topcoats for appearance and anticorrosion.

Achieved environmental benefits

Minimisation of hexavalent chromium released.

Cross-media effects

MSDS-based alternatives may be as toxic as Cr(VI).

Technical considerations relevant to applicability

Chromium-free solutions on the market are not yet fully able to provide zinc corrosion protection equivalent to chromate conversion coatings. These new processes still have some limitations with regard to the level of corrosion protection and the required bonding capability with any subsequent polymeric layer applied for functional and/or decorative purposes. There are chrome-free solutions, comparable to chrome conversion coating solutions, for aluminium. The substitution systems which have been successfully developed by the aluminium coating industry have proven their quality in the years since 2006 [175, ESTAL, 2024].

Driving force for implementation

~~As for Section .~~

Legislative requirements.

Reference literature

[3, CETS, 2002] [76, BSTSA, , 104, UBA, 2003] (Personal communication, Johannes Lusser, ESTAL) [152, ESTAL, 2004] Technical specifications for aluminium surface treatment: QUALICOAT, [175, ESTAL, 2024].

4.2.7.6.7.4 Substitution by chromium (III) conversion coatings for chromium (VI) conversion layers

Note to the TWG: this technique was moved from Chapter 6 in existing BREF according to TWG's initial positions].

Description
Section describes the drivers to change from Cr(VI) passivation treatments. These are summarised in Driving force for implementation, below.

Achieved environmental benefits
Reduction of Cr(VI) in waste water discharges.

Cross-media effects
Higher process temperature and energy use.
May require additional organic (lacquer) layer.
The complexing agents may have adverse effects in waste water treatment plant.

Environmental performance and operational data
In a research project, supported by the Ministry of Science and Research, SurTech GmbH developed a procedure for the production of 300 nm thick chromium (III) layers on electroplated iron (called Chromitierung). The conversion layer is completely free of hexavalent chrome and has a greenish appearance. This green colour (caused by interference bands) disappears after adding an organic layer. The thickness of the "Chromitierung" layer is reached by a high chrome concentration in the solution, an increased operating temperature of 60 °C and the employment of suitable complex ligands. By using dark pigments into the conversion layer of the "Chromitierung" it can be given a black colour comparable to the black Cr(VI) chromate finishing. Workpieces electroplated with nickel or cobalt can also be treated with chromium (III) layers.

In salt spray tests the corrosion protection of both systems is approximately equal.

Driving force for implementation
The development of alternatives to using hexavalent chromium electroplating solutions is driven by health and safety in the workplace and environmental toxicity (chromium metal plated on a surface has no adverse health effects). See Section 4.9.6.

In addition to occupational health issues associated with the use of Cr(VI), the use of Cr(VI) as a passivation (conversion) layer is under pressure because of its restriction in new vehicles by the ELV Directive and its banning in electrical and electronics applications by the RoHS directive see 4.9.6.

Example plants

Reference literature
A research project of the German Ministry of science and Technology "replacement of Chromium(VI) in zinc passivations" Foerderkennzeichen 01ZH9414/7
[98, EC, 2003], [99, EC, 2000]
http://www.faradaytechnology.com/tech-briefs/Cr(III)%20Electroplating%20TECH%20Brief.pdf
[177, TWG, 2020].

4.2.7.6.8 Chromic acid anodising

Description

See Section 2.5.13.

Applicability
Used ~~largely prior to powder coating but also~~ in aerospace, electronics and other specialist applications, as residues cause no corrosion with aluminium or alloy substrates.

While chromic acid anodising was used in the aerospace and military industry, it has largely been replaced by anodising in tataric acid or tataric/sulphuric acid (TSA) electrolytes [175, ESTAL, 2024].

Reference literature
[90, COM 2020], [175, ESTAL, 2024].

4.2.7.6.9 Phosphochromating (phosphating with chromium)

Description
Sealers and phosphochromate finishes can contain hexavalent chromium. Phospho-cromating processes for aluminium produce layers containing trivalent chrome and phosphates. Many of these can be replaced with non-Cr(VI) systems. Examples systems based on are silanes, zirconium and titanium.

It has been proven in the years since 2006 that hexavalent chromium can successfully be replaced in the pretreatment of aluminium. In phosphochromating, all applications of chromium(VI) have been successfully replaced [175, ESTAL, 2024].

Achieved environmental benefits
Minimisation of Cr(VI) and hence discharges to air and water.

Cross-media effects
Some of the alternatives may be as toxic as Cr(VI) (according to the materials safety data sheets).

Driving force for implementation
Occupational health, ELV and REE Directives.

Reference literature
[71, BSTSA, , ESTAL, 2004 #152] [98, EC, 2003, 99, EC, 2000], [175, ESTAL, 2024]

4.2.7.7 Substitution for mechanical polishing and buffing

Description
Acid copper plating has an excellent levelling capability. It can sometimes be used to replace polishing and buffing processes.

Achieved environmental benefits
Reduction or elimination of dust and noise from mechanical processes.

Environmental performance and operational data
Specification of the basic roughness and the necessary layer thickness are not given.

Cross-media effects
Increased waste water treatment requirements.

Technical considerations relevant to applicability

Suitable for workpieces prior to decorative nickel and copper plating. In some cases, it is still necessary to polish the 'acid' copper coating. The size of the defects removed by these two processes are not comparable; moreover, mechanical polishing is often associated with a demand to change the geometrical characteristics of the part. This substitution technique does not achieve certain shapes (rounded).

Economics
Investment in polishing and buffing is replaced by investment in acid copper processing.

Driving force for implementation
Simplified health and safety requirements.

Reference literature
[3, CETS, 2002, 113, Austria, 2003].[CETS, 176 2024]

4.2.7.8 Minimisation of the use of solvents containing hazardous substances ~~Substitution and choices for degreasing~~

4.2.7.8.1 Mechanical pre-cleaning- centrifuging

Description
Excessive oil and grease can be removed mechanically, i.e. by centrifuging or by air knife (see Section 2.3.5 for alternatives) before other forms of degreasing, such as chemical or solvent.

Achieved environmental benefits
Extends the life of degreasing solutions. Savings in chemicals and other inputs for degreasing. Reduction in wastes produced.

Environmental performance and operational data
The majority of oil deposits on small components can be removed by centrifugal force, providing the components can withstand the mechanical load without distortion, e.g. screws, bolts, nuts and nails. In most cases, removed oil can be recycled after filtering. Cleaning is often improved by warming the components to decrease the viscosity of the oil.

Workpieces can be destroyed or surfaces for decorative finishing damaged.

Cross-media effects
Power consumption in centrifuging and other mechanical techniques.

Technical considerations relevant to applicability
The majority of small oiled components, usually undergoing barrel treatment.
Energy used for heating components prior to centrifuging.

Driving force for implementation
Reduced subsequent degreasing treatment, reducing degreasing chemicals, power consumption, and improving quality.

Reference literature
[3, CETS, 2002]

4.2.7.8.1 Solvent degreasing

Description
See Section 2.3.3.

Achieved environmental benefits
Low heat consumption.

Environmental performance and operational data
Good cleaning efficiency, quick drying.

Cross-media effects
Because of the classification of certain CHCs as potentially carcinogenic materials (e.g. tetrachoethylene PER, EC 204-825-9 with harmonised classification for toxic to aquatic life with long lasting effects and is suspected of causing cancer), their water-endangering potential and problems with emissions to the air and their use is strongly regulated (see Driving forces for implementation, below). Alternative solvents are inflammable.

The use and control of this technique may be discussed in the BREF on the Surface Treatment using Solvents.

Technical considerations relevant to applicability
Almost universally applicable, see Section 2.3.3

Driving force for implementation
Used for high specification work, e.g. some aerospace or military applications.
Used where water-based treatments can damage the surface being treated.

Example plants
Have been widely used.

Reference literature
[90, COM 2020] [12, PARCOM, 1992, 93, EC, 2000, 96, EC, 2003, 97, EC, 1999]
[165, Tempany, 2004]

4.2.7.8.2 Chemical aqueous (soak) degreasing

Description
This section refers to cyanide-free aqueous degreasing, see Section 2.3. Cleaners can be of varying pH strengths and surfactant types and concentrations, according to the input oil/grease load, the substrate being treated and the requirements of the subsequent processes.

Achieved environmental benefits
The acids and alkalis used are simple and easy to treat in typical waste water treatment plants, unless strong chelating agents are present (see EDTA, Section 4.9.1 and waste water treatment, Section 4.16.8).

Environmental performance and operational data
Short process solution life, depending on the throughput and the amount of oil and grease removed.

Cross-media effects
Process tanks operate at 40- 90 °C and may require fume extraction to remove water vapour and alkaline or acid fumes.

Metals can be stripped from the substrate surface, (including trace elements such as lead, in some steels. They can be separated after pH adjustment.

Used acid or alkali solutions are often treated separately as they create a large pH change which may not be accommodated by continuous flow waste water treatment plants.

The surfactants present are not usually eliminated by a typical waste water treatment plant. Cleaning solutions may need to be separated from other process effluents to avoid interference with the waste water treatment plant by excess surfactants.

Maintenance can extend bath lives, see Section 4.11.13

Technical considerations relevant to applicability
Water-based degreasing systems offer well proven alternatives to solvent-based systems in almost all cases.

Cleaning processes for zinc and aluminium must be at or near neutral pH.

Emulsifying degreasing solutions have better degreasing efficiency, but are more difficult to regenerate than unstable emulsion (weak emulsion) systems. Applicability may need to be determined in each case.

Driving force for implementation
Health and safety, replacing solvents in the workplace.

Example plants
Worldwide usage.

Reference literature
[IHOBE, 1997 #6; UBA, 2003 #104, CETS, 2002 #3[124, Germany, 2003]

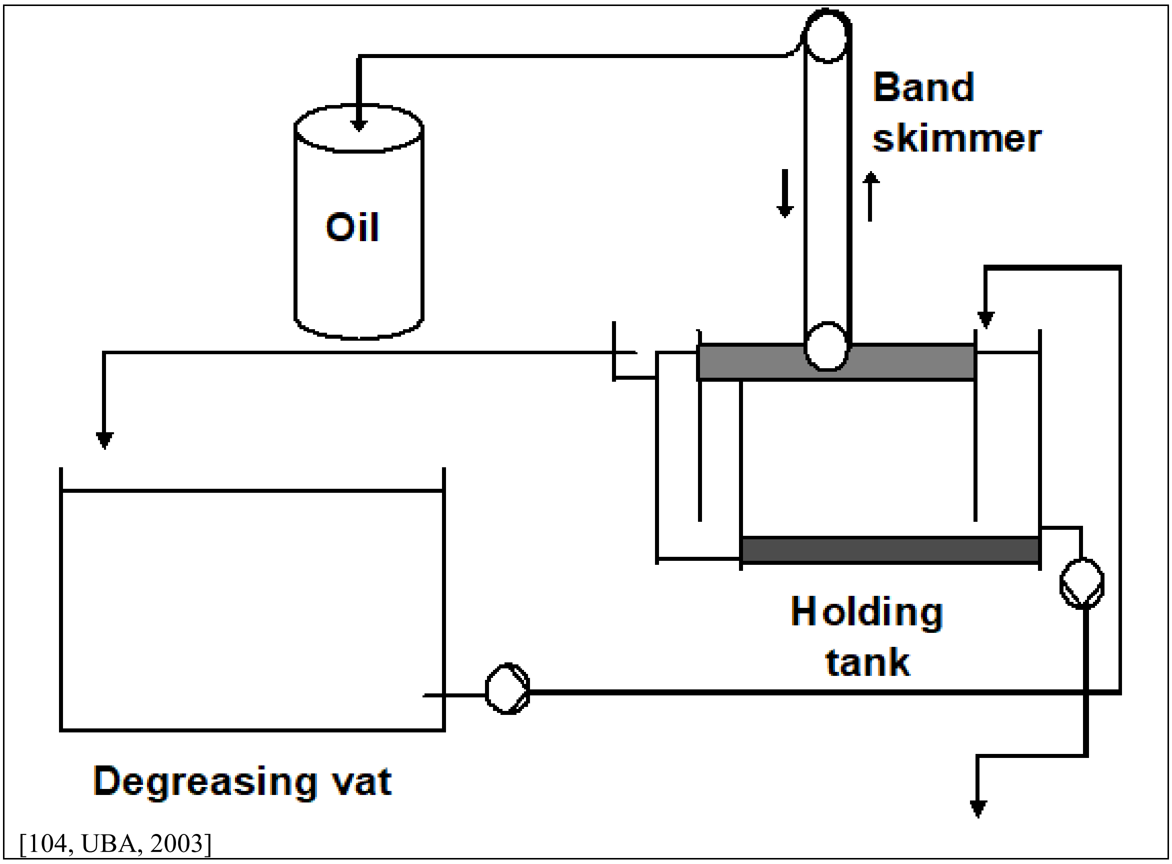
4.2.7.8.3 Weak emulsion degreasing

Description
This is a variation of chemical aqueous degreasing, using a more easily maintained solution. Surface-active agents used in weak emulsion degreasing solutions are developed chemically so they do not form a stable emulsion with the removed oils and greases. The degreasing tanks are drained to a holding tank (usually for a group of degreasing tanks) for the removal of floating oils and sediments. Weak emulsion cleaning solution separates by itself, so that simple mechanical systems (skimmers) can be used for the removal of the oil. By the continuous removal of contamination via the holding tank and feedback of the cleaned degreasing solutions in the bath, a high service lifetime is achieved.

Weak emulsion degreasing systems offers thereby a compromise between the two requirements for degreasing systems:

- a smaller (but still sufficiently high) oil-absorbing capacity than strongly emulsifying degreasing baths;
- they can be substantially more easily regenerated and re-used.

The type of systems to be used can be derived from these characteristics.



[104, UBA, 2003]

Figure 4-40: Weak emulsion degreasing system with holding tank for cleaning

Achieved environmental benefits

Minimisation of chemical and power consumption in cleaning.

Environmental performance and operational data

The advantage of a weak emulsion system is that the solution is constantly being refreshed by having the oil removed.

Weak emulsion degreasing can leave grease/oil films on the panels of barrels- especially from the first bath. This film can be carried through all the vats in the plant. The grease/oil films from cleaners with weak emulsions can block ion-exchanger resins and membranes for membrane processes if these are used for recirculating rinses in the plant. These effects do not exist with stable emulsions

Cross-media effects

Small additional power consumption required for pumping and oil recovery.

Technical considerations relevant to applicability

Numerous cases are known in practice, where the conversion to a weak emulsion degreasing systems has given satisfactory cleaning.
Workpieces with strongly adhering pollution or with very viscous oils or grease on the surface cannot be cleaned by weak emulsion systems.
Strongly emulsifying systems have better degreasing capabilities, but are more difficult to regenerate. It is advisable to determine applicability on a case by case basis.

Economics

The investment in this type of plant may be high particularly if taken in conjunction with the maintenance options in Sections 4.11.13. A complex investment is only likely to be cost-effective if the process line and the amounts of oil and grease involved are large.

Driving force for implementation
Improved down-stream process control.

Reference literature
[104, UBA, 2003], [118, ESTAL, 2003], [113, Austria, 2003].

4.2.7.8.4 Biological degreasing

Although often referred to as a substitute technique, this is a maintenance technique for weak alkali degreasing baths that overcome their short lifetime by constant bypass regeneration. It is described in full in Section 4.11.13.4

4.2.7.8.5 Dry ice

Description
See Section 2.3.5.3

Achieved environmental benefits
Removal of oil, grease and particles, paint, etc. without the use of solvents.
Dry waste containing only removed components.

Environmental performance and operational data
See Section 2.3.

Cross-media effects
Noise and energy to form and propel dry ice pellets.

Technical considerations relevant to applicability
This method is used mainly for cleaning pressing forms and other special parts. In special cases it is used to strip coatings (organic and metallic). It requires accessible surfaces.

Driving force for implementation
Removal of paint without solvents and solvent emissions.

Reference literature
[116, Czech-Republic, 2003]; CETS, 2003 #115]
[176 CETS, 2024]

4.2.7.8.6 Ultrasonic cleaning

Description
Ultrasonic cleaning uses high frequency sound waves to improve the cleaning efficiency of aqueous, semi-aqueous and solvent cleaners. By generating zones of high and low pressure in the liquid, the sound waves create microscopic vacuum bubbles that implode when the sound wave moves and the zone changes from negative to positive pressure: this is called cavitation. If this occurs at the surface to be cleaned, the pressure cycles lead to local impacts, resulting in a mechanical action at the surface. Theoretically, localised pressures of >1000 bar are generated, dislodging grease and dirt.

Cleaning agents make this a viable process in aqueous solutions.

Achieved environmental benefits
More effective cleaning with less hazardous chemicals, when using aqueous solutions.

Environmental performance and operational data
Process advantages: the surface that needs to be clean is not attacked; good degreasing efficiency and short operation time. Suitable for high specification cleaning.

Chemically efficient cleaners and higher temperature accelerate the process. Cleaners can be:

- alkaline (pH 8 – 14) although >pH10 may attack some substrates such as aluminium, zinc)
- neutral (pH 7 – 9.5) are used to remove dirt
- acid (pH 2 – 6). These remove oils and grease, although not as well as alkaline agents. They are used for cleaning oxidised surfaces.

Organic solvents have good properties for removing pastes and have the advantage of drying fast. They are expensive and more toxic than aqueous solutions.

The possible imbalance of the transducers can cause wave shock zones and dead zones, giving uneven cleaning.

Parts may fall from jogs due to vibration.

Cross-media effects
Waste water may include includes phosphates, surfactants, polishing paste and metals contained in it (copper and zinc).
Causes high frequency noise, which may be above 85dB.
A power consumption of 10 W per litre is reported.
Solvent systems contain volatile organic solvents.

Technical considerations relevant to applicability
Widely applicable, except for bulk treatment in plastic barrels. Does not attack surfaces to be cleaned (such as copper, zinc). Space is needed for transmitters.

Economics
Cost for installation in an automatic electroplating line with this system is approximately EUR 80000 (2004).

Driving force for implementation
Wide applicability and high quality of cleaning.

Example plants
At least two installations in Portugal.

Installation A: 250 litres, uses an aqueous degreasing bath without silicates and with neutral pH; removes polishing paste:

working temperature:	60 ºC
bath duration:	1 week
ultrasound power:	1200 W.

Installation B:

bath working temperature:	55- 60 ºC (heating by electrical means)
bath solution life:	90 days
consumption:	50 kg of chemicals/month
process disadvantages:	cost of the equipment.

Reference literature

(Personal correspondence. S Gomes, Instituto do Ambiente, Portugal) [159, TWG, 2004]
~~See Annex 8.8~~
[176 CETS, 2024]

4.2.7.8.7 Electrolytic cleaning with pH control

Description
Electrolysis in a degreasing solution is used to remove grease and dirt prior to the coating operation (see Sections 2.3.8 and 2.9.3.1). The degreasing solution is continuously monitored using pH to measure its effectiveness and to control the addition of new solution.

Achieved environmental benefits
Minimises the use of degreasing solution and the amount of waste solution requiring treatment. Reduces the volume of waste water and sludge from the waste water treatment plant.

Environmental performance and operational data
The process reduces the contamination of the plating solutions and contributes to less rejects of the finished product.

Cross-media effects
Production of an explosive mixture of gases (O_2 and H_2).

Technical considerations relevant to applicability
New and existing plants prior to the coating process sections.

Economics
Approximate costs for large scale coil installations are an initial investment of EUR >0.8/t along with operating costs of EUR 0.015- 0.8/t installed.

Driving force for implementation
Process quality and efficiency.

Example plants
Many coil coating plants.

Reference literature
[19, Eurofer, 2003]

4.2.7.8.8 High-performance degreasing systems

Description
For high quality cleaning, aqueous systems are used which can be supplemented by electrolytic action. High quality cleaning is essential with modern process solutions such as acid zinc, etc.

In the case of strongly oiled parts, multistage degreasing can be advantageous. For the first stage, a hot water pre-degreasing or an unstable emulsion cleaning solution is used (see Section 4.9.14.4). For a second stage, a more strongly emulsifying cleaning solution is used. Also the combination of any two degreasing baths in sequence with the second, cleaner bath being used to replenish or replace the first, dirtier bath extends the service life of the degreasing solutions considerably.

Achieved environmental benefits
Extension of life of degreasing solutions. Reduction of reworking.

Cross-media effects
Energy consumption in higher temperature systems.

Technical considerations relevant to applicability
The process is limited to treatment of parts on supports. It is totally unsuitable for bulk processing in plastic drums.

Economics
Case-specific.

Driving force for implementation
Improved quality of workpieces or substrate for subsequent processing.

Reference literature
[3, CETS, 2002, 104, UBA, 2003]
[176 CETS, 2024]

4.2.7.9 Other degreasing techniques

Description
~~Many a~~Alternatives are e.g.~~mentioned in Section 0, such as~~:

- air knives and rollers: for sheet metal, flat pressed components and wire, the majority of oil can be removed by passing through a divider that can be mechanical (a wringer roller) or an air knife
- cyanide degreasing: thought to be obsolete except to remove traces of glue
- hot water: hot water (80-90 °C) without chemicals can remove the majority of oil and grease. This method is used mainly in the automotive industry when cleaning pressed sheet steel. Using a high pressure water jet further improves the effect.
- hand wiping: large and/or high value components can be cleaned manually with cloth or paper wipers.

Some of these are newer techniques (e.g. air knives, dry ice) and are not widely used. Hand wiping is for specific applications, e.g. for high value components.

Achieved environmental benefits
Extends the life of degreasing solutions.

Cross-media effects
Hand wiping can produce large amounts of wastes, such as paper wipers and solvents. In addition, the use of solvents is poorly controlled.

Technical considerations relevant to applicability
Depends on size and type of components: see Description, above.

Driving force for implementation

Reference literature
[3, CETS, 2002, 112, Assogalvanica, 2003] [90, COM 2020 , 129, Spain, 2003]
[176 CETS, 2024]

4.2.8 Prevention and reduction of emissions to air ~~Air emission batement techniques~~

[Note to the TWG: This section corresponds to the Section 4.18 of the original STM BREF]

Chapter 2 identifies processes which lead to emissions of concern, for example: pickling, certain etching processes, brightening, certain plating tanks, etc. Typical substances emitted to the air are described in Section 3. For workers' health and safety it is often necessary to limit certain emissions inside surface treatment installations: whilst the overall potential emission load to the environment does not change, emission abatement techniques, such as scrubbing, may have cross-media impacts (for example to waste water and in energy consumption). Good environmental practice in preventing emissions can be complementary to occupational health objectives.

It is widespread practice to minimise the amount of humid and/or corrosive fumes. This not only protects employee health, but also:

- protects workpieces or substrates in storage or in the various stages of processing, see Section 4.2.6.3
- protects the installation infrastructure
- protects control systems in process control and other sensitive equipment (computers, etc).

[80, INRS, , 104, UBA, 2003]

Some or all of these measures may be used together.

Where the extracted air contains materials that may cause environmental harm (as described in the appropriate processes in Chapters 2 and 4), the air can be treated by options described in Section 4.2.8.2.4

4.2.8.1 Diffuse emissions to air

4.2.8.1.1 Additives

Description

Use of non-fluorinated additives in the treatment vat that can reduce the generation of gases and aerosols, e.g. Cr(VI) aerosols, HF, NO_X.

Achieved environmental benefits

~~According to manufacturer's data, in pickling solutions, the formation of nitrite ions and Cr(VI) ions are prevented by pickling additives. The emissions of HF and~~ ~~NO_X~~ ~~can also be reduced so that it is not necessary to install an exhaust air scrubber.~~

~~It is also possible to be reduce or prevent Cr(VI) aerosol emissions from chromium plating tanks by the use of fluorinated additives but note that these are based on PFOS, see Section 1.4.4.4 and Annex. Aerosols from alkaline etching or anodising can be prevented by using surfactants. For both processes there are unfluorinated surfactants which are used with success.~~

~~Reduced formation of harmful species, therefore reducing their concentration and emission.~~
~~Prevention of the formation of harmful mists or aerosols (especially for Cr(VI) plating).~~
~~Air extraction may not be needed as a foam layer may be formed which is sufficient to minimise the release of hazardous substances to air.~~

Additives play a crucial role in enhancing the performance and efficiency of the treatment process. Here are some examples of non-fluorinated additives that can be used in treatment vats:

- Wetting agents:
  - Polyethylene glycol (PEG);
  - Polypropylene glycol (PPG);
  - Ethoxylated alcohols (e.g. C12-C14 ethoxylates).
- Emulsifiers:
  - Alkylphenol ethoxylates (e.g. nonylphenol ethoxylates);
  - Fatty acid ethoxylates (e.g. lauryl ethoxylates);

  - Sorbitan esters (e.g. sorbitan oleate).
- Corrosion inhibitors:
  - Sodium nitrite ($NaNO_2$);
  - Sodium benzoate;
  - Triazoles (e.g. benzotriazole, tolyltriazole).
- Foam suppressants:
  - Silicones (e.g. dimethylsilicone, methylphenylsilicone);
  - Polydimethylsiloxane (PDMS).
- pH adjusters:
  - Sodium hydroxide (NaOH);
  - Potassium hydroxide (KOH);
  - Triethanolamine (TEA).
- Chelating agents:
  - Ethylenediaminetetraacetic acid (EDTA);
  - Diethylenetriamine pentaacetic acid (DTPA);
  - Hydroxyethyliminodiacetic acid (HEIDA).
- Surfactants:
  - Anionic surfactants (e.g. sodium lauryl sulphate, sodium laureth sulphate);
  - Nonionic surfactants (e.g. ethoxylated alcohols, sorbitan esters).

Additives can be used in various surface treatment processes, such as:

- cleaning and degreasing;
- pickling and acid cleaning;
- passivation;
- painting and coating;
- electroplating.

Additionally, the technique involves the monitoring and control of humidity and corrosion levels to ensure their effectiveness and reduce the need for additional additives.

Cross-media effects
~~PFOS (polyfluorinated octyl sulphonate) is used in suppressing Cr(VI) mists, and in other applications. It is toxic, bio-accumulative and persistent (see Annex).~~

Environmental performance and operational data
Additives can also improve product quality.

Applicability
~~See individual applications.~~
Only applicable when additives are compatible with the applied vat solution chemistry.

Economics
May in some cases achieve sufficiently low emissions without the need for air extraction and/or reduce the size, complexity and cost of extraction equipment.

Driving force for implementation
Occupational heath and safety legislation as well as emission limit values.

Example plants

Reference literature
~~[3, CETS, 2002, 113, Austria, 2003, 159, TWG, 2004]~~ [168, TWG, 2023] [176, CETS, 2024]

4.2.8.1.2 Covered treatment baths

[Moved here from Section 4.3.3.5]

Description

Treatment baths generating gases and aerosols containing hazardous substances, not equipped with a fume exhaust system, are covered using lids for example and are maintained in negative pressure.

Technical information

Covering the tanks when either the immersion time for a jig or barrel needs extended time or the baths are not used minimises the emissions to the workplace atmosphere, and subsequently to the environment. Containing the air space above the vat by using lids reduces the amount of air to be withdrawn and treated. A description of some options for lids is given in this section and an example can be seen in the following figure.

Graindorge S.A. and Agence de l'eau Seine-Normandie

Figure 4-41: Jig line with lids on vats and air extraction

Containment is discussed in several BREFs (see Reference Literature). The containment of the sources of potential emissions minimises the amount of emission and airflow, although the airflow may need treatment.

Edge exhausts are normally employed to meet industrial health and safety requirements and various configurations are described in Section 4.2.8.2.2.

Flooating insulation sections are adapted to the shape of workpieces treated.

Achieved environmental benefits

High environmental benefit.
Reduction of fugitive emissions to air.

Cross-media effects

None.

Applicability

Generally applicable to new and existing plants.

Operational data

There are practical difficulties in some applications, such as space, access for maintenance, etc.

Economics

The initial investment is EUR 0.015-0.8/t installed with maintenance requirements at EUR 0.00- 0.15/t.

Driving force for implementation
Workplace environmental conditions, health and safety legislation.

Example plants
Many continuous electroplating lines.

Reference literature
[176 CETS, 2024]

~~4.2.8.1.3~~ Extraction of emissions as close as possible to the emission source ~~Air extraction, lids and treatment techniques~~

Description
Pollutant emissions from treatment vats are captured as close as possible to the emission source and extracted using, for example, enclosures, fixed or movable extraction hoods, centralised mechanical extraction. The collected off-gases may be treated by an abatement system before being released.

Technical description
Edge exhausts are normally employed to meet industrial health and safety requirements ~~and various configurations are described in Section~~.

The quantity of exhaust air sucked off by the edge exhaust, and the quantity of pollutants it contains are influenced by the following parameters:

- tank size
- continuous or intermittent operation of the bath
- bath temperature
- physico-chemical characteristics of the assigned chemicals
- classification and permissible concentration at the workplace
- use in conjunction with pickling additives to decrease and/or avoid of the emissions of HF and NO_X gases and Cr(VI) aerosols
- emission control procedures, etc.
- types, size and density of particulates
- the space between the exhaust slots and the surface of the vat
- the strength of the electric currents in electrolytic processes
- the type of bath agitation used (such as air, pumped recirculated flow or eductor).

The pollutants emitted with the drawn off exhaust air are separated where necessary to achieve emission standards by the following exhaust air cleaning devices:

- exhaust air scrubbers with fill materials and droplet separators
- exhaust air scrubbers with the following combinations:
    - cyanide and acid separation in an alkaline scrubber
    - nitrogen oxides and hydrofluoric in an acid scrubber
    - exhaust air containing Cr(VI) by droplet separators
- mist filters used for aerosols and droplets, such as Cr(VI)
- droplet separators for aerosols and droplets, such as Cr(VI), which may be followed by filters
- cyclones, electrostatic precipitators or filters (for examples for dusts from mechanical polishing).

These are described in the BREF on waste water and waste gas treatment in the chemical sector for extraction systems.

Organic solvents, such as VOCs from solvent degreasing, are emitted, they are discussed with in the BREF on the surface treatment using solvents.

The industry generally produces a small source of NO_X. Major uses are in pickling and brightening, and emissions are low with typical air scrubber systems, without the need for catalytic reduction (see Economics below).

In the case of some combinations of different systems, there are slight deviations to the exhaust air purification measures described above.

Overall achieved environmental benefits

Additives can decrease the formation of gases and Cr(VI) aerosols and may extend the life of pickling acids.

Lids reduce the amount of gases and aerosols emitted to the air.

Section 0 show that the use of simple extraction systems using droplet separators and/or counter-flow scrubbing readily achieved normal target values.

No data are available for the effectiveness on emissions of the other process measures (additives and lids).

Overall cross-media effects

Air extraction can have a significant effect on power consumption in three ways:

- additional electricity to power fans and pumps
- unwanted loss of heated workspace air during working periods when outside temperatures are below about 12 °C (this may be more significant in Northern and Central Europe)
- unwanted cooling of process solutions by increasing evaporation requiring additional process energy input.

Additives may be harmful to health and the environment, see Section 1.4.4.4.

Overall operational data

Options to reduce the volume of extracted air and decrease the energy losses are discussed in Section 4.2.8.2.2, below.

Overall applicability

One or more of these options is suitable for all installations.

Overall economics

It is not cost-effective for the industry as a whole to install catalytic reduction for NO_X.

Overall driving force for implementation

Workplace health and safety.

Reference literature

~~[66, PPRC, 2003, 80, INRS, 104, UBA, 2003] [87, EIPPCB, , EIPPCB, #155, EIPPCB, #86] [90, COM 2020].~~ [168, TWG, 2023]

4.2.8.2 Chanelled emissions to air

4.2.8.2.1 Minimising the number of emission points

[Note to the TWG: please provide information to complete the 10-heading template below, e.g. on operational data]

Description

The combined treatment of waste gases with similar characteristics ensures more effective and efficient treatment compared to the separate treatment of individual waste gas streams. The combination of waste gases is carried out considering technical (e.g. compatibility of the individual waste gas streams), environmental (e.g. maximising recovery of materials or pollutant abatement) and economic factors (e.g. distance between different emission points). Care is taken that limiting the number of emission points does not lead to the dilution of emissions.

Technical description

Emissions from the same type of processes that are generating waste gases with similar characteristics are combined and treated together for better treatment efficiency and to reduce the energy consumption associated with the operation of multiple abatement systems.

Achieved environmental benefits

- Energy savings.
- Improved abatement efficiency of emissions to air.
- Recovery of materials (e.g. dust).

Environmental performance and operational data

Cross-media effects

None expected.

Technical considerations relevant to applicability

Generally applicable. The extent to which the number of emission points can be optimised depends on technical (e.g. compatibility of the individual waste gas streams) and economic factors (e.g. distance between different emission points, energy consumption).

Economics

Cost will depend on technical and economic factors. Monitoring costs may be reduced due to the lower number of emission points.

Driving force for implementation

Reduction of monitoring and abatement costs due to the lower number of emission points.

Example plants

Widely used.

Reference literature

4.2.8.2.2 Reduction of the volume of extracted air

Description

This includes techniques such as the reduction of the free surface area above vats, applying a specific airflow above the process vats, enclosure of plating lines and adjustment of the air extraction operating period.

Technical description

The most common system uses extraction hoods located laterally to the entrance area for plating jigs on flight bars and plating barrels above processing vats.

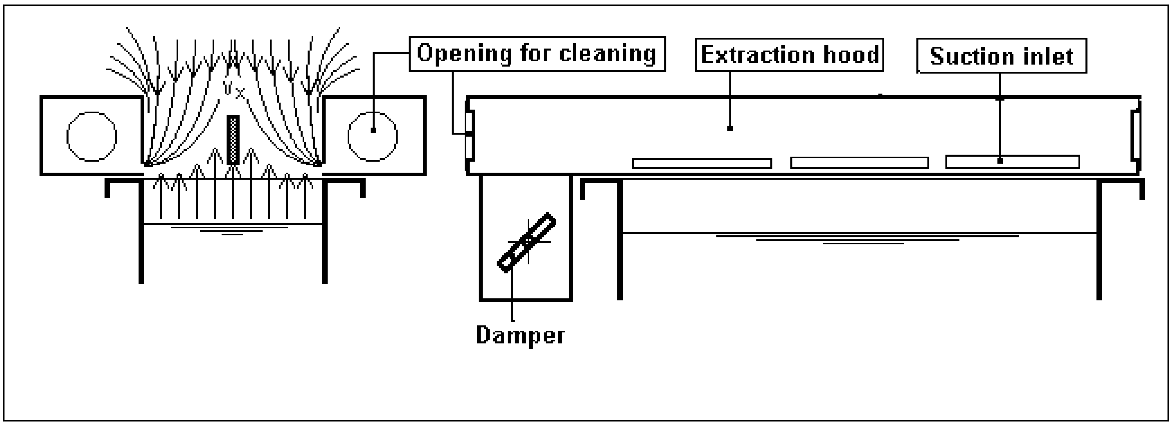


Figure 4-42: Example of fume extraction on top of treatment tank

The efficiency of the air extraction is determined by the minimal air velocity (vx) necessary to capture the uprising vapour, fumes or aerosols at the most distant point from the extraction hood.

Values for vx differ between 0.2 m^3/s capture velocity for moderate water vapours and 0.5 m^3/s for aerosols from hard chromium plating solutions.

The volume of air to be extracted depends on the free surface area of the processing solution.

It can be calculated by the following equations:

Single-sided extraction (W <0.5 m) V = 2 vx L W (W/L)0.2

Double-sided extraction (W >0.5 m) V = 2 vx L W (W/2L)0.2

V = volume of extracted air, in m^3/s
vx = minimal air velocity at point x, ~~m^3/s~~ in m/s
L = length of extraction area, in metres
W = width of extraction area, in metres.

Single-sided extraction is normally used for tanks of width W<0.5 m, and double-sided extraction for wider tanks (W >0.5 m).

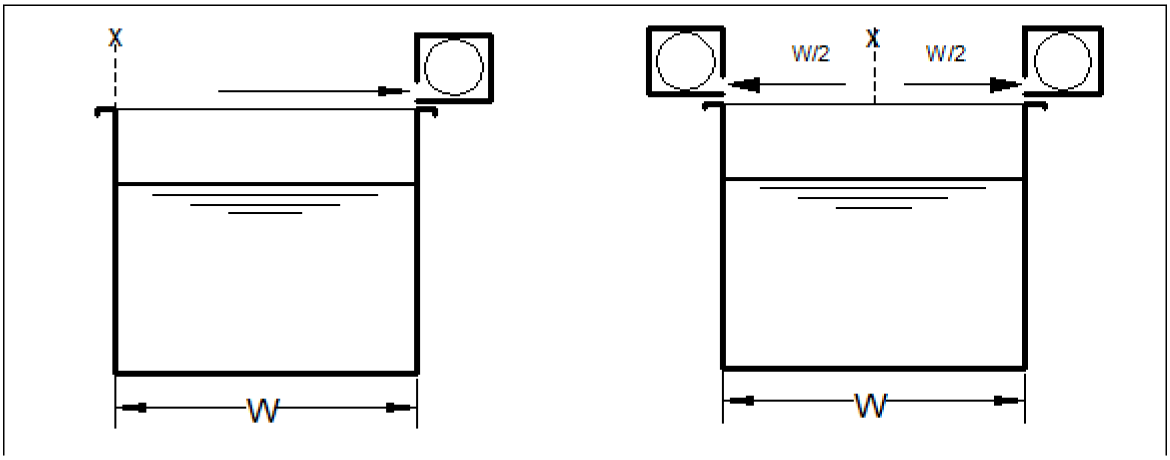


Figure 4-43: Single-sided extraction (W <0.5 m)	Figure 4-44:Double-sided extraction (W >0.5 m)

There are ~~three~~ four options to reduce the volume of extracted air:

(1) Reduction of free surface area above tanks
Figure 4-46 and Figure 4-47 show different means of minimising the air volume extracted and thus energy consumption.

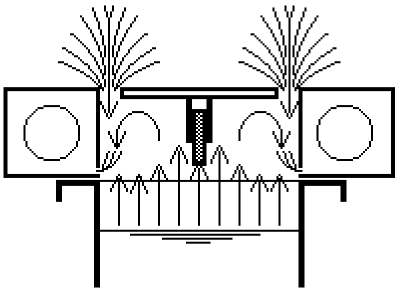


Figure 4-45: Lid protecting free surface area, fixed to and moved with the flight bar

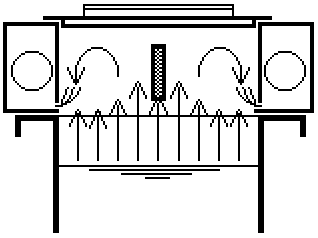


Figure 4-46: Lid protecting free surface area above extraction hood, movable by the transporter

Figure 4-46: Since hazardous fumes or aerosols are generated mainly during processing, lids fixed to and moved with the flight bar are a suitable means for reducing the volume of extracted air by 60 – 75 % of the normal rate without a reduction in the surface area.

Figure 4-47: These lids cover all process stations where vapour, fumes or aerosols are generated at any time except during loading and unloading of the stations. The reduction in extraction rate increases may be more than 90 % (subject to a German patent). A major advantage of this system is that these lids need no drive at the station itself, since they are moved simultaneously with the drip tray of the transporter.

Lids hinged to the tank, driven individually and automatically opening and closing when jigs and barrels enter and leave the processing tank are another appropriate but more expensive design. Usually this system is combined with a device designed to automatically increase the volume of extracted air when the lids are opened. A reduction in extraction rate of up to 90 % may be achieved.

(2) Push-pull system

This method is designed to create an airflow over the surface of the processing bath. It works with an extraction hood opposite a blowing duct. The surface of the processing solution must not have any frame or obstacle to the airflow. ~~Therefore its application remains quite limited.~~

This system involves both ‘push’ and ‘pull’ airflows to create an effective ventilation system that captures and removes contaminants from the workspace.

In a push-pull air extraction system:

1. The ‘push’ airflow: Fresh air is supplied into the workspace around the process vats, typically through a vent or duct. This fresh air helps to dilute and push the contaminants away from the working area, including the vat and surrounding surfaces.

2. The ‘pull’ airflow: Exhaust hoods or fans are placed above the process vats to create a strong negative pressure, pulling the contaminated air up and away from the operator and the vat. The hoods are connected with filters or scrubbers to capture and remove airborne contaminants, such as alkaline emissions (NH_3, H_2S), solvents, and metal particulates.

Push-pull extraction systems were reported by Plant AT005 (in pickling, activation, descaling and desmutting processes) and Plant FR036 (anodising and subsequent sealing).

(3) Enclosure of the plating line
Recently, the complete segregation of the process plant has been achieved in some installations. The plating line is installed inside an enclosure, while all plant operations, the plant management systems, and the loading/unloading stations are located outside. Since a substantial amount of extracted air is still necessary to prevent corrosion of the equipment within the enclosure, an energy saving higher than the figures for other techniques cannot be expected.

(4) Adjusting the air extraction operating period
Air extraction can be operated during operating periods for the solutions of concern, and when conditions require, such as when process solutions are fully heated and working. Care may be taken that the air extraction system does not operate when it is not required, especially when outside temperatures are low and/or workplace cooling or heating are functioning. Timers can be installed.

Achieved environmental benefits
Reduction of the volume of extracted air reduces energy consumption and any required treatment processes, chemicals, etc.

Applicability
Attention needs to be paid to energy efficiency in all installations using air extraction.
Process control is feasible for all installations. Other options will be site-specific.

Where the processing line is enclosed, the maintenance of the plant and solutions may become more complicated and time-consuming This technique is likely to be most effective with new installations, rather than retrofitting.

Economics
Case-specific, but see the Example Plant below where the operational savings gave a two year payback, and one year payback if capital savings are included.

Driving force for implementation
Health and safety in the work place.

Example plant
Goodrich Aerospace Landing Gear Division, Tullahoma, Tennessee, US, AT005, FR036 [168, TWG, 2023]

Reference literature
[3, CETS, 2002, 113, Austria, 2003] [168, TWG, 2023], [176, CETS, 2024]

4.2.8.2.3 Off-gas extraction as close as possible to the emission source

Description
Off-gases are extracted using, for example, full enclosure, edge or lip extraction.

Technical description
Off-gases from processes which are likely to result in the release into the air of pollutants are extracted as close as possible to the emission source using techniques such as: full enclosure, edge or lip extraction, mobile extraction hoods.

Table 4-14 below provides a non-exhaustive list of substances and/or activities whose fugitive emissions may have local environmental impacts and the conditions when they need air extraction. In some cases, this is related to health and safety inside the workplace.

Table 4-15: Solutions and activities which may require extraction of off-gasess

<table>
<tr><th>Type of solution or activity</th><th colspan="2">Solutions needing air extraction</th></tr>
<tr><td colspan="3">In all cases:</td></tr>
<tr><td>Cyanide</td><td colspan="2"></td></tr>
<tr><td>Cadmium</td><td colspan="2"></td></tr>
<tr><td>Hexavalent chromium</td><td colspan="2">Solutions which are used for electroplating, and/or are heated and/or are agitated with air</td></tr>
<tr><td>Nickel solutions</td><td colspan="2">Solutions agitated with air</td></tr>
<tr><td>Ammonia</td><td colspan="2">Solutions emitting ammonia, either where ammonia is a component or a breakdown product</td></tr>
<tr><td>Dust producing activities such as polishing and linishing</td><td colspan="2"></td></tr>
<tr><td>Using insoluble anodes</td><td colspan="2">In all solutions hydrogen and/or oxygen are formed and there is a risk of deflagration, see individual processes and techniques in Chapters 2 and 4.</td></tr>
<tr><td colspan="3">Acid solutions</td></tr>
<tr><td></td><td>Solutions not needing extraction</td><td>Solutions needing extraction</td></tr>
<tr><td>Processes containing nitric acid with emissions of NO_X</td><td></td><td>Processes for the surface treatment of metals which are likely to result in the release into the air of any acid-forming oxide of nitrogen include:
• chemical brightening of aluminium
• bright dipping or chemical polishing of copper alloys
• pickling using nitric acid, which may also contain hydrofluoric acid
• in-situ cleaning using nitric acid
• chemical stripping using nitric acid</td></tr>
<tr><td>Pickling and stripping using hydrochloric acid</td><td>Hydrochloric acid used at ambient temperatures and concentrations below 50 vol % technical grade with water generally does not evolve HCl gas or fumes which require extraction for health and safety reasons</td><td>Hydrochloric acid used at higher concentrations and/or at elevated temperatures generates significant releases of HCl gas or fume which requires extraction for health and safety reasons and to prevent corrosion in the workplace</td></tr>
</table>

Pickling and stripping using sulphuric acid	Sulphuric acid used at temperatures below 60 °C generally does not evolve acid mists which require extraction for health and safety reasons	Sulphuric acid used at temperatures above 60 °C releases a fine aerosol of the acid which requires extraction for health and safety reasons and to prevent corrosion in the workplace
Pickling using hydrofluoric acid		In all cases
Alkali solutions		
Aqueous alkaline cleaning	Alkaline cleaning chemicals are non-volatile and do not require fume extraction for health and safety reasons or local environmental protection	Alkaline cleaning tanks operating above 60 °C can generate significant amounts of water vapour which may be extracted for operator comfort and to prevent corrosion

Achieved environmental benefits

Reduction of diffuse emissions to air and maintenance of occupational health standards within the workplace.

Environmental performance and operational data

See the reported emission levels for emissions to air in the relevant sections in Chapter 3.

Cross-media effects

Extraction of off-gases requires energy.

Technical considerations relevant to applicability

Generally applicable.

Economics

Driving force for implementation

Legal requirements

Example plants

Many plants in the data collection reported extraction of off-gases.

Reference literature

[168, TWG, 2023]

4.2.8.2.4 Off-gas treatment

4.2.8.2.4.1 Adsorption

Description

The removal of pollutants from a process off-gas or waste gas stream by retention on a solid surface (activated carbon is typically used as the adsorbent). Adsorption may be regenerative or non-regenerative.

General information on this technique is also provided in the CWW BREF [87, COM 2016].

Technical description

Adsorption is a heterogeneous reaction in which gas molecules are retained on a solid or liquid surface (the adsorbent is also referred to as a molecular sieve) that prefers specific compounds to others and thus removes them from effluent streams. When the surface has adsorbed as much as it can, the adsorbent is replaced or the adsorbed content is desorbed as part of the regeneration of the adsorbent. When desorbed, the contaminants are usually at a higher concentration and can either be recovered or disposed of.

Typical adsorbents include:

- granular activated carbon (GAC), the most common adsorbent with a wide efficiency range and not restricted to polar or non-polar compounds; GAC can be impregnated, e.g. with oxidants such as potassium permanganate or with sulphur compounds (improving the retention of heavy metals);
- zeolites, with properties depending on their manufacture, working either as mere molecular sieves, selective ion exchangers or hydrophobic VOC adsorbers;
- macroporous polymer particles, which are used as granules or beads, without being highly selective with respect to VOCs;
- silica gel;
- sodium-aluminium silicates.

The application of adsorption encompasses:

- the recovery of VOCs (raw material, product, solvent, etc.) for reuse or recirculation; it may be used as a stand-alone system, as a concentration step to improve the viability of further recovery operations such as membrane separation or to treat the tail gas emissions from an abatement system;
- the abatement of pollutants that cannot be recirculated or otherwise used, possibly with GAC as an adsorbent which is then not regenerated but incinerated;
- its use as a guard filter after final treatment facilities.

Example plants
BE001, BE004, BE017, DE072, DE073, DE074, FR032, IT002 and MT001.

Reference literature
[168, TWG 2023]

4.2.8.2.4.2 Aerosol/droplet separator

Description
A fill material is used to condense aerosols and droplets. Condensate is usually treated in a waste water treatment plant.

General information on this technique is also provided in the CWW BREF [87, COM 2016].

Example plants
Widely used; 26 plants (87 emission points) in the STM data collection.

Reference literature
[168, TWG 2023]

4.2.8.2.4.3 Biofilter

Description
The waste gas stream is passed through a bed of organic material (such as peat, heather, compost, root wood, tree bark, softwood and different kinds of combinations) or some inert material (such as clay, activated carbon, and polyurethane), where it is biologically oxidised by naturally occurring microorganisms into carbon dioxide, water, inorganic salts and biomass.

Technical description

Biofiltration is based on the ability of microbes living in a fibre-peat filter bed to oxygenate malodorous gases and convert them into odourless compounds. The gas to be purified is blown by a fan through a bed of humid filter material, exiting odourless from the upper side. The odorous compounds are adsorbed in the water phase and are decomposed by microorganisms living on the filter material. The good performance of the filter depends on the balance between the supply of nutrients (compounds for abatement/decomposition) and the number of microorganisms.

In foundries, biofilters are applied for the removal of odorous gases, which mainly consist of amines from the off-gas from cold-box core-making processes and for the removal of VOCs (e.g. benzene) from casting shop exhaust gases.

Critical parameters for good functioning of the biofilter are as follows:

- *Permeability of the filter layer*: Gases need to flow through the bed in good contact with the filter bed material. An excess of fine material in the filter bed may cause clogging, pressure build-up and blowout of bed material.
- *Wetting of the filter medium*: A water dispersion system may be installed for continuous or intermittent wetting of the bed material.
- *Conditioning of the exhaust gas*: The exhaust gases need to be moistened before entering the filter. For optimum operation, a constant temperature (30 ºC) has to be maintained. This may require preheating of the exhaust gas.
- *Adequate water treatment*: The biofilter produces residual water, containing phenol and cresol. This is treated in a waste water system before disposal or recirculation. Recirculation requires an additional salt removal step.

Introduction of the biofilter technique in a German foundry required a long optimisation period, until it was able to function satisfactorily. It was found that the following characteristics appear to be important:

- Closure of the biofilter beds with a lid, in order to prevent CO- and condensation problems throughout the installation. The filtered air is evacuated through a centralised chimney.
- Close control of water quality (e.g. salt content), especially when applying a system not producing waste water.
- The addition of nutrient salts to the sprinkling water, to maintain bed activity.
- Control of the pH value of the bed material and the addition of lime to maintain a neutral pH value.

Further information on biofilters may also be found in the CWW BREF [179, COM 2016].

Achieved environmental benefits

Reduction of odourous and/or VOC emissions. The elimination of benzene and other VOCs takes place in biofilters but may not be regarded as reliable. The efficiency varies remarkably according to a wide spectrum of factors, such as weather conditions, age of substrates, etc. The use of biofilters alone is therefore not valid as a stand-alone technique for the reduction of VOCs. Their main purpose consists of the reduction of odour.

Environmental performance and operational data

When operating a biofilter, one of the main problems is to prevent the filter material from drying out or becoming waterlogged in places, thereby enabling a uniform flow through the filter bed. Thus, biofilters reach the limits of their performance in the presence of the following exhaust air characteristics:

- strongly fluctuating exhaust air constituents in terms of type and concentration;
- discontinuous exhaust air flow;

- thermal and chemical instabilities caused by peak loads of temperature, dust, disinfectants, steam, etc.

Additionally, disadvantages are often the large space requirements of these systems, the cost-intensive fan energy for increasing the pressure and the permanent watering.

Cross-media effects
The biofilter produces a waste water flow. This may be recirculated internally after treatment, yielding a sludge cake for disposal.

Energy is consumed during the transfer of the off-gas to and through the filter, as well as for the surrounding equipment.

It has been reported that emissions of N_2O, a greenhouse gas, may be a problem.

Technical considerations relevant to applicability
In principal, bioscrubbers can be applied in new and existing plants. The required operating system depends on two conditions: the odour load and the hall suction. When the application of bioscrubbers is technically evaluated:

- the planned water flow and the amount of additives must be adapted to the odour load;
- the uptime of the casting facility must be considered due to its consequence for energy consumption.

When no odours are generated, it is possible to turn the system off manually. A time limit for downtime of the bioscrubber does not exist. The plant can operate continuously 24 hours a day.

It has to be considered that the microorganisms require relatively constant environmental conditions.

Economics

Driving force for implementation
- Reduction of nuisance effects (mainly odour) on neighbouring locations.
- Legal requirements.

Example plants
AT001, AT002 and DE066.

Reference literature
[168, TWG 2023]

4.2.8.2.4.4 Cyclone

Description
Equipment for the removal of dust from an off-gas stream based on imparting centrifugal forces, usually within a conical chamber. Cyclones are mainly used as a pretreatment before further dust abatement or abatement of organic compounds. Multicyclones may also be used.

See the CWW BREF [179, COM 2016]

Environmental performance and operational data
Cyclones can be used alone, but are often used in combination with other waste gas treatment techniques.

Example plants
BE001, CZ007, ES012, ES016, ES020, IT002 and IT010.

Reference literature
[168, TWG 2023]

4.2.8.2.4.5 Fabric filter

Description
Fabric filters, often referred to as bag filters, are constructed from porous woven or felted fabric through which gases are passed to remove particles. Fabric filters can be in the form of sheets, cartridges or bags with a number of individual fabric filter units housed together in a group. The use of a fabric filter requires the selection of a fabric suitable for the characteristics of the waste gas and the maximum operating temperature.

See the CWW BREF [179, COM 2016]

Example plants
Widely used; 14 plants (36 emission points) in the STM data collection.

Reference literature
[168, TWG 2023]

4.2.8.2.4.6 Demister

Description
Demisters are filter devices that remove entrained liquid droplets from a gas stream. They consist of a woven structure of metal or plastic wires, with a high specific surface area. Through their momentum, small droplets present in the gas stream impinge against the wires and coalesce into bigger drops.

Technical description
The most common mist filters (mist eliminators, demisters) are mesh pad filters. Mesh pad filters usually consist of woven or knitted metallic or synthetic material monofilament in either a random or specific configuration and are used for deep-bed filtration, which takes place over the entire depth of the filter. Solid dust particles remain in the filter until it is saturated and thus has to be cleaned by flushing. When the mist filter is used to collect droplets and/or aerosols, it is usually self-cleaning, drained by the liquid. It works by mechanical impingement and is velocity-dependent. Baffle angle separators are also commonly used as mist filters.

Demisters often form an integrated part of other techniques, for example gas scrubbers.

Example plants
Widely used; 16 plants (41 emission points) in the STM data collection.

Reference literature
[168, TWG 2023]

4.2.8.2.4.7 Wet scrubbing

Description
The removal of gaseous or particulate pollutants from a process off-gas or waste gas stream via mass transfer to a suitable liquid, often water or an aqueous solution. It may involve a chemical reaction (e.g. in an acid or alkaline scrubber).

Environmental performance and operational data

Wet scrubbing is used alone or in combination with other waste gas treatment techniques.

Reported data from five plants (7 EPs) using wet scrubbing show a range for dust emissions from 1.1 mg/Nm^3 to 84 mg/Nm^3 with 4 out of 6 EPs with emission levels below 17 mg/Nm^3 [169, TWG 2021]

Example plants

Widely used; 82 plants (311 emission points) in the STM data collection.

Reference literature

[168, TWG 2023]

4.2.8.2.4.8 Thermal oxidation

Description

Abatement technique which oxidises combustible compounds in a waste gas stream by heating it with air or oxygen to above its auto-ignition point in a combustion chamber and maintaining it at a high temperature long enough to complete its combustion to carbon dioxide and water. The typical combustion temperature is between 800 °C and 1 000 °C.

Several types of thermal oxidation are operated:

- Straight thermal oxidation: thermal oxidation without energy recovery from the combustion.
- Recuperative thermal oxidation: thermal oxidation using the heat of the waste gases by indirect heat transfer.
- Regenerative thermal oxidation: thermal oxidation where the incoming waste gas stream is heated when passing through a ceramic-packed bed before entering the combustion chamber. The purified hot gases exit this chamber by passing through one (or more) ceramic-packed bed(s) (cooled by an incoming waste gas stream in an earlier combustion cycle). This reheated packed bed then begins a new combustion cycle by preheating a new incoming waste gas stream.

Technical description

Thermal oxidation is used as an abatement technique to reduce emissions of organic compounds (e.g. TVOC, benzene).

Further information is provided in the CWW BREF [87, COM 2016].

Achieved environmental benefits

- Reduced emissions to air.
- Possible energy recovery.

Environmental performance and operational data

Thermal oxidation is used alone or in combination with other waste gas treatment techniques (e.g. combined with pretreatment by condensation or adsorption or with post-treatment by absorption). Removal efficiencies for organic compounds typically range from 95 % to more than 99.99 %.

Optimisation of thermal oxidation can reduce the emissions of NO_X and CO. This is carried out by:

- optimising the design of the oxidiser:
    - residence time;

    - mixing of the flows (e.g. natural diffusion between turbulent streams, changes in flow direction);
    - combustion chamber;
- monitoring the combustion parameters:
    - oxygen content;
    - carbon monoxide concentration;
    - temperature;
- inspecting the burners regularly, and cleaning them when necessary.

When the oxidised VOCs contain sulphur and/or halogens, further emissions of sulphur dioxide and/or hydrogen halides might be expected. This might require an additional waste gas treatment after thermal oxidation (e.g. absorption).

Further information is provided in the CWW BREF [87, COM 2016].

Cross-media effects

- Generation of NO_X and CO and potentially of other pollutants (e.g. HCl, SO_2, PCDD/F).
- Consumption of fuel in the case of non-autothermal operation.

Technical considerations relevant to applicability

Straight thermal oxidation is generally applicable. Applicability of recuperative and regenerative thermal oxidation to existing plants may be restricted by design and/or operational constraints.

Further information is provided in the CWW BREF [87, COM 2016].

Economics

Driving force for implementation

- Legal requirements.
- Local conditions.

Example plants

Widely used; 14 plants (27 emission points) in the STM data collection.

Reference literature

[168, TWG 2023]

4.2.8.2.4.9 Catalytic thermal oxidation

Description

Abatement technique which oxidises combustible compounds in a waste gas stream with air or oxygen on a catalyst bed. The catalyst enables oxidation at lower temperatures and in smaller equipment compared to thermal oxidation. The typical oxidation temperature is between 200 °C and 600 °C.

Achieved environmental benefits

Removal efficiencies depend on several parameters, but with an optimal choice of the catalytic system efficiencies of 95-99 % are achieved.

Compared to thermal oxidation (see Section 4.2.8.2.4.9), less additional fuel is needed, typically the required temperature range is 250-400 °C. Applying a catalyst in combination with recuperation of the exhaust heat requires less energy than recuperative oxidation without a catalyst.

Environmental performance and operational data

VOC concentrations of up to 5 g/Nm^3 can be treated. This technique can be applied for airflows in the range of 10-30 000 Nm^3/h. However, it is most suitable for discontinuous airflows of up to 10 000 Nm^3/h.

At inlet temperatures above 400 °C, no preheating is required to reach the start temperature of the catalyst. Normally oil is not used as a fuel, due to the sulphur content and related toxicity to the catalyst.

4.2.8.2.4.10 Plasma abatement

Description

Plasma abatement is a process that uses high-energy plasma to decompose and neutralise hazardous gases, such as volatile organic compounds (VOCs), toxic chemicals, and greenhouse gases.

Technical description

The process involves the following steps:

- Plasma generation: A high-energy electrical discharge is created, typically using a radio frequency (RF) or microwave energy source, to generate a plasma field.
- Gas ionisation: The plasma field ionises the hazardous gas molecules, breaking them down into highly reactive species, such as ions, free radicals, and electrons.
- Chemical reaction: The ionised gas molecules react with each other and with the plasma field, leading to the formation of new, safer compounds.
- Decomposition: The hazardous gas molecules are decomposed into simpler, non-toxic components, such as nitrogen, oxygen, water vapour and carbon dioxide.
- By-product formation: The resulting by-products are typically inert and harmless, such as water vapour, carbon dioxide and nitrogen.

Environmental performance and operational data

High efficiency: Plasma abatement can achieve high destruction efficiencies, often exceeding 99.9%.

Flexibility: Plasma abatement can be used to treat a wide range of hazardous gases and can be integrated with existing pollution control systems.

Economics

Low operating costs: The process can be energy-efficient, especially when compared to traditional thermal abatement methods.

4.2.8.2.5 Emissions from the thermal treatment of off-gases

4.2.8.2.5.1 Optimised combustion

Description

Good design of the combustion chambers, burners and associated equipment/devices is combined with optimisation of combustion conditions (e.g. the temperature and residence time in the combustion zone, efficient mixing of the fuel and combustion air) and the regular planned maintenance of the combustion system according to suppliers' recommendations.

Achieved environmental benefits

- Reduced emissions.
- Increased energy efficiency.

Environmental performance and operational data

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Economics
No information provided.

Driving force for implementation
Legal requirements.

4.2.8.2.5.2 Low-NO_X burners

Description
The technique (including ultra-low-NO_X burners) is based on the principle of reducing peak flame temperatures. The air/fuel mixing reduces the availability of oxygen and reduces the peak flame temperature, thus retarding the conversion of fuel-bound nitrogen to NO_X and the formation of thermal NO_X, while maintaining high combustion efficiency.

Technical description
Low-NO_X burner is a general term for a series of burners that combine several design features to reduce the NO_X emission level. The main principles of these burners are the reduction in peak flame temperature, the reduction in residence time in the high-temperature zone and the reduction in oxygen availability in the combustion zone. This is generally achieved by air staging, fuel staging and/or internal flue-gas recirculation. A common mode of operation of low-NO_X burners is the creation of a fuel-rich zone within the flame. This favours the conversion of fixed nitrogen, chemically bound fuel-nitrogen, to N_2. It also has the effect of reducing the peak flame temperature. Both fuel and thermal NO_X mechanisms are retarded and the formation of NO_X is reduced. There are two main types of low-NO_X burners which both involve the use of staged combustion to achieve the desired effect. These are air-staged and fuel-staged burners.

Achieved environmental benefits
- Reduced NO_X emissions.
- Increased energy efficiency.

Environmental performance and operational data

Cross-media effects
None.

Technical considerations relevant to applicability
Applicability to existing plants may be restricted by furnace design and/or operational constraints.

Economics
No information provided.

Driving force for implementation
Legal requirements.

4.2.8.3 Techniques to reduce odour

4.2.8.3.1 Odour management plan

[Note to the TWG: please provide information to complete the 10-heading template below, e.g. on operational data and economics]

Description
An odour management plan (OMP) is part of the environmental management system (EMS) of the installation (see Section 5.4.10) and includes elements to prevent or reduce odorous nuisances.

Technical description
The odour management plan includes the following:

- A protocol containing appropriate actions and timelines.
- A protocol for conducting odour monitoring. It may be complemented by measurement/estimation of odour exposure (e.g. according to EN 16841-1 or-2) or estimation of odour impact.
- A protocol for response to identified odour incidents (including the management of complaints: identification of operations carried out, weather conditions such as temperature, wind direction, rainfall, communication with the authority and with complainant, etc.)
- An odour prevention and reduction programme designed to identify the source(s), to measure/estimate odour exposure, to characterise the contributions of the sources, and to implement prevention and/or reduction measures.

Achieved environmental benefits
Prevention or reduction of the emissions of those odorous releases that may be offensive and detectable beyond the boundaries of the site.

Environmental performance and operational data

Cross-media effects
None identified.

Technical considerations relevant to applicability
The applicability is restricted to cases where an odour nuisance at sensitive receptors is expected and/or has been substantiated.

Economics
No information provided.

Driving force for implementation
- Legal requirements.
- Local conditions.

4.2.8.3.2 Periodic monitoring of odour emissions

Description
Odour can be monitored using the following:

- EN standards (e.g. dynamic olfactometry according to EN 13725 in order to determine the odour concentration and/or EN 16841-1 or-2 in order to determine the odour exposure).
- Alternative methods (e.g. estimation of odour impact) for which no EN standards are available. In such a case, ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality can be used.

The monitoring frequency is determined in the odour management plan.

Technical description
The techniques include:

- for odour concentration determination (expressed in OUE/m^3, to control limit values): dynamic olfactometry (measured according to the European standard EN 13725);
- for odour in ambient air: the grid method (according to the European standard EN 16841-1) or the plume method (according to the European standard EN 16841-2) to determine the odour exposure;
- for odour perception in the surrounding area (impact): odour surveys (see odour intensity mapping and odour wheels);
- electronic noses.

To determine the odour concentration, an air sample must be taken. The sampling techniques are similar to those used for measuring individual compounds. Techniques for odour monitoring are described in the ROM [59, COM 2018] and the CWW BREF [87, COM 2016].

Achieved environmental benefits
Monitoring helps to maintain the proper operation and minimise odorous emissions.

Environmental performance and operational data
See the ROM and the CWW BREF.

Cross-media effects
None identified.

Technical considerations relevant to applicability
The applicability is restricted to cases where an odour nuisance at sensitive receptors is expected and/or has been substantiated.

Economics
See the ROM and the CWW BREF [87, COM 2016].

Driving force for implementation
- Legal requirements.
- Local conditions.
- Complaints from neighbours.

4.2.8.3.3 Collect/channel odourous emissions

Description
Capture and treatment of odorous emissions during the relevant odourous operations.

Technical description
This technique involves the installation of aspiration or ventilation and abatement systems, e.g. hoods, that capture and treat odorous emissions from surface treatment processes or directly associated activities, such as:

- treatment baths;
- combustion products from burn-wet abatement systems;
- drilling and other mechanical treatments on resin-coated pieces;
- gases from the powder-coating oven;
- mixing of raw chemicals;
- odours generated by sludge;
- fugitive solvent emissions;
- wafer-etching and cleaning proceschambers (dry etch), water treatment plant H_2SO_4 (sulphur odour);
- WWTP (sludge or during maintenance).

Achieved environmental benefits

- Improved air quality.
- Safer working environment.

Environmental performance and operational data

Cross-media effects
None reported.

Technical considerations relevant to applicability
The applicability is restricted to cases where an odour nuisance at sensitive receptors is expected and/or has been substantiated.

~~4.2.9~~ Noise ~~and vibrations~~

[Note to the TWG: This section corresponds to the Section 4.19 of the original STM BREF. Part of the contents from Section 2.13.4 in the existing STM BREF were included too.]

~~**Description**~~
~~It is good practice to reduce noise from the installation so impact upon the local community is not significant. Noise can be eliminated or reduced at source (in-process), such as extracting hydrogen produced by electrolysis and so preventing explosions across the top of vats with certain electrolytic processes. Delivery transport can also have an impact locally, and can be managed by reducing deliveries and/or managing delivery times.~~

~~Noise reduction can be achieved through engineering noise control measures where required, such as installation of silencers to large fans, use of acoustic enclosures where practicable for equipment with high or tonal noise levels, etc.~~

~~Effective plant operation includes closure of bay doors.~~

~~**Achieved environmental benefits**~~
~~Reduced noise.~~

~~**Cross-media effects**~~
~~Use of silencers can lead to an increase in energy as pressure drops increase.~~
~~Closing bay doors can increase demands on internal ventilation and cooling.~~

~~**Operational data**~~
~~Site-specific~~

~~**Applicability**~~
~~To new and existing plants.~~

~~**Economics**~~
~~Case specific, but usually no payback. Increased cost of ventilation with workplace doors closed.~~

~~**Driving force for implementation**~~
~~Prevention of noise complaints. Compliance with occupational health legislation.~~

~~**Example plants**~~
~~SOFRA-PCB, Mennecy, France.~~

~~**Reference literature**~~
~~[19, Eurofer, 2003], [115, CETS, 2003].~~

Sources of noise
The loading and unloading of loose components during delivery in stillages and loading for processing in barrels can give non-continuous peaks. Linishing and polishing generate continuous levels. Both may have associated in-house health effects.

For occupational health and safety it is often necessary to install air extractors combined with exhaust air scrubbers. The extractor motors and fans working at high rotational speeds can have deleterious effects outside the site buildings [121, France, 2003].

Other noise sources include refrigeration systems, heating systems, delivery vehicles, etc. [158, Portugal, 2004].

4.2.9.1 Noise management plan

[Note to the TWG: please provide information to complete the 10-heading template below, e.g. on operational data and economics]

Description
To set up, implement and regularly review a noise management plan as part of the environmental management system (EMS) (see Section 4.2.1) that includes all of the following elements:

- a protocol containing appropriate actions and timelines;
- a protocol for monitoring emissions of noise;
- a protocol for responding to identified noise events, e.g. complaints and/or taking corrective actions;
- a noise reduction programme designed to identify the source(s), to measure/estimate noise exposure, to characterise the contributions of the sources to the overall noise emissions and to implement prevention and/or reduction measures.

Technical description
As part of the EMS, a noise management plan is implemented and regularly reviewed. A noise management plan normally includes the following:

- Description of the main sources of noise (including infrequent sources) and the nearest noise-sensitive locations, including the following for each main source of noise within the installation:
    - the source and its location on a scaled plan of the site;
    - whether the noise is continuous/intermittent, fixed or mobile;
    - the hours of operation;
    - a description of the noise, e.g. clatter, whine, hiss, screech, hum, bangs, clicks, thumps or has tonal elements;

  - its contribution to the overall site noise emission, e.g. categorised as high, medium or low unless supporting data are available.
- The above information for the operation of infrequent sources of noise (such as infrequently operated/seasonal operations, cleaning/maintenance activities, on site deliveries/collections/transport or out-of-hours activities, emergency generators or pumps and alarm testing).
- Details of the appropriate noise surveys, measurements, investigations (which can involve detailed assessments of sound power levels for individual plant items) or modelling that may be necessary for either new or existing installations taking into consideration the potential for noise problems.
- Description of a protocol for response to identified noise incidents, e.g. complaints.
- Appropriate actions to be undertaken and timelines.

The overall reduction of noise levels involves developing a noise reduction plan. Here each of the sources needs to be checked and evaluated. Alternative techniques with lower noise levels may be applied and/or point sources may be enclosed.

Useful tools for the effective application of this technique may be:
- periodic noise monitoring;
- development of noise maps and associated noise calculations;
- periodic meetings and discussions with neighbours to identify noise nuisance issues.

Achieved environmental benefits
Reduction of noise emissions.

Environmental performance and operational data
See Technical description above.

Cross-media effects
None.

Technical considerations relevant to applicability
The applicability is restricted to cases where a noise nuisance at sensitive receptors is expected and/or has been substantiated.

Economics

Driving force for implementation
- Legal requirements.
- Local conditions.
- Good relations with neighbours and occupational health and safety.

Example plants
Widely used.

Reference literature
[168, TWG, 2023]

4.2.9.2 Appropiate location of equipment and buildings

[Note to the TWG: please provide information to complete the 10-heading template below, e.g. on operational data]

Description

Increasing the distance between the emitter and the receiver, by using buildings as noise screens and by relocating equipment and/or building openings (e.g. exits or entrances of the buildings).

Technical description
Noise impact is reduced by increasing the distance between the emitter and the receiver, by using buildings as noise screens and by relocating noisy equipment and/or building openings. Furthermore, construction of buildings or natural barriers, such as growing trees and bushes between the protected area and the noisy activity, can be carried out.

Achieved environmental benefits
Reduction of noise perception in the areas nearby.

Environmental performance and operational data

Cross-media effects
None identified.

Technical considerations relevant to applicability
For existing plants, the relocation of equipment and building openings may not be applicable due to a lack of space and/or excessive costs.

Economics
Relocation of equipment and entrances/exits entails an associated cost.

Driving force for implementation

- Legal requirements.
- Local conditions.

Example plants
20 plants from the STM data collection.

Reference literature
[168, TWG, 2023]

4.2.9.3 Noise control and abatement equipment

[Note to the TWG: please provide information to complete the 10-heading template below, e.g. on operational data]

Description
Installation of low-noise equipment and insertion of obstacles between noise emitters and receivers e.g. partial or full enclosure.

Technical description
This includes techniques such as:

- use of noise reducers;
- use of acoustic insulation of equipment;
- use of e.g. direct drive motors, low-noise compressors, pumps and fans, low-noise transportation equipment;
- enclosure of noisy equipment and processes (e.g. unloading of raw materials, compressors, fans, finishing);
- use of building materials with good sound insulation properties (e.g. for walls, roofs, windows, doors;
- inserting obstacles between emitters and receivers (e.g. protection walls, embankments).

Achieved environmental benefits
Reduction of noise emissions.

Environmental performance and operational data

Cross-media effects
None identified.

Technical considerations relevant to applicability
Applicability to existing plants may be restricted by a lack of space. For new plants, the design of the plant should make the insertion of obstacles unnecessary.

Economics
Investment cost of the noise control equipment.

Driving force for implementation

- Legal requirements.
- Local conditions.

Example plants
Widely applied.

Reference literature
[168, TWG, 2023]

4.2.9.4 Operational measures

[Note to the TWG: please provide information to complete the 10-heading template below, e.g. on operational data and economics]

Description
These include techniques such as:

- inspection and maintenance of equipment;
- closing of doors and windows of enclosed areas, if possible, or use of self-closing doors;
- equipment operation by experienced staff;
- avoidance of noisy activities at night, if possible;
- provisions for noise control during production and maintenance activities, transport and handling of raw materials, e.g. reducing the number of material transfer operations, reducing the height from which pieces fall onto hard surfaces.

Technical description
Operational measures are applied in order to prevent or to reduce noise emissions.

Doors and windows of covered areas have to be kept closed during noisy operations.

Noisy activities (e.g. transport) are avoided at night, e.g. reducing the number of material transfer operations, reducing the height from which pieces fall onto hard surfaces.

Achieved environmental benefits
Reduction of noise emissions.

Environmental performance and operational data

Cross-media effects
None identified.

Technical considerations relevant to applicability
Generally applicable.

Driving force for implementation

- Legal requirements.
- Local conditions.

Example plants
Widely used.

Reference literature
[168, TWG, 2023]

4.2.10 Waste water emissions prevention and reduction

[Note to the TWG: This section corresponds to the Section 4.16 of the existing STM BREF]
[Note to the TWG: This section was completely reordered compared to the existing STM BREF]
[Note to the TWG: Some contents from Chapter 2 have been moved here in their corresponding techniques]

The bulk of emissions to the environment from an installation for the surface treatment of metals and plastics occur to water, see Section 1.4.2. Minimisation (including minimisation spillages), recycling and re-use are important issues for the management of waste waters [13, UNEP, et al., 2002] and are dealt with in Sections 4.2.6.7 and 4.2.6.8.

Further information on the techniques described below is provided in the CWW BREF [87, COM 2016]. By applying one or a combination of the techniques described, significant reductions of emissions to water and lower water consumption can be achieved.

~~Waste water treatment is described extensively elsewhere, such as generally in the BREF on waste water/waste gas systems [87, EIPPCB,], and specifically for this sector [6, IHOBE, 1997, 21, Agences de l'Eau de France, et al., 2002]. The following sections are therefore a brief description of relevant techniques.~~

~~Process waters are usually treated in a waste water treatment plant with a sequence of process steps, see Section 0, which also illustrates a typical waste water treatment plant (Figure 2-45).~~

4.2.10.1 Waste water management and treatment strategy

Description
Implementation of an integrated strategy for waste water management and treatment that includes an appropriate combination of the techniques given below with the following order of priority:

- process-integrated techniques and techniques to recover and reuse process flows (see other sections related to optimisation and low-water-use equipment in Chapter 4, particular Section 4.2.5 and Section 4.2.6);
- techniques to recover and reuse process liquors (see sections related to resource efficiency in Chapter 4 in particular Section 4.2.6);

- separate collection of waste water streams and pastes (e.g. coating) containing high loads of pollutants that cannot be adequately treated by biological treatment; these waste water streams and pastes are either pretreated or handled as waste;
- (final) waste water treatment techniques.

Technical description

The strategy for waste water management and treatment is based on the information provided by the inventory of waste water streams (see Section 4.2.1.2). The effluents from STM processes are characterised and the pollutants present in them are evaluated.

Based on this information, the appropriate treatment options are selected. Usually the goal is to find a cost-effective combination of treatment methods offering an optimum environmental performance. Special pretreatment may be needed to remove the compounds that are insufficiently abated during biological treatment (e.g. toxic compounds, poorly or non-biodegradable and/or non-bioeliminable organic compounds, organic compounds that are present in high concentrations, or metals) and to protect the biological waste water treatment plant (e.g. against inhibitory or toxic compounds).

An appropriate choice normally requires treatability and/or pilot studies. Many ‘local’ factors, varying from site to site, may influence the selection, e.g. plant location, size and layout of the processes, type of discharge (direct, indirect), quality of the receiving water body, limitations and constraints on an installation imposed by other legislation.

Source reduction options and/or special pretreatment considered for hazardous and poorly or non-biodegradable and/or non-bioeliminable substances present in the effluents (waste water streams) will be selected by considering the options for:

- reduction at the source (e.g. by use of process-integrated techniques, choice of raw materials, auxiliary chemicals, etc.);
- collection (drainage) system (e.g. suitable for segregation and separate pretreatment of different tributary waste water streams);
- treatment methods (e.g. suited to abate a specific pollutant or generic, suitable for abatement of many pollutants).

Descriptions of applicable waste water treatment techniques are given in Section 4.2.10.3.

Achieved environmental benefits

- Reduction of the waste water volume.
- Reduced pollutant loads sent to the waste water treatment plant.
- Reduction of emissions to water.

Environmental performance and operational data

Physico-chemical treatments are commonly used before biological treatment to ensure appropriate abatement levels.

In the case of indirect discharge, it is ensured that the level of emission of the remaining pollutants in the effluent leaving the plant does not have a negative impact on the downstream WWTP or on the efficiency of this downstream installation at treating those remaining pollutants.

Cross-media effects

See the CWW BREF [87, COM 2016].

Technical considerations relevant to applicability

See the CWW BREF [87, COM 2016].

Economics

See the CWW BREF [87, COM 2016].

Driving force for implementation

- Environmental legislation (reducing and effectively abating the pollutant load).
- Economics (savings due to lower discharge fees).

Example plants

According to the data collection, some plants use various combinations of process-integrated and waste water treatment techniques.

Reference literature

[168, TWG, 2023]

~~Identification of problem flows~~

~~**Description**~~

~~Changes in sources or types of process chemicals can create problems in waste water treatment, by unknowingly introducing chemicals that interfere with the process treatments. They are usually either surfactants that interfere with flocculation and/or settlement processes, or complexing agents that prevent metals precipitating. They can be tested prior to their introduction into production.~~

~~**Achieved environmental benefits**~~

~~Consistency of waste water treatment to required levels.~~

~~**Cross-media effects**~~

~~None.~~

~~**Operational data**~~

~~Changes in sources or types of process chemicals can be tested for simply, by mixing samples of the usual waste water (taken prior to settlement, but after pH adjustment and flocculation) with expected dilutions of the new chemicals and checking for any detrimental effects, such as poor settlement of solids, higher than usual metals levels in the supernatant liquid, etc. If any problems are identified, then either:~~

- ~~the new solution is rejected~~
- ~~the waste water treatment system is changed to compensate.~~

~~**Applicability**~~

~~All changes of source or type of process chemicals (usually mixtures and/or proprietary chemicals). Does not apply to single substances, such as acids, etc.~~

~~**Economics**~~

~~Low cost: only the cost of the relevant analysis.~~

~~**Driving force for implementation**~~

~~Cost savings in resolving waste water treatment problems and breaches of permit conditions.~~

~~**Example plants**~~

~~Collini GmbH, Austria~~

~~**Reference literature**~~

~~(Personal communication, Martin Peter, Collini GmbH) [159, TWG, 2004]~~

4.2.10.2 Elimination and/or separation of the individual pollutants at the point of generation

Description
Some chemicals are most effectively managed by treating them separately before mixing with other effluents.

Waste water streams containing hazardous substances (e.g. toxic metals, free CN, PFAS) are collected separately from other waste water streams and treated according to their content using, for example, chemical precipitation, chemical reduction, adsorption, filtration, ion exchange, before any mixing with other waste water streams.

Other chemicals such as pickling acids and chemical degreasers, are discharged irregularly and in large quantities that can exceed the capacity of a continuous-flow treatment plant, and can cause breaches of permit conditions. They can be managed by:

- avoiding bulk discharges (for example, see counterflow pickling)
- containing in bulk and bleeding to the in-house waste water treatment plant over a period of time, to stay within the internal treatment plant's capacity (Note: it is not good practice to use this technique to discharge by dilution to the municipal waste water treatment plant)
- containing in bulk and using alkali solutions to neutralise acid solutions (such as alkali degreasers to neutralise acid pickling solutions)
- batch managing and discharging the effluent,
- disposing of waste solutions that cannot be successfully treated in the waste water treatment plant for third party recovery or as wastes.

In some cases, chemicals may be kept separate to assist with third party recovery, as well as reducing waste water treatment requirements, such as pickling acids.

The pretreatment is carried out as part of an integrated strategy for waste water management and treatment (see Section 4.2.10.1) and is generally necessary to:

- protect the (downstream) biological waste water treatment plant against inhibitory or toxic compounds;
- remove compounds that are insufficiently abated during biological waste water treatment (e.g. toxic compounds, poorly biodegradable organic compounds, organic compounds that are present in high loads or metals);
- remove compounds that could otherwise be stripped to air from the collection system or during biological waste water treatment (e.g. sulphide);
- remove compounds that have other negative effects (e.g. corrosion of equipment; unwanted reaction with other substances; contamination of waste water sludge).
- remove the above-mentioned compounds including PFAS and chromium-(VI)-containing compounds.

The pretreatment of these waste water streams is generally carried out in such a way as to avoid dilution. The pretreatment techniques used depend on the pollutants targeted and may include adsorption, filtration, precipitation, chemical oxidation or chemical reduction.

Achieved environmental benefits
For some substances, contaminant treatment and removal is only possible after separate treatment.

Avoidance of bulk discharges exceeding treatment plant capacity and breach of permit conditions.

Use of waste alkali solutions (such as degreasers) to neutralise waste acid solutions saving chemicals.

Cross-media effects
Will be case-dependent.

Operational data
Flows containing cyanide-, nitrite- and chromate must be pretreated separately before being mixed together or with other waste waters. For example:

- nitrites can be oxidised or reduced; both reaction types need a slightly acid solution (pH 3 – 4)
- cyanide oxidation must be accomplished in alkaline solution (pH >10)
- chromate reduction takes place at pH values <2.5.

In order to limit the use of additional chemicals, acid waste water can be neutralised with alkaline waste water: they must, however, be free of complexing agents.

Other substances can be managed separately to reduce the amount of contaminant discharged, and reducing or eliminating the need for further treatment. Examples are the use of countercurrent rinsing and evaporation to close the materials loop from copper, nickel and chromium plating, and the use of electrolytic cells with chromium and nickel plating.

Cadmium (and mercury) processes (see Section 2.2.1.5.5) are subject to other legislation. In Germany, legislation requires that they are separated and treated according to BAT before mixing with other effluents. A similar approach is taken in the UK.

Applicability
It is good practice to consider every process discharge point whether treatment (or recycling or re-use) is better carried out on the separated stream, before mixing flows for subsequent treatment.
When using waste alkali flows to neutralise waste acids, additional chemicals may be required to achieve a suitable pH for discharge through a flocculation system.

Economics
In some specific cases, capital and treatment costs may be significantly reduced by treating individual waste water streams separately. However, usually the cost for treating separated streams is higher.

Driving force for implementation
The specific process chemistry will dictate which chemicals may require separation.
Separate treatment streams may be more efficient and cost-effective.

Example plants
Townrow (Hi-Tech) Plating Ltd, Sheffield, UK for countercurrent rinsing and electrolytic treatment of chromium and nickel drag-out streams.
Merrydale Industries Ltd, Wednesbury, UK for countercurrent rinsing and evaporation closing the loop for copper, nickel and chromium plating.
Frost Electroplating Co. Ltd, Birmingham, UK, for closing the loop on nickel plating by four-stage countercurrent rinsing with evaporation.
Metal Colours Ltd, Slough, UK, for countercurrent pickling.
SGI, Plaisir, CIRE Bellegarde, and SOFRA-PCB, Champoreaux, France for the treatment of separate streams, then bulking for final treatments and settlement.

Reference literature
[18, Tempany, 2002, 156, France, 2003] [12, PARCOM, 1992, 13, UNEP, et al., 2002] [124, Germany, 2003].

4.2.10.3 Individual waste water treatment techniques

[Note to the TWG: Contents from Section 2.13.1 in the existing STM BREF are included in their corresponding techniques below].

Various treatment techniques are mentioned in the following sections. Some of them are also used for process solution maintenance, treatment of incoming water and for treating waste waters prior to recycling.

There are a number of techniques that are used for treating water and water-based solutions, and are widely used in the surface treatment of metals for:

- treating incoming water supplies
- treating waste waters prior to discharge or for re-use
- process solution maintenance
- in-process materials recovery. This may also serve as process solution maintenance

The basic techniques only vary slightly according (e.g. choice of resins for ion exchange) to the application, they are briefly described here and more fully in Chapter 4. They are well described elsewhere, and some are especially useful when considering closing the loop for process materials, see Section 4.2.6.8 [162, USEPA, 2000].

The use of individual treatment techniques should be carefully weighed up considering the situation (e.g. balance of acid and alkaline waste water streams), local regulations versus potential environmental benefits achievable at the respective installation and the resources available [175, ESTAL 2024].

4.2.10.3.1 Preliminary, primary and general treatment

4.2.10.3.1.1 Equalisation / Buffer storage

Description
Balancing of flows and pollutant loads by using tanks, basins or other management techniques.

Technical description
Equalisation and buffering facilities ensure reasonably constant conditions of certain parameters, especially pH, hydraulic load (or flow rate) and contaminant loads/concentrations for the effective operation of downstream waste water treatment plants (WWTPs).

Achieved environmental benefits
This technique enables downstream treatment techniques to operate at the optimum efficiency. It makes use of mixing effects to offset extremes of important WWTP operating parameters (e.g. temperature, pH).

Environmental performance and operational data
The retention times of equalisation tanks are typically 12-24 hours; in adverse climatic or other local conditions the retention times may be even longer.

Cross-media effects
Excessive retention of waste water in the equalisation tank may lead to odour emissions.

Technical considerations relevant to applicability
Generally, there are no technical restrictions to the applicability of this technique.

Economics
The cost of constructing and operating an equalisation tank needs to be compared with the savings associated with the smooth operation of the downstream treatment techniques and compliance with environmental standards.

Equalisation / buffer storage may reduce waste water discharge costs (fees, taxes) in the case of indirect (sewer) discharge due to lower daily inflow of effluent. The discharged flow can be spread to 7 days instead of 5 (working) days per week.

Driving force for implementation
- Compliance with environmental standards.
- Protection and proper operation of downstream treatment techniques.

Reference literature
[87, COM 2016]

4.2.10.3.1.2 Neutralisation

Description
Neutralisation is the process by which the pH of the incoming waste water is adjusted to a neutral pH level (approximately 7) by the addition of chemicals. Sodium hydroxide (NaOH) or calcium hydroxide ($Ca(OH)_2$) is generally used to increase the pH, whereas sulphuric acid (H_2SO_4), hydrochloric acid (HCl) or carbon dioxide (CO_2) is used to decrease the pH. The precipitation of some substances may occur during neutralisation.

Achieved environmental benefits
Neutralisation avoids the effects of strongly acidic or alkaline waste waters, e.g. corrosion or lowering of the efficiency of biological treatment downstream.

Environmental performance and operational data
The neutralisation of process waste water requires a tank of sufficient volume to assure the appropriate hydraulic retention time. The mixing capacity should be sufficient to keep the tank completely mixed.

The CO_2 from flue-gases is often introduced to neutralise waste waters with a high pH in the textile sector.

Cross-media effects
Increased concentration of salts in the waste waters (as a result of chemical neutralisation) and the solid waste generated (e.g. precipitate) may need to be disposed of.

Technical considerations relevant to applicability
Generally, there are no technical restrictions to applicability of this technique.

Economics
No information provided.

Driving force
Compliance with legal requirements to limit pollution to a receiving water body.

Example plants
Neutralisation is widely used, 95 plants (118 emission points).

Reference literature
[87, COM 2016], [168, TWG, 2023]

4.2.10.3.1.3 Physical separation

Physical separation techniques were reported by 23 plants (26 emission points) in the STM data collection [168, TWG, 2023].

4.2.10.3.1.3.1 Screening

Description
Screening is the mechanical separation/removal of insoluble contaminants such as fibre and fluff from textile effluent by coarse or fine screens.

Technical description
Screening devices are classified based on the size of the material they remove (the screenings).

Fine screens (with openings as small as 100-200 µm) typically used for textile effluents are fixed parabolic (curved), rotary drum and rotary disk. Fine screens can be either movable or fixed in a vertical, inclined or horizontal position and must be cleaned by rakes, teeth or brushes.

Achieved environmental benefits
Reduced suspended solids and BOD/COD emission levels.

Environmental performance and operational data
The use of fine screens produces effects similar to primary sludge removal in primary sedimentation. Fine screens are capable of removing 20-35 % of suspended solids and BOD_5.

The screens must be mechanically cleaned; the cleaning of oils and grease from fine screens may cause some difficulties.

Typical pollutants targeted are gross solids, suspended solids, and oil/grease.

Example plants
See Section 4.2.10.3.1.3

Reference literature
[168, TWG, 2023]

4.2.10.3.1.3.2 Grit separation

Description
[87, COM 2016]
Grit separation is the removal of sand and gravel from rainwater. Grit chambers are part of the WWTP and are usually situated immediately downstream of the screen installed as protection for downstream techniques (equipment) from coarse and fibrous material.

Example plants
See Section 4.2.10.3.1.3.

Reference literature
[168, TWG, 2023]

4.2.10.3.1.3.3 Hydrocyclone

Description
[87, COM 2016]
A hydrocyclone is used to separate suspended solids with a diameter of 5 µm to 1 000 µm that are likely to sink and resistant to shearing forces. It separates the particles by using the centrifugal force generated as the liquid enters the cyclone tangentially at high speeds and is accelerated by the conical middle section. This creates a liquid vortex in the cyclone. The smaller the diameter of the cyclone, the greater the centrifugal force that will be generated as the liquid is forced to turn sharply. Light components leave the hydrocyclone through the top, while heavier components are collected at the bottom.

Example plants
See Section 4.2.10.3.1.3.

Reference literature
[168, TWG, 2023]

4.2.10.3.1.3.4 Oil-water separation

Description
[87, COM 2016]
An oil-water separator is a piece of plumbing equipment designed to intercept most greases (by gravitation) before they enter the biological waste water treatment.

The typical oil-water separators are: the American Petroleum Institute (API) separator (an open rectangular basin and a flight scraper), the parallel plate interceptor (PPI) (equipped with plates parallel to the current to enlarge the active surface area and oil skimming device) and the corrugated plate interceptor (CPI) (equipped with corrugated plate packs placed countercurrently and an oil skimming device). The skimmer device has to be regularly maintained. Skimmed oil is handled as waste.

~~Separation of oils and greases (hydrocarbons) from waste water~~

Generally the separation of oils and greases is undertaken while managing the degreasing solutions. In special cases, a de-oiling of raw waste water before the inorganic treatment is necessary~~, and the procedures for this application are described in Section~~

Example plants
See Section 4.2.10.3.1.3.

Reference literature
[168, TWG, 2023]

4.2.10.3.2 Physico-chemical treatment

4.2.10.3.2.1 Absorption

See more information in CWW BREF [87, COM 2016].

Example plants
CZ007 and IT029.

Reference literature
[168, TWG, 2023]

4.2.10.3.2.2 Adsorption

Description

[87, COM 2016]

Adsorption is the transfer of soluble substances (solutes) from the waste water phase to the surface of solid, highly porous particles (the adsorbent). The adsorbent has a finite capacity for removing compounds. When this capacity is exhausted, the adsorbent is 'spent' and has to be replaced by fresh material. The spent adsorbent either has to be regenerated or incinerated.

Potential adsorbents for adsorptive waste water purification are activated carbon, lignite coke, aluminium oxide and adsorber resins.

Typical pollutants targeted are adsorbable dissolved non-biodegradable or inhibitory pollutants (e.g. AOX in dyestuffs, organophosphorus flame retardants). As regards PFAS, the effectiveness on fluorotelomeres is low.

Example plants

Widely used; 21 plants (23 emission points)

Reference literature

[168, TWG, 2023]

4.2.10.3.2.3 Chemical oxidation

Description

[87, COM 2016]

Chemical oxidation is the conversion of pollutants by chemical oxidising agents other than oxygen/air or bacteria into similar but less harmful or hazardous compounds and/or to short-chained and more easily degradable or biodegradable organic components. Chemical oxidation is used for the treatment of selected segregated waste water streams containing non-biodegradable/bioeliminable substances (i.e. with high COD loads) which might disturb the biological process in a downstream biological WWTP, or which have properties which are too harmful to allow them to be released into an ordinary sewer.

Chemical oxidising agents include:

- chlorine;
- sodium or calcium hypochlorite;
- chlorine dioxide;
- ozone (with or without UV light);
- hydrogen peroxide;
- hydroxyl radicals generated by hydrogen peroxide (known as the Advanced Oxidation
- Process) in combination with:
    - ferrous salts (Fenton's agent); see [87, COM 2016] for a detailed description of an oxidation technique involving hydrogen peroxide and a ferrous ion catalyst;
    - ozone;
    - UV light;
    - pressure;
    - temperature.

A special type of chemical oxidation is wet oxidation (WO). It is the reaction of oxygen in the aqueous phase at a high pressure and temperature, and is used to increase the solubility of oxygen in water.

Alkaline hydrolysis is widely practised by hank dyers on the first yarn scour bowl spent liquors. The first bowl of the yarn scour is where most of the dirt and spinning oils are washed away from yarn and if the yarn has been pretreated with permethrin (which sometimes occurs in Europe and Türkiye) then this can also be partially washed into the liquor. As source control of permethrin-containing raw materials is very hard to achieve in practice (e.g. by better control of the supply chain or extensive testing of every incoming hank), most operators choose to use alkaline hydrolysis to control and prevent emissions of permethrin [190, Seaman S. 2019].

The alkaline treatment process is as follows: set up an alkaline treatment bath for the first bowl liquor which comprises 4 g/litre of sodium hydroxide dissolved into the liquor followed by a minimum 2-hour boil (at 98-100 °C) in a sealed stainless steel tank. This destroys any residual permethrin in the liquor which should then be mixed back into the predominantly acidic main effluent to give the final effluent balanced pH with minimal or zero permethrin (well below any relevant discharge consent limit).

Typical pollutants targeted are oxidisable dissolved non-biodegradable or inhibitory pollutants (e.g. optical brighteners and azo dyestuffs, and sulphide).

Example plants
Widely used; 18 plants (20 emission points).

Reference literature
[168, TWG, 2023]

4.2.10.3.2.3.1 Cyanide oxidation

Description
Cyanides can be removed from waste water using different procedures:

- oxidation with different oxidising agents:
  - sodium hypochlorite
  - hydrogen peroxide
  - oxygen (O_2)
  - ozone (O_3)
  - anodic oxidation (electrolysis)
  - potassium monopersulphate.
- transfer into insoluble metal complexes (e.g. iron cyanide connections)
- removal by ion exchangers
- destruction of the cyanide by thermal procedures
- radiation-assisted oxidation (oxidising agents and UV radiation)
- anodic oxidation.

In practice, the chemical oxidation of cyanide is the most commonly used technique.

Achieved environmental benefits
Destruction of cyanide.

Cross-media effects
Use of chemicals and energy (for thermal, radiation and anodic techniques) and the possible production of AOX if using hypochlorite.

Operational data
The use of sodium hypochlorite is associated with the formation of organic chlorine compounds, measured as AOX. For this reason, the replacement of sodium hypochlorite as an oxidising agent in the cyanide oxidation has been much discussed. However, since none of the alternatives mentioned show a universal solution for efficient cyanide destruction, the employment of sodium hypochlorite is still the most used procedure.

Anodic oxidation is a suitable technology for the destruction of cyanide complexes in process solutions containing cyanide and rinsing waters from zinc and copper plating. The residual cyanide content attainable with the anodic oxidation is below 0.1 g/l. A limit value of <0.2 mg/l is achieved by an additional chemical treatment with sodium hypochlorite. Additionally to the cyanide destruction, the dissolved metals are recovered and can be re-used.

Applicability
Chemical oxidation is widely used. Hydrogen peroxide can readily replace hypochlorite, but the cost is higher.

Driving force for implementation
Water protection policies and legislation.

Example plants

Reference literature
[21, Agences de l'Eau de France, et al., 2002] [12, PARCOM, 1992] [126, Netherlands, 2003] [113, Austria, 2003] [124, Germany, 2003] [104, UBA, 2003]

4.2.10.3.2.4 Chemical reduction

Description
[87, COM 2016]
Chemical reduction is the conversion of pollutants by chemical reducing agents into similar but less harmful or hazardous compounds. Common chemical reducing agents include sulphur dioxide; sodium hydrogen sulphite/metabisulphite; ferrous sulphate; sodium sulphide and sodium hydrogen sulphide; urea or amidosulphonic acid (at low pH).

These chemicals are brought into contact with the waste species under appropriate pH and concentration conditions. Chemical reduction normally results in products that can be treated more easily in downstream treatment facilities such as a chemical precipitation unit.

Typical pollutants targeted are reducible dissolved non-biodegradable or inhibitory pollutants (e.g. hexavalent chromium (Cr(VI)).

Example plants
Widely used; 44 plants (51 emission points).

Reference literature
[168, TWG, 2023]

4.2.10.3.2.4.1 Chromate treatment

Description
Hexavalent chromium compounds (chromates or dichromate) are difficult to precipitate and are normally reduced to trivalent (chromium (III) ions), which are subsequently precipitated as chromium (III) hydroxide on neutralisation. The reduction is made at pH values under 2.5. The most common reducing agent is sodium hydrogen sulphite (bisulphite).

If only a small amount of chromium (VI) is present at high pH values, the reaction can also be carried out in the alkaline region with sodium dithionite or iron II. No addition of acid is needed.

Achieved environmental benefits
Reduction and removal of chromium (VI).

Cross-media effects
Care should be taken with sodium hydrogen sulphite (bisulphite), as SO_x fumes are formed. Workplace ventilation may be required.

When using iron (II), more sludge and therefore waste will be generated in the waste water treatment (as iron (III) hydroxide).

Applicability
Widely used.

Driving force for implementation
Water pollution protection legislation.

Reference literature
[21, Agences de l'Eau de France, et al., 2002] [124, Germany, 2003]

4.2.10.3.2.5 Crystallisation

Various evaporation and cooling systems are used to bring solutions to a super-saturation point where solid crystals form and can be separated from solution.

This is not widely used in the aluminium surface treatment installations in the EU [175, ESTAL 2024].

Environmental considerations
Energy requirements for heating or cooling

Example plants
ES013.

Reference literature
[168, TWG, 2023]

4.2.10.3.2.6 Electrodialysis

Anions and cations are removed from solutions with an applied electric field in cells with alternating anion- and cation-permeable membranes

4.2.10.3.2.7 Evaporation

Description
[87, COM 2016]
Evaporation of waste water is a distillation process where water is the volatile substance, leaving the concentrate as bottom residue to be handled (e.g. recycled or disposed of). The aim of this operation is to reduce the volume of waste water or to concentrate mother liquors. The volatile steam is collected in a condenser and the condensed water is, if necessary after subsequent treatment, recycled.

There are many types of evaporators: natural circulation evaporators; short-tube vertical evaporators; basket-type evaporators; falling film evaporators; agitated thin film evaporators.

Atmospheric evaporation occurs when solutions are heated. As a basic technique, it reduces the volume of process solutions and allows drag-out to be returned or fresh chemicals to be added to the process solution. It can be increased by using air agitation and/or using an evaporator. The evaporator may be filled with a packing material to increase the air-to-water evaporation surface. Evaporators are often used with a condenser to recover distilled water.

~~**Environmental considerations**~~
Evaporators can often beneficially use the heat from the solution when the process is self-heating, e.g. from the electrical current passed. The heat lost then assists with cooling the solution.

Reduced pressure and elevated temperature combine to separate constituents with relatively high volatility from constituents with lower volatility, e.g. removal of water from an acid plating solution. Evaporating the process solution (e.g., acid distillation) from contaminant phases with higher volatility can also purify process solutions. Multiple stages may be used to increase separation purity, to reduce energy requirements, or to accomplish multiple phase separations.

~~**Environmental considerations**~~
Energy requirements for heating and evacuation to vacuum conditions.

Typical pollutants targeted are soluble contaminants (e.g. salts).

Example plants
Widely used; 11 plants (12 emission points).

Reference literature
[168, TWG, 2023]

4.2.10.3.2.8 Electrolysis – plating out

Transition metals can be removed from waste water streams by plating out on high surface area electrodes in metal recovery cells. It can also be used in combination with ion exchange as a means to concentrate metal ions.

Environmental considerations
At concentrations below about 10 mg/l the metal deposition becomes very inefficient with 10 to 100 times the theoretical energy requirement actually needed for metal deposition.

Example plants
AT010 and DE036.

Reference literature
[168, TWG, 2023]

~~Electrolysis – oxidation~~

~~It is possible to oxidise both unwanted organic by-products and metals in solutions, such as Cr(III) to Cr(VI). This can be done with or without a ceramic membrane, depending on current density conditions.~~

4.2.10.3.2.9 Ion exchange~~ – resin~~

Description
The retention of ionic pollutants from waste water and their replacement by more acceptable ions using an ion exchange resin. The pollutants are temporarily retained and afterwards released into a regeneration or backwashing liquid. Targeted pollutants are ionic dissolved non-

biodegradable or inhibitory pollutants, e.g. metals. More information is provided in the CWW BREF [87, COM 2016].

Technical description

Resins

Ions in solution are selectively removed by exchanging positions with resin-functional groups. The direct ion exchange treatment of waste water provides a means of concentrating multivalent cations for subsequent treatment on column regeneration or by plating out [3, CETS, 2002], [159, TWG, 2004].

The use of ion exchange resins in waste water treatment is more common in the plating industry, but rare in anodising [175, ESTAL 2024].

Electrodeionisation

Ions are removed using conventional ion exchange resins. An electric current is used to continuously regenerate the resin, instead of regeneration chemicals.

Liquid/liquid

Ionic contaminants are removed from process solutions into immiscible primary liquid extraction solutions. Secondary liquid extraction solutions are used to remove the contaminants and to regenerate the primary extraction solution.

So far, the only application is ammoniacal etch solutions that are regenerated by removal and recovery of copper, with a closed loop extraction solution system.

~~Environmental considerations~~ Cross-media effects

Ion exchange requires energy for pumping during use and regeneration, and also requires extensive chemical dosing; the chemical requirement for metal ion capture is generally three to four times the theoretical requirement.

Example plants

Widely used; 46 plants (51 emission points).

Reference literature

[168, TWG, 2023]

4.2.10.3.2.10 Acid (resin) sorption (retardation)

Description

Acid (resin) sorption is configured similarly to ion exchange. Resins are designed to selectively adsorb mineral acids while excluding metal salts (adsorption phase). Purified acid is recovered for re-use when the resin is regenerated with water (desorption phase).

The water consumption in the desorption phase may be substantial. The use of this technology may also result in the additional purchase of acid chemicals for waste water neutralisation depending on the waste water streams in the respective installation [175, ESTAL 2024].

See also more information on retardation (acid resin sorption) in Section 4.2.6.5.3.

4.2.10.3.2.11 Nitrogen removal by nitrification/denitrification

Description

Nitrogen, or more precisely organic nitrogen compounds (e.g. urea, ammonium), is removed by a special biological treatment that consists of two steps:

- Aerobic nitrification, where special microorganisms oxidise ammonium (NH_4^+) to the intermediate nitrite (NO_2^-) which is further converted to nitrate (NO_3^-). Ammonium can also be oxidised to nitrite without further conversion to nitrate.
- Anoxic denitrification, where microorganisms convert nitrate into nitrogen gas.

Nitrification may not be applicable in the case of high chloride concentrations (i.e. around 10 g/l) and when the reduction of the chloride concentration prior to nitrification would not be justified by the environmental benefits. Nitrification is not applicable when the temperature of the waste water is low (e.g. below 12 °C).

Example plants

Reference literature
[168, TWG, 2023]

4.2.10.3.2.11.1 Nitrite treatment

Description
Nitrite can be oxidised either to nitrate or reduced to nitrogen. Both reactions take place in weak acid conditions around pH 4.

Achieved environmental benefits
Destruction of nitrite.

Environmental performance and operational data
For oxidation, H_2O_2 is normally used. Sodium hypochlorite was used most frequently as a nitrite oxidising agent, but use is decreasing because of the possibility of associated AOX formation.

The reducing agent is normally amidosulphuric acid. The disadvantage of this reaction relates to a high sulphate concentration in the waste water. It is also possible to use urea; however, this has the disadvantage that the reaction needs a temperature of 60 °C. It is possible to reduce this with hydrogen sulphite, but it is not often used as it causes a high concentration of sulphate into the waste water.

In an acid solution, nitrite can easily be reduced using sulphamic acid.

The use of sodium dithionite and Fe (II) would eliminate some cross-media effects.

Air extraction may be necessary as pH lowering with high nitrite concentrations leads to the formation of nitrous gases. Since nitrous gases by themselves dissolve badly in water, an exhaust air scrubber with alkali solution may be necessary, although this may not remove all nitrous gases produced from high concentration solutions. In batch treatment, it may be necessary to add a small amount of oxidising agent before reducing pH.

Cross-media effects
Possible AOX formation if hypochlorite is used.
Low pH with high nitrite concentrations can lead to NO_X formation.
Any excess sodium dithionite can complex with meals ions.

Applicability
Widely used.

Driving force for implementation
Water pollution protection legislation.

Reference literature
[21, Agences de l'Eau de France, et al., 2002], [104, UBA, 2003], [124, Germany, 2003, Austria, 2003 #113]

4.2.10.3.3 Biological treatment

Description
Use of microorganisms for waste water treatment (e.g. anaerobic treatment, aerobic treatment). Targeted pollutants are biodegradable organic compounds. More information is provided in the CWW [87, COM 2016] BREF.

4.2.10.3.4 Solids removal

4.2.10.3.4.1 Coagulation and flocculation

Description
Coagulation and flocculation occur in successive steps which are intended to overcome the forces stabilising the suspended particles, allowing particle collision and growth of floc.

Coagulation is the first step. It aims at destabilising the particles’ charge by neutralising their electrical surface charge. This is carried out by adding coagulants with charges opposite to those of the suspended solids to the waste water. This allows the particles to stick together into slightly larger particles.

Flocculation is a gentle mixing stage which aims at increasing the particle size. Collisions of microfloc particles cause them to bond to produce larger floc. This occurs in the presence of inorganic (formed by the coagulant) or added organic polymers. Contact times for flocculation range from 15 or 20 minutes to an hour or more.

Once the floc has reached the optimum size and strength, the waste water can be brought to sedimentation (see Section 4.2.10.3.2.14.1).

Typical pollutants targeted are suspended solids and particulate-bound non-biodegradable or inhibitory pollutants (e.g. metals in dyestuffs).

Example plants
Widely used.

Reference literature
[168, TWG, 2023]

4.2.10.3.4.2 ~~Flocculation and p~~Precipitation of metals

The ultimate process control is by precipitating metals separately (adjusting the pH to its optimum value for the metal) but this is not possible and economically feasible in many cases. If there are many processes and process baths, and separation of different waste water streams is difficult, metals can be precipitated simultaneously (co-precipitation) [120, Finland, 2003]. A mixture of discharges from processes makes it more difficult to maintain the optimum pH balance for precipitation for all the dissolved metals.

It is important to note that the total dissolved ion content may also affect the solubility of metals, and this can be increased by water-saving measures and the discharge of ion-exchange regeneration solutions. (Personal communication, Ministry of Environment, Slovenia).

The final cleaning of effluent by using chelating cation exchange resin can then be more efficient. The efficiency of chelating cation exchange resin also depends on the effluent pH. The optimum pH is different for each metal.

4.2.10.3.4.2.1 Hydroxide precipitation

Description

~~This is described in Section 0.~~The removal of the transition metals is made via neutralisation and then precipitation at pH values of 9- 11. A water-solid mixture results from the precipitation, usually referred to as electroplating sludge (dependent on source activities).

Achieved environmental benefits

Removal of transition metals from the effluent.

Environmental performance and operational data

Combining the different waste water streams for precipitation together has the effect that metals with poor precipitation characteristics are precipitated by those metal hydroxides with good precipitation characteristic, so it is possible to reach a better result with common precipitation. For example, nickel co-precipitation with other metal ions, and the co-precipitation of cadmium and FeII at pH 9. The emission value of cadmium in this case can be lower than 0.1mg/l. If precipitated separately, it is not possible to achieve such low cadmium levels.

On the other hand, some heavy metals, e.g. cadmium, lead and nickel need a high pH value for precipitation. Under these conditions, it is possible that other metal hydroxides, e.g. zinc, chromium, tin and aluminium, will be redissolved, so it may become necessary to have a separate precipitation at lower pH values with other precipitation agents, such as calcium or sodium hydroxides

The solubility of the metals increases with increased neutral salt concentrations. The metals partly precipitate in very fine particles (especially lead and tin), therefore the addition of flocculating agents (iron (III) chloride, lime) and/or flocculants (polyelectrolyte) are necessary for better separation and filtration. However, this leads to an increase in the quantity of sludge (waste) produced as iron compounds and lime need to be added in significant quantities. Polyelectrolytes have a much higher charge density and need a far lower dose rate.

To meet stringent emission limit values, fine filtration may also be necessary. Sometimes a post-treatment is also necessary, for example with sulphide and/or selective ion exchangers.

Cadmium may be treated separately (see Section 2.2.1.5.5).

Technical considerations relevant to applicability

Widely used. Settlement tanks need space and may be costly to install.
In all cases, the choice between precipitating separately or co-precipitating metal ions must be made after tests of treatment have been carried out.

Driving force for implementation

Water protection policy and legislation

Reference literature

[21, Agences de l'Eau de France, et al., 2002] [12, PARCOM, 1992] [126, Netherlands, 2003] [121, France, 2003, 124, Germany, 2003].

4.2.10.3.4.2.2 Sulphide precipitation

Description

If the hydroxide precipitation followed by a post-cleaning stage with selective ion exchangers is not sufficient to meet limit values for discharge, a precipitation with sodium sulphide or organosulphide can achieve lower levels~~, see~~ . Since the solubility of the metal sulphides is generally substantially lower than that of the metal hydroxides, smaller residual concentrations can be achieved with sulphide precipitation.

Table 4-16: Solubility products of metal hydroxides and sulphides

	Solubility product (g/l)	
Metal	**Hydroxide**	**Sulphide**
Aluminium	2 x 10^{-32}	-
Lead	1 x 10^{-7} to 10^{-13}	3 x 10^{-28}
Cadmium	1.3 x 10^{-14}	5.1 x 10^{-29}
Chromium (III)	3 x 10^{-28}	-
Iron (II)	2 x 10^{-15}	3.7 x 10^{-19}
Iron (III)	8.7 x 10^{-38}	-
Copper	2 x 10^{-19}	8 x 10^{-45}
Nickel	5.8 x 10^{-15}	1 x 10^{-26}
Silver	1.24 x 10^{-8}	1.6 x 10^{-49}
Zinc	4 x 10^{-17}	6.9 x 10^{-26}
Zinc(II)	6 x 10^{-25}	1 x 10^{-20}
UBA		

Achieved environmental benefits
Low emission values for transition metals.

Environmental performance and operational data
The addition of a flocculant is necessary with metal sulphides precipitation as the precipitates formed, as well as colloidal sulphur, are very fine and neither settle nor are filtered easily.

Cross-media effects
Avoid acid conditions to prevent emission of hydrogen sulphide. Excess sulphide must be eliminated by using iron salts

Handling of sulphide sludges can be difficult, with finer precipitates giving poor settlement and filtration properties.

Economics
[21, Agences de l'Eau de France, et al., 2002]

Driving force for implementation
Water protection policy and legislation; low emission values where environmental quality standards require.

Reference literature
[82, Agences de l'Eau, 1996, 104, UBA, 2003], [113, Austria, 2003], [12, PARCOM, 1992, Netherlands, 2003 #126].

4.2.10.3.4.2.3 Other flocculating agents

Description
Other flocculation agents are used:

- inorganic salts, such as of Fe(III) and aluminium
- organic polymers with a high molecular mass (10^6 to 10^7), an ionic structure (either anionic or cationic) and a high charge density. For surface treatment industries, anionic polymers are most often used.

Achieved environmental benefits

Increased flocculation and improved precipitation.

Operational data
Generally mixed in a separate tank and dosed into the flocculating system prior to precipitation.

Cross-media effects
Inorganic salts can increase the bulk of material to be disposed of or managed subsequently.
The addition of flocculating agents may assist with subsequent dewatering processes, with no further additions necessary.

Technical considerations relevant to applicability
Applicability is readily determined by on-site tests.

Economics
Can increase the efficiency of an existing waste water treatment plant. Low capital and operational costs.

Driving force for implementation
Water protection policy and legislation; low emission values where environmental quality standards require.

Reference literature
[21, Agences de l'Eau de France, et al., 2002] [12, PARCOM, 1992, Netherlands, 2003 #126]

4.2.10.3.4.3 Complexing agents

Description
Complexing agents used in certain processes make the precipitation of transition metals more difficult, if they are mixed before treatment with other waste waters.

Copper can be precipitated from complexes by reduction with sodium dithionite, but excess dithionite mobilises copper from the hydroxide, preventing precipitation and copper is discharged in the effluent. By using stronger reducing agents, like sodium hypophosphite, other metals such as nickel and tin can be reduced. The metals are frequently precipitated as sulphides from hard complexes. Cationic metal complexes with ammonia or amines such as triethanolamine and Quadrol can be removed with weakly acid cation exchangers (for example, selective ion exchange resins with iminodiacetate groups). However, treatment with ion exchangers is not possible in solutions with citrate, EDTA and NTA.
The most common complexing agents are cyanides, polyphosphates, amines, citric acid, tartaric acid, gluconic acid, ammonia, NTA, ~~EDTA~~, and Quadrol.

~~Using another procedure, all EDTA is destroyed in the presence of UV radiation and hydrogen peroxide. The copper largely has to be eliminated from the solution by electrolytic separation prior to using this technique. After the destruction of the Cu/EDTA complex, free copper is precipitated.~~

EDTA is no longer widely used, may still be present in degreaser formulations.

Achieved environmental benefits
This technique ensures that metals are not solubilised and carried into municipal waste water treatment or re-solubilised in the wider aquatic environment.

Environmental performance and operational data
Where using complexing agents, particularly strong ones, separation of metals and complexing agents as far as possible prior to other treatments (such as flocculation and precipitation of the metal) is advisable.

Cross-media effects

Additional chemicals and energy consumption, depending on the technique used.

The addition of complexing agents can degrade the receiving environment, and there is no guarantee that all metals are properly complexed.

Driving force for implementation
Water protection policy and legislation; low emission values where local environmental quality standards requires.

Reference literature
[12, PARCOM, 1992, Netherlands, 2003 #126, 104, UBA, 2003, 113, Austria, 2003]
[176, CETS, 2024]

4.2.10.3.4.4 Precipitation of anions

4.2.10.3.4.4.1 Fluoride precipitation

Description
Free fluoride ions can be precipitated with calcium, for example when neutralising with lime.

Achieved environmental benefits
Meeting fluoride emission standards.

Environmental performance and operational data
Fluoride precipitation can only be carried out quantitatively if least one calcium equivalent is present for every fluoride equivalent. Otherwise, additional calcium ions must be added, for example as calcium chloride.

Technical considerations relevant to applicability
Complex fluorides, such as BF_4, AlF_6 or SiF_6, cannot be precipitated perfectly with calcium compounds.

Driving force for implementation
Water pollution protection legislation.

Reference literature
[3, CETS, 2002] [113, Austria, 2003]

4.2.10.3.4.4.2 Phosphate precipitation

Description
It may be necessary to reduce phosphate levels when the effluent is discharged to surface water or to municipal waste water treatment which does not treat phosphates. A release of 4 kg/day of phosphorus corresponds to the release from 1000 inhabitants (in the EU-15).

However, when it is required, it is rarely a problem, since sufficient metal ions are nearly always present in surface treatment waste waters to form insoluble phosphate compounds. If this is not the case, iron or aluminium compounds can be added. Precipitation can also be achieved with lime at pH values over 10.

Achieved environmental benefits
Meeting phosphate emission limit values where applicable. Phosphate is a major contributing factor to eutrophication. The discharge of a few kilos of phosphorus can have a strong impact on a river according to the size of the receiving flow.

Environmental performance and operational data
The precipitation of polyphosphates and phosphonates is difficult. In many cases, it is difficult to meet the environmental quality standards for total phosphorous (especially when directly discharging to surface water).

Cross-media effects
Additional chemicals may be required.

Driving force for implementation
Where water legislation and local environmental quality standards require.

Reference literature
[121, France, 2003] [3, CETS, 2002, 159, TWG, 2004]

4.2.10.3.4.4.3 Sulphate precipitation

Description
Treatment for sulphate is rarely required, although sulphate control may be locally important for the protection of receiving sewerage systems. Where applicable, discharge limit values are normally high, about 1000 mg/l, and sulphate is readily precipitated as calcium sulphate.

Achieved environmental benefits
Meeting sulphate emission limit values where applicable, usually for discharge to a foul sewer.

Environmental performance and operational data
According to its solubility product, calcium sulphate has a solubility of 1404 mg/l as sulphate. This rises strongly with increasing neutral salt concentration, so that in the presence of 1 val/l neutral salt (this corresponds to a concentration of approximately 58.5 g/l common salt) the sulphate only precipitates at concentrations of 5000 mg/l, which corresponds to the solubility of the calcium sulphate. Different neutral salts have thereby a different influence on the attainable precipitation.

Cross-media effects
The use of additional chemicals
Sulphate precipitation creates more sludge for disposal
Precipitation of sulphate may also cause problems with recycling of sludges, such as the use of aluminium hydroxide sludge

Technical considerations relevant to applicability
It is usually not necessary to eliminate sulphate. Corrosion in sewers is caused in anaerobic conditions by certain bacteria utilising the oxygen in the sulphate and forming sulphuric acid. In some cases with effluents over 1000 mg/l, it may be better to protect or change the materials used in the sewerage system to those with more acid resistance, or treat the sewage to maintain aerobic conditions (such as by dosing with hydrogen peroxide). This will depend on the materials used in the construction of the sewerage system and the dilution with other waste water in the municipal sewage plant.

Driving force for implementation
Where water legislation and local environmental quality standards require.

Reference literature
[3, CETS, 2002] [113, Austria, 2003] [118, ESTAL, 2003] [18, Tempany, 2002, Germany, 2003 #124, ESTAL, 2003 #118]

4.2.10.3.4.5 Other treatments~~Final treatment prior to discharge~~

~~**General description**~~
After precipitating the unwanted dissolved materials (principally the metal hydroxides), these and other materials in suspension are separated from the liquid by one of the following techniques:

- sedimentation (static)
- flotation
- filtration.

Traditionally, sedimentation has been used, followed by flotation. However, when considering revamping or updating waste water treatment plants to meet lower emission levels, and especially in conjunction with other objectives for recycling water and sludges, filtration techniques are increasingly considered.

The choice of techniques will therefore depend on factors including:

- the size and type of particles, including their settling properties
- the existing waste water treatment plant
- existing or planned changes in production and solutions (see Section 4.2.6.8.12)
- volume of waste water throughout
- the space available.

4.2.10.3.4.5.1 Sedimentation

Description
Sedimentation, or clarification, is the separation of suspended particles and floating material by gravitational settling.

The settled solids are removed as sludge from the bottom, whereas floated material is skimmed from the water surface. When the particles cannot be separated by simple gravitational means, e.g. when they are too small and their density is too close to that of water or they form colloids, special chemicals are added to cause the solids to settle, such as aluminium sulphate (alum); ferric sulphate; ferric chloride; lime; polyaluminium chloride; polyaluminium sulphate; cationic organic polymers.

Typical pollutants targeted are suspended solids and particulate-bound metals or non-biodegradable or inhibitory pollutants.

Description of the three static sedimentation techniques

(1) Sedimentation tanks
Also called sedimentation or flat tanks, upward flow (for centre-fed circular tanks), horizontal flow (for rectangular tanks) with a scrapper to move sludge to the bottom.

- advantages:
    - adapted to high flowrates
    - easy collection of sludges
    - good inertia to changes in effluent quality
- disadvantages:
    - difficult separation of the hydraulic flow into laminar flows
    - large structure (with large area) and sludge removal equipment may be complicated, therefore high cost
    - extraction of sludges can cause turbulence.

(2) Hopper bottom
Also called cylindro-conical or conical. Influent supplied through centre and downwards (but sufficiently far from the sludge not to affect the accumulated sludge. Steep sides (angle of cone must be >60 °) therefore no scrapers needed, extracted sequentially.

- advantages
    - simple design and equipment
    - sludge removal is easy, but sludge may accumulate on sloping sides (which can be overcome by a centrally driven scraper)
    - reduced maintenance
- disadvantages
    - not suitable for high flowrates
    - risk of sludge blockages.

(3) Laminar or tube settlers
Sedimentation tank where plates are used to enlarge the sedimentation surface

- advantages
    - small area, high capacity
- disadvantages
    - sensitive to the quality of flocculation and to load variations
    - sludges produced are not very thick, so a large volume sludge holding tank is required
    - frequent cleaning of the plates is required.

Achieved environmental benefits
Achievement of waste water emission limit values.
Recovery of sludges containing metal
Low energy usage, only pumping to require head (height).

~~**Cross-media effects, Operational data, Applicability**~~
~~See Descriptions, above~~

Economics
Site-specific

Driving force for implementation
Required to complete typical waste water treatment plants.

Reference literature
[21, Agences de l'Eau de France, et al., 2002, 87, EIPPCB,]

Example plants
Widely used.

Reference literature
[168, TWG, 2023]

4.2.10.3.4.5.2 Flotation

Description
Solid particles (or liquid particles such as oil or grease) are combined with air bubbles producing particle/air clusters which float to the surface of a tank and are removed.

Technical description
Flotation is a process in which solid or liquid particles or particulates are separated from the waste water phase by attaching to fine gas bubbles, usually air. The buoyant particles

accumulate at the water surface and are collected with skimmers. Flocculant additives, such as aluminium and ferric salts, activated silica and various organic polymers, are commonly used to support the flotation process. Their function, besides coagulation and flocculation, is to create a surface or a structure able to absorb or entrap the gas bubbles.

There are three methods of flotation: vacuum flotation, induced gas flotation (IGF) / induced air flotation (IAF) and dissolved gas flotation (DGF) / dissolved air flotation (DAF).

Typical pollutants targeted are suspended solids and particulate-bound non-biodegradable or inhibitory pollutants.

Achieved environmental benefits
Achievement of waste water emission limit values.
Recovery of sludges containing metal.
Possible reduction in anti-foaming agents, surfactants and activated carbon.

Environmental performance and operational data
Three methods are used:

- vacuum flotation, where air is dissolved at atmospheric pressure followed by a pressure drop to allow formation of bubbles
- induced air flotation, (IAF) where fine bubbles are formed and drawn into the waste water via an induction device such as a venturi or orifice plate
- dissolved air flotation (DAF) where pressurised air is dissolved into the waste water or part of the waste water and subsequently released as small bubble.

The advantages and disadvantages are:

- advantages
  - high efficiency
  - floatation speed greater than that obtained by static sedimentation, which implies smaller installations than static sedimentation.
  - pre-thickening of sludges.

- disadvantages
  - requirement for high quality flocculation to guarantee good adhesion of the air bubbles to the suspended solids
  - settings (for pressurisation) require monitoring.

Cross-media effects
May require more coagulant than sedimentation.
Higher power consumption than sedimentation.

Technical considerations relevant to applicability
~~See Description above.~~Generally applicable.
~~New and existing plants.~~

Economics
Site-specific
Smaller size allows more room for production capacity.

Driving force for implementation
Required to complete typical waste water treatment plant.

Example plants
Industria Galvanica Dalla Torre Ermanno e Figli SpA, Fontane di Villaorba, Italy.

Reference literature
[21, Agences de l'Eau de France, et al., 2002, 87, EIPPCB,] (Personal communication, Lorenzo Dalla Torre)
[168, TWG, 2023]

4.2.10.3.4.5.3 Filtration

Description
For waste waters (not sludge dewatering) filtration is applied to:

- meet to meet emission values lower than can be met by sedimentation or flotation
- when considering revamping or updating waste water treatment to meet these lower values for changes in plant operation.

In conjunction with other objectives for recycling water and sludges

~~For a list and a summary of applications and references to descriptions of these techniques, see Section .~~

There are two categories of techniques:

(1) Traditional media:
Sand filters, upward or downward flow, by gravity or pressure
Other filter media, such as cellulose. ~~(see Section)~~

(2) Membrane filtering techniques
Tangential filtration: microfiltration and ultrafiltration (see Section 4.2.10.3.2.13.5.2.2)

Semi-permeable membranes: nanofiltration and reverse osmosis (see Section 4.2.6.8.8.2)

There are many types of filtration. On the smaller scale they start with cellulose (paper) sheets usually clamped in filters (sometimes layered with activated carbon or other absorbents), and cartridges. On a larger scale, sand filters are used for cleaning raw water or polishing effluents, and belt filters or filters presses are used with higher solids applications such as waste water sludges, often in conjunction with coagulants.

~~**Environmental considerations**~~
Pumps (with an associated energy demand) are usually require for filtering, although in some cases (such as some sand filters) gravity is sufficient.

The filter medium, with the filtrate is usually disposed of as a waste.

Economics
Site-specific

Driving force for implementation
Lower waste water emission values
Small size of technique
Enables water re-use and recycling.

Reference literature
[21, Agences de l'Eau de France, et al., 2002]

4.2.10.3.4.5.3.1 (Sand) filtration

Description

[77, COM 2016]
Filtration is the separation of solids from waste water effluents passing through a porous medium. In the case of sand filtration, this medium is sand (or a similar granular medium). This technique is rarely used as a stand-alone treatment and is generally combined with the sedimentation of solids (see Section 4.2.10.3.2.13.5.1) or flotation (see Section 4.2.10.11.1.4.2.2).

Typical pollutants targeted are suspended solids and particulate-bound non-biodegradable or inhibitory pollutants.

Example plants

Reference literature
[168, TWG, 2023]

4.2.10.3.4.5.3.2 Membrane microfiltration, ultrafiltration, nanofiltration and reverse osmosis

Description
[77, COM 2016]
Microfiltration (MF) and ultrafiltration (UF) are membrane processes that retain certain substances contained in waste waters on one side of the membrane. The liquid that permeates through the membrane is referred to as the permeate. The liquid that is retained is referred to as the concentrate. The driving force of the process is the pressure difference across the membrane. Both are special and elaborate filtration techniques using ‘pore-type’ membranes which operate like sieves. The solvent and particles of molecular size can pass through the pores, whereas suspended particles, colloidal particles, bacteria, viruses, and even larger macromolecules are held back.

As regards PFAS, nanofiltration is effective regardless of PFAS and for fluorotelomeres.

Technical description
There are various types of membrane filtration and their use depends on their pore size. These systems are pressurised because of the small pore size.

- microfiltration (MF) is a membrane filtration technology that uses low applied pressures with pore sizes in the range of 0.02 to 10 microns to separate relatively large particles in the macromolecular to micro particle size range (approximate molecular weights >100000)
- ultrafiltration (UF) passes ions and rejects macromolecules (0.005 to 0.1 micron) and removes organics from process solutions
- nanofiltration (NF) is used for larger size rejection than reverse osmosis (rejects molecules larger than 0.001 to 0.008 microns).

This technique may be used for process solution maintenance too.

Reverse osmosis
Effectivel~~y~~ filtration of ions through a semi-permeable membrane at high pressure, that provides an alternative means of concentrating metal impurities for subsequent removal. This approach can be capital intensive and any solids, together with organics, have to be removed prior to treatment.[3, CETS, 2002].

~~**Environmental considerations**~~
~~The technique runs at high pressures with a subsequent energy demand.~~

Cross-media effects ~~**Environmental considerations**~~
Energy is used in pressurising the systems.

Example plants

Reference literature
[178 IGEDD 2022] [168, TWG, 2023]

4.2.10.3.4.5.3.3 Diffusion dialysis

Description
Diffusion dialysis is a membrane separation process that typically uses an anionic exchange membrane to transport acid anions and protons from waste acid solutions into deionised water streams (for treatment in waste water treatment plant) and the acid is recovered.

4.2.10.3.4.5.3.4 Membrane electrolysis

Description
Membrane electrolysis uses one or more ion-selective membranes to separate electrolyte solutions within an electrolysis cell. The membranes are ion-permeable and selective. Cation membranes pass cations such as Cu and Al, but reject anions. Anion membranes pass anions, such as sulphates and chlorides, but reject cations

Cross-media effects ~~**Environmental considerations**~~
The electrolytic reactions may generate hazardous gases, depending on the solutions.

4.2.10.4 Combining techniques (e.g. for PFAS abatement)

Description
Typical waste water treatment plants rely on a combination of techniques e.g. to abate PFAS. ~~see Section 0and other sections of 0 for descriptions of typical waste water treatment plant. Newer techniques can be combined for point source applications and combined flows (see Section 4.2.6.8.12)~~

Technical description
There are various methods for removing PFAS from industrial waste water and drainage water, either separation/concentration techniques or destruction techniques.

Separation/concentration techniques, such as granular activated carbon (GAC), ion exchange resins, and membrane-based techniques, are currently the most widely applied methods in Flanders for abating PFAS. These techniques are effective in concentrating PFAS but do not destroy them, necessitating further treatment or disposal of the concentrated PFAS waste.

Destruction techniques, on the other hand, aim to break down PFAS into less harmful substances. Incineration of industrial waste water is the only destruction technique currently applied on a commercial scale in Flanders. However, other emerging techniques, such as supercritical water oxidation (SCWO) and non-thermal plasma treatment, show potential but require additional research and development to become commercially viable.

Waste water in the STM sector generally has a complex composition. In addition to the presence of PFAS, there are other organic and inorganic components in the matrix that may negatively affect the removal of PFAS. As a result, the application of a single abatement technique is often insufficient to efficiently remove PFAS from waste water, and a combination of the abatement techniques listed below is necessary.

- activated carbon (specifically selected for the removal of PFAS);
- ion exchange resins (specifically selected for the removal of PFAS);
- coagulation/flocculation (specific coagulants/reactants for the removal of PFAS);
- membrane-based techniques (NF and/or RO);
- foam fractionation;
- vacuum evaporation;
- thermal incineration (limited volumes).

In Flanders, the reporting limit for PFAS in industrial waste water has been reduced from 100 ng/l to 20 ng/l for quantitative PFAS and 50 ng/l for indicative PFAS.

The primary source of PFAS in STM plant waste water is the intentional use of 6:2 fluorotelomer sulphonate (6:2 FTS) as a mist suppressant during the hard chromium plating process with hexavalent chromium (Cr VI). However, PFAS can also enter the waste water through other known and unknown processes. For instance, PFAS is sometimes intentionally used in autocatalytic nickel plating combined with polytetrafluoroethylene (PTFE). Even when 6:2 FTS is the only PFAS used, other short- and long-chain PFAS can still be present in the waste water due to factors such as PFAS (bio)transformation, impurities, or other unidentified sources. Additionally, although perfluorooctanesulphonic acid (PFOS) is no longer used as a mist suppressant, it can still leach into the waste water from historical use. Therefore, it is crucial for water treatment processes to address all PFAS present in the waste water.

The technique or combination of techniques selected for the treatment of PFAS-contaminated waste water depends on various factors, including:

- the type of PFAS;
- the concentration of PFAS in the influent;
- the nature of the matrix;
- the capacity/flow rate that needs to be treated;
- the final concentrations that need to be achieved.

Therefore, there is no universal technique suitable for every situation, necessitating an individual approach for each specific case. The choice of technique or combination of techniques should be supported by a characterisation of the industrial waste water including the types of PFAS that were identified in the inventory of inputs and outputs, potentially supplemented with additional lab/pilot tests. Moreover, the design and management of these techniques must be specifically optimised for the removal of PFAS from industrial waste water, necessary pretreatment techniques must be applied to improve the efficiency and protect the operation of the water treatment techniques, and the technique must be properly monitored to ensure efficient PFAS removal.

The removal of PFAS from waste water can be achieved by applying one or a combination of following techniques:

Technique	Description

Activated carbon	Activated carbon is a microporous, inert carbon matrix with a large internal surface area, making it highly suitable for adsorbing a wide range of organic micropollutants, COD, and some metals in organic complexes. It is produced from various materials such as wood, coal, and coconut, and is available in powdered (PAC), granular (GAC), or impregnated forms. In industrial applications, closed filters in a lead-lag configuration are commonly used.
Ion exchange resins	Ion exchange is a proven technique widely used for softening, demineralisation, and selective removal of pollutants such as heavy metals. This technique is highly effective, easy to apply, has large absorption capacities, low material usage, and can be regenerated. It consists of a housing filled with synthetic resin that removes unwanted ions from an aqueous stream by exchanging them with less harmful ions and through adsorption. In industrial applications, closed filters in a lead-lag configuration are commonly used.
Coagulation flocculation	Coagulation destabilises colloidal solutions, allowing pollutants to clump into flocs, which are then removed through sedimentation or flotation. While conventional coagulants (e.g. $Fe(III)Cl_3$, PAC) are ineffective for PFAS removal, there are coagulants/reactants available specifically designed for the removal of PFAS.
Membrane-based techniques (NF and/or RO)	Membrane-based techniques remove substances from an aqueous stream using membranes, including microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO). The effectiveness depends on the technique, which determines the substances removed and the pressures used, based on physical separation by molecular weight/size and chemical interactions with the membrane material. These techniques, proven in various sectors for waste water treatment, desalination, and water production, result in two separate streams: purified permeate and concentrate, and NF and RO are effective for PFAS removal.
Foam fractionation	Concentrating and separating surfactants, such as PFAS or other recalcitrant substances, from a solution into a foam phase is achieved by introducing gas bubbles into a narrow column of the solution. The gas bubbles, created by injecting gas at the bottom in a reactor, carry the surfactants to the foam layer at the surface. The foam is treated in multiple stages to increase concentration. This semi-batch process requires multiple reactors in parallel for continuous treatment.
Vacuum evaporation	Evaporation reduces waste water volume by removing water, leaving non-volatile components in a concentrated residual fraction, and recovering purified water through distillation. Volatile compounds need separate post-treatment. For zero liquid discharge (ZLD), additional crystallisation or drying steps are required to crystallise dissolved substances and remove the remaining water, with techniques like mechanical vapour recompression combined with falling-film evaporation or vacuum evaporation with a heat pump being suitable for low-flow, high-concentration waste water.

Thermal incineration	Incineration is defined as the destruction (mineralisation) of pollutants through heat in the presence of oxygen. The heat is directly applied to liquid streams in an incineration facility, with various types of incinerators used, such as grate furnaces, fluidised bed furnaces, and rotary kilns. Key parameters for high destruction efficiency include combustion temperature, residence time, and turbulence, typically ranging from 600 °C to 1 000°C and 2 to 4 seconds residence time.

Achieved environmental benefits

Reduction or prevention of PFAS emissions to water.

Environmental performance and operational data

Based on the information collected in the Flemish BAT study on the removal of PFAS from industrial waste water, most techniques or combinations of techniques are able to remove all measurable PFAS below 100 ng/L. In a limited number of cases, it was demonstrated that purification to <20 ng/l for all measurable PFAS is possible. Difficulties are mainly experienced with removing short-chain PFAS, particularly PFBA, under this limit. For long-chain PFAS, there are already several cases where they could be removed to below 20 ng/l; however, with very high influent PFAS concentrations and/or complex matrices, this remains difficult to achieve. In this study, no general achievable concentrations for each of the separate water treatment techniques could be identified. The effluent concentrations that can be achieved depend on the following factors:

- influent concentrations of PFAS;
- types of PFAS;
- nature of the matrix;
- flow rate/capacity that needs to be treated.

The table below summarises the performance, removal efficiencies for short- and long-chain PFAS, and the effects of the matrix for the water treatment techniques. In the section ‘Effects of the Matrix’ in the table below, specific parameters are indicated to show whether the respective technique can effectively handle the presence of those parameters in the treated water, for which pretreatment may be necessary:

Water treatment technique	**Performance**			**Removal efficiency**		**Effects of the matrix**				
	EBCT*/ residence time	**Capacity**	**Volume reduction**	**Short chain PFAS**	**Long chain PFAS**	**TSS**	**Fe/Mn**	**COD**	**Conduc tivity**	**pH**
Activated carbon	15-45 min	0,1 – 100 m³/h	10 000 – 100 000:1	<50-99%	90-100%	-	-	-	ND**	-/+
Ion exchange resins	2-10 min	0,1 – 100 m³/h	30 000-1 000 000:1	90->99%	90->99%	-	-	-/+	-	0
Coagulation flocculation	30 – 60 min	ND	8000:1	40 – 60%	90 – 99,99%	+	+	+	ND	ND
Membrane-based techniques	NF -	0,1 – 1000 m³/h	3 – 5:1	50 – 99%	95 – 99%	-	-	-/+	-/+	-/+
	RO -	0,1 – 1000 m³/h	3 – 5:1	>99%	>99%	-	-	-/+	-/+	-/+
Foam fractionation	30 – 45 min	0,5 – 40 m³/h	40 000 – 40 000 000:1	0 – 99%	99,5 – 99,99%	+	+	+	+	ND
Vacuum evaporation	ND	0,05 – 100 m³/h	5 – 50:1	99%	99%	+	-	+	+	+
Thermal incineration	2 – 4s	Very limited	-	>99,99%	>99,99%	+	+	+	+	+

NB. *EBCT = Empty Bed Contact Time. **ND = No Data.

- “-”: The technique is especially sensitive to the presence of the respective parameter and experiences serious negative effects from a high concentration of it on the removal efficiency of PFAS.
- “-”: The technique cannot handle and experiences negative effects from a high concentration of the respective parameter on the removal efficiency of PFAS.
- “-/+”: The specific nature of the parameter determines whether the technique can effectively handle a high concentration of the respective parameter. The technique may or may not experience a negative effect from a high concentration of the parameter on the removal efficiency of PFAS. The effect depends on the specific nature of the parameter.
- “+”: The technique can effectively handle and experiences no effect or possibly a positive effect from a high concentration of the respective parameter on the removal efficiency of PFAS.

Cross-media effects

Each of the techniques has adverse cross-media effects depending on the nature and composition of the waste water, and the technique in question, including:

- formation of PFAS-containing concentrates;
- formation of PFAS-containing and/or non-PFAS-containing waste that needs further processing/incineration. This waste can include adsorption media, high concentration PFAS-containing foam fractions, sludges from flocculation, backwashing or applied pretreatment techniques;
- increased energy consumption;
- increased raw material consumption;
- potential emissions to the air.

The table below describes the cross-media effects of each of the water treatment techniques:

Water treatment technique	Concentrate Formation	Waste	Energy	Raw material	Air
Activated carbon	0	-	0	-	0
Ion exchange resins	0	-	0	-	0
Coagulation flocculation	0	-	-/0	-	0
Membrane-based techniques	-	0	-	-	0
Foam fractionation	0	-	-	0	-/0
Vacuum evaporation	-	0	-	0	-/0
Thermal incineration	0	+	-	0	-

NB

- “-”: negative effect;
- “-/0”: no or negative effect depending on the situation;
- “0”: no/negligible impact;
- “+”: positive effect.

Technical considerations relevant to applicability

Most of the treatment techniques, except for thermal incineration, do not have direct emissions to the air. However, if the further processing and incineration of solid or liquid waste streams are considered, there are specific air emissions associated with them.

The water treatment technique most commonly applied within the STM sector specifically for the removal of PFAS is activated carbon, utilising two or more filters in series. Nevertheless, other techniques such as ion exchange, coagulation/flocculation, membrane-based techniques, and vacuum evaporation are widely used within the sector, typically aimed at removing pollutants other than PFAS. However, these techniques could also be applied throughout the sector for PFAS removal. Moreover, in some cases, existing water treatment techniques, such as ion exchange and vacuum evaporation, can simultaneously remove PFAS along with the pollutants they were originally designed for.

Thermal incineration is only a relevant technique if the volume of the waste water to be treated is limited (e.g. less than 40 m^3/month). Foam fractionation is not typically performed within the STM sector but has proven effective for the removal of PFAS in other sectors, which was indicated in the Flemish BAT study for the abatement of PFAS emissions to water.

Technically, the choice of a single adsorption technique is suitable for the removal of PFAS from waste water as long as sufficient filters are placed in series. This is considered technically feasible for waste water with relatively simple matrices and limited PFAS concentrations. It is important to select the optimal type of adsorption material (e.g. activated carbon, ion exchange resin) specifically for the type of PFAS to be removed. For waste water with complex matrices and high PFAS concentrations, very large amounts of adsorbents may be needed if only one adsorption technique is applied. This can also be the case for situations with high concentrations of short-chain PFAS, such as PFBA, where breakthrough will occur quickly, necessitating frequent filter changes. This results in high operating costs, and a significant environmental impact due to the production and eventual processing (reactivation, regeneration, or incineration) of the adsorbents.

Therefore, in most cases, a combination of techniques will be necessary for such situations. Three approaches can be followed:

- A technique or combination of techniques for the initial bulk removal of PFAS, followed by one or more polishing steps based on adsorption techniques to remove the remaining PFAS concentrations.
- A technique or combination of techniques for concentrating the PFAS contamination into a smaller volume of concentrate stream, which can be further treated with other techniques or disposed of for incineration. An additional polishing step using adsorption techniques may also be necessary. Concentrating PFAS can improve the efficiency of downstream techniques in terms of both removal efficiency and energy consumption.
- Direct degradation of PFAS by disposing of limited volumes for direct incineration of the waste water or formed concentrates.

The characterisation of the specific industrial waste water to be treated is always necessary to support the balanced selection of the technique(s). Additionally, in certain situations, supplementary exploratory lab/pilot tests may be necessary to further support this choice of technique or combination of techniques. The following parameters can determine the choice of technique or combination of techniques:

- type of PFAS;
- the concentration of PFAS in the influent;
- the nature of the matrix;
- the capacity/flow rate that needs to be treated;
- the final concentrations that need to be achieved.

Economics

The costs of the applied technique(s) vary widely. Generally, adsorption techniques are the cheapest, but, with high concentrations and the presence of short-chain PFAS, costs can increase significantly. Therefore, in some situations, combining these with other techniques can result in more efficient and cost-effective PFAS removal. This should be considered when selecting the technique (or combination of techniques) for each specific situation. Evaporation/vacuum evaporation, and thermal incineration are the most cost-intensive technologies, which are economically favourable only in a limited number of situations (i.e. low flow rates/low capacities, complex matrices). In most cases, these techniques are combined with methods that produce concentrates to reduce the volume to be treated.

The following factors can influence the OPEX and/or CAPEX of the technique(s) applied:

- quality, type and consumption of raw materials (e.g. adsorption materials);
- flow rate to be treated;
- PFAS types and concentrations;
- presence of co-contaminants (i.e. matrix);
- pretreatment requirements;
- installation costs vs. mobile installations;
- maintenance and replacement frequency;
- waste transport, disposal and processing;
- monitoring costs;
- energy consumption.

Driving force for implementation

- Legal requirements
- Reduced environmental impact.

Example plants

Example plants from the data collection that have successfully implemented this technique are: BE_003, BE_011 and BE_015.

Case information from installation BE_015:

General information

- **Main activity**: Electrolytic plating, including hard chromium plating and phosphating.
- **Total permitted volume of treatment vats**: 136.96 m^3.
- **History of PFAS use**: PFOS was used as a mist suppressent in the treatment vat for hard chromium plating (using Cr(VI)). Since 2014 the use of PFOS has been discontinued and replaced by an alternative ‘ANKOR Dyne 30 MS’ which contains the PFAS 6:2 FTS. The treatment vats for hard chromium plating were not replaced. Therefore, still relevant concentrations of PFOS remain present in the treatment vats. Hard chromium plating (using Cr(VI)) is still performed at this facility.
- **Presence of PFAS in waste water emissions:** Waste water from treatment vats and rinsing vats associated with hard chromium plating are treated separately by a series of activated carbon filters (see below). Thanks to the high removal efficiency for PFOS, the minority of PFOS still detected in the waste water at the point of emission come from the treated waste water. The majority of PFOS and other PFAS detected at the point of emission are due to other unknown, diffuse sources.

Reference literature

[168, TWG, 2023], [167, BE contribution, 2024].

4.2.10.4.1 Zero discharge techniques

Various techniques can be used in conjunction with water minimisation techniques (see Sections 4.2.6.7 and 4.2.6.8 ~~and Annex~~) to minimise discharges of all a processing line or an installation to zero. Note: this is different to closing the loop for one process chemistry within a line, see Section 4.2.6.8.11.

Examples of techniques to achieve zero discharge are:

- thermal
- membrane
- ion exchange.

Description
The individual techniques are described under Section 4.2.10.3.2.14.2.2 ~~and .~~

Achieved environmental benefits
Reduction in all contaminants discharged.
Recovery of cleaned water for application in the process.

Cross-media effects
Energy for thermal techniques, pressure pumps and/or electrical power for membrane techniques.

Ion exchange resins require the consumption of other ions (Na, Cl, acids, alkali, depending on the resin type) in the same valency proportions as the ions they absorb.

The techniques can produce wastes that may be more toxic and/or difficult to handle than the sludges produced from a typical waste water treatment plant.

Technical considerations relevant to applicability
It is generally easy and more environmentally efficient to achieve a closed loop for specific processes, ~~such as nickel or chromium plating~~.
May not be applicable to plants with large discharge volumes.

Economics
Although costs are site-specific, as zero discharge is approached, the costs for incremental discharge reductions can increase significantly in proportion to the benefits achieved.
[176, CETS, 2024]

Reference literature
[168, TWG, 2023]

4.2.10.4.1.1 Thermal procedures

Description
As well as the classical waste water treatment by chemico-physical procedures, it is possible to avoid the discharge of waste water completely by the use of evaporation techniques. Instead of the metal hydroxides, a mixture of water-soluble salts results from evaporation, whose disposal requires a deposit in a suitable landfill, possibly with solidification.
At present, two basic techniques are available for evaporation of the effluent:

- vacuum evaporators with vapour compression and
- infrared evaporators at atmospheric pressure.

Example plants
[AT_009], [BE_003], [DE_023] and [SE_005] from the STM data collection.

Reference literature
[168, TWG, 2023]

4.2.10.4.1.1.1 Vacuum evaporators with vapour compression

Description
By the use of vacuum evaporators with vapour compression it is possible to lower the energy demand to an economic level.

Achieved environmental benefits
Zero water discharge can be achieved from an installation or from certain process steps

Environmental performance and operational data
The evaporator produces a concentrate which requires an additional drying procedure. Thus the investment and operating cost rises to an extent where this technology is usually only economic in exceptional cases.
The water quality produced is very high, with conductivity from 90 mS to 200 µS.

Cross-media effects
Increased energy usage in evaporation and concentrate drying. Waste produced may be more difficult to manage than conventional sludges.

Cyanide can be evaporated with the water.

Technical considerations relevant to applicability
This is only technically possible by the use of a large energy input and high capital plant investment. There may little or no environmental benefit or requirement to clean a waste water discharge containing ‘neutral’ salts (i.e. alkali metal salts, Na, K, Ca) left from traditional treatments. There are three possible cases:

- **small effluent quantity**: effluent quantity may be drastically reduced by in-plant measures described in Sections 4.2.6.7 and 4.2.6.8. The concentration of the soluble contents then rises accordingly. It may then become difficult to treat the effluent by classical methods and be difficult to meet strict concentration values for effluent and sewage regulations. In such a case, evaporation can be more economic than conventional treatment, despite the energy consumption
- **ingredients difficult to remove by normal operation** complexing agents such as EDTA are difficult to destroy in the effluent. However, their use is essential for some processes and specifications. For an installation which relies on using such chemicals, the complete evaporation of the relevant flows may be the only solution
- **regulation**: an enterprise whose production has no waste water discharge may be free from, or less subject to, supervision by the environmental regulatory authorities and any related costs.

Economics
~~See Operational data.~~

Driving force for implementation
~~See Applicability.~~

~~**Example plants**~~
~~See Annex and Annex .~~

Reference literature
[104, UBA, 2003] [124, Germany, 2003, 128, Portugal, 2003].

4.2.10.4.1.1.2 Infrared evaporators

Description

The liquid to be evaporated is placed in a conical container. The liquid surface is then warmed with infrared radiation produced by a gas infrared emitter. Controlled and bubble-free evaporation is achieved by radiation absorption as the liquid presents an extremely thin layer at the 'shallow end'. The crystallised solids sink in the residual water because of their higher specific gravity in the 'cold' layers of the evaporator. The crystal mash formed is discharged via a valve to a filter bag. The filtered mother liquor is fed back to the evaporator vessel. The water vapour mixture leaves the evaporator by an extraction system.

Achieved environmental benefits
Zero discharge from all or part of an installation.

Environmental performance and operational data
Advantages of this technique:

- durable, resistant technology
- direct, contact-less heating
- clean exhaust gas because of aerosol evaporation
- consistent performance with salt solutions, acids and alkalines
- fully automatic salt discharge possible
- reducing or oxidising atmosphere in the evaporator area as required
- no pollution and/or encrustation problems
- no additional chemicals needed, for example for cleaning purposes
- very high plant throughput availability due to safe continuous operation
- Cr(VI) reduction is possible without additional chemicals
- evaporating on ammonia solutions without effluent problems
- noiseless operation.

Cross-media effects
Increased energy usage in evaporation; the energy consumption of 100 m^3 natural gas per m^3 of water evaporated is high.

Waste produced may be more difficult to manage than conventional sludges.

Ammonia may be volatilised into the air.

Technical considerations relevant to applicability
~~See Section .~~

Economics
Capital costs are likely to be lower than for a typical waste water treatment plant operated to BAT standards. High running costs, although a combination of infrared evaporator and reverse osmosis reduces the energy costs

Driving force for implementation
~~See Applicability.~~

Reference literature
[124, Germany, 2003] [104, UBA, 2003, 113, Austria, 2003]

4.2.10.4.2 Membrane technologies with physico-chemical processes

Description
Thermal procedures present advantages when considering the quality of the treatment (allowing for recycling). However, the investment and operating costs are more significant [55, France, 2003].

The classical waste water treatment by physico-chemical procedures can be improved using membranes technology. At present, there are two basic technical solutions using membranes:

- ultrafiltration, obtaining very low concentrations in metals and organics (e.g. Ni concentration after treatment by ultrafiltration can be lower than 0.1 mg/l) rather than with classical physico-chemical treatment, when it is very difficult to reach 0.5 mg/l for waste water from nickel plating. However, a chemical treatment is necessary before ultrafiltration, such as hydroxide or sulphide precipitation
- combining ultrafiltration and reverse osmosis allowing ‘zero water discharge’.

4.2.10.4.2.1 Treatment combination using ultrafiltration

Description
The main difference between classical physico-chemical treatment and ultrafiltration treatment is the use of membranes instead of settling. Some metals in solution may need treatment with reducing agents before ultrafiltration.

Achieved environmental benefits
Zero water discharge from all or part of an installation when concentration of dissolved products allows recycling.
No suspended solids.
The concentration of metals is much lower than with the classical procedures.
Increasing the treatment capacity only requires more membrane units.

Environmental performance and operational data
Uses little space compared with some other techniques.

Cross-media effects
Problems of clogging in relation to membranes which needs different plant management.
Wastes generated from treatment.

Technical considerations relevant to applicability
This technique may also be considered for:

- very high quality treatment requirement (recycling requirements and strict environmental quality standards)
- medium and large projects, this technique will provide an excellent quality (suspended solids close to zero, very low metals concentration, reduced COD etc)
- an old waste water treatment plant being revamped (for discharge quality and/or capacity of treatment) implementing ultrafiltration in place of settlement, as it provides a high quality level of treatment with reduced investment and in reduced space.

This technique is less applicable where there is a low volume to treat or for highly concentrated waste water (high TDS).

Economics
Important economy on investment and operating cost levels in comparison with thermal procedures.

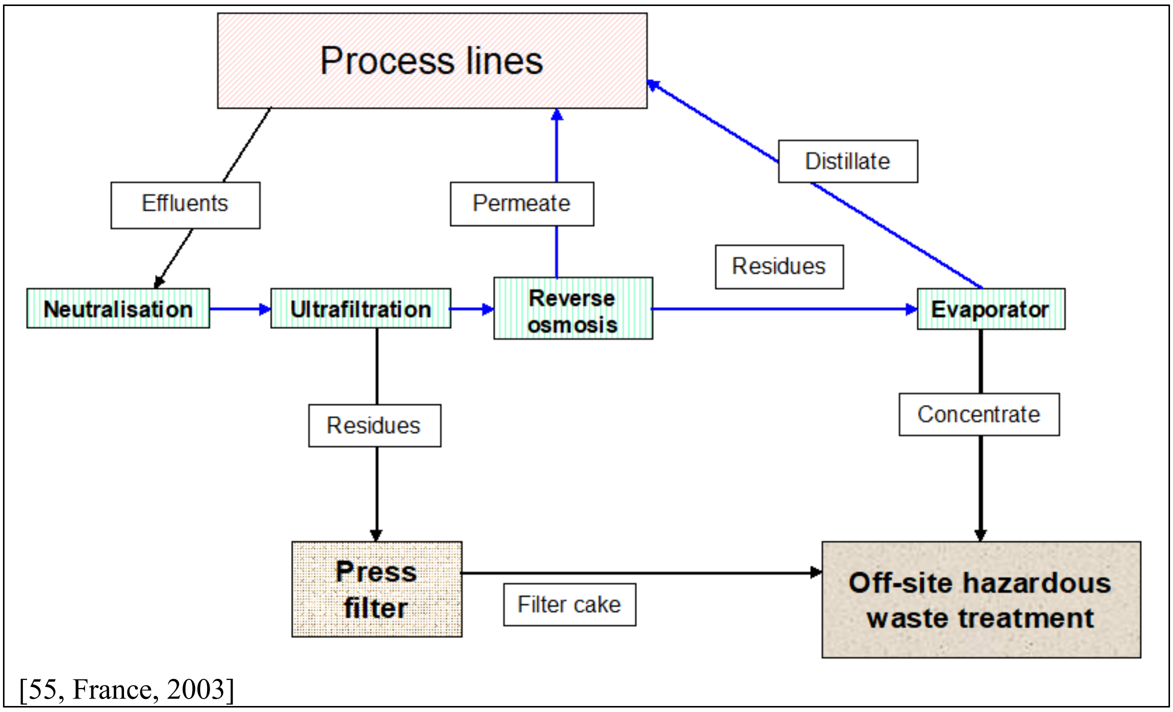
Driving force for implementation
~~See Applicability, above.~~

Example~~s~~ plants
About 80 plants have been working for six years in western Europe.

Reference literature
[156, France, 2003]

4.2.10.4.2.2 Treatment using combination of ultrafiltration and reverse osmosis

Description
The treatment in a first step is based on ultrafiltration (see Section 4.2.10.3.2.14.2.2), followed by reverse osmosis in a second step, see 4.2.10.5. This reduces salt and organic concentrations in order to obtain a very high quality water, permitting recycling for very sensitive uses.



[55, France, 2003]

Figure 4-47: Treatment using a combination of ultrafiltration and reverse osmosis

Achieved environmental benefits
Zero water discharge.
The technical solution generates two different qualities of water for recycling (medium quality for secondary functions and high quality for sensitive functions such as final rinsing by spray). This use of two different qualities of recycled water reduces operating costs.

Environmental performance and operational data
Advantages of this technique:

- very high level of quality
- low investment and operating costs
- easy possibility of graduation in the treatment quality (after ultrafiltration or after reverse osmosis)
- possibility of evolution of the treatment capacity
- very compact unit (low height and/or small area where these are limiting factors).

Cross-media effects
More complex solution (different stages). Not adapted for very small projects or high concentrations.
Can produce concentrated wastes.

Economics
Important reduction for investment and operating costs in comparison with thermal procedures.

Driving force for implementation
See Applicability.

Example plants
Four plants working in France with this technique (the first one since 2001).

Reference literature
[55, France, 2003]

~~Monitoring, final control and discharging of waste waters~~
[Note to the TWG: The technique below was replaced with technique in Section 4.2.2.3]

~~Prior to discharge, the effluent is checked to ensure it complies with local permit conditions in line with a monitoring programme, see Annex 0, and the BREF on the general principles of monitoring [91, EIPPCB,].~~

~~Discharge may be:~~

- ~~continuous with:~~
    - ~~continuous online monitoring for key parameters such as pH~~
    - ~~frequent manual checking of key parameters, such as pH, metals, cyanide (as appropriate to the installation's activities)~~
    - ~~a combination of both.~~
- ~~batch discharge with prior checking for key parameters such as pH, metals, cyanide (as appropriate to the installation's activities). This is required in Germany [124, Germany, 2003].~~

~~Both options can form part of a management system (see Section 4.2.1.1) and when the effluent falls outside of the limit values, action can be initiated. This may be instigated by automatic alarms with online systems, or manually with manual checking.~~

~~Description~~
~~It is advisable to design the monitoring programme to ensure that the installation meets its permit requirements.~~

~~Achieved environmental benefits~~
~~Meeting permit requirements.~~

~~Cross-media effects~~
~~For continuous discharges, poorly trained, poorly maintained and/or inspected online systems or lack of sufficient manual inspection and analytical results can allow the discharge of out-of-limit effluents.~~

~~For batch discharges, poorly trained supervision, or supervision without adequate analytical results can allow the discharge of out-of-limit effluents.~~

~~Operational data~~
~~Staff carrying out this function need adequate training supported by adequate analytical information, whether from online monitoring, 'spot tests' or laboratory results.~~

~~Staff carrying out manual monitoring may be easily distracted from completing testing and inspection.~~

~~Online monitoring equipment needs regular maintenance and calibration by appropriately trained staff.~~

~~**Applicability**~~
~~All sites discharging to watercourses or public or central waste water treatment systems.~~

~~**Economics**~~
~~Continuous discharge with regular manual inspection may appear cheapest. However, this must be compared with the risk and costs of breaches in permit conditions.~~

~~Online monitoring equipment must be regularly maintained for the same reasons, but may recover the cost of manual inspections in a relatively short time.~~
~~Batch discharge after testing is expensive in capital investment in tanks sufficient to take a flow period, or possibly two or more tanks operated in sequence. This also requires inspection and analysis prior to discharge.~~

~~**Driving force for implementation**~~
~~Compliance with environmental legislation.~~

~~**Example plants**~~
~~In Germany, all surface treatment plants with effluent operation on a batch basis.~~
~~For France, see monitoring, in Annex 0.~~

~~**Reference literature**~~
~~[124, Germany, 2003] [56, France, 2003, 91, EIPPCB, , 104, UBA, 2003]~~

4.2.11 Residues and circular economy

~~Waste management techniques~~

[Note to the TWG:This section corresponds to the Section 4.17 of the original STM BREF]

[Note to the TWG:contents from Section 2.13.2 in the exisiting STM BREF have been merged in their corresponding techniques below]

~~Generation and management of waste~~
~~Annex IV (point 3) of the IPPC Directive requires the operator to '*further the recovery and recycling of substances generated and used the process and of waste, where appropriate*'.~~

The rinsing processes in surface treatment installations produce rinse-waters containing concentrates. In addition to rinse-waters, the following waste waters streams can also contain metals:

- used process solutions from the electrochemical processes (electrolytes);
- used process solutions from chemical coating processes;
- used process solutions from the pre- and post-treatment (cleaning, pickling, phosphating and chemical conversion);
- solutions from separation and regeneration processes, such as ion exchange, retardation, dialysis, electrolysis;
- solutions from associated activities, such as exhaust scrubbers and filters, as well as from plant cleaning.

Generally the solutions and effluents are discharged into the effluent system. The treatment of the streams containing metal in the system essentially precipitates the dissolved metal ions as insoluble compounds. Normal precipitation with caustic soda solution and/or lime precipitates the metals as hydroxides and/or oxide hydrates. Precipitation may also be as carbonates and sulphides. The sludge produced has a water content of usually over 95 % and is drained by means of filter presses to about 60 % water content and is disposed of in this form as sludge.

The amount of sludge depends on various processing factors:

- contamination of the input material
- amount of metal oxides dissolved or eroded from the workpiece/substrate surfaces
- discharge of process solution dragged-out by the workpieces/substrate
- service lifetime of the process solutions.

That means that the generation of sludge without internal recycling measures is directly proportional to the drag out and the service lives of the process solutions. Generally, the metal losses by drag out related to the metal input material lies between 5 and 30 %.

Surface treatment sludge is usually a mixture of metal hydroxides. It contains all non-ferrous metals used during the process, the workpiece substrate metals iron and aluminium, as well as calcium, potassium and sodium from the precipitation chemicals.
Depending on the plating process, the non-ferrous metal contents (Cu, Ni) can amount to up to 30 %, for example, with monosludges (i.e. sludges from one process type only). The major part of the electroplating sludge is a mixture and has non-ferrous metal contents of about 10 %, as Table 4.19 shows.

Table 4-17: Typical composition of electroplating sludge from different sources

	Cu %	**Ni %**	**Zn %**	**Pb %**	**Cr %**	**Fe %**	**Ca %**	**Cl %**	**SO_4 %**	**Water %**
Cu sludge	5 – 10	1- 5	1- 5	0- 1	0- 2	5- 15	2- 10	0- 3	0- 20	50- 70
Ni sludge	0- 2	10- 15	1	0- 1	0- 2	0- 5	0- 5	0- 3	0- 5	50- 70
Mixed sludge	0- 2	0- 2	2- 3	0- 1	0- 2	5- 15	5- 15	0- 3	5- 20	50- 70
UBA										

Some liquid wastes, such as end-of-life electrolytes or layer conversion solution may also be concentrated and treated in the in-house waste water treatment plant.

Other wastes can be re-used or recycled internally or externally, see 4.2.12.3. In order to facilitate this, it may be good practice to separate or concentrate certain waste streams, to increase or maintain their usefulness.

4.2.11.1 Residues management plan

Description
A residues management plan is part of the EMS (see Section 4.2.1) and comprises a set of measures aiming to:

- minimise the generation of residues;
- optimise the reuse, recycling and/or recovery of residues;
- ensure the proper disposal of waste.

The measures are prioritised according to the waste hierarchy given in Directive 2008/98/EC.

Technical description
A variety of techniques can be used for residue optimisation including:

- basic housekeeping techniques;
- statistical measurement techniques;
- application of clean technologies;

- use of process chemicals before their expiry date;
- use of residues as secondary raw material or as fuel.

In particular, a residue/waste management plan could be based on the five-stage hierarchy of Directive (EU) 2018/851 and the Commission notice on technical guidance on the classification of waste 2018/C 124/01, and include the following:

- Identifying, characterising and quantifying each of the residue/waste streams generated. Maintaining a residue/waste tracking system can help operators to record the quantity, nature, origin and, where relevant, the destination, frequency of collection, mode of transport and treatment method of any residue/waste which is disposed of or recovered on that site.
- Identifying the current or proposed handling arrangements, and possibilities to implement circular economy.
- Fully describing how each residue stream is proposed to be recovered or disposed of. If it is to be disposed of, the plan explains why recovery is not technically or economically possible and then describes/explains the measures planned to avoid or reduce the impact on the environment.
- Practical techniques to reduce the amount of waste sent for disposal may include the following:
    - applying housekeeping operations; these can be as simple as sweeping prior to washing floors and can substantially reduce residue volumes;
    - established criteria associated for example with the maximum storage time of process chemicals are clearly established and relevant parameters are monitored to avoid the process chemicals perishing or the expiry date being exceeded;
    - separate capture of high-loaded waste streams from low-concentrated effluent to allow more efficient treatment;
    - separate collection of unavoidable solid waste;
    - reduction of packaging;
    - use of returnable containers.

Achieved environmental benefits

- Increased material efficiency.
- Reduced amount of waste sent for disposal.
- Minimisation of residues through recycling of process residues and reuse of recycled materials along with raw material savings.

Environmental performance and operational data

Cross-media effects

None identified.

Technical considerations relevant to applicability

The level of detail and the degree of formalisation of the residues management plan will generally be related to the nature, scale and complexity of the installation.

Economics

Associated personnel cost.

Driving force for implementation

- Reduced cost due to increased material efficiency.
- Legal requirements. The prevention of waste generation is a principle of the IED (Directive 2010/75/EU 2010 as amended by Directive (EU) 2024/1785) and the Waste Framework Directive (WFD, Directive EU/2018/851).

Example plants
Widely used.

Reference literature
[168, TWG, 2023].

4.2.11.2 Waste minimisation and avoidance

There are four key factors for the avoidance and minimisation of waste in surface treatment processes, and they are described in the appropriate sections:

- reducing the amount of hazardous material in the waste, see Substitution, in Section 4.2.7;
- extension of the service lifetime of the process solutions, see Process Solution Maintenance, in Section 4.2.6.5;
- decrease of the drag-out of process solutions, and feedback of the dragged-out process solutions into the process tanks, see Section 4.2.6.7.
- ~~, see Section 4.7.~~

4.2.11.2.1 Process line optimisation

See Section 4.2.6.2.1.

4.2.11.2.2 Automatic systems for the preparation and dosing of process chemical

See Section 4.2.6.4.1.

4.2.11.2.3 Advanced process monitoring and control systems

See Section 4.2.6.4.3.1.

4.2.11.2.4 Minimisation of reworking and optimised process line

See Sections 4.2.1.7, 4.2.6.2.1 and 4.2.6.4.1.

4.2.11.2.5 Reduction, reuse and recycling of packaging

[Note to the TWG: Please provide information to complete the 10-heading template below, e.g. on economics]

Description
For product packaging, this includes techniques such as:

- use of light and high-capacity packaging to reduce the specific consumption of packaging materials (e.g. high-expansion plastic films);
- use of reusable packaging (e.g. reusable pallets, metal boxes);
- use of recycled plastic films;
- use of a reduced amount of printed plastic films (e.g. printed banderole) to facilitate downstream recycling.

For the packaging of chemical substances and mixtures, this includes techniques such as:

- storage, preferably in large containers;
- reuse of packaging;
- return to the supplier;
- sending for material recycling.

Technical description
Suppliers may take back their empty containers (plastic, wood, metal) for recycling. The use of the largest container possible may be considered.

Achieved environmental benefits
Reduction of packaging materials and associated residues.

Environmental performance and operational data
Plastic film contains up to 50 % post-consumer recycled plastic.

Cross-media effects
None identified.

Technical considerations relevant to applicability
Generally applicable.

Economics

Driving force for implementation
Circular economy.

Example plants
Plants [BE_004], [ES_010], [ES_030], [FR_015], [FR_031], [IE_001] and [IT_008] of the STM data collection.

Reference literature
[168, TWG, 2023].

4.2.11.2.6 Timely use of process chemicals

Description
Criteria are clearly established associated, for example, with maximum storage time of process chemicals, and relevant parameters are monitored to avoid process chemicals perishing.

Technical description
The technique involves the timely application of chemicals to ensure their effectiveness and reduce the need for reapplication. This may include the use of chemical metering systems, dosing equipment, and monitoring systems to optimise chemical use.

Achieved environmental benefits
- Reduced chemical use.
- Decreased waste generation.
- Improved water quality.

Environmental performance and operational data

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Economics

Driving force for implementation

- Reduced costs.
- Iimproved safety.

Example plants
Widely use.

Reference literature
[168, TWG, 2023]

4.2.11.2.7 Optimised sludge handling

Description
This is achieved by, for example, reducing the discharges from rinsing and treatment vats so that the quantity of sludge generated is minimised, or by using sludge dewatering, drying or stabilisation.

Technical description
Sludge dewatering, drying or stabilisation.

Sludge dewatering
Solids removed from the main effluent by precipitation or filtering may be further concentrated using a filter press, belt press or centrifuge to produce a cake manageable as a solid. Filter press treatment of metal hydroxide sludge at pressures above 15 bars can give a final cake with 15-35 % solids. The final solids of sludges from anodising rarely rise above 25 % [118, ESTAL, 2003, Sheasby, 2002 #132].

Sludge stabilisation
In some cases, such as where waste management regulations require, sludge may be stabilised [21, Agences de l'Eau de France, et al., 2002], although this is usually carried out off-site by specialist waste management contractors, [89, EIPPCB,]. For solidification, two main types of binder are used:

- hydraulic, such as cements, fly ashes from cement kilns or coal-fired power generation
- hydrocarbon-based, such as tars or bitumen (a process derived from the nuclear industry).

Drying of the sludge may be required prior to stabilisation.

Environmental considerations
The volume of waste solidified with hydraulic binders increases in volume 1.5 to 2 fold.

Waste treated with hydraulic binders (such as lime) may have a pozzolanic action and develop mechanical properties that increase stability with time. However, the surface active agents present may interfere with this reaction.

Sludge drying
Filter cake may be further dried to lower water content.

Environmental considerations

Drying requires 450 kWh of thermal energy per tonne. Waste heat from other processes can be used.

Drying may create a powdery waste at a water content of less than 40 %. This may cause more dust problems in handling than a solid cake.

Dried sludge containing residues of oxidising components, such as H_2O_2, NaOCl or persulphates, are reported to heat up through exothermal reactions when stored in big bags, (tonne bags) and may eventually spontaneously combust [3, CETS, 2002].

In some cases, drying sludge may assist subsequent processing, such as solidification.

Achieved environmental benefits
Reduced amount of waste generated.

Environmental performance and operational data

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Economics

Driving force for implementation
Cost savings.

Example plants
Widely used.

Reference literature
[168, TWG, 2023]

4.2.11.2.8 Minimisation of reworking and optimised process line

See Section 4.2.6.5.15.1.

4.2.11.2.9 Contained areas for plating with hazardous substances

Description
Areas where plating with hazardous substances (e.g. Cd, Cr(VI)) is taking place are contained to avoid cross-contamination. Waste water streams from these areas are collected separately and treated according to their content (see BAT 19).

See also Section 4.2.1.4.

4.2.11.3 Separate collection and storage of wastes contaminated with hazardous substances

Description
Wastes containing hazardous substances are collected and stored separately, with special regard given to the substances fulfilling the criteria referred to in Article 57 of Regulation (EC) No

1907/2006 and substances addressed in restrictions referred to in Annex XVII to Regulation (EC) No 1907/2006 (e.g. sludges and filter cakes, aqueous rinsing liquids).

Technical description

Storage and handling of waste containing hazardous substances and substances of very high concern should follow the same rules that apply for storage and handling of these substances (see Section 4.2.1.4.5). These wastes may contain high loads of pollutants, e.g. metals including chromium(VI) and PFAS.

Liquid wastes

Some waste process solutions may be stored and disposed of as liquid waste, sent for specialist recycling or recovery or disposed of as hazardous wastes. Examples are autocatalytic plating solutions, spent etchants and sludges from anodising.

Other solid wastes

Surface treatment of metals and plastics generates other industrial wastes. These normally comprise the used packaging from raw materials (chemicals) and incoming workpieces or substrates, as well as discarded equipment such as broken jigs and barrels. Coloured bins with a colour code can be used to improve waste sortage in the production plant.

Achieved environmental benefits

Prevention of the uncontrolled emissions of hazardous substances to air, water and soil.

Environmental performance and operational data

It is possible to prevent hazardous substances entering waste water and the soil by storing waste containing hazardous substances in an appropriate manner and disposing of it via a qualified processing company.

Cross-media effects

None.

Technical considerations relevant to applicability

Generally applicable.

Economics

Driving force for implementation

Environmental waste and chemical legislation (e.g. environmental quality standards, EU LoW 200/532/EC and REACH).

Example plants

Widely used.

Reference literature

[177, TWG, 2020] [168, TWG, 2023]

4.2.12 Techniques contributing to industrial symbiosis

4.2.12.1 Use of excess heat in another plant or for local district heating

Description

Use of excess heat generated by one plant at another plant that requires heat; and use of excess heat generated for space heating and hot water supply in nearby buildings.

Technical description

This technique involves the installation of a heat recovery system that captures excess heat from industrial processes and transfers it to a district heating network. The heat can then be distributed to nearby buildings or factories for space heating and hot water supply through a network of pipes and heat exchangers. The system can be designed to handle various types of heat, including steam and hot water.

Achieved environmental benefits

- Reduced energy consumption.
- Decreased greenhouse gas emissions.
- Improved overall energy efficiency.

Environmental performance and operational data

Actual plant-specific performance data may vary depending on the specific processes involved and the efficiency of the heat recovery system.

Cross-media effects

None reported.

Technical considerations relevant to applicability

Applicability may be restricted by the lack of a suitable heat demand.

Economics

Implementing the technique can lead to significant cost savings by reducing energy consumption and lowering the reliance on fossil fuels. The specific economics of this technique will depend on the efficiency of the heat recovery system, the cost of energy, and the potential for revenue from selling excess heat to the district heating network

Driving force for implementation

- Cost savings.
- Regulatory requirements and incentives.

Example plants

Example plants from the data collection that have successfully implemented this technique are: CZ_006 and SE_004.

Reference literature

[168, TWG, 2023]

4.2.12.2 Exchange of waste water among plants

Description

The technique involves the sharing between different plants of specific waste water flows that are treated in the WWTP.

Technical description

This technique involves the installation of a waste water management system that connects multiple processes or facilities, allowing for the exchange and treatment of waste water, e.g. the use of waste water (acids) from the electrogalvanising line to neutralisate external alkaline waters. The system can be designed to handle various types of waste water, including contaminated water, run-off, and process water. The shared waste water can then be treated and reused within the facility or released to the environment after appropriate treatment.

Achieved environmental benefits

- Reduced chemical use.

- Improved waste water quality.
- Decreased waste water discharge.

By sharing and treating waste water, this technique can help reduce the overall environmental impact of the surface treatment of metals and plastics industry and promote resource conservation.

Environmental performance and operational data
Actual plant-specific performance data for the technique may vary depending on the specific waste water sources and the efficiency of the waste water management system.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable as long as the waste water sources and treatment facilities are compatible.

Economics
Significant cost savings can be made by reducing chemical use and waste water treatment costs. The specific economics of this technique will depend on the efficiency of the waste water management system, the cost of chemicals, and the potential for revenue from selling treated waste water to other facilities.

Driving force for implementationcost savings,
- Reduced chemical use.
- Improved waste water management.
- Regulatory requirements and incentives, such as water quality standards and waste water discharge limits.

Example plants
Widely used. Example plants from the data collection that have successfully implemented this technique are: DE_066, ES_007 and NL_002.

Reference literature
[168, TWG, 2023]

~~4.2.12.3~~ External recovery of materials from ~~valorisation of~~ wastes~~Re-use and recycling of waste~~

Description
Wastes that cannot be recovered internally, e.g. scrap metals or plastic workpiece losses, may be valorised externally by third parties.

To assist with this, it may be good practice to keep these waste streams separate to maintain a concentration of components that makes recovery viable or to prevent contamination, such as contamination of aluminium hydroxide sludge with heavy metals.

Technical description
The following are examples of external valorisation:

- hydro and pyrometallurgical companies engaged in non-ferrous metal refining. Part of the electroplating sludge may have a high value material content and recycling by third parties can be arranged in many cases. Recycling includes refining of the metals copper, nickel, chromium and zinc from suitable electroplating sludge as metals or metal compounds manufacture of usable metal concentrates
- phosphoric and chromic acids, spent etching solutions, etc.

- aluminium hydroxide from anodising can be precipitated and recycled, for example as a coagulant for sewage treatment. (Note: the rinsing waters from colouring and sealing processes may contain heavy metals and it is advisable to collect sludge separately from these waste water streams if re-use is required)
- inorganic chemical companies and the glass and ceramics industry which use metals or metal compounds intentionally in the manufacture of products.

Techniques where the metals are merged non-specifically into mineral matrices (glass, ceramics, cement) are not considered recycling, but may be an option. Note that European legislation now controls the amount of hexavalent chromium in cement.
In the surface treatment installation used electrolytes, coating and conversion solutions which are no longer suitable for regeneration become liquid waste. These solutions can be transferred under certain conditions to the chemical suppliers for re-use in the direct manufacture of new electrolytes.

The preferred aim is the recovery for use of the raw material, i.e. winning the metals copper, nickel and zinc from the redundant electrolytes. This technique also exists in principle for semi-concentrates such as the contents of the static rinses. It may be favourable to further concentrate these strong solutions by evaporation or other concentration techniques which lowers the transport costs and at the same time increases the valuable material content.

Achieved environmental benefits
Recovery of commodity metals which are conservative (i.e. non-degradable).
Re-use of materials instead of discarding them.Replacement of fresh raw materials by re-used ones.

Environmental performance and operational data
Actual plant-specific performance data may vary depending on the specific waste materials and the efficiency of the waste management system.

It is advisable to consider the balance of recovery and recycling. For instance, some in-process re-use in the process solution may recover a small amount of metal, but reduce the metal content of the installation’s sludge below the environmental and economic recovery breakeven point. The sludge then disposed of may still contain more metal than could have been recovered.

Recycling opportunities are favoured if the streams within the effluent system are kept separate according to their metal contents. The amount of separation applied depends on the requirements of the recycling companies.

Copper, nickel, chromium and zinc are regularly recovered. Some small quantities of precious metals, tin, lead and cadmium also arise. Sodium and calcium occur as precipitating chemicals. Re-use is technically possible if sludges are produced by appropriate pre- or post-treatment measures which satisfy the requirements of recycling plants in their consistency and material composition. These requirements include:

- physical parameters such as consistency and water contentmeeting or exceeding the minimum content of usable metals
- producing a mixture of metals which is usable
- minimum content of substances which disturb the recycling process.

The requirements of the recycling plants for consistency and composition of the electroplating sludge differ substantially from each other, depending on the particular recycling process and require assessing on a case by case basis.

Cross-media effects
Emissions from, and energy used in recovery processes.
Chemicals used to achieve a suitable waste for reprocessing.

Technical considerations relevant to applicability
Dependent on the availability of suitable re-use options and the suitability of the sludge.
For instance, recovered chromium oxides with high chloride content may not be suitable for recovery of the chromium in some processes.

Transport (distance to the recycler) may also be a factor to be considered.

Economics
Case-dependent.
Cost savings by reducing waste disposal costs and promoting the reuse of waste materials ~~Cost of disposal of surface treatment wastes, which are usually classed as hazardous.~~

Driving force for implementation

- Increasing disposal costs for hazardous wastes.
- Cost savings, e.g. by decreased energy consumption.
- Resource conservation and waste reduction.
- Regulatory requirements and incentives such as landfill taxes and recycling targets.

Example plants
WRC Gmbh, Wurzen (Germany). Example plants from the data collection that have successfully implemented this technique are: AT_0013, DE_066, IT_029 and NL_002.

Reference literature
~~[104, UBA, 2003], [30, EC, 2003, 152, ESTAL, 2004, 155, EIPPCB,], [89, EIPPCB,]~~[168, TWG, 2023]

4.2.12.4 Reuse of anodes

[Note to the TWG: please provide information to complete the 10-heading template below, e.g. on operational data and economics]

Description
Spent anodes are reused, e.g. tin anodes in a hot-dip galvanising plant.

Technical description
Spent anodes that cannot be used at one plant due to the change in their characteristics are sent to another plant to be reused according to the process specifications in the new plant.

Achieved environmental benefits

- Decrease of raw materials consumption.
- Energy savings.

Environmental performance and operational data

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Economics

Driving force for implementation

- Cost savings.
- Promotion of circularity.

Example plants

Reference literature

[168, TWG, 2023]

4.3 Techniques to consider in the determination of BAT for specific activities

4.3.1 Electroplating and chemical plating

4.3.1.1 Material efficiency

4.3.1.1.1 Process-integrated automated plating

Note to the TWG: this technique was moved from Chapter 6 in the existing BREF].

Description
In large-scale plating of uniform cylindrical workpieces, the anode is shaped to fit around the workpiece and spinning it rapidly, creating a high field intensity that allows fast plating. An automated sealed system delivers and removes the electrolyte, while a central processing system handles returned electrolytes, keeping the production line waste-free and minimising waste water.

Technical description
A project was initiated to integrate the electroplating processes into the production line to minimise the process costs and environmental impacts (it is referred to as FIO in German).

The technology is particularly suited to uniform cylindrical workpieces manufactured in large numbers. The anode is then shaped to fit around the workpiece (the cathode), leaving a very small space between the cathode and the anode and creating an extremely high field intensity. During plating, the anode is spun rapidly, which creates turbulence in the electrolyte, preventing ion transport in the diffusion layer which is the limiting factor.

The combination of these two factors allows the electroplating to proceed rapidly, permitting the process to be integrated into a production line.

An automatic sealed system delivers the electrolyte and removes it when it becomes exhausted. A separate central processing system for returned electrolytes keeps the production line waste and waste water free. Automation of the process means that staff are not exposed to any chemicals.

Achieved environmental benefits
Waste- and waste water-free plating on the process line.
Deletion of production steps with a pollution load, such as degreasing and pickling.

Cross-media effects
No data provided

Technical considerations relevant to applicability
~~Close co-operation (interdependence) between the operators and the chemical suppliers.~~
~~The process requires the use of proprietary chemicals and all the used chemicals must be returned to the supplier.~~ Applicability may be restricted by product specifications.

Economics
No data provided.

Driving force for implementation
Workpieces have to be taken from the production line to the plating line for coating, then returned for further processing or assembly. This creates additional work, as well increasing the number of steps generating pollution loads, for example, greasing, degreasing and pickling.

Example plants

~~At the moment, the FIO technique is not in use. However~~ Pilot attempts were promoted by the German Ministry for Science and Technology:

- KVS plastics processing and service GmbH: KVS, the developers and manufacturers of the FIO technique, could not establish FIO on the market. The largest problem was the interdependence between the user and the chemicals supplier. For many operators, the level of dependence on the chemical supplier is thought to be too high a risk
- Siemens corporation,-Central Department of Production and Logistics: The silver plating of copper tubes was integrated into the manufacturing process for experimental purpose. The promising beginning was not transferred to mass production because of the sales of that production section to another company
- Bosch: The procedure was technically feasible, however for unknown reasons it was not transferred to mass production. Partial results of the research project (some recycling technologies) are still in use in the company.

Reference literature
BMBF Verbundvorhaben (joint project) 'Manufacturing-integrated surface treatment (FIO)' FKZ 01ZH9503; 01ZH9504/4; 01ZH95098 [104, UBA, 2003] [177, TWG, 2020]

4.3.1.1.2 Switching the polarisation of the electrodes in the electrolytic processes

Description
The polarisation of electrodes in electrolytic degreasing and in electrolytic pickling processes is switched at regular time intervals.

Technical description
See Section 4.2.6.4.3.3.

Technical considerations relevant to applicability
Only applicable in plants with bipolar electrodes.

Example plants
DE033, DE045, FR035 and IT032.

Reference literature
[168, TWG, 2023]

4.3.1.1.3 Reduction of drag-out in jig (rack) processing

Description
Drag-out reduction, e.g. by:

- optimised position of workpieces to avoid retention of process liquids;
- adjustment of draining time when withdrawing the jigs;
- regular inspection and maintenance of jigs to avoid fissures retaining process solution;
- optimisation of workpieces to minimise spaces trapping process solution.

Technical description
Arranging the largest surfaces of the workpieces in a vertical position at the jigs (racks) allows the adhering solution to run down to the bottom edge of the workpieces.

The longer dimensions of the articles are normally arranged horizontally and/or slightly inclined to allow the adhering solution to run down, improving drainage.

The lower edge of all articles may be tilted to allow the droplets to cohere and facilitate dripping down above the process tank.

When lifted out of the process solution, the jigs may be tilted in such a way that large droplets can be formed faster and drip down from the lowest point of the suspended articles.
Allow sufficient drainage time above the process tank to let the adhering liquid to cohere and form droplets which will drip from the articles.

By slow withdrawal of the jigs from the process solution, the drag-out volume can be decreased considerably. Therefore, slow withdrawal and a sufficient drainage time above the process tank can significantly minimise drag-out. Withdrawal and dwell times given in Table 4-17 below are valid for some specific processes and are given as indication only. The times vary according to the specific processes.

Table 4-18: Withdrawal and dwell times for jigs

Process	Minimum time withdrawal (seconds)	Minimum time dwell (seconds)
Plating	10	10
Cleaning/pickling	8	7
Passivation	10	10
Seals/lacquers	10	5

Cup-shaped recesses are normally avoided where possible, and cup-shaped components are jigged cup-side down on the incline so process solution is not carried into the rinse-water.

In some cases, arrangements can be made by dialogue with customers for components with high drag-out retention, such as cup-shaped components, to be manufactured with drainage holes.

Dripping of process solution on other articles arranged lower on the jig is normally addressed by suitable positioning of the workpieces.

Automatically or manually inserted draining pans below the jigs will collect any drippings and prevent contamination of subsequent tanks and solutions (where immediately adjacent vats are not used). A fast transfer of the racks from one tank to the next also minimises this.

Drag-out by jigs can be reduced by inclining supporting arms to avoid horizontal surfaces from which the adherent solution cannot easily run off.

A normal inspection and maintenance task is to check the insulation coating of the jigs to ensure smooth surfaces, with no fissures or cracks in damaged insulation to trap and retain solution. It is good practice to regularly inspect jigs for defective insulation so they can be identified for replacement or repair.

Jig insulation coatings are normally hydrophobic to assist draining of drag-out.

Jigs may be rinsed or sprayed with water, or blown with air to remove dragged-out solution (see Section 4.6.6).

Optimisation of workpieces is arranged with workpiece providers and customers to ensure that the possible spaces for trapping process solution are avoided or kept minimal.

Achieved environmental benefits
This is a key step in reducing the loss of soluble chemicals from process vats to the environment via rinsing.

Cross-media effects
None reported.

Environmental performance and operational data

Where a rapid stopping of the surface reaction is required, this is often achieved by rapid dilution of the remaining process solution on the surface, particularly for:

- hexavalent chromium passivation
- etching, brightening and sealing of aluminium, magnesium and their alloys
- zincate dipping
- pickling
- pre-dip when activating plastic
- activating prior to chromium plating
- colour lightening after alkali zinc.

In some processes drainage time may affect the quality of the treated surface, such as where a delay causes de-activation of, or damage to, the surface between treatments, such as between nickel plating followed by chromium plating.
For problems with blowing or spraying, see Section 4.2.6.7.7.

The dragged-out volume is:

$$\boxed{W = 0.02A \cdot \sqrt{\frac{a \cdot p}{t \cdot d}}}$$

where:

W is the volume withdrawn in cm^3
A is the surface area of the article in cm^2
a is the vertical length of the article in cm
p is the dynamic viscosity of the process solution in Poise (1 Poise = 0.1 Pascal second)
t is the withdrawal time in seconds
d is the density of the process solution.

The surface roughness of the articles was found to have no effect on the volume of drag-out.

Actual drag-out measurements can be determined by chemical or measuring the increase in volume. In the absence of such data, the following typical data can be used for rack plating:

- flat surfaces 0.1 l/m^2
- contoured surfaces 0.2 l/m^2
- the equation above is for flatter shapes. A typical value for cup shapes is 1 l/m^2.

Technical considerations relevant to applicability

All jig (rack) plants. Applicability of optimisation of workpieces may be restricted by product specifications.

Economics

All these measures can be incorporated into the operation of any jig (rack) plant. Jigs have a relatively short operating life, are not capital intensive, and design can be improved and implemented over time. Correct positioning of workpieces on jigs is usually achieved by staff training.

Other measures, such as draining and dwell time will depend on transporter control equipment being used.

Increasing time for draining can reduce throughput and machine capacity.

Driving force for implementation

Cost savings in chemical usage and reduction in waste water treatment costs.

Example plants
Many plants in the STM data collection.

Reference literature
K. G. Soderberg (Proceedings of the American Electroplaters' Society 24 (1936) pp. 233- 249), [3, CETS, 2002] [118, ESTAL, 2003](personal communications, TWG members) [113, Austria, 2003], [104, UBA, 2003], [168, TWG, 2023] [168, TWG, 2023].

4.3.1.1.4 Reduction of drag-out in barrel processing

Description
Drag-out reduction, e.g. by:

- appropriate choice of barrels materials, e.g. hydrophobic plastic;
- regular inspection and maintenance of barrels for worn areas, damage, recesses or bulges that may retain process solution;
- withdrawing slowly to minimise the volume of liquid dragged out;
- rotating intermittently;
- rinsing using a pipe inside the barrel;
- ensuring the bores of holes in the barrel bodies have sufficient cross-sectional area in relation to the required thickness of the panels to minimise capillary effects;
- ensuring that the proportion of holes in the barrel bodies is the highest for allowing drainage while retaining mechanical strength;
- replacing holes with mesh plugs;
- fitting drainage ledges between tanks canted back to the process tank;
- inclining the barrel from one end.

Technical description
The plastic material of the barrel normally has a smooth surface and is inspected for worn areas and the formation of recesses or bulges around the holes.

The bores of holes in the panels usually have a sufficient cross-section to minimise capillary effects, and the thickness of the panels of the cylinder is just thick enough to meet the mechanical strength requirements.

The total proportion of the body of the barrel that is perforated is usually as high as possible to allow the drag-out to drop back easily into the process tank. This also improves the efficiency of the whole plating process by allowing easier solution access and decreasing voltage drop.

A further reduction of drag-out can be attained by intermittent rotation of the barrel above the process tank while draining (such as rotating for about 90 degrees, stopping for at least 10 seconds, next sequence of intermittent rotation, etc.).

More reduction of drag-out can been achieved by the application of draining ledges within the barrels to allow the draining liquid to flow together and to drain out of the rotating barrel.

Drag-out can be reduced dramatically by blowing excess solution out of the barrel while draining over the bath. With hot baths, the barrels can be rinsed with water or sprayed (see Section 4.2.6.7.7), although for barrels, sparging is more effective: sparging is where pipe is constructed within the barrel and runs rinse-water inside the barrels and through the workpieces.

In a barrel, the workpieces usually lie with the main surfaces horizontal. To achieve better draining, inclined lifting of the barrels from the tanks can be considered. The suspension and hoisting systems may be adapted to this requirement. However, in conventional systems this is difficult to achieve.

The application of mesh plugs instead of holes has proven successful, by reducing the length of the bores in the panels of the cylinder body of the barrel. The drag-out can be decreased, and the voltage drop at the perforation is effectively reduced.

Achieved environmental benefits
This is a key step in reducing loss of soluble chemicals from process vats to the environment via rinsing.

Environmental performance and operational data
As with jig plating, where a rapid stopping of the surface reaction is required, this is often achieved by rapid dilution of the remaining process solution on the surface. In some processes excessive drainage time may affect the quality of the treated surface.~~, see Sections 0 and 1.1.1.1.1.~~

To minimise the volume of liquid dragged out, the barrel may be withdrawn from the liquid slowly to decrease the drag-out effectively, with a sufficient draining time afterwards as described in Table 4.3.

Table 4-19: Withdrawal and dwell times for barrels

		Minimum time		
Process	**Holes (mm)**	**Withdrawal (seconds)**	**Dwell (seconds)**	**Stationary periods** (see Note*)
Plating	2	5	24	3 x 6
	3	5	20	3 x 6
	4	5	16	2 x 6
	>6	5	12	2 x 6
Cleaning/pickling	2	5	24	3 x 6
	3	5	20	3 x 6
	4	5	16	2 x 6
	>6	5	12	2 x 6
Passivation	2	5	16	1 x 6
	3	5	12	1 x 6
	4	5	8	1 x 6
	>6	5	4	1 x 6
Seals	2	5	24	3 x 6
	3	5	20	3 x 6
	4	5	16	2 x 6
	>6	5	12	2 x 6
CETS Italy, Assogalvanica				
Note*: barrel is rotated one, two or three times through 90° with a 6 second dwell period.				

Actual drag-out measurements can be determined by measuring the increase in chemical concentration in the first rinse or measuring the increase in volume.

Data for zinc barrel plating is given in and :

Table 4-20: Drag-out retention, barrel diameter 380 mm with 8 mm holes

	760 mm barrel width	**1200 mm barrel width**
Flat and contoured surfaces	1 – 2 l/barrel	2 – 3 l/barrel
Cup shapes	2 – 4 l/barrel	3 – 6 l/barrel

Table 4-21: Drag-out retention, barrel diameter 380 mm with 2 mm holes

	760 mm barrel width	1200 mm barrel width
Flat and contoured surfaces	2 – 4 l/barrel	3 – 5 l/barrel
Cup shapes	3 – 6 l/barrel	4 – 8 l/barrel

In some processes, such as chromium passivation, excessive drainage time may affect the quality of treated surface, see Section 2.5. Where a rapid stopping of the surface reaction is required this is often achieved by rapid dilution of the remaining process solution on the surface.

Cross-media effects
When blowing out the barrel with air or water spray, care must be taken to ensure that the removed solutions fall into the bath below, and to minimise droplets or particles in the air. Removed solutions could be harmful in the workplace atmosphere, in the outside environment and may contaminate other processes (see Section 4.2.6.7.7).

Technical considerations relevant to applicability
All barrel process activities. The applicability of ensuring sufficient cross-sectional area of the bores of holes in the barrel bodies, ensuring the highest proportion of holes in the barrel, replacing holes with mesh plugs, fitting drainage ledges between tanks canted back to the process tank, inclining the barrel from one end may be restricted by product specifications.

Economics
Many of these measures can be incorporated into the operation of any barrel plant. Barrels have a limited operating life, require maintenance, are not capital intensive, and design can be improved and implemented gradually.

Other measures, such as draining and dwell time, will depend on the transporter control equipment used.

Increasing time for draining can reduce throughput and machine capacity.

Driving force for implementation
Savings in chemicals and other inputs for degreasing. Reduction in wastes produced.

Example plants
Exhall Plating, Ltd, Coventry, UK.
Collini GmbH, Austria.

Reference literature
[3, CETS, 2002],[113, Austria, 2003], [104, UBA, 2003] [165, Tempany, 2004](personal communication, Martin Peter, GmbH, Collini GmbH)

4.3.1.2 Emissions to air

4.3.1.2.1 Off-gas extraction as close as possible to the emission source

See Section 4.2.8.2.3.

4.3.1.2.2 Adsorption

See Section 4.2.8.2.4.1.

4.3.1.2.3 Aerosol/droplet separator

See Section 4.2.8.2.4.3.

4.3.1.2.4 Biofilter

See Section 4.2.8.2.4.4.

4.3.1.2.5 Cyclone

See Section 4.2.8.2.4.5.

4.3.1.2.6 Fabric filter

See Section 4.2.8.2.4.6.

4.3.1.2.7 Demister

See Section 4.2.8.2.4.7.

4.3.1.2.8 Wet scrubber

See Section 4.2.8.2.4.8.

4.3.1.2.9 Thermal oxidation

Description
Abatement technique which oxidises combustible compounds in a waste gas stream by heating it with air or oxygen to above its auto-ignition point in a combustion chamber and maintaining it at a high temperature long enough to complete its combustion to carbon dioxide and water. The typical combustion temperature is between 800 °C and 1 000 °C.

Several types of thermal oxidation are operated:

- Straight thermal oxidation: thermal oxidation without energy recovery from the combustion.
- Recuperative thermal oxidation: thermal oxidation using the heat of the waste gases by indirect heat transfer.
- Regenerative thermal oxidation: thermal oxidation where the incoming waste gas stream is heated when passing through a ceramic-packed bed before entering the combustion chamber. The purified hot gases exit this chamber by passing through one (or more) ceramic-packed bed(s) (cooled by an incoming waste gas stream in an earlier combustion cycle). This reheated packed bed then begins a new combustion cycle by preheating a new incoming waste gas stream.

Technical description
See Section 4.2.8.2.4.9.

Technical considerations relevant to applicability
Applicability may be restricted where the energy demand is excessive due to the low concentration of the compound(s) concerned in the process off-gases. Applicability of recuperative and regenerative thermal oxidation to existing plants may be restricted by design and/or operational constraints.

Example plants

AT005, AT016, BE018, CZ012, ES014, FR011 and IT032.

Reference literature
[168, TWG, 2023]

4.3.1.2.10 Optimised combustion

See Section 4.2.8.2.5.1.

4.3.1.2.11 Low-NO_X burner

See Section 4.2.8.2.5.2.

4.3.2 Aluminium coil, sheet conversion coating and anodising

4.3.2.1 Material efficiency

4.3.2.1.1 Recovery of caustic etch solution

Description
A regeneration system recirculates the etch solution continuously between the etch tank and a separate crystalliser tank, where the etch solution is seeded with alumina crystals in a separate crystalliser tank. It is then possible to regenerate the etch solution without scale building up. The hydrated alumina crystals formed in the crystalliser settle out in a settlement section. Regenerated etch solution, with reduced aluminium and increased free caustic levels, feeds back to the etch bath directly from the top of the crystalliser. Alumina crystals are withdrawn periodically from the bottom of the crystalliser and dewatered in a vacuum filter.

See also Section 4.2.6.5.5.

Applicability
May not be applicable in cases where the use of additives to achieve a specific surface specification interferes with the process or prevents the reuse of the alumina.

4.3.2.1.2 Agitation of process solution

Description
Agitation of process solution (e.g. with air injection or hydraulic turbulence) for improving efficiency.

See also Section 4.2.6.4.2.

Applicability
Generally applicable.

Driving force for implementation
Process efficiency including cost and quality.

Example plants
BE005, CZ011, DE001, DE002, DE003, DE005, DE006, DE007, DE008, DE012, DE078, ES020, FR027, FR033 and FR036 [168, TWG, 2023].

Reference data

[168, TWG, 2023].

4.3.2.1.3 Automatic systems for the preparation and dosing of process chemicals

Description
Automatic systems are used for weighing, dosing, dissolving, measuring and dispensing of process chemicals.

More information is available in Section 4.2.6.4.3.1.

Applicability
Generally applicable.

Driving force for implementation
Material efficiency including cost and quality.

Example plants
DE001, DE002, DE003, DE005, DE006, DE007, DE008, DE009, DE010, DE012, DE059, ES001, ES020, FI004, FR023, FR027 and FR029 [168, TWG, 2023].

Reference data
[168, TWG, 2023].

4.3.2.2 Water efficiency

4.3.2.2.1 Recirculation of rinsing water

Description
In multiple rinsing, rinsing water from the subsequent rinsing steps is used in the previous rinsing steps.

Technical description
See information in Sections 2.4.10.4 and 4.2.6.8.10.

Achieved environmental benefits
Significant reduction in water consumption within the process, with a commensurate reduction in waste water volumes and treatment.

Applicability
Generally applicable to new and existing plants for rinsing.

Economics

Driving force for implementation
Process efficiency.

Example plants
CZ011, DE059, FI004 and FR023 [168, TWG, 2023]

Reference literature
[168, TWG, 2023]

4.3.2.2.2 Recirculation of rinsing water from etching and surface treatment to the treatment baths

Description
Rinsing water from etching and surface treatment is collected and undergoes treatment to remove contaminats. The treated water is then returned as water input to the treatment vats.

Technical description
See more information in Section 4.3.3.4.2.

Environmental performance and operational data
It is essential to ensure that the recirculated water maintains the desired chemical composition and concentration for the processes where it will be reused, which may require regular monitoring and adjustments to the recirculation system.

Achieved environmental benefits
Reduction of the consumption of fresh chemicals and water, lower operational costs and reduction of waste generation.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Driving force for implementation
Reduction of chemicals and water consumption and of the associated operational cost.

Example plants
FR027, FR032, ES012, ES021, ES020 and DE010 [168, TWG, 2023]

Reference literature
[168, TWG, 2023]

4.3.2.2.3 Recovery and/or reuse of water (e.g. from cooling, rinsing or after waste water treatment)

Description
This includes:

- use of cooling water for rinsing;
- use of the output water from the cooling system to re-new water in the next rinsing vats instead of adding fresh water;
- use of spent rinsing water for cooling the etching baths.

Environmental performance and operational data
It is essential to ensure that the recirculated water maintains the desired chemical composition and concentration for the processes where it will be reused, which may require regular monitoring and adjustments to the recirculation system.

Achieved environmental benefits
Reduction of the consumption of fresh chemicals and water, lower operational costs and reduction of waste generation.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Driving force for implementation
Reduction of chemicals and water consumption and of the associated operational cost.

Example plants
ES010, ES012 and DE010 [168, TWG, 2023]

Reference literature
[168, TWG, 2023]

4.3.2.2.4 Use of closed cooling systems

Description
Closed systems use a secondary system, such as refrigeration, for cooling the recirculating coolant in the primary system.

Technical description

Environmental performance and operational data
In closed cooling systems, the coolant is not in contact with the outside air. This minimises corrosion and there is no build-up of dissolved solids. The cooling system may be refrigerated or pass through fan-cooled radiators.

Achieved environmental benefits
Reduction of the consumption of fresh water, lower operational costs and reduction of waste generation.

Cross-media effects
Electricity is consumed for pumping and for chilling in refrigerated systems.

Technical considerations relevant to applicability
Generally applicable.

Driving force for implementation
Reduction of water consumption and of the associated operational cost.

Example plants
BE001, DE003, DE005, DE006, ES012, ES020, DE012, FR016 and PL001 [168, TWG, 2023]

Reference literature
[168, TWG, 2023]

4.3.2.3 Energy efficiency

4.3.2.3.1 Heat recovery fron the anodising sealing baths

Description
The heat of spent sealing solutions can be used to heat the water used for a new sealing process, either by using a heat exchanger or by piping the incoming cold water through the hot sealing solution. See also Section 4.2.3.6.4.

Applicability
Generally applicable

4.3.2.3.2 Use of medium-temperature sealing systems in anodising of aluminium

Description
The hot water sealing method typically operates at a temperature range of 90 °C to 100 °C, lower than some alternative sealing processes that require temperatures up to 160 °C. In addition, it can be combined with reuse of hot water that is readily available.

Technical considerations relevant to applicability
Generally applicable.

Example plants
DE012.

Reference literature
[168, TWG, 2023]

4.3.2.3.3 Combined heat and power generation

Description
Combined generation of heat and electricity where the heat (mainly from the steam that leaves the turbine) is used for producing hot water/steam to be used in industrial processes/activities or in a district heating/cooling network.

Applicability
Applicability may be limited by the availability of a consistent and adequate heat demand.

Example plants
DE001.

Reference literature
[168, TWG, 2023]

4.3.2.3.4 Ambient cooling

Description
Use of ambient air for cooling of equipment and processes.

Technical description
In cold weather conditions, when the outside temperature is below 7 °C, ambient cooling using outside air can be used for cooling equipment, production halls or processes. This passive cooling technique takes advantage of the lower ambient temperature to dissipate heat from the system, reducing the need for energy-intensive mechanical cooling systems such as air conditioners or chillers.

During ambient cooling, warm air from the equipment, room or process is expelled outside, while the cooler outside air is drawn in to absorb the excess heat. This process continues until the desired temperature is reached or the outside air temperature becomes too warm to maintain the cooling effect.

Applicability
Applicability may be limited due to prevailing climatic conditions.

Environmental performance and operational data

There are various factors that may influence the suitability and efficiency of the technique such as the following:

- Temperature efficiency: As the outside temperature drops, the cooling efficiency of ambient cooling increases. However, when the temperature approaches the dew point, condensation may occur, which could lead to moisture-related issues.
- Insulation: Proper insulation of the equipment, rooms, or pipes is essential to minimise heat loss and improve the efficiency of the ambient cooling process.
- Airflow management: Ensuring proper airflow is crucial for effective heat exchange. This includes optimising the placement of air inlets and outlets, as well as minimising obstructions that could impede air movement.
- Compatibility: Ambient cooling may not be suitable for all applications, particularly those that require a specific temperature range or have sensitive components that could be affected by cold temperatures.
- Safety: In extremely cold weather conditions, precautions should be taken to prevent freezing of pipes, equipment, or sensitive components.

In warmer weather conditions, ambient cooling may still be effective, but its efficiency will be lower, and supplemental cooling methods may be required to maintain the desired temperature. High humidity can also affect the performance of ambient cooling, as it reduces the heat transfer capacity of the air.

Example plants
DE001.

Reference literature
[168, TWG, 2023]

4.3.2.4 Emissions to air

4.3.2.4.1 Off-gas extraction as close as possible to the emission source

Description
Off-gases are extracted using, for example, full enclosure, edge or lip extraction.

Technical description
See Section 4.2.8.2.3.

Example plants
Many plants in the STM data collection [168, TWG, 2023]

Reference literature
[168, TWG, 2023]

4.3.3 Continuous steel coil coating

[Note to the TWG: This section corresponds to Section 4.14 of the existing BREF]

4.3.3.1 Material efficiency

4.3.3.1.1 ~~Using digital~~ Advanced process monitoring and control systems

Description
~~Digital process control systems collect data and react on the processes in real time.~~
More information is available in ~~See~~ Section 4.2.6.4.1.

Achieved environmental benefits
Improved plant efficiency and product quality as well as lowering the emissions.

Cross-media effects
None.

Applicability
Generally applicable in new and existing plants.

Economics
Initial investment is high: EUR >0.8/t installed, with high operating and maintenance costs of EUR >0.8/t (2003 data).

Driving force for implementation
Process efficiency and quality requirements.

Example plants
Many continuous electroplating lines in Europe ~~EU-15~~.

Reference literature
[19, Eurofer, 2003]

4.3.3.1.2 Squeeze rolls

Description
The remaining solutions or rinse-waters on the steel strip are removed from the strip by squeeze rolls before leaving each section. This ensures that the drag out of solution into the next section is minimised as is the loss of chemicals and contamination of rinse-waters.

See also information for drag-out reduction in Section 4.2.6.7.

Achieved environmental benefits
There is significant reduction of raw material consumption. This then reduces the rinsing water needed and the waste water volumes. There is a consequent reduction in treatment chemicals and sludge produced at the waste water treatment plant.

Cross-media effects
No ~~negative~~ cross-media effects.

Environmental performance and operational data
See emissions from the process, waste sludge, water usage and raw material usage, in Section 3.3.

Technical considerations relevant to applicability
Generally applicable to new and existing plants after the plating section and passivation sections

Economics
The initial investment is moderate ~~at about~~ and can be estimated around EUR 50 k ~~>0.015 - 0.8/t~~ per cell installed and the operating costs are low, at about EUR 0.001- 0.15/t (EUROFER input in [167, TWG, 2023]).

Driving force for implementation
Process efficiency including cost and quality.

Example plants
AT013, BE002, DE031, DE034, ES005, ES006, ES008, FR004 and SK001 [168, TWG, 2023].

Reference literature
[19, Eurofer, 2003] [167, TWG, 2023], [168, TWG, 2023].

4.3.3.1.3 Electrolytic strip cleaning

Description
Before coating, the strip must be perfectly clean. Oil from the previous step (temper mill) is removed by an electrolytic process.

Technical description.
See Section 4.2.7.17.7

Technical considerations relevant to applicability
Generally applicable. This technique is part of electrolytic strip coating, mandatory to ensure tin or zinc adhesion.

Reference literature
Eurofer submission in [167, TWG, 2023].

4.3.3.1.4 Use of ultrafiltration systems to regenerate degreasing solution

Description
Electrolyte used for strip cleaning is recirculated in a closed loop; before reuse, the oil residues contained are filtrated.

More information is available in ~~See~~ Section 4.2.6.5.13.6.

Achieved environmental benefits
Compared to an open loop system, it drastically reduces the quantity to treat.

Technical considerations relevant to applicability
Generally applicable. All existing and new lines are normally equipped.

Economics
Cost saving by recirculating cleaning electrolyte.

Example plants
BE002, DE031, DE034 and IT010.

Reference literature
[19, Eurofer, 2003] [167, TWG, 2023], [168, TWG, 2023]

4.3.3.1.5 Cascade (multiple) use of degreasing solutions

Description
Strip degreasing typically involves two or three electrolytic cells. A shared electrolyte solution is utilised. Fresh electrolyte is introduced in the final cell, and a backward counterflow mechanism enables its reuse in the preceding cells.

Technical description
See more information in Section 4.2.6.5.13.1.

Achieved environmental benefits

Reduction of the quantity of cleaning solution in operation.

Technical considerations relevant to applicability
Generally applicable. Applicable to all existing and new lines, normally part of standard design.

Driving force for implementation
Cost saving by reducing the quantity of cleaning solution and waste reduction.

Example plants
AT013, BE002 and DE034.

Reference literature
[19, Eurofer, 2003] [167, TWG, 2023] [168, TWG, 2023]

4.3.3.1.6 Control of the acidity ~~bath~~ in the pickling section

Description
This includes adjusting the concentration, temperature and flow rate of the acid solution. More information is available in Sections 4.2.6.4.3.1 and 4.2.6.5.14.

4.3.3.1.7 Ultrasonic cleaning

Description
Cleaning using high-frequency vibrations to loosen the adhered contamination.

Technical description
An ultrasonic cleaner generates high-frequency vibrations through a liquid (usually water-based detergents), i.e. ranging from about 20 000 to 100 000 cycles per second. The vibrations create microscopic bubbles in the liquid that then collapse on items that are immersed in the liquid, creating a cleaning action.

More information is available in Section 4.2.7.17.6 and in [174, COM, 2020]

Achieved environmental benefits
No solvent-based cleaning agents are used and VOC emissions are eliminated.

Cross-media effects
Noise levels might increase. And energy consumption may increase due to the need to heat the water-based mixture.

Technical considerations relevant to applicability
The applicability may be restricted by the type of process, the substrate or equipment to be cleaned and the type of contamination.

It is not applicable for substrates and parts that might be damaged by the ultrasonic vibrations.

Driving force for implementation
Workplace health and safety.

Example plants
IT010.

Reference literature
[168, TWG 20203]

4.3.3.1.8 Control and management of electrolyte consumption

Description

~~For~~ In tin plating: Following the plating section, the strip passes through a rinse section drag-out. To minimise the loss of electrolyte, the electrolyte is spray rinsed with a dilute solution of PSA and tin, it is then returned to an electrolyte recirculation tank. An evaporator system is then used to condense the dilute electrolyte solution through evaporation, ~~and~~ which is then returned to the process for re-use.

~~For~~ In acid zinc plating: An evaporator in a closed loop with a scrubber (for the plating cells) as with the zinc electrolyte tanks and the plating rinse cells, concentrates the ions (Zn^{++}, SO_4^-) in the residue and produces distilled water from the steam. The concentrated ions are re-used and injected into the electrolyte while the distilled water is re-used and injected into the different processes.

See also Sections 4.2.6.8.2 and 4.2.6.8.5.

Achieved environmental benefits

Reduction of raw material consumption as the electrolyte is re-used. Reduction of waste water volumes and sludge from the waste water treatment plant.

Cross-media effects

None.

Environmental performance and operational data

See emissions from the process, waste sludge, water usage and raw material usage, Section 3.3

Technical considerations relevant to applicability

Generally applicable to new and existing plants.

Economics

For tin: Initial investment is EUR 0.015 to 0.8/t installed with operating and maintenance costs of EUR 0.015 to 0.8/t (2003 data).

For zinc: The initial investment is EUR >0.8/t installed, with EUR 0.015 to >0.8/t (2003 data) for operating and maintenance costs.

Driving force for implementation

Process efficiency and product quality.

Example plants

Many continuous electroplating plants in the EU~~-15~~.

Reference literature

[19, Eurofer, 2003]

4.3.3.1.9 Switching the polarisation of the electrodes in the electrolytic processes

Description

The polarisation of electrodes in electrolytic degreasing and in electrolytic pickling processes is switched at regular time intervals.

Technical description

See Section 4.2.6.4.3.3.

Technical considerations relevant to applicability
Only applicable in plants with bipolar electrodes.

Example plants
DE034 and SK001.

Reference literature
[168, TWG 2023]

4.3.3.1.10 Optimisation of the anode-cathode gap

Description
A mechanism of adjusting the gap as a function of the ~~processed~~ strip to be processed (width-thickness-flatness).

Achieved environmental benefits
Optimisation of the energy consumption, reduction of the contacts between anode and strip surface, increasing quality and cutting strip rejections.

Environmental performance and operational data
This technique helps to optimise the coating process by ensuring uniformity and efficiency. The gap between the rollers in the coil coating line is adjusted according to the specific dimensions and characteristics of the strip to avoid issues such as wrinkling, edge waviness, and inconsistent coating thickness. This enables better control over the final product’s quality and performance.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable. ~~To new lines.~~

Economics
The initial investment is EUR 0.001 to 0.15/t installed with operating and maintenance costs of EUR 0.001 to 0.15/t (2003 data).

Driving force for implementation
Process efficiency, reduced energy consumption.

Example plants
Many continuous electroplating plants in the EU ~~15~~.

Reference literature
[19, Eurofer, 2003]

4.3.3.1.11 Polishing the conductor roll

Description
Oscillating abrasive blades continuously polish the conductor rolls surface avoiding zinc and or nickel build-up.

Achieved environmental benefits
Longer conductor roll lifetime, longer processing time, minimisation of strip surface defects.

Cross-media effects
None.

Operational data

Technical considerations relevant to applicability
Generally applicable to new and existing lines.

Economics
The initial investment is EUR 0.015 to 0.8/t installed, with operating and maintenance costs of EUR 0.001 to 0.15/t (2003 data).

Driving force for implementation
Productivity, conductor rolls lifetime, plated strip yield and quality.

Example plants
Many continuous electroplating plants in the EU~~-15~~

Reference literature
[19, Eurofer, 2003]

4.3.3.1.12 Using edge polishers

Description
Removal of zinc dendrites formed at the strip edges in zinc electroplating cells equipped with low anode-cathode gaps.

Achieved environmental benefits
Minimisation of strip surface defects (dents).

Cross-media effects
Material losses.

Technical considerations relevant to applicability
Generally applicable to new and existing lines ~~in the EU-15~~.

Economics
The initial investment is EUR 0.001 to 0.15/t installed, with operating and maintenance costs of EUR 0.001 to 0.15/t (2003 data).

Driving force for implementation
Plated strip yield and quality to customer's requirements.

Example plants
Many continuous electroplating plants

Reference literature
[19, Eurofer, 2003]

4.3.3.1.13 Using edge masks

Description
Edge masks move between the anode and the strip to avoid zinc dendrites and zinc overthrow (when plating one side only) at the strip edges.

Achieved environmental benefits
~~Environmental benefit low.~~
Avoids side trimming (material loss), minimisation of strip surface defects.

Cross-media effects

None.

Technical considerations relevant to applicability
Applicability may be restricted if the anode-cathode gap is not wide enough. Generally applicable to new ~~lines~~ and existing lines if the anode-cathode gap is wide enough.

Economics
The initial investment is medium, with medium operating and maintenance costs.

Driving force for implementation
Plated strip yield and quality.

Example plants
Many continuous electroplating plants use this technique in the EU~~-15~~.

Reference literature
[19, Eurofer, 2003]

4.3.3.1.14 ~~Minimise~~ Optimised use of oil ~~by covered electrostatic oilers~~

Description
Use of covered electrostatic oilers where the anticorrosion or deep drawing oil is heated and electrostatically deposited on the surface. The splashed oil is collected and reused.

Technical description
A light oil (anticorrosion or deep drawing oil) is heated and electrostatically deposited on the surface. The oil layer weight lies within a narrow range. The machine is covered and the splashed oil is collected and re-used. Electrostatic application is a more efficient and effective method of coating to minimise the amount of oil used within the system.

Achieved environmental benefits
Reduction of raw material consumption, minimises waste and oil fume emissions.

Technical considerations relevant to applicability
Applicability in existing plants may be restricted by a lack of space.~~To new plants and existing plants if space is available.~~

Economics
The initial investment is EUR >0.8/t installed with EUR 0.015 to 0.8/t operating costs (2003 data).

Driving force for implementation
Primarily customer requirements, then process efficiency.

Example plants
Many continuous electroplating plants.

In the STM data collection, plants: AT013, ES006, ES007, ES008 and SK001.

Reference literature
[19, Eurofer, 2003], [168, TWG, 2023]

4.3.3.1.15 Maintenance of process solutions

See also Section 4.2.6.5. where specific examples of applications for coil coating are described.

4.3.3.1.15.1 Cleaning and recirculation of degreasing baths

Description
Spent degreasing solution is cleaned; the oil residues out of the regeneration devices are recovered for heat recovery; the treated degreasing bath is recycled within the degreasing section. See also Section 4.2.6.5.13.

Achieved environmental benefits
Significant reduction of alkaline chemical consumption, reduction of water and sludge volumes in the waste water treatment plant.

Cross-media effects
Increases section energy consumption.

Technical considerations relevant to applicability
Generally applicable. ~~To new and existing plant, if space is available.~~

Economics
The investment costs are EUR 0.015 to 0.8/t installed and operating costs are EUR 0.001 to 0.15/t (2003 data).

Driving force for implementation
Process efficiency primarily.

Example plants
In several continuous electroplating lines ~~in the EU-15~~.

Reference literature
[19, Eurofer, 2003]

4.3.3.1.15.2 Continuous filtering and re-use of the zinc bath

Description
By-pass mechanical filtering for bath regeneration and internal recycling is used for cleaning zinc baths.

Achieved environmental benefits
Environmental benefit are medium.
Reduces materials input (Zn, H_2SO_4), water consumption, waste water and sludge releases.

Cross-media effects
Low amount of energy used for pumping through filters.

Technical considerations relevant to applicability
Generally applicable. ~~To new and existing lines if space is available~~

Economics
The initial investment is medium, with medium operating and maintenance costs.

Driving force for implementation
Process efficiency, primarily customer requirements.

Example plants
Many continuous electroplating plants ~~in the EU-15~~.

Reference literature
[19, Eurofer, 2003]

4.3.3.1.15.3 Continuous filtering (removal of iron) and re-use of the zinc bath

Description
The electrolyte is circulated through an off-line tank and treated with H_2O_2 to oxidise Fe(II) into Fe(III). The $Fe(OH)_3$ is collected either by precipitation or by an ion exchanger.

Achieved environmental benefits
Reduces materials input (Zn, H_2SO_4), water consumptions, waste water and sludge releases, reduces strip defects.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable. ~~To new and existing lines, if space is available.~~

Economics
The initial investment is EUR 0.015 to 0.8/t installed, with EUR 0.015 to for 0.8/t operating and maintenance costs.

Driving force for implementation
Process efficiency, primarily customer requirements.

Example plants
Many continuous electroplating plants ~~in the EU-15~~.

Reference literature
[19, Eurofer, 2003]

4.3.3.1.15.4 Cleaning and regeneration of the phosphate bath

See Section 4.2.6.5.12.

4.3.3.1.15.5 Cleaning and regeneration of the chromate bath

Description
See techniques given in Section 4.2.6.5. Spent chromate bath is filtered; the concentrations in metallic ions and the pH are adjusted. The regenerated chromate solution is re-used.

Achieved environmental benefits
Environmental benefit is high: reduces chemicals consumption, reduces water and sludge releases

Cross-media effects
Depends on regeneration techniques used.

Technical considerations relevant to applicability
Generally applicable. ~~To new and existing plants, if space is available~~

Economics

The investment costs are EUR 0.015 to 0.8/t installed and operating costs are EUR 0.001 to 0.15/t (2003 data).

Driving force for implementation
Process efficiency primarily.

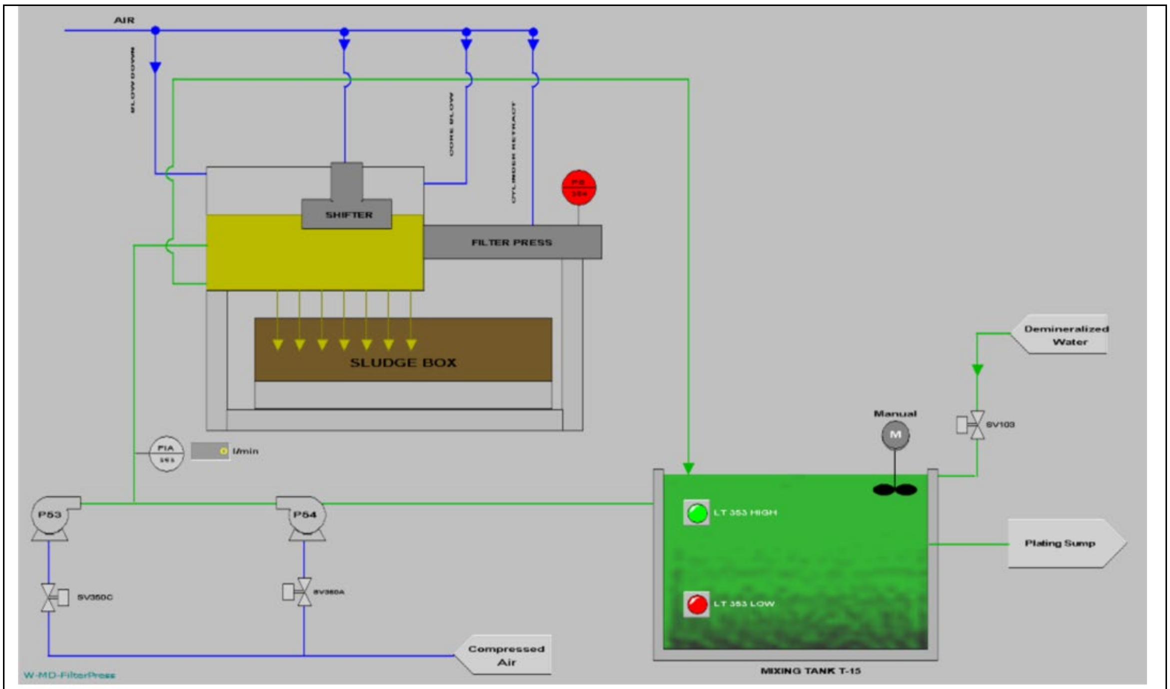
Example plants
Several continuous electroplating lines

Reference literature
[19, Eurofer, 2003]

4.3.3.1.16 Recovery of residual tin ~~metals~~ from recirculation tanks

Description
The tin from the recirculation tanks can be recovered through the use of a filter press that separates tin sludge from electrolyte within the tin line operation. Separated tin sludge contains approximately 60% tin and can be externally recovered. ~~treatment of the waste waters by precipitation using lime and then reprocessing by a metal reprocessor.~~

Technical description
The layout of the filter press installation is shown in the following figure.



Source: (EUROFER input in [167, TWG, 2023])

Figure 4-48: Layout of the filter press system

Achieved environmental benefits
Reduction in waste to landfill and recovery of the raw material.

Cross-media effects
Lime used in the process.

Technical considerations relevant to applicability

Generally applicable to new and existing plants.

Economics
The initial investment is EUR 0.015 to 0.8/t installed along with maintenance costs of EUR 0.015 to 0.8/t (2003 data).

Driving force for implementation
Process efficiency and reduction in waste disposal costs and quality improvement.

Reference literature
[19, Eurofer, 2003], [167, TWG, 2023]

~~4.3.3.2 Oil tight trays~~

[This technique is proposed for deletion as it is a repetition of technique in Section 4.2.6.1.2]

~~**Description**~~
~~Leakage from hydraulic systems to soils, surface and groundwater is prevented through use of oil tight trays.~~

~~**Achieved environmental benefits**~~
~~Minimises the possible release of oil to land and water.~~

~~**Applicability**~~
~~New and existing plants~~

~~**Cross-media effects**~~
~~None.~~

~~**Operational data**~~
~~Improves operator health and safety, by reducing slippage on oily floors.~~

~~**Economics**~~
~~Initial investment is low EUR 0.001 – 0.15/tonne installed, with low operating costs 0.001 – EUR 0.15/tonne installed.~~

~~**Driving Force for Implementation**~~
~~Process efficiency.~~
~~Health and safety.~~

~~**Example plants**~~
~~Many continuous electroplating lines in EU-15.~~

~~**Reference literature**~~
~~[19, Eurofer, 2003]~~

4.3.3.3 Energy efficiency

4.3.3.3.1 Energy-efficient motors

Description
See Section 4.2.3.3.1 on the application of energy-efficient motors where motors are used in the process.

Achieved environmental benefits
Reduction in energy consumption on the line.

Cross-media effects
None

Applicability
Can be used in new plant or as replacement parts

Economics
The initial investment is medium: EUR 0.015 – 0.8/t installed.
Operating costs are low EUR 0.001 to 0.15/t.

Driving force for implementation
Process efficiency.

Example plants
Many continuous electroplating lines in EU-15.

Reference literature
[19, Eurofer, 2003]

4.3.3.3.2 Raising the conductivity of the electrolyte

[This technique is proposed for deletion by EUROFER (EUROFER input in [167, TWG, 2023]) based on the argument that conducting chemical compounds may change the crystalline structure of the deposit, something that sometimes is desired as a brightener but in other cases it is not]

4.3.3.4 Water efficiency

4.3.3.4.1 Re-cycling of quench waters

Description
To produce a bright finish on the product following flow melting in tin plating, the strip is cooled via a water quench. This water is recycled and re-used until it is disposed of when there is too high a build-up of tin.

Applicability
Generally applicable to new and existing plants.

Economics
The initial investment is EUR 0.015 to 0.8/t installed, along with operating costs of EUR 0.015 to 0.8/t (2003 data).

Driving force for implementation
Process quality and customer requirements

Example plants
Many continuous electroplating lines in EU~~-15~~.

Reference literature
[19, Eurofer, 2003]

4.3.3.4.2 Recirculation of rinsing water ~~Use of cascade rinse systems~~

Description
In multiple rinsing, rinsing water from the subsequent rinsing steps is used in the previous rinsing steps. ~~The first spray water is recycled back to the initial stages.~~

Technical description
See information in Sections 2.4.10.4 and 4.2.6.8.10.

Achieved environmental benefits
Significant reduction in water consumption within the process, with a commensurate reduction in waste water volumes and treatment.

Applicability
Generally applicable to new and existing plants for rinsing.

Economics
The initial investment is EUR 0.015 to 0.8/t installed with an operating and maintenance cost of EUR >0.8/t (2003 data).

Driving force for implementation
Process efficiency.

Example plants
AT013, BE002, DE031, DE034, ES006, ES007, ES008 and FR004 [168, TWG, 2023]

Reference literature
[19, Eurofer, 2003], [168, TWG, 2023]

4.3.3.4.3 Recirculation of rinsing water from etching and surface treatment to the treatment baths

Description
Rinsing water from etching and surface treatment is collected and undergoes treatment to remove contaminats. The treated water is then returned as water input to the treatment vats.

Technical description
The rinsing water, which has been used to clean and prepare the metal strip’s surface for chemical treatment, contains residues of the chemicals used in the etching and surface treatment processes. By returning this water to the treatment baths, the chemicals can be reused, and the overall consumption of water and fresh chemicals is reduced.

The collected water is then transferred to a treatment system, which may include filtration, sedimentation, and/or chemical treatment to remove impurities and contaminants.

The treated water is then returned to the treatment baths, where it can be reused for subsequent etching and surface treatment processes.

Environmental performance and operational data
It is essential to ensure that the recirculated water maintains the desired chemical composition and concentration for the processes where it will be reused, which may require regular monitoring and adjustments to the recirculation system.

Achieved environmental benefits
Reduction of the consumption of fresh chemicals and water, lower operational costs and reduction of waste generation.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Driving force for implementation
Reduction of chemicals and water consumption and of the associated operational cost.

Example plants
BE002, ES008, FR004 [168, TWG, 2023]

Reference literature
[168, TWG, 2023]

4.3.3.4.4 Use of closed cooling systems

Description
Closed systems use a secondary system, such as refrigeration, for cooling the recirculating coolant in the primary system.

Technical description

Environmental performance and operational data
In closed cooling systems, the coolant is not in contact with the outside air. This minimises corrosion and there is no build-up of dissolved solids. The cooling system may be refrigerated or pass through fan-cooled radiators.

Achieved environmental benefits
Reduction of the consumption of fresh water, lower operational costs and reduction of waste generation.

Cross-media effects
Electricity is consumed for pumping and for chilling in refrigerated systems.

Technical considerations relevant to applicability
Generally applicable.

Driving force for implementation
Reduction of water consumption and of the associated operational cost.

Example plants
DE031, ES005, ES008, FR004 and SK001 [168, TWG, 2023].

Reference literature
[168, TWG, 2023]

4.3.3.4.5 Use of condensate recovery steam pipes

Description
Condensate recovery steam pipes are used in steam systems to collect and return condensed steam (condensate) back to the boiler for reuse.

Technical description
In a steam system, as the steam flows through piping, it can lose heat and eventually condense back into water. Condensate recovery pipes are installed to collect this condensed water, which can still carry a significant amount of heat energy.

The condensate recovery system typically consists of a network of pipes that transport the condensate back to the boiler, along with traps, separators and pumps to ensure efficient and effective collection and return of the condensate.

Achieved environmental benefits
The primary purpose of this system is to improve energy efficiency and reduce water consumption by recycling the condensate.

By returning the condensate to the boiler, less fresh water is needed and the system's overall efficiency is improved as the heat energy in the condensate is utilised again in the boiler, reducing energy consumption and operational costs.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Economics
Cost associated with the installation and maintenance of the pipes network.

Driving force for implementation
Reduction of energy and water consumption and of the associated operational cost.

Example plants
ES007 and SK001 [168, TWG, 2023].

Reference literature
[168, TWG, 2023]

4.3.3.5 ~~Control of~~ Emissions to air

4.3.3.5.1 Off-gas extraction as close as possible to the emission source

Description
Off-gases are extracted using, for example, full enclosure, edge or lip extraction.

Technical description
See Section 4.2.8.2.3. For coil processing, to reduce emissions to air and to maintain occupational health standards within the workplace, air can be extracted from cleaning, pickling, plating and chemical treatment sections. An abatement ~~scrubber~~ system using, for example, wet scrubbers and demisters is used to remove contaminants.

Achieved environmental benefits
Reduction in emissions to air.

Cross-media effects
Increase in energy consumption. Increase in the amount of waste water ~~s~~ requiring treatment.

Environmental performance and operational data
See the relevant emissions from the process~~, waste sludge, and water usage,~~ in Section 3.3.4.

Applicability
Generally applicable to new and existing plants.

Economics

The initial investment is EUR >0.8/t installed, with operating and maintenance costs of EUR >0.8/t (2003 data).

Driving force for implementation
Workplace environmental and health and safety legislation.
Avoids deterioration of installations and buildings through corrosion.

Example plants
Many continuous electroplating plants in the EU.

In the STM data collection: BE002, ES006, IT010 and SK001 [168, TWG, 2023]

Reference literature
[19, Eurofer, 2003], [168, TWG, 2023]

4.3.4 Printed circuit board processing

[Note to the TWG: This section corresponds to Section 4.15 of the existing BREF]

4.3.4.1 Material efficiency

4.3.4.1.1 Optimisation of dry resist development

Description
Monitoring and control of the concentration and temperature of the developer solution. When necessary, the developer solution is replenished by adding fresh solution.

Achieved environmental benefits
Raw material savings and process optimisation.

Technical considerations relevant to applicability
Generally applicable.

Driving force for implementation
Product quality.

Example plants
AT001, AT002, BE004, DE040 and DE060 [168, TWG, 2023].

Reference literature
[168, TWG, 2023]

4.3.4.1.2 Optimised oxide processes using less chemicals in the manufacturing of inner layers

Description
This includes the use of the brown oxide process that consists of hydrogen peroxide, organic additives and chloride running at 30 °C.

Technical description
Section 2.6.2.6 describes the black and brown oxide processes, and refers to newer processes. The black oxide is produced using chemicals such as sodium hypochlorite at high temperatures (approximately 80 °C). This is increasingly being replaced by the brown oxide process, which uses less hazardous chemicals such as sulphuric acid, hydrogen peroxide and organic additives which are biodegradable at temperatures of approximately 30 °C. The elementary copper is oxidised to copper (I) and preserved by additives.

However, other processes are now emerging (sometimes referred to as oxide alternative treatmentssee Section 4.3.4.1.3). Developments of these processes are rapid and driven by ever-increasing higher technical requirements

Achieved environmental benefits
Use of less hazardous chemicals.
Lower temperatures.
Less waste water is produced (see Environmental performane and operational data, below).

Technical considerations relevant to applicability
Generally applicable.

Cross-media effects
When a new solution is made (which becomes necessary every 24 months), the used solution is treated in a batch process by alkaline precipitation.

The acidic exhaust air is neutralised by an air scrubber.

Environmental performance and operational data
The concentration of the individual components is kept at a constant level by replenishing chemicals depending on the production volume. This replenishment equalises the loss of liquid which occurs by evaporation. Thus, hardly any effluents are generated.

Driving force for implementation
Product quality.
Workplace health and safety.

Example plants
BE004 and DE066 [168, TWG, 2023].
~~Major PCB producers in Germany use the brown oxide technique.~~
~~Alternative techniques are used in Finland.~~

Reference literature
[122, UBA, 2003], [159, TWG, 2004], [168, TWG, 2023]

4.3.4.1.3 Use of oxide-alternative techniques in the manufacturing of inner layers

Description
This includes techniques such as direct metallisation, sputtering, pulse reverse plating, and atomic layer deposition.

Technical description
Some oxide-alternative techniques for inner layer manufacturing include the following:

1. Direct metallisation: This technique involves depositing a thin layer of metal, such as copper or silver, directly onto the surface of the dielectric material without the need for an oxide layer. This can be achieved using techniques like sputtering, electroplating, or electroless plating. Direct metallisation offers improved adhesion and reduced process steps compared to traditional oxide techniques.

2. Sputtering: Sputtering is a vacuum deposition process that involves bombarding a target material with high-energy ions, causing it to eject atoms that then deposit onto the substrate. This technique can be used to deposit metal layers directly onto dielectric materials, eliminating the need for an oxide layer. Sputtering offers high-quality, uniform deposits and can be used for various metals, such as copper, silver and gold.

3. Pulse reverse plating (PRP): PRP is a modified electroplating process that uses alternating current (AC) to deposit metal onto the dielectric material. The reverse pulse helps to avoid the formation of oxide layers, resulting in a smoother, more uniform deposit. PRP can be used for depositing copper, nickel and other metals.

4. Electroplating with additives: In this technique, additives are introduced in the electroplating solution to improve adhesion and reduce the need for an oxide layer. These additives can include surfactants, organic binders, or organic modifiers that promote the formation of a stable metal layer on the dielectric surface.

5. Atomic layer deposition (ALD): ALD is a thin-film deposition technique that involves sequential, self-limiting surface reactions to deposit thin films of various materials, including metals. This technique can be used to deposit metal layers directly onto dielectric materials, eliminating the need for an oxide layer. ALD offers excellent control over film thickness and uniformity, but it is a relatively slow process compared to other techniques.

Achieved environmental benefits
The alternative techniques referred to above offer advantages in terms of efficiency, cost and environmental impact compared to traditional oxide methods in inner layer manufacturing.

Technical considerations relevant to applicability
Applicability may be restricted by process and product specifications.

Driving force for implementation

- Product quality.
- Workplace health and safety.

4.3.4.1.4 Etching optimisation

Description
This includes:

- online monitoring of acidic etchant and adjustment of HCl concentration;
- recirculation of the rinsing water of the first cascade into the etching solution while the etching parameters are kept at a constant level.

Technical description
See Section 2.6.2.9. It is good practice to monitor acidic etchant (HCl + H_20_2) online. The concentration of hydrochloric acid is determined via a titrator and replenished if necessary. The redox potential can also be monitored via a redox electrode and the hydrogen peroxide replenished.

Alkaline etching is conducted in a horizontal production line equipped with oscillation and special nozzles for an effective removal of copper. The solution is initiated by incorporating some etched copper. This solution is replenished continuously. The replenisher solution contains, among other substances, ammonium salts (chloride, sulphate, carbonates). By using ammonia the solution is adjusted to a pH level of 8 – 9.5.

After the etching process it is good practice to recirculate the rinsing water of the first cascade into the etching solution. The etching parameters are kept at a constant level as far as possible by continuously controlling and replenishing the solution with regeneration chemicals. Part of the solution is continuously discharged from the etching equipment. The copper (II) chloride waste solution resulting from the etching process is collected in a storage tank and is reconditioned externally by specialised companies into copper salts and hydrochloric acid. These basic materials can be fed into industrial processes again.

Acidic exhaust fumes may be removed via an air scrubber filled with an alkaline solution (NaOH) for neutralisation.

Achieved environmental benefits
Optimisation of chemicals usage and minimisation of water usage.
Recovery of copper and etchants from the used solutions.

Cross-media effects
Transport, storage and handling of waste solutions.
Alkali air scrubber solutions can be treated in a typical waste water treatment plant

Applicability
To all etching systems.

Driving force for implementation
Product quality.
Workplace air quality standards.

Example plants
All major PCB manufacturers.

Reference literature
[122, UBA, 2003]

4.3.4.1.5 Recycling of alkali etchants online with copper recovery ~~(liquid-liquid ion-exchange)~~

Description
The alkaline ammonia etching solution is regenerated and the dissolved copper is recovered on site in a closed loop.

Technical description
The alkaline ammonia etching solution can be regenerated and the dissolved copper can be recovered on-site by a commercially available process. The patented unit is installed in a closed loop within an alkaline etching system shown in Figure 4-47 and achieves the following functions:

- continual regeneration of the alkaline etchant bath
- uninterrupted recovery of the etchant copper in high purity form.
- purification of the rinsing water for re-use after etching.

Used etchant with 150 g/l of copper is passed through the first immiscible organic liquid extraction solution (in the Recycling equipment) and is returned as regenerated etchant with 110 g/l of copper. The solvent is now loaded with 50 g/l of copper.

Spent rinse-water with 5 g/l (5000 mg/l) of copper goes through a second immiscible organic liquid extraction solution (in the Recycling equipment) and comes out as regenerated rinse-water with 5 – 6 mg/l of copper. The immiscible organic liquid from this second extraction is loaded with an additional 5 g/l of copper.

The immiscible organic liquid is passed through a third extractor containing water-based electrolyte, has its copper load removed, and is returned to the first extractor. After the third extractor, the electrolyte is loaded with approximately 55 g/l of copper.

The copper is plated from the electrolyte onto the cathode in the electrowinning (electrolytic) cell.

Description of chemistry

For etching metallic copper from printed circuit boards:

$$Cu° + Cu(NH_3)_4Cl_2 \rightarrow 2\ Cu(NH_3)_2Cl \text{ (dissolution)}$$

$$2\ Cu(NH_3)_2Cl + 0.5O_2 + 2\ NH_3 + 2\ NH_4Cl \rightarrow 2\ Cu(NH_3)_4Cl_2 + H_2O \text{ (oxidation)}$$

In summary:

$$Cu° + 2\ NH_3 + 2\ NH_4Cl + 0.5\ O_2 \rightarrow Cu(NH_3)_4Cl_2 + H_2O$$

For extracting copper from spent etchant and used rinse-water (where R represents the molecule in the immiscible organic liquid extraction solution):

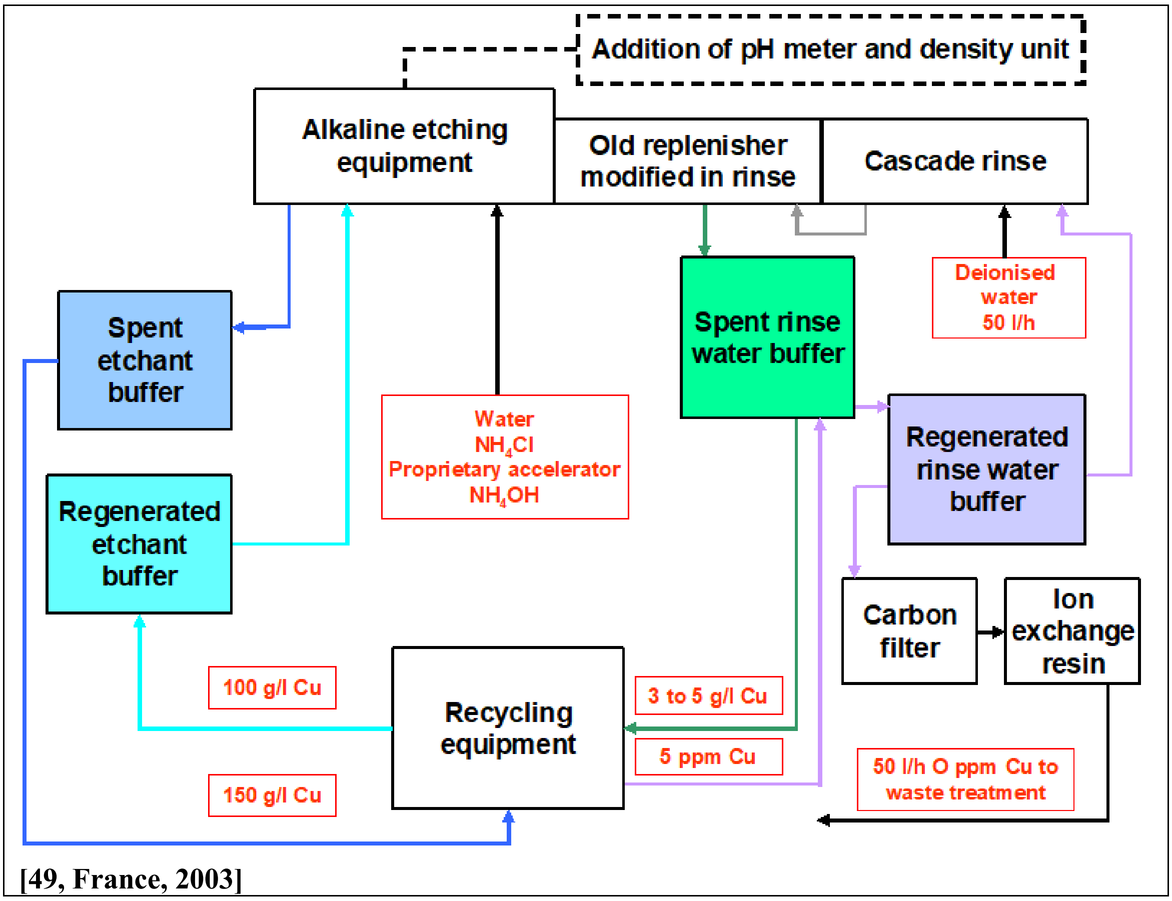
$$Cu(NH_3)_4Cl_2 + 2\ RH \text{ (org)} \rightarrow CuR_2 \text{ (org)} + 2\ NH_3 + 2\ NH_4Cl$$

For extracting copper from the organic liquid to the electrolyte:

$$CuR_2 \text{ (org)} + H_2SO_4 \rightarrow CuSO_4 + 2\ RH \text{ (org)}$$

For electrowinning copper metal from the electrolyte:

$$CuSO_4 + H_2O \rightarrow Cu° + H_2SO_4 + 0.5\ O_2$$



[49, France, 2003]

Figure 4-49: Recycling of alkali etchant in printed circuit board manufacture

Achieved environmental benefits

Reduction of ammonia and copper in the effluent.
Recovery of about 600 kg high quality copper per month (in example plant).
Decreased noise to local residential property from delivery and disposal vehicles.

Cross-media effects

Some additional power consumption for the unit.
The copper recovered is too high purity to re-use in-plant and is sold to a supplier.

Operational data

The equipment must be maintained by a skilled operator

Applicability

Alkali copper etchants.
Patented process.

Economics

Investment of EUR 100000 to 150000 (year 2003).
Payback: more than three years cost recovery from the resale of high quality copper, reduced effluent treatment and cost of replenishing etchant solution.

Driving force for implementation

Improved production quality of the printed circuit boards due to:

- constant etchant strength which allows constant speed through the etching process
- less handling problems of hazardous chemicals in delivery and disposal
- reduction of replenisher addition
- less tanker deliveries, with decreased noise.

Other advantages:

- no storage of spent etchant
- no transport and delivery of etchant solutions, reducing handling risks, etc.
- reduced noise and improved public perception of operation in neighbouring residential area.

Example plants

SOFRA-PCB, Mennecy, France.

Reference literature

[49, France, 2003]

4.3.4.1.6 Tin recovery from stripping of etch tin resist ~~Stripping of etch (tin) resist~~

Description

Recovery of tin contained in the precipitated sludge that results from the treatment of rinsing water and the concentrate.

Technical description

~~In horizontal production lines,~~An acidic medium containing nitric acid is applied by spray for stripping the etch resist (see Section 2.6.2.10). Organic complexing agents are present which require additional steps for the disposal of effluents. The rinsing waters and the concentrate have to be collected separately and treated with an organosulphide compound. The precipitate can be sent for recycling as a tin-rich sludge. The used concentrates may be disposed of externally.

Achieved environmental benefits
Separate treatment enables waste water treatment prior to discharge.
The tin may be recovered from the sludge produced.

Cross-media effects
Use of additional treatment chemicals.

Applicability
To all etch resist processes.

Driving force for implementation
Waste water policy and legislation.

Example plants
~~Most PCB plants in Germany.~~
AT002, BE004 and DE066 [168, TWG, 2023].

Reference literature
[12, PARCOM, 1992, 122, UBA, 2003], [168, TWG, 2023]

4.3.4.1.7 Rinsing between steps

See Sections 4.2.6.7 and 4.2.6.8. PCBs are usually operated in horizontal in-line modules, but the same techniques are applicable as for the other processes. In addition, squeeze rollers are used for PCBs which greatly assist with the prevention of drag-in and drag-out.

4.3.4.1.8 Electroless (autocatalytic) plating

Description
Electroless plating, also known as autocatalytic plating, is a chemical process used to deposit a thin layer of metal onto a substrate without the use of an electric current. In the context of printed circuit board (PCB) manufacturing, electroless plating is commonly used to deposit copper, nickel and gold onto the PCB surface.

Technical description
The electroless plating process involves immersing the PCB into a chemical bath containing a reducing agent, a metal salt and other additives. The reducing agent, typically sodium hypophosphite or dimethylamine borane, donates electrons to the metal ions in the bath, causing them to be deposited onto the PCB surface.

The main steps are as follows:
- Pretreatment: The PCB is cleaned and activated to ensure good adhesion between the metal deposit and the substrate.
- Immersion: The PCB is immersed into the electroless plating bath, which contains the metal salt, reducing agent, and other additives.
- Deposition: The reducing agent donates electrons to the metal ions, causing them to be deposited onto the PCB's surface.
- Post-treatment: The PCB is rinsed and dried to remove any residual chemicals.

Environmental performance and operational data
Electroless plating offers several advantages, including the following:

- Uniform deposition: Electroless plating produces a uniform layer of metal across the entire PCB surface, regardless of the complexity of the design.

- High aspect ratio: Electroless plating can deposit metal into small features and vias, making it ideal for high-density PCBs.
- Low cost: Electroless plating is a relatively low-cost process compared to other metal deposition techniques.
- Environmentally friendly: Electroless plating is a more environmentally friendly process than traditional electroplating methods, as it does not require the use of toxic chemicals or heavy metals.

Electroless plating is commonly used in PCB manufacturing for the following:

- Copper deposition: Electroless copper deposition is used to create a thin layer of copper on the PCB's surface, which serves as a seed layer for subsequent copper plating.
- Nickel deposition: Electroless nickel deposition is used to create a corrosion-resistant layer on the PCB's surface.
- Gold deposition: Electroless gold deposition is used to create a thin layer of gold on the PCB's surface, which provides a very reliable and corrosion-resistant finish.

See other solution maintenance techniques in Section 4.2.6.8.

Example plants
Electroless plating was reported by Plants BE004 and DE066 [168, TWG, 2023].

Reference literature
[168, TWG, 2023]

4.3.4.1.9 Optimisation of PCB electroplating ~~PCBs~~

Description
This includes the use of direct air injection, combined with oscillation and vibration of the boards. The panel is fixed in the lower part of the bath to ensure an optimum exchange of electrolytes inside the holes. The individual baths are served by automatic carriers.

Technical description
~~See the general issues applicable to electroplating in the Sections 4.2.6.4 to . In order to obtain a metal deposition as even as possible for PCBs it is state of the art~~ In vertical installations ~~to~~ use of direct air injection, combined with oscillation and vibration of the boards. In addition, the panel is fixed in the lower part of the bath so that an optimum exchange of electrolytes inside the holes is possible across the whole panel (usually 600 x 600 mm). The individual baths (micro etching, acid dipping, electroplating and rinsing) are served by automatic carriers.

Direct air injection: This method involves injecting air directly into the electroplating bath to create a consistent flow of electrolyte around the PCB. This helps to prevent the formation of air pockets and ensures that the metal ions are evenly distributed.

Oscillation and vibration of the boards: The PCBs are gently oscillated or vibrated during the electroplating process to further enhance the distribution of metal ions and prevent the formation of nodules or other defects.

Panel fixation: The PCB panel is secured in the lower part of the bath to facilitate optimal exchange of electrolytes within the holes and across the entire panel. This is typically done for panels measuring 600 x 600 mm.

Automatic carriers: The individual baths, including micro etching, acid dipping, electroplating, and rinsing, are served by automatic carriers. These carriers transport the PCBs through each stage of the process, ensuring efficient and consistent treatment.

The use of direct air injection, oscillation and vibration of the boards, panel fixation, and automatic carriers is still common in many vertical electroplating installations. However, modern PCB manufacturing has introduced new technologies and techniques to further improve the electroplating process.

Advancements and refinements
Improved electrolyte management: Modern electroplating systems often feature advanced electrolyte management systems, which provide better control over electrolyte composition, temperature, and flow rates.

Pulse plating and pulse reverse plating: These techniques involve applying a pulsed current or reversing the current polarity to improve metal deposition uniformity and reduce defects.

Vertical continuous plating (VCP) systems: VCP systems use a continuous process to electroplate PCBs, eliminating the need for batch processing and reducing production time.

Automated process control: Modern electroplating systems often feature advanced automation and process control systems, which enable real-time monitoring and adjustment of the electroplating process.

New electroplating chemistries: New electroplating chemistries and additives that improve metal deposition uniformity, reduce environmental impact, and enhance overall PCB quality are under development.

Achieved environmental benefits
- Minimisation of rejects.
- Improved metal deposition uniformity.
- reduced risk of defects and irregularities.
- enhanced overall quality of the PCBs.
- increased efficiency and productivity.
- Better control over the electroplating process.

Cross-media effects
See agitation, Section 4.2.6.4.2

Driving force for implementation
Production quality.

Reference literature
[122, UBA, 2003]

4.3.4.1.10 Optimisation of dry resist development ~~of dry resist by sodium carbonate~~

Description
Monitoring and control of the concentration and temperature of the developer solution. When necessary, the developer solution is replenished by adding fresh solution.

Technical description
The equipment for the development of dry resist consists of the development unit and a smaller downstream chamber which contains a fresh solution of sodium carbonate (see Section 2.6.2.8)

In order to reduce the drag-out of contaminated developer solution into the following fresh water rinsing zones, the panel surface is rinsed with clean developer solution.

The manifolds are equipped with an oscillation to bridge the mechanical effect of the spray nozzles and a better exchange of solution. The fan jet nozzles are to be installed at an angle of approximately 30- 40° transverse to the direction of process. In the case of multiple nozzle bars these may be installed against each other. This step uses water and chemicals economically

It is good practice to control the concentration of the developer solution (0.8 – 1.0 % Na_2CO_3) by conductivity, to check by laboratory analysis and to replenish it when necessary by adding fresh solution. Used solution is collected as effluent in a buffer vat; fresh solution is added from a sodium carbonate mixer (containing 10 % soda) and the following rinsing cascade as per requirement.

It is good practice to separately treat the effluents that are loaded with resist. There are various treatments are available for this, such as ultrafiltration.

Achieved environmental benefits
Minimises chemical and water usage.
Minimises the effect of batch discharging to the waste water treatment plant

Applicability
All dry resist developers.

Economics
The use of ultrafiltration for the effluent may depend on the amount of water discharged. Ultrafiltration is reported to be cheaper than precipitation.

Example plants
BE004 and DE066 [168, TWG, 2023].
Schweizer Electronic AG, Ruwel AG, Germany.

Reference literature
[122, UBA, 2003], [168, TWG, 2023]

4.3.4.1.11 Resist stripping

Description
The cured dry resist is removed by either a proprietary solution or sodium hydroxide solution (approximately 20 ml/l), see Section 2.6.2.8. When this solution is sprayed onto the resist it swells and comes off as flakes. The coarse particles may be separated by a centrifuge and disposed of as waste. The effluent, which is loaded with resist, may be discharged either directly or via a buffer vat into ultrafiltration equipment and cleaned with final pH adjustment.

Achieved environmental benefits
Removal of solids from waste water.

Cross-media effects
Resist waste generated.

Applicability
To all resist stripping in PCB installations, but see Economics, below.

Economics
Cost of centrifuging and ultrafiltration.

Driving force for implementation
Waste water policy and legislation.

Example plants
Plants AT002, BE004 and DE066 [168, TWG, 2023].

Many PCB plants in Germany.

Reference literature
[122, UBA, 2003], [12, PARCOM, 1992], [168, TWG, 2023]

4.3.4.1.12 Laser direct imaging

Description
A highly focused laser beam is used to directly expose the photoresist, creating the pattern without the need for a photomask or film.

Technical description
Considerable problems can occur with misalignment or distortion in the production of primary images on inner and outer layers, causing problems with hole alignment. Laser direct imaging is in use for primary imaging, but the technique is too slow for high volume production. It is mainly used for production of prototypes and smaller series.

~~Laser direct imaging is also being developed for solder mask imaging, but laser imageable solder masks are not available currently available (mid-2004).~~

Environmental benefits
No films required for the imaging process.
No developing media and rinsing processes from diazo silver halide films.
More precise imaging and less rejects with better material usage.

Technical considerations relevant to applicability
Generally applicable.

Example plants
AT001, AT002, BE004, DE040 and DE066 [168, TWG, 2023].

Reference literature
[122, UBA, 2003] [159, TWG, 2004] [168, TWG, 2023]

4.3.4.1.13 High density interconnects (HDI)

Description
HDI technology produces PCBs with a higher wiring density per unit area than traditional PCBs using sequential lamination and laser drilling to form the microvias (tiny interlayer connections).

Technical description
HDI technology achieves higher packing density of electronic sub-assemblies. A dense primary image is achieved by using new types of hole generation, giving smaller hole diameters and smaller track width.

Smaller holes can be generated by various methods like the following:~~laser, plasma or photo-processes. Development started in the early 1990s but is still not finalised.~~

- Laser drilling: a common method for creating microvias. It uses a high-powered laser to remove material and create a hole through the PCB substrate.
- Plasma etching: it uses a high-energy plasma to etch away the PCB material and create a microvia. This method is often used in combination with other techniques, such as laser drilling or photoprocesses.

- Photoprocesses: Photoprocesses, such as photoresist coating and exposure, can be used to create microvias. In this method, a photoresist material is applied to the PCB, exposed to light through a mask, and then developed to create a pattern of microvias.
- UV-YAG laser drilling: UV-YAG lasers are used to create microvias with high aspect ratios and small diameters. This method is often used for creating microvias in high-density interconnect (HDI) PCBs.
- CO_2 laser drilling: CO_2 lasers are used to create microvias in some cases, especially for larger diameter microvias.
- Chemical etching: Chemical etching is a method that uses chemicals to etch away the PCB material and create a microvia. This method is not as common as other methods but can be used in certain situations.
- Advanced mechanical drilling: While traditional mechanical drilling is not typically used for microvias, some advanced mechanical drilling systems can create microvias with diameters as small as 0.1 mm.

Environmental benefit
Smaller sub-assemblies requiring less material.

Technical considerations relevant to applicability
Generally applicable.

Example plants
AT001, AT002, BE004, DE040 and DE066 [168, TWG, 2023].

Reference literature
[122, UBA, 2003], [168, TWG, 2023]

4.3.4.1.14 Embedded passives

Description
The technology includes the direct integration of resistors, capacitors and inductors into the PCB layers or structure using techniques such as laser direct imaging, additive manufacturing or plating processes.

Technical description
Embedded passives is a technology which enables the manufacture of smaller boards with more functionality and improved high frequency performance. The principle is to remove the discrete resistors and capacitors from the surface and embed them in the inner layers of a PCB.
There are several different technologies available for embedded passives, from thin laminate type of materials to various kinds of paste solutions."

Environmental performance and operational data
The main environmental benefit from the application of embedded passives in semiconductor manufacturing is the reduction of waste and the minimisation of the environmental footprint associated with the production and disposal of discrete passive components.

Embedded passives involve integrating passive components, such as resistors, capacitors and inductors, directly into the printed circuit board (PCB) or semiconductor substrate, rather than attaching them as separate components.

This can lead to several environmental benefits, including reduced material usage, decreased waste generation, lower energy consumption, reduced usage of chemicals usage, smaller product size and improved recyclability.

Technical considerations relevant to applicability

Applicability may be limited due to product specifications (e.g. for complex or high-density designs).

Example plants
DE066 [168, TWG, 2023].

Reference literature
[159, TWG, 2004], [168, TWG, 2023]

4.3.4.1.15 Disposal of solutions

Description
Certain process baths usually contain strong complexing agents, for example:

- immersion or direct plating, see (e.g. copper, nickel, precious metals)
- black or brown oxide

They should be identified (see Section4.2.1.2) and require either:

- destruction of the complexing agents (which may be on-site or off-site) prior to treatment of the metals (see Section 4.2.10); or
- disposal off-site (with and without recovery, see Section 4.2.11.

Achieved environmental benefits
Avoids disruption of the waste water treatment system.

Cross-media effects
Increased waste production.

Applicability
All direct plating solutions.

Example plants
Plants AT001 and BE004 [168, TWG, 2023].
Most major PCB producers in Germany and Finland.

Reference literature
[122, UBA, 2003] [159, TWG, 2004], [168, TWG, 2023]

4.3.4.2 Water efficiency

4.3.4.2.1 Recirculation of rinsing water

Description
In multiple rinsing, rinsing water from the subsequent rinsing steps is used in the previous rinsing steps.

Technical description
See information in Sections 2.4.10.4 and 4.2.6.8.10.

Achieved environmental benefits
Significant reduction in water consumption within the process, with a commensurate reduction in waste water volumes and treatment.

Applicability

Generally applicable to new and existing plants for rinsing.

Economics

Driving force for implementation
Process efficiency.

Example plants
AT002 and DE066 [168, TWG, 2023].

Reference literature
[168, TWG, 2023]

4.3.4.2.2 Recirculation of rinsing water from etching and surface treatment to the treatment baths

Description
Rinsing water from etching and surface treatment is collected and undergoes treatment to remove contaminats. The treated water is then returned as water input to the treatment vats.

Technical description
This technique is a water recirculation system in printed circuit board (PCB) manufacturing. In the PCB manufacturing process, water is used in various steps like etching, plating, and cleaning. This generates a significant amount of spent rinsing water containing chemicals and contaminants.

Traditionally, this spent rinsing water is discharged as industrial waste water, which requires proper treatment before disposal.

The water recirculation system aims to recover and reuse spent rinsing water, reducing the amount of fresh water needed for the process.

The recovered water is treated to remove contaminants and impurities, making it suitable for reintroduction into the main process tank. This treatment process may involve filtration, ion exchange, or other methods to remove dissolved solids and chemicals.

The recycled water can be used to compensate for evaporation losses in the process tank, ensuring a consistent water level and reducing the need for fresh water input.

Additionally, the recovered water can be part of an autodosing system, which automatically adjusts the water input based on the process requirements. This helps maintain optimal water usage and further reduces the reliance on fresh water.

See also information in Section 4.3.3.4.2.

Environmental performance and operational data
It is essential to ensure that the recirculated water maintains the desired chemical composition and concentration for the processes where it will be reused, which may require regular monitoring and adjustments to the recirculation system.

Achieved environmental benefits
Reduction of the consumption of fresh chemicals and water, lower operational costs and reduction of waste water generation.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Driving force for implementation
Reduction of water consumption and of the associated operational cost.

Example plants
BE004 [168, TWG, 2023].

Reference literature
[168, TWG, 2023]

4.3.4.2.3 Use of closed cooling systems

Description
Closed systems use a secondary system, such as refrigeration, for cooling the recirculating coolant in the primary system.

Environmental performance and operational data
In closed cooling systems, the coolant is not in contact with the outside air. This minimises corrosion and there is no build-up of dissolved solids. The cooling system may be refrigerated or pass through fan-cooled radiators.

Achieved environmental benefits
Reduction of the consumption of fresh water, lower operational costs and reduction of waste generation.

Cross-media effects
Electricity is consumed for pumping and for chilling in refrigerated systems.

Technical considerations relevant to applicability
Generally applicable.

Driving force for implementation
Reduction of water consumption and of the associated operational cost.

Example plants
AT001, AT002 and DE040 [168, TWG, 2023].

Reference literature
[168, TWG, 2023]

4.3.4.2.4 Reuse of clean process water

Description
Clean process water (nearly not polluted) is fed in to the ion exchange system that treats the incoming fresh water.

Technical description

Environmental performance and operational data

Achieved environmental benefits
Reduction of the consumption of fresh water, lower operational costs and reduction of waste generation.

Cross-media effects

Technical considerations relevant to applicability
Generally applicable.

Driving force for implementation
Reduction of water consumption and of the associated operational cost.

Example plants
DE066 [168, TWG, 2023].

Reference literature
[168, TWG, 2023]

4.3.4.3 Substitution of hazardous substances

4.3.4.3.1 EDTA substitution

Description
Substitution of EDTA by using alternative EDTA-free alternative solutions.

Technical description
Use of alternative degreasing solutions that do not contain EDTA. These alternative solutions may include derivatives of gluconic or tartaric acid.

See also Section 4.2.7.4.

Achieved environmental benefits
Reduction in the use of a persistent and potentially bioaccumulative chelating agent.

Technical consideration srelevant to applicability
Applicability may be restricted by product specifications..

Economics
The cost of EDTA substitution by alternative degreasing solutions depends on the specific alternative degreasing solution used and its performance in various applications.

Driving force for implementation
Environmental concerns and regulatory compliance.

Example plants
Plant BE004 reported having used EDTA-free electroless Cu plating since 2006 [168, TWG, 2023].

Reference literature
[168, TWG, 2023]

4.3.4.4 Emissions to air

4.3.4.4.1 Off-gas extraction as close as possible to the emission source

Description
Off-gases are extracted using, for example, full enclosure, edge or lip extraction.

Technical description
See Section 4.2.8.2.3.

Example plants
All PCB manufacturing plants in the STM data collection [168, TWG, 2023].

Reference literature
[168, TWG, 2023]

4.3.4.4.2 Substitution of high-VOC-content resins in the application of solder mask

Description
Substitution of high-VOC resins with alternatives that have a low VOC and high solid content or are VOC-free.

Technical description
This is a technique for the optimisation of solvent emissions from the application of solder masks.

The solder masks used consist of epoxy and acrylate resins. They contain photo-initiators and fillers. Increasingly, aqueous alkaline lacquer systems are used. Prior to exposure, they are soluble in aqueous alkaline solutions; and are developed in a 1 – 3 % solution of sodium carbonate. The effluent may be treated by ultrafiltration or by a precipitation method using an acidic medium and then disposed of.

However, even aqueous alkaline solder masks contain up to 50 % solvents (i.e. methoxypropyl acetate). Consequently, installations with an annual consumption of solvents of 5 – 15 t/yr. (threshold value) are subject to the provisions of Chapter 5 of and Annex VII to the IED~~Solvent Emissions Directive (SED).~~ In order to stay below the emission limit values, the PCB manufacturer either has to persuade his supplier to increase the percentage of solid contents within the lacquer system or has to install suitable treatment systems to the air extraction systems (e.g. condensation, incineration, biological filters).

Achieved environmental benefits
The reduction of VOC emissions.

Cross-media effects
Increased power consumption for additional equipment.

Applicability
To all solder mask applications, especially those within the SED limits.

Economics
The cost of additional air treatment systems.

Driving force for implementation
~~Solvent Emissions Directive [97, EC, 1999].~~

Example plants

DE066 [168, TWG, 2023].

Reference literature
[122, UBA, 2003], [168, TWG, 2023]

4.3.5 Semiconductors manufacturing

4.3.5.1 Material efficiency

4.3.5.1.1 Process optimisation

Description
Process optimisation includes:

- optimisation of cleaning processes to reduce the consumption of acids and ammonia;
- optimisation of etching processes to reduce the consumption of acids;
- optimisation of polishing processes to reduce the generation of slurries;
- optimisation of physical vapour deposition (PVD) processes to reduce the consumption of gases and liquids;
- optimisation of stripping processes to reduce the consumption of strippers;
- automation of chemical dosage in baths.

Achieved environmental benefits
Reduction in the quantity of materials used and the quantity of generated residues.

Cross-media effects
Increased energy consumption for additional equipment.

Technical consideration srelevant to applicability
Generally applicable.

Economics
No significant cost associated with these measures.

Driving force for implementation
Process efficiency.

Example plants
- Optimisation of cleaning processes to reduce the consumption of acids and ammonia: Plants FR03A and FR031.
- Optimisation of etching processes to reduce the consumption of acids: Plants FR03A and FR031.
- Optimisation of polishing processes to reduce the generation of slurries: Plants FR03A and FR031.
- Optimisation of physical vapour deposition (PVD) processes to reduce the consumption of gases and liquids: Plants FR03A and FR031.
- Optimisation of stripping processes to reduce the consumption of strippers: Plants FR03A and FR031.
- Automation of chemical dosage in baths: Plants IE001 and MT001.

Reference literature
[168, TWG, 2023]

4.3.5.1.2 Maintenance of process solutions

See Section 4.2.6.5.

Example plants
Plants IE001 and FR031.

Reference literature
[168, TWG, 2023]

4.3.5.1.3 Recovery of process metals

See also Section 4.2.6.5.15.

Technical description
Electrolytic recovery of copper or electrowinning (EW) involves the use of an electric current to reduce dissolved copper ions (Cu^{2+}) from a solution onto a cathode (a negatively charged electrode), where they are deposited as solid copper metal.

The process includes the following steps:

- Pretreatment: The waste water or waste material is treated to remove impurities and adjust the pH and temperature.
- Electrolysis: The pre-treated solution is pumped into an electrolytic cell, where an electric current is applied between the anode (positively charged) and cathode (negatively charged). The anode is typically made of a corrosion-resistant material, such as stainless steel or titanium.
- Copper deposition: At the cathode, the copper ions (Cu^{2+}) are reduced to solid copper metal, which deposits onto the cathode surface.
- Copper collection: The deposited copper is periodically collected from the cathode, washed, and dried to produce a high-purity copper product.

Environmental performance and operational data
EW can recover high-purity copper (up to 99.99%).

The associated energy consumption is low compared to traditional smelting and refining processes. In addition, the quantity of generated waste is low as well as reducing the need for chemical reagents

Example plants
Plant IE001 reported the electrolytic recovery of Cu from Cu-containing solutions to generate Cu balls.

Reference literature
[168, TWG, 2023]

4.3.5.2 Water efficiency

4.3.5.2.1 Use of closed cooling systems

Description
Water or a water-glycol mixture is circulated through a series of heat exchangers, chillers and cooling towers without the need for external water sources.

Heat generated by equipment like furnaces, chemical vapour deposition (CVD) systems and etching tools is transferred to the circulating fluid, which then dissipates the heat in the cooling tower or heat exchanger. The fluid is continuously recirculated and cooled, allowing for efficient heat management without the need for fresh water input.

See also Section 4.3.2.2.4.

Example plants
FR03A.

Reference literature
[168, TWG, 2023]

4.3.5.2.2 Reuse of spent ultra-pure water

Description
Reuse of spent ultra-pure water in other processes as cooling water (e.g. in chillers, pumps and other heat-generated processes).

See also Section 4.2.5.5.

Example plants
DE074 and DE076.

Reference literature
[168, TWG, 2023]

4.3.5.3 Energy efficiency

4.3.5.3.1 Use of front-opening unified pods (FOUPS) or standard mechanical interface (SMIF)

Description
Use of specialised sealed containers to transfer and store silicon wafers in enclosed clean conditions (class 1) without being exposed to the surrounding airflow. In this way, less energy is needed compared to maintaining the whole surrounding environment at class 1 conditions.

Technical description
In semiconductor manufacturing, Front-Opening Unified Pods (FOUPs) are specialised sealed containers used to transport and store silicon wafers during the production process. These containers are designed to maintain a clean environment, preventing contamination of the delicate wafers. FOUPS are compatible with automated handling systems and wafer-processing tools in a clean-room environment, ensuring minimal human intervention, which reduces particle contamination and improves overall production efficiency.

The use of FOUPS is critical in advanced semiconductor manufacturing, especially in processes involving high-volume wafer handling, as they help ensure the integrity and quality of the semiconductor devices being produced.

FOUPs are considered the state-of-the-art technology for 300 mm fabs. They are part of the automated system that transports the wafers around the fab.

SMIFs (standard mechanical interfaces) are still used in fabs operating at 200 mm or lower. In those fabs, the wafers were contained in SMIFs which are carried around the fab manually (by workers).

The key differences between SMIFs and FOUPs are as follows:

- In terms of design: SMIFs have a removable lid, while FOUPs have a front-opening door.
- In terms of contamination control: FOUPs provide better contamination control due to the front-opening design, which reduces wafer exposure to the outside environment.
- In terms of ease of use: FOUPs are generally easier to use, as the front-opening door allows for faster and more convenient loading and unloading of wafers.
- In terms of industry adoption: FOUPs have largely replaced SMIFs in modern semiconductor manufacturing due to their improved design and contamination control capabilities.

The key technical features of FOUPs are as follows:

Material composition
FOUPs are made from high-purity, static-dissipative, low outgassing polymers (such as polycarbonate) and fluoropolymers to prevent any chemical contamination of wafers. These materials are chosen for their clean-room compatibility and ability to resist chemical degradation.

Front-opening design
The front-opening feature allows automated systems (e.g. robotic arms) to access wafers without human intervention, reducing the contamination risk. The door mechanism typically includes an O-ring or gasket (made from fluoroelastomers) to ensure airtight sealing when the door is closed, preventing airborne particles from entering.

Wafer slots and spacing
Inside the FOUP, wafers are held in precisely spaced grooves to prevent any direct contact or movement during transport. Each wafer slot is designed to ensure that the wafer edges rest securely, avoiding damage or particle generation.

Environmental control
FOUPs are engineered to maintain a strictly controlled environment with minimal particulate generation. Some advanced FOUPs integrate mechanisms to control humidity and chemical exposure. They may also feature purge capabilities (with inert gases like nitrogen) to remove any residual volatile organic compounds (VOCs) or moisture.

Handling and automation
FOUPs are designed for full compatibility with the SEMI E84 standard for automated material handling systems (AMHS) used in semiconductor fabs. They incorporate standardised kinematic coupling interfaces at the base, allowing automated wafer transport robots to align and move them efficiently. They also include identification features like RFID tags and barcodes for tracking and process integration.

Particle control
FOUPs are subjected to rigorous clean-room protocols to ensure low particle generation. Over time, continuous use can cause micro-particle buildup inside the FOUP, so they are often cleaned using specialised cleaning processes (e.g. ultra-pure water or particle-removal techniques like mega sonic cleaning) between uses.

Temperature and pressure stability
FOUPs must be thermally stable to withstand varying fab conditions, such as movement from ambient areas to heated wafer-processing equipment. They are designed to endure small pressure changes that might occur in vacuum chambers during processes like deposition or etching without deforming or releasing particles.

Achieved environmental benefits

Contamination control and reduction in energy consumption in clean-room design

FOUPs help maintain ultra-clean conditions for wafers, eliminating the need for continuous high-grade clean-room environments across the entire fab. As FOUPs act as mini clean environments for wafers, fabs can reduce the size of critical high-energy, controlled environments. Instead of maintaining an entire clean room at ISO Class 1 or 2 (the highest clean-room standards), fabs can lower the grade in non-critical areas, thus reducing energy consumption in air filtration, temperature control and air circulation systems. This localised cleanliness minimises the need for energy-intensive systems throughout the entire fab.

Reduced airflow and temperature control needs

Semiconductor fabs rely heavily on laminar airflow to maintain cleanliness, requiring extensive HVAC (heating, ventilation and air conditioning) systems that consume significant amounts of energy. The use of FOUPs reduces the need for stringent laminar airflow in all areas of the fab. Since wafers are enclosed in FOUPs between processing steps, airflow requirements can be relaxed in areas where wafers are stored or transported, leading to lower energy use for HVAC systems.

Minimised use of dehumidification and pressure control

Maintaining the required humidity and pressure levels in semiconductor fabs is energy-intensive. Since FOUPs maintain a controlled internal environment for wafers, fabs can limit the use of extreme dehumidification and pressure control across the entire facility. By only focusing on the critical processing areas rather than the entire clean room, fabs achieve significant energy savings.

Enhanced automation and reduced human interaction

FOUPs are fully compatible with automated wafer handling systems, which minimises manual intervention. The automated handling reduces the energy costs associated with human-centric processes, such as the need for airlocks and additional air filtration systems around human activity zones. Moreover, fewer interruptions in air circulation due to human entry/exit points also conserve energy.

Higher yield and process efficiency

FOUPs help protect wafers from contamination that can lead to defects, reducing the number of rejected or reworked wafers. Lower defect rates mean fewer wafers are scrapped, reducing the overall energy and material consumption required to manufacture working semiconductor devices. The higher yield directly correlates with a reduction in the overall energy footprint per chip produced.

Energy savings in tool utilisation

FOUPs are designed to integrate seamlessly with semiconductor processing tools in the fab. This tight integration allows for better tool utilisation and optimised production flows. As FOUPs standardise wafer handling, tools spend less time waiting for manual loading/unloading, improving throughput and reducing idle times, which in turn lowers the energy consumption of manufacturing equipment.

Cross-media effects

Associated resource consumption:

Material use

FOUPs are made from high-purity, static-dissipative polymers, often polycarbonate or fluoropolymers. The production of these materials requires significant resources and energy. Additionally, the fabrication of FOUPs involves processes that can contribute to environmental impacts, including emissions and waste.

Energy consumption

The production, cleaning and maintenance of FOUPs involve energy use. For instance, the cleaning processes for FOUPs often require high-energy inputs, such as in ultrasonic or mega sonic cleaning, which can contribute to a larger environmental footprint.

Waste generation

End-of-life disposal

FOUPs have a finite lifespan and eventually need to be disposed of. The disposal of FOUPs, especially those made from polymers and other composite materials, can pose challenges. If not properly managed, these materials can contribute to plastic waste. Recycling options may be limited depending on the materials used and local recycling infrastructure.

Cleaning chemicals

The cleaning processes for FOUPs involve chemicals that need to be managed and disposed of properly. Improper disposal of these chemicals can have adverse environmental effects.

Chemical use and contamination risks

Chemical outgassing

While FOUPs are designed to minimise contamination, the materials used can outgas certain chemicals over time. If not properly managed, these emissions could potentially contribute to air quality issues, although the quantities involved are typically small.

Cleaning and maintenance

The chemicals used in cleaning FOUPs, such as solvents or detergents, can also pose environmental risks if not handled and disposed of correctly. The management of these chemicals requires careful adherence to environmental regulations to mitigate potential impacts.

Infrastructure and resource demand

Infrastructure requirements

The use of FOUPs requires specialised handling equipment and infrastructure, such as automated material handling systems (AMHS).

Environmental performance and operational data

Wafer size restrictions

Primarily for 300mm wafers: FOUPs are designed for 300 mm wafers, which are the standard in advanced semiconductor manufacturing. However, many legacy fabs still make 200 mm wafers or smaller sizes, where older cassette-based systems or SMIF (standard mechanical interface) pods are more prevalent. The transition to FOUPs for smaller wafer sizes was not a goal of the design to begin with. Consequently, FOUPS are not viable for fabs operating at 200 mm or smaller sizes.

Compatibility issues with legacy equipment

Legacy tooling and infrastructure: Many older semiconductor fabs use equipment that is not designed to accommodate FOUPs. The shift from open cassettes or SMIF pods to FOUPs would require extensive upgrades or replacements of handling systems, processing tools and storage systems. The cost and complexity of retrofitting these fabs to use FOUPs can be prohibitive, which is why many older fabs continue to rely on more traditional wafer handling systems.

Process-specific constraints

Not suitable for certain process steps: Some specialised process steps, particularly in the early stages of wafer manufacturing or when handling fragile, thin wafers (like in the production of MEMS (micro-electromechanical systems) or compound semiconductors), may not fully benefit from FOUP-based handling systems. In these cases, alternative wafer handling systems, such as open cassettes, can offer more flexibility and lower the risk of wafer damage.

Wet processing and chemical exposure

FOUPs are not always suitable for all wet processing steps. Certain chemical processes may require the wafers to be handled in different, non-FOUP containers due to specific material incompatibilities or handling needs.

Automation requirements

Dependence on advanced automation: FOUPs are tightly integrated with advanced automated material handling systems (AMHS), including robotics for wafer transport and load ports on semiconductor tools. For fabs that lack the necessary automation infrastructure, the use of FOUPs is impractical. These fabs would need to invest in an extensive automation overhaul to integrate FOUPs effectively, which may not be cost-effective for every fab.

Complexity of integration
In high-mix, low-volume manufacturing environments, where fabs frequently switch between different product types and process flows, the complexity of managing and automating FOUP handling can be a challenge. Flexible, manual handling systems may be more appropriate in such cases.

Potential for particle buildup
Contamination risk over time: Although FOUPs are designed to minimise contamination, they can accumulate particles or outgas over time, especially in environments with less stringent maintenance practices. FOUP cleaning and monitoring must be rigorously maintained to ensure that they continue to provide the necessary level of wafer protection.

Slow adoption in certain semiconductor segments
Non-silicon wafers: Semiconductor segments that use non-silicon materials, such as compound semiconductors (e.g. gallium nitride or gallium arsenide), may not rely as heavily on FOUPs. These industries often have unique handling requirements that differ from the traditional silicon wafer manufacturing process, and they may prioritise flexibility over the stringent cleanliness provided by FOUPs.

Technical considerations relevant to applicability
Generally applicable.

Economics
High initial investment: FOUPs, along with the automated handling systems they require, represent a significant capital investment.

Operating and maintenance costs: The associated costs of maintaining and cleaning FOUPs, along with the infrastructure required to support them, can be high. Cleaning processes to maintain low contamination levels are complex, and periodic maintenance or replacements are required to ensure proper sealing and functionality.

Driving force for implementation
Local conditions and regulatory requirements
Strict clean-room standards: Semiconductor fabs in regions with stringent clean-room standards (e.g. ISO 14644-1 for clean-room classification) are more likely to adopt FOUPs.

Occupational safety and health regulations: EU health and safety directives can drive the need for safer automated handling to reduce worker exposure to hazardous chemicals and wafer damage from manual handling.

Compliance with SEMI standards: FOUPs are standardised according to SEMI E47.1 and SEMI E84 (for automated transport), which helps fabs comply with global semiconductor manufacturing standards.

Non-environmental triggers:
Increased yield and product quality
FOUPs significantly reduce particulate contamination, resulting in higher wafer yield and improved product quality in semiconductor manufacturing. This is critical given that tiny defects affect chip functionality.

Maintaining wafer integrity throughout the process (due to reduced handling) helps improve chip reliability, particularly in markets like the automotive or aerospace ones, where chip failure can have severe consequences.

Economic incentives
Government subsidies and tax incentives: In regions where governments incentivise semiconductor production (e.g. EU Chips Act, US CHIPS Act or Taiwan's industrial policies), there may be subsidies or tax breaks tied to the implementation of cutting-edge manufacturing technologies, including the use of FOUPs and other automation systems.

Cost savings from automation: FOUP adoption can lead to reduced labour costs by minimising manual wafer handling and increasing throughput. Automation also reduces human error and wafer damage, saving costs on rework and scrapped wafers.

Increased throughput and efficiency
FOUPs integrate seamlessly with automated material handling systems (AMHS), enabling more efficient wafer transport, reducing delays in production, and allowing fabs to increase throughput, which is a critical factor in high-volume manufacturing fabs.

R&D and innovation grants
In regions prioritising the development of advanced semiconductor manufacturing technologies, such as through research grants and public-private partnerships, FOUPs are often adopted as part of broader innovation and technology upgrades. This is common in countries aiming to advance their global positioning in the semiconductor market.

Industry-specific drivers
Advanced node manufacturing: The shift to smaller process nodes (e.g. 7 nm, 5 nm and beyond) requires more stringent contamination control and handling precision, making FOUPs indispensable for fabs producing cutting-edge chips.

Competition in high-tech sectors: The need to remain competitive in sectors like consumer electronics, 5G, AI and autonomous vehicles pushes fabs to implement techniques that improve yield and product reliability. FOUPs help ensure process consistency and precision, giving fabs a competitive edge.

FOUPs were first introduced in the early 1990s. The adoption of FOUPs became more widespread during the late 1990s and early 2000s, driven by the semiconductor industry’s shift to larger wafer sizes (such as 300 mm) and the need for more stringent contamination control and automation in fabrication facilities.

Example plants
FOUPs are used in all 300 mm fabs located in the EU and globally.
SMIFs: Plant FR03A [168, TWG 2023].

Reference literature
[179, ESIA 2024], [168, TWG 2023]

4.3.5.4 Emissions to air

4.3.5.4.1 Point-of-use abatement

Description
Point-of-use (POU) abatement in semiconductor manufacturing refers to the process of capturing and treating hazardous emissions directly at the source where they are generated, typically at individual manufacturing tools.

Technical description

In semiconductor manufacturing, many processes involve the use of toxic, corrosive or environmentally harmful substances like fluorinated greenhouse gases, volatile organic compounds (VOCs), and other reactive chemicals. These are used in processes like etching, deposition and cleaning, which may produce hazardous emissions.

POU abatement systems are installed at the point of emission to treat these harmful substances before they are released into the environment. The systems use techniques such as combustion, chemical scrubbing or thermal decomposition to neutralise or significantly reduce the pollutants.

The primary goals of POU abatement in semiconductor fabs include: (i) worker safety, i.e. protecting workers by removing harmful substances at the point of generation, POU systems protect workers from exposure to toxic chemicals; (ii) environmental protection, POU abatement contributes to the reduction of harmful emissions and the reduction of greenhouse gas emissions into the atmosphere.

Point-of-use (POU) abatement in semiconductor manufacturing is a localised emission control strategy that addresses hazardous process gases and by-products directly at the process tool level. Semiconductor fabrication involves the use of reactive gases such as perfluorinated compounds (PFCs), hydrogen chloride (HCl), and other volatile organic compounds (VOCs) in processes like chemical vapour deposition (CVD), etching and cleaning. These processes generate harmful emissions, including hazardous air pollutants (HAPs) and potent greenhouse gases (GHGs).

POU abatement systems are engineered to treat these emissions immediately after they are generated, using a combination of the following technologies, depending on the specific circumstances at an individual site:

- Thermal oxidation: This method burns or combusts gases at high temperatures (typically 800–1 200°C) to convert harmful compounds into less harmful by-products, such as carbon dioxide (CO_2) and water vapour (H_2O). This is particularly effective for treating VOCs and PFCs. See Section 4.2.8.2.4.9.
- Plasma abatement: In this technique, plasma is generated to ionise gases and break them down into safer components.
- Wet scrubbing: Polluted gas streams are passed through a liquid scrubbing solution that absorbs and neutralises the harmful substances, typically through chemical reactions. Wet scrubbers are effective for acidic gases like HCl and HF and basic gasses e.g. NH_3. Wet scrubbers can be used also as a second-tier central abatement solution to capture the same compounds. See Section 4.2.8.2.4.8.
- Catalytic oxidation: This is a lower-temperature method where a catalyst is used to promote the oxidation of gases into safer byproducts. Catalysts, such as platinum or palladium, lower the energy required for the oxidation reactions, making this an energy-efficient option. See Section 4.2.8.2.4.10.
- Dry scrubbing (adsorption): This method uses adsorbent materials like activated carbon or zeolites to capture and bind gas molecules on their surfaces. It is useful for trapping hazardous emissions, such as low-concentration VOCs. See Section 4.2.8.2.4.2.

POU abatement is critical for reducing the emissions of hazardous pollutants and greenhouse gas emissions. These systems are strategically installed at the exhaust points of individual process chambers, minimising the spread of contaminants throughout the facility and reducing the overall load on centralised abatement systems.

Achieved environmental benefits

Point-of-use (POU) abatement systems in semiconductor manufacturing achieve significant environmental benefits by directly treating harmful emissions at the source. The key environmental benefits include the following:

- Reduction of direct greenhouse gas (GHG) emissions (scope 1 emissions). Semiconductor manufacturing uses perfluorinated compounds (PFCs) and other high global warming potential (GWP) gases. POU abatement systems can reduce emissions of these gases by up to 95% or more through thermal oxidation, plasma treatment, adsorption or catalytic processes. This significantly contributes to reducing the carbon footprint of semiconductor production.
- Minimisation of harmful air pollutants. Many process gases used in semiconductor fabrication, such as hydrogen chloride (HCl), cyclopentaoctafluoride (C_5F_8), and ammonia (NH_3), are harmful. POU systems can reduce emissions of these hazardous pollutants by neutralising or capturing them, protecting local air quality and reducing health risks for workers and nearby communities.
- Compliance with environmental regulations. POU abatement helps semiconductor manufacturers meet regulatory requirements.
- Reduction of volatile organic compounds (VOCs). VOCs, emitted during various semiconductor processes, contribute to the formation of ground-level ozone and smog. POU abatement systems significantly reduce VOC emissions, helping to improve air quality and comply with limits on ozone-precursor emissions.
- Enhanced water conservation. Wet scrubbers, a component of some POU abatement systems, can be designed to recycle scrubbing liquids, thereby reducing the overall water consumption. This is especially relevant in semiconductor manufacturing, where water efficiency is critical.
- Greenhouse gas emissions reduction. PFCs and other fluorinated gases used in semiconductor manufacturing have a high GWP. POU systems target these gases directly to reduce the industry's contribution to greenhouse gas emissions by breaking down these compounds into less harmful substances, such as CO_2 and water vapour, with a lower GWP.
- Worker safety. Reducing the release of toxic chemicals like HF, HCl and VOCs improves indoor air quality within the manufacturing facility, safeguarding workers from potential exposure to hazardous substances. This reduces health risks associated with long-term exposure to these chemicals. POU also reduces the risk of undesired chemical reactions.

Cross-media effects

Energy consumption and carbon footprint

Any abatement technology needs energy. Some POU abatement technologies, such as thermal oxidisers, require high temperatures (800–1 200°C) to break down gases. Depending on the technology used, this contributes to the scope 1 and/or scope 2 emissions of sites.

Mitigation: Enhancing the energy efficiency of abatement technologies and/or integrating renewable energy sources, helps to reduce this impact.

Generation of secondary pollutants

NOx formation: High-temperature thermal abatement usually results in the formation of nitrogen oxides (NO_X) as a by-product of combustion. NO_X is a precursor to smog and acid rain, potentially shifting air quality concerns from one type of pollutant (GHGs or hazardous air pollutants) to another.

Mitigation: This effect can be minimised by adjusting the operating conditions, using selective catalytic reduction (SCR) or other post-treatment methods to control NO_X emissions. However, SCR can result in an increased water pollution, making it harder to reuse the water.

Water consumption and emissions to water

Water usage in wet scrubbers: Wet scrubbers, commonly used in abatement systems for gases like HF or HCl, require significant amounts of water to absorb and neutralise harmful chemicals. This may increase the facility's overall water consumption.

Waste water generation: The scrubbing process can generate contaminated waste water containing dissolved pollutants such as acids or fluorides, which must be treated before discharge.

Mitigation: Recycling scrubbing water, using closed-loop water treatment systems and using water treatment chemicals can reduce the overall water use footprint and minimise waste water discharge.

Waste generation
Some abatement technologies, such as adsorption systems using activated carbon or chemical scrubbers, produce solid waste in the form of spent adsorbent materials or sludge. These wastes can contain hazardous substances, requiring proper handling, disposal or regeneration.
Mitigation: Using regeneration systems for adsorbents (e.g. carbon regeneration) and minimising the use of hazardous chemicals in scrubbers can reduce the volume of waste generated.

Use of chemicals
Chemical scrubber reagents: POU abatement systems like wet and chemical scrubbers often require reagents (e.g. caustic solutions, acids, or oxidisers) to neutralise harmful gases. These chemicals must be produced, transported and stored, potentially increasing the facility’s resource consumption and chemical handling risks.
Mitigation: Choosing less hazardous, renewable or recyclable chemicals and optimising reagent usage can help mitigate these cross-media impacts.

CO_2 generation from chemical breakdown
CO_2 emissions: While POU systems effectively break down high-GWP gases (e.g. PFCs), many abatement technologies convert these gases into CO_2, which is less harmful in terms of global warming potential. However, this increases the overall CO_2 emissions of the facility.
Mitigation: Efforts are required to reduce overall GHG emissions through energy efficiency and increasing abatement efficiency (destruction and removal efficiency, DRE).

Potential air quality trade-offs
Particulate matter: Some POU abatement methods can generate particulate matter (PM) as a by-product. This can have local air quality implications if the process is not properly managed.
Mitigation: Installing filter systems, using alternative abatement technologies that minimise particulate generation can reduce this risk.

Material degradation and corrosion
Corrosive gases: Most abatement processes may lead to the release of corrosive by-products. This can lead to degradation of abatement equipment, increasing maintenance needs and potentially causing leaks or equipment failures that could introduce pollutants into the environment.
Mitigation: Using corrosion-resistant materials and performing regular maintenance checks can help prevent equipment failures and environmental releases.

Heat generation
Abatement technologies that rely on high temperatures contributes to heat generation, affecting the ambient temperature in localised areas.
Mitigation: Implementing heat recovery and cooling systems can mitigate these cross-media effects.

Environmental performance and operational data
Abatement efficiency for certain gases

- Restriction: Some abatement systems, particularly thermal oxidisers and wet scrubbers, may have problems to treat specific gases effectively, such as the following:
    - Carbon tetrafluoride (CF_4) and sulphur hexafluoride (SF_6): Highly stable, these gases are resistant to decomposition, requiring advanced techniques, which may be more complex, energy and water consuming, as well as expensive.
    - Other perfluorinated compounds (PFCs): While thermal oxidisers can treat PFCs, complete abatement often requires extremely high temperatures and extended residence times.

- Impact: Manufacturers in Europe may need to adopt advanced, often more expensive, abatement technologies to meet EU regulations, which may affect the competitiveness of the European semiconductor industry.

Equipment compatibility and retrofit limitations

- Restriction: Not all existing semiconductor manufacturing equipment is designed to be compatible with POU abatement systems. Retrofitting older tools and/or fabs with modern POU systems may be technically infeasible and/or cost prohibitive.
- Impact: Manufacturers may face technical constraints when trying to integrate POU abatement into legacy systems or during tool upgrades. In some cases, other abatement systems may be more feasible if extensive retrofitting is required.

Nitrogen oxides (NO_X) emissions from high-temperature systems

- Restriction: High-temperature abatement systems (e.g. thermal oxidisers) can generate nitrogen oxides (NO_X) as a by-product of combustion, especially when treating nitrogen-containing gases. NO_X is a regulated air pollutant in the EU, with limits on its emission under the Ambient Air Quality Directive.
- Impact: Manufacturers might be forced to implement additional NO_X control measures, which increases the cost and complexity of POU abatement systems.

Space and infrastructure constraints

- Restriction: POU abatement systems need to be installed directly at the point of gas generation (typically on individual process tools), which can require significant space in already crowded fab environments. Space limitations in existing facilities can restrict the number or type of POU systems that can be deployed.
- Impact: Manufacturers may be forced to choose between POU abatement and other abatement systems, balancing space constraints with operational efficiency. In some cases, the available footprint in fabs may limit the use of specific abatement technologies.

Heat emissions

- Restriction: Some POU abatement technologies, particularly thermal oxidisers, generate significant heat, which can impact the working environment. Thermal emissions may increase energy and water consumption for cooling systems in the facility. Abatement systems running on fossil fuels may generate GHG emissions to an extent that outweighs the GHG emissions reductions.
- Impact: Manufacturers may need to invest in heat recovery systems, adding further complexity and cost to the installation and operation of POU systems.

Economics

POU abatement systems can involve high upfront and operating costs. Furthermore, for some systems the operating costs can be higher compared to others.

High capital expenditures on POU systems can create a financial burden, particularly for smaller manufacturers. Balancing compliance with regulations while managing cost-effectiveness can be a significant challenge.

Technical considerations relevant to applicability

Generally applicable.

Example plants

Plants IE001 and IT022 [168, TWG 2023].

Reference literature

[179, ESIA 2024], [168, TWG 2023]

4.3.5.4.2 Off-gas extraction as close as possible to the emission source

Description
Off-gases are extracted using, for example, full enclosure, edge or lip extraction.

Technical description
See Section 4.2.8.2.3.

Example plants
All semiconductor manufacturing plants in the STM data collection [168, TWG, 2023].

Reference literature
[168, TWG, 2023]

4.3.5.5 Substitution of hazardous substances

4.3.5.5.1 Use of lead-free alternatives

Description
Lead-free solders typically contain tin (Sn), silver (Ag) and copper (Cu) as the primary components, with various additional elements such as bismuth (Bi), indium (In) and antimony (Sb) used to improve properties like melting temperature, wetting and mechanical strength.

Technical desscription
Identifying alternative 'lead-free' (Pb-free) lead finish materials for use in the solder plating or coating operations of semiconductor and electronics industries is a challenging process. Stringent visual, mechanical, electrical and chemical requirements need to be fullfiled by the alternative solder before it can be released for production. These requirements include acceptable melting point, good wettability/solderability, high adhesion/mechanical strength, and excellent conductivity. The solder must also allow high-volume production, inspection, and if necessary, rework, while remaining reliable and cheap. The main alternatives are described below.

Pure Tin. Tin has good wettability/solderability over a large range of substrates, making it an excellent choice for lead finish through tin plating. However, it has some distinct disadvantages in its pure form. Pure tin has a tendency to exhibit 'tin pest' at temperatures below 13 °C, making it structurally inadequate in low-temperature applications. Pure tin also has a tendency to form tin whiskers which can cause lead-to-lead shorting.

Tin-Zinc. Sn-9wt.%Zn has a melting temperature of 198 °C, making it a close alternative to eutectic Sn-Pb solder. Once solidified, it exhibits large grains with a fine and uniform two-phase eutectic colony.

Tin-Copper. Sn-0.7%Cu is the eutectic composition of the Sn-Cu binary system. This solder alloy is relatively cheap, has fine grains and exhibits good solderability. However, due to the high percentage of Sn, it is also prone to tin whiskers and tin pest. It melts at 227 °C.

Tin-Bismuth. Sn and Bi form a eutectic alloy at 42%Sn and 58% Bi, which melts at an excessively low temperature of 138 °C. However, at 3% Bi the melting temperature is about 215-220 °C. Sn-Bi solder tends to be brittle and can also exhibit tin whiskers at compositions wherein Sn% is high. If slowly cooled, large grains arise, the boundaries of which may serve as precipitation points for Sn, resulting in cracks.

Tin-Silver. Sn-3.5%Ag exhibits good solderability and mechanical properties and has the longest history of reliable usage as a lead-free solder. However, it is expensive, prone to tin whiskers due to the high Sn content. Increasing Ag% to > 5% will result in drastically higher melting temperatures.

Tin-Indium. 52%In-48%Sn has likewise been used as 'lead-free' solder material in semiconductors applications. In-Sn is eutectic at 50.9In49.1Sn. In-Sn solder exhibits a substantially lower melting temperature.

Tin-silver-copper. Sn-AG-Cu solder, which is eutectic at 3.9% Ag and 0.6% Cu, exhibits a melting temperature of about 217 °C. Copper may be difficult to stabilise in this alloy.

Nickel-Palladium. Ni-Pd as an alternative lead-free solder was introduced by Texas Instruments (TI) to the semiconductor industry in 1989. Since then, TI has shipped millions of units that used this 'lead-free' lead finish material.

Envvironmental performance and operational data

Surface mounting of units on boards requires the exposure of the device package to high temperature to melt the lead finish for board soldering. A lot of the alternative 'lead-free' solder materials being considered for use require a peak soldering temperature of about 250-260 °C, versus the peak temperature of 230-235 °C for Sn-Pb solder. This means that lead-free interconnectors will need a higher temperature for board mounting and will therefore be subjected to more severe thermomechanical stresses during the process

An essential aspect of developing a 'lead-free' solder plating process for interconnectors assembly is the reliability testing of existing package designs to determine if they will still withstand the board mounting process at the higher temperature under the same moisture sensitivity classification. If not, either the package's Moisture Sensitivity Level (MSL) classification should be downgraded or a new material set or package design should be implemented to ensure that the new 'lead-free' board mounting process does not introduce any reliability risks.

Technical consideration srelevant to applicability

Applicability may be limited by product specifications.

Example plants

IE001 and MT001.

Reference literature

[168, TWG, 2023] [https://www.eesemi.com/pbfree.htm]

4.3.5.5.2 Cyanide substitution

Description

This includes the use of the following:

- Thiourea(CH_4N_2S)-based processes. These involve the formation of soluble thiourea complexes, which can be easily separated from the metal ions and regenerated for reuse.
- Thiosulphate-based processes: Sodium thiosulphate ($Na_2S_2O_3$) is used for the dissolution of gold and silver. The thiosulphate complexes can be reduced to elemental metal using a suitable reducing agent.
- Ionic liquids: Room-temperature ionic liquids (RTILs) can be used as non-aqueous media for the dissolution of gold and silver.
- Use of electrochemical processes, such as electroless deposition and electrodeposition. These involve the transfer of metal ions between an anode and cathode in an electrolyte solution, with the metal ions selectively deposited onto the cathode surface.

Technical consideration srelevant to applicability

Generally applicable.

Example plants
IE001.

Reference literature
[168, TWG, 2023]

4.3.5.5.3 Remote plasma chamber cleaning

Description
A remote plasma is generated using an electric discharge in a chamber filled with NF_3 gas. The plasma breaks down the NF_3 molecules, generating highly reactive fluorine radicals that react with and remove organic and inorganic contaminants from the chamber surface.

Technical description
It is a method for cleaning of the interior surfaces of process chambers, such as chemical vapour deposition (CVD), physical vapour deposition (PVD) and etch chambers, without exposing the substrates to the cleaning plasma.

Remote plasma cleaning uses a plasma source located outside the process chamber to generate reactive species, such as radicals and ions, that are then transported into the chamber through a gas flow or other means. These reactive species then react with contaminants on the chamber surfaces, breaking them down and allowing them to be removed through a gas flow or other means.

The main advantages are as follows:
Reduced damage to substrates:
By keeping the plasma source outside the process chamber, remote plasma cleaning minimises the risk of damage to substrates from high-energy ions and radicals.

Improved chamber cleaning:
Remote plasma cleaning can effectively remove contaminants from chamber surfaces, improving process consistency and reducing the risk of defects.

Increased process flexibility:
Remote plasma cleaning can be used to clean chambers between processes, allowing for faster process switching and increased productivity.

Reduced chemical usage:
Remote plasma cleaning can reduce the need for chemical cleaning agents, minimising waste and environmental impact.

Improved safety:
Remote plasma cleaning reduces the risk of exposure to hazardous chemicals and plasma radiation, improving operator safety.

Remote plasma cleaning is commonly used in various semiconductor manufacturing processes, including:

- CVD and PVD chamber cleaning;
- etch chamber cleaning;
- ashing and stripping processes;
- chamber seasoning and passivation.

Technical consideration srelevant to applicability

Generally applicable.

Reference literature
[168, TWG, 2023]

4.3.6 Porcelain (vitreous) enamelling of metals

4.3.6.1 Material efficiency

4.3.6.1.1 Optimisation of raw material consumption

Description
Optimisation of raw material consumption includes techniques such as:

- optimisation of the use of raw materials, such as enamel powder (minimising excess powder) and metal substrates;
- use of recycled enamel;
- optimisation of the metal surface preparation process.

Technical description
A. Optimisation of the use of raw materials, such as enamel powder (minimising excess powder) and metal substrates

This technique involves streamlining the use of raw materials, such as enamel powder and metal substrates, to minimise waste and reduce consumption. The objective is to achieve the same level of product quality while using fewer resources.

Minimising excess enamel powder, can be achieved by using techniques such as:

- optimising powder application rates;
- using powder recovery systems;
- improving powder handling and storage.

Metal substrate optimisation is achieved by using techniques to reduce the generation of metal waste, such as:

- optimising metal sheet cutting and shaping;
- using metal scrap recycling;
- improving metal surface preparation.

Achieved environmental benefits
- Reduced raw material costs.
- Minimised waste and environmental impact.
- Improved product quality and consistency.
- Increased efficiency and productivity.
- Enhanced competitiveness and profitability.

B. Use of recycled enamel

Use of recycled enamel (also mentioned as reclaimed or reprocessed enamel) involves the collection and processing of waste enamel materials, such as:

- overspray: excess enamel that is sprayed onto the metal but does not adhere to the metal surface;

- runs and drips: enamel that has flowed off the metal surface during the firing process.
- scrap metal: enamelled metal that is scrapped or rejected during production.

The collected waste enamel is then processed to remove contaminants, crushed or ground into a fine powder, and mixed with virgin enamel materials. This reclaimed enamel can be used in various porcelain enamelling applications, including the following:

- Ground coat: The first layer of enamel applied to the metal, which provides a strong bond between the metal and subsequent enamel layers.
- Cover coat: The final layer of enamel, which provides colour, gloss, and corrosion resistance.
- Enamel slips: A mixture of reclaimed enamel and other materials, used for repairing or touching up existing enamel coatings.

Examples of using recycled enamel include the following:

- In the 1990s, the US Enamel Council developed a programme to recycle porcelain enamel waste, which resulted in the recovery of over 10 000 tons of enamel per year.
- The German company, Eisenwerk Brühl, uses a patented process to recycle porcelain enamel waste, which is then used in their own production of enamelled cast iron products.
- The Chinese company, Foshan Shunde Ceramic Research Institute, has developed a technology to recycle porcelain enamel waste and use it in the production of enamelled steel products.

Environmental performance and operational data

Use of recycled enamel has some limitations, related to the following:

- The colour consistency: Recycled enamel may not match the exact colour of virgin enamel materials.
- the enamel properties: The properties of recycled enamel, such as its melting point or thermal expansion, may differ from those of virgin enamel materials.

C. Optimisation of metal surface preparation process

This technique involves refining the process of preparing metal surfaces for enamel coating to minimise waste, reduce costs and improve product quality.

This is achieved by implementing techniques such as the following:

- Cleaning and degreasing: Implementing effective cleaning and degreasing methods to remove dirt, oil, and other contaminants from the metal surface.
- Grinding and polishing: Optimising grinding and polishing techniques to achieve the desired surface finish while minimising metal removal.
- Pickling and etching: Using pickling and etching processes to remove surface impurities and create a strong bond between the metal and enamel.
- Drying and handling: Improving drying and handling procedures to prevent surface damage and contamination.

Achieved environmental benefits:

- Improved enamel adhesion and durability.
- Reduced metal waste and energy consumption.
- Enhanced product quality and appearance.
- Increased efficiency and productivity.
- Cost savings through reduced material waste and energy consumption.

4.3.6.1.2 Optimisation of process control

Description
Optimisation of process control includes:

- implementing advanced process control systems and monitoring including real-time data analysis;
- predictive maintenance;
- process automation.

See more information in Section 4.2.6.4.1.

4.3.6.1.3 Improvement of pickling efficiency

Description
Agitation of process solution (e.g. with air injection or hydraulic turbulence).

See more information in Section 4.2.6.4.2.

4.3.6.1.4 Optimisation of degreasing

Description
Degreasing optimisation also includes the use of oil separators for the maintenance of degreasing solutions.

See more information in Section 4.2.6.5.13.

4.3.6.1.5 Recovery of acids/alkalis

Description
Spent treatment solutions with high acidity or alkalinity are recovered and used for on-site physico-chemical waste water neutralisation.

See more information in Section 4.2.5.5.

4.3.6.2 Energy efficiency

4.3.6.2.1 Selection of an energy-efficient type of furnace

Description
Furnace energy efficiency is taken into consideration for the furnace selection, e.g. furnaces that allow the preheating and drying of incoming charge prior to the melting zone.

Achieved environmental benefits
Reduced energy consumption.

Technical considerations relevant to applicability
Only applicable to new plants and/or major plant upgrades.

Economics
No information provided.

Driving force for implementation

Reduction of energy consumption and related cost savings.

Example plants
Widely used.

4.3.6.2.2 Furnace automation and control

Description
The heating process is optimised by using a computer system controlling key parameters such as furnace and feedstock temperature, air to fuel ratio and the furnace pressure.

Technical description
Furnace automation takes care of the combustion, the energy consumption, material handling, temperature control of the feedstock and process safety continuously. In addition, it enables adjustment of the air to fuel ratio for optimum combustion, which in turn minimises NO_X emissions.

The furnace control system collects all the necessary data related to the operation of the furnace such as the equipment utilisation, the furnace temperature and pressure, the inputs and outputs and the energy consumption (fuel/electricity). The data can be visualised in real time by the plant operator and can be transferred for further analysis. Furnace logs including data on operating modes, operating times, temperature curves and fuel consumption figures can be stored for quality assurance purposes.

Achieved environmental benefits
Optimised furnace operation.

Environmental performance and operational data
No information proided.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Economics
No information provided.

Driving force for implementation
Increased efficiency of furnace operation and productivity.

Example plants
Widely used.

4.3.6.2.3 Techniques for maximising the thermal efficiency of furnaces

Description
Measures taken to maximise the efficiency of energy conversion furnaces while minimising emissions. This is achieved by applying a series of process optimisation measures according to the furnace type including optimisation of the temperature (e.g. efficient mixing of the fuel and combustion air) and residence time in the combustion zone, and use of furnace automation and control (see Section 4.3.6.2.2).

Technical description

Measures include the following:

- *Optimisation of operational regime*: The furnace is operated in its optimum regime as much as possible.
- *Avoidance of excess temperature*: Measures are taken to avoid excess temperatures of the melt and reduce the superheating temperatures.
- *Minimisation of air losses*.

Achieved environmental benefits
Increased furnace efficiency, lower energy consumption.

Cross-media effects
None.

Technical considerations relevant to applicability
Generally applicable.

Driving force for implementation
- Optimisation of furnace operation.
- Legal requirements.

Example plants
Widely used.

4.4 Techniques to consider in the determination of emerging techniques for specific activities

4.4.1 Electroplating and chemical plating

4.4.1.1 Additive surface modification of plastic workpieces

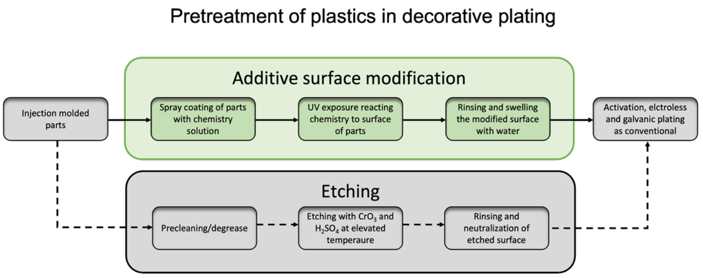
Description

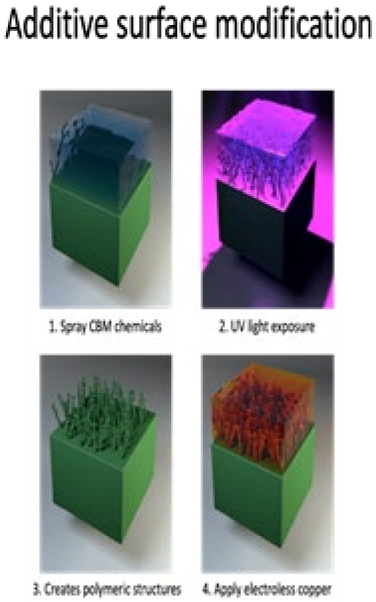
Parts are coated prior to plating with a monomer solution followed by exposure to an energy source, resulting in the modification of surface properties, e.g. hydrophilic.

Technical description

Plastic surfaces in general are hydrophobic and not particulary susceptible to electrochemical deposition of metals. To overcome these disadvantageous properties, the plastic substrate needs to be pretreated in order to make it more hydrophilic and to alter the electrochemical environment. Current techniques use etching with metal salts, acids and heat to deteriorate the chemical structure of the surface layer in the plastic. The candidate technique described here achieves similar changes in hydrophilicity and electrochemical environment, but in an additive manner.

Parts are coated with a monomer solution followed by exposure to an energy source. This results in an addition of molecules to the surface of the plastic. This method is referred to as 'grafting' and the added molecules as 'graft polymer'. The graft polymer has hydrophilic properties, as well as electrochemical properties suitable for metal deposition. The solution is an engineered chemistry with initiators and catalysts that minimise the energy required for the modification of the surface.





Source: [167, TWG, 2023]

Figure 4-50: Additive surface modification

Achieved environmental benefits

Hexavalent chromium in pretreatment of plastics is eliminated. Reduced energy consumption in pretreatment of plastics compared to other etching processes (CrO3 and Mn3+) is expected. A less hazardousous work environment, waste water free from metals and reduced water consumption are other plausible benefits.

Environmental performance and operational data
Currently limited environmental performance and operational data are available.

The technique is not yet in industrial production, but several projects at an industrial scale are ongoing. In 2019 the technique participated in a round robin benchmark test of alternative pretreatment techniques for plastics. The test was designed and conducted by Fachverband Galvanisierte Kunststoffe (FGK). The suggested technique is referred to as ‘Verfahren 4’. In that test, the durability of plated ABS and ABS/PC products was evaluated in different climate tests. The results showed equal or better performance compared to competing alternative techniques using manganese-based etchants. As a response to these results, the technique has been developed to optimise performance on plating-grade ABS and ABS/PC material. A second set of ABS parts with the developed technique is currently being evaluated by FGK and results are expected in early 2022.

Two industrialising projects are also currently ongoing. One project is in cooperation with a leading Swedish producer of sanitary fittings. In that project, product quality has been approved by the producer and investigations into economical feasibility for investment and production are currently going on. The other project involves a larger Spanish injection moulding and plating company. This project is evaluating automotive parts treated with additive surface modification and how the technique performs in their existing plating facility.

The technique could also be implemented on other thermoplastics, such as PA and PP. Those plastics are generally not used for plating due to difficulties to achieve an acceptable quality in the finished products. The technique is also evaluated for other purposes besides decorative plating, such as electronics with both thermoplastic and thermosets as substrate.

Cross-media effects
The technique uses solvent to dilute and administer chemistry on a surface. This use of solvent requires measurments to reduce emissions of VOCs. Washing and swelling of the synthesised polymer produce waste water containing organic compounds and possibly harmful residues and products. This waste water requires treatment to reduce the oxygen demand and to make it safe for reuse or release.

Technical considerations relevant to applicability
Applicability may be restricted by product specifications.

Economics
Raw material costs for the technique are estimated at EUR 0.03 per treated square metre. Further economical analyses to reveal production and investment costs are ongoing. Savings are expected in raw material costs, energy use, waste treatment and water usage. Increased costs are expected in labour, industrial premises and investment.

Driving force for implementation
The main driving force for implementation is substition of hexavalent chromium in pretreatment of plastics. The possibility to use other plastics, which cannot be plated with current technology, may also be a driving force in some applications. Savings in the use of energy, water and chemicals are also possible economic and environmental driving forces, but more data would be needed to determine those benefits.

Reference literature
SE contribution to [167, TWG, 2023]

~~4.4.1.2 Substitution by trivalent chromium plating for hexavalent chromium in hard chromium applications using modified pulse current~~

~~Description~~

~~The process uses a simplified trivalent chromium electroplating solution based on chromium sulphate. The current waveform is proprietary (patents pending) and includes pulse-reverse current. Chromium has been deposited at up to 250µm successfully and could be deposited to any thickness. Hardness, rate of deposition and post-finishing for thick coatings are the same as for chromium from hexavalent solutions. Colour for thin layers is the same (chrome-blue) as from hexavalent chromium. The process retains the advantages of Cr III solutions, such as lower concentrations, higher current efficiency and tolerance to sulphate and chloride dragged-in from any previous nickel plating stages. Lack of organic additives will reduce or eliminate solution maintenance with activated carbon.~~

~~Table 4-22: Comparison of hard chromium plating by traditional Cr(VI) and modified pulse current Cr(III)~~

	~~Plating rate µm/min~~	**~~Current efficiency~~**	**~~Hardness (VHN*) prior to post-hardening~~**	**~~Process sequence~~**
~~Automotive OEM** Cr(VI)~~	~~0.8~~	~~24 %~~	~~772~~	~~• 3-step precleaning~~ ~~• Plating~~ ~~• 1-step post-treatment~~
~~Cr(III) process~~	~~1.2~~	~~30 %~~	~~777~~	~~• 3-step precleaning~~ ~~• Plating~~ ~~• 1-step post-treatment~~
~~Note: * VHN = Vickers Hardness Number (measurement of hardness)~~ ~~** OEM = Original Equipment Manufacturer~~				

~~Achieved environmental benefits~~

~~Replaces hexavalent chromium solutions, with reduced waste gas and waste water treatments. Solution concentrations are the same as existing Cr(III) chemistry and up to ten times lower than Cr(VI) solutions.~~

~~Higher current efficiency, therefore less power consumption.~~

~~No chloride electrolyte, so no production of chlorine.~~

~~Requires no organic additives to suppress chlorine formation, or such as PFOS to suppress mist formation or to improve throw, etc.~~

~~A further stage of development will confirm if it can be operated as a closed loop system.~~

~~Cross-media effects~~

~~None~~

~~Operational data: Status of development~~

~~The process has been patented and is at pre-production verification in three key projects:~~

- ~~comparative testing (against Cr(VI) plated components) of 11” (28cm) rotors for pumps handling abrasive slurries (such as in mining, oil exploration and cement handling). Completion Spring 2004~~
- ~~rollers in large-scale steel rolling mill. Completion in Summer 2004~~
- ~~compliance with military specifications through an approved Commercial Technology for Maintenance Activity (CTMA) project involving the US Department of Defence and military maintenance depots with the National Centre for Manufacturing Sciences (Michigan, US; CTMA promotes new techniques which reduce health, safety and environmental risks in military applications). Completion in 2005.~~

~~**Applicability**~~
~~Intended applicability is full replacement of Cr(VI) electroplating for hard chromium treatments.~~

~~**Economics**~~
~~Likely future operating costs: The system is chromium sulphate based, which is currently slightly more expensive than existing CrIII chemistry (increased usage may reduce market price). However, no organic additives are used, reducing cost and maintenance. Electricity costs are likely to be half of present costs. Reduced effluent treatment chemicals, and possible reduction in waste produced.~~

~~Likely future capital costs: Power supply: up to double the cost of a traditional DC supply.~~
~~Reduced requirements for waste gas and waste water treatment equipment.~~

~~**Driving force for implementation**~~
~~The development of alternatives to using hexavalent chromium electroplating solutions is driven by health and safety in the workplace and environmental toxicity (chromium metal plated on a surface has no adverse health effects). See Section .~~

~~**Example plants**~~
~~See Operational data~~

~~**References**~~
~~http://www.nttc.edu/resources/funding/awards/epa/pollution00/Phase2/renz.asp~~
~~http://www.newmoa.org/prevention/p2tech/ [108, NEWMOA, 2003]~~

~~4.4.1.3 Aluminium and aluminium alloy plating from organic electrolytes~~

~~**Description**~~
~~The possibility of production scale plating of aluminium onto steel is attractive because of the high corrosion protection such a system offers. It would also enable substitution for more toxic metals such as cadmium, zinc and nickel, as well as chromium used in passivation of zinc, etc.~~

~~However it is not possible to electroplate pure aluminium onto steel workpieces from an aqueous solution.~~

~~The problem which has not been solved so far industrially, is applying an even, pure aluminium layer on a workpiece, without stressing it thermally. Due to the negative potential of 1.7 V for aluminium in the electromotive series of elements, the electro-chemical deposition from an aqueous solution is not possible in the electroplating shop.~~

~~A technology electroplating from non- aqueous solvents has been described for many years on laboratory and pilot scales. It has now been developed for the first time on an industrial scale for plating with aluminium or aluminium-magnesium alloys first in Germany. This has shown the technology to be feasible economically~~

~~A production plant with a 3 m^3 process tank was built, which can take workpieces up to 1500 x 600 mm. On a three-shift operation a maximum of 30 racks can be treated per day, which corresponds to the capacity of a middle sized electroplating plating unit.~~

~~After a conventional pretreatment (degreasing, pickling) the workpieces are dried in a bath with high boiling esters. Because of the high reactivity of the electrolytes with air and water the processing step must take place in a totally enclosed plant. The jigs are placed in the processing vat via an air-lock.~~

~~Achieved environmental benefits~~
~~Substitution by aluminium for more toxic metals such as cadmium, zinc and nickel.~~
~~There is no drag out of electrolyte, rinsing or any subsequent waste water and waste.~~

~~Cross-media effects~~
~~Because of the high reactivity of the electrolytes, the plating part of the plant must be a perfectly closed system.~~

~~Emissions to water, to air and/or waste are likely to be:~~

- ~~waste water from the conventional degreasing and pickles~~
- ~~toluene from the air-lock and diffuse sources~~
- ~~waste as used electrolytes.~~

~~The used process solution is difficult to deal with and is managed off site, where any associated emissions of toluene, etc. will occur.~~

~~Operational data~~
~~As an electrolyte an aluminium alkyl complex dissolved in toluene is used. The anodes consist of super-pure aluminium or aluminium/magnesium alloy. The current yield is almost 100 % and the deposition speed is approximately 10 µm per hour. The service lifetime of the electrolytes is approximately six months. Currently, predominantly steel parts are coated such as screws, nuts, springs, etc., for the automotive industry.~~

~~Handling the highly inflammable and explosive electrolytes requires completely new safety precautions, which go a far beyond any normal electroplating shop.~~
~~Economics~~
~~No data provided~~

~~Driving force for implementation~~
~~High corrosion protection offered by aluminium coating.~~
~~Substitution by aluminium coating for more toxic metals.~~

~~Example plants~~
~~See Reference literature.~~

~~Reference literature~~
~~Projects funded by the German Federal Ministry of Science and Technology "Development and testing of a low-waste technology for the electro-deposition of aluminium coatings on all base materials of technical importance" (Sedec Galvano Aluminium KG; FKZ 01ZH 0326 and FKZ 01ZH8501) and UBA-Project: "Development and Scale up of an environmentally friendly galvanic process to deposit high purity aluminium layers on metal pieces" (Aluminal Oberflächentechnik GmbH; FKZ 30441-5/41). [104, UBA, 2003]~~

4.4.2 Printed circuit boards

[Based on the information submitted with the data collection ([168, TWG, 2023]), the three techniques below are now proposed as BAT candidates

4.4.2.1 Laser direct imaging

~~Considerable problems can occur with misalignment or distortion in the production of primary images on inner and outer layers, causing problems with hole alignment. Laser direct imaging is in use for primary imaging, but the technique is too slow for high volume production. It is mainly used for production of prototypes and smaller series.~~
~~Laser direct imaging is also being developed for solder mask imaging, but laser imageable solder masks are not available currently available (mid-2004).~~

~~Environmental benefits~~

~~No films required for the imaging process~~

~~No developing media and rinsing processes from diazo silver halide films~~

~~More precise imaging and less rejects with better material usage.~~

~~Reference literature~~

~~[122, UBA, 2003] [159, TWG, 2004]~~

4.4.2.2 High density interconnects (HDI)

~~Description~~

~~HDI technology achieves higher packing density of electronic sub-assemblies. A dense primary image is achieved by using new types of hole generation, giving smaller hole diameters and smaller track width.~~

~~Smaller holes can be generated by laser, plasma or photo-processes. Development started in the early 1990s but is still not finalised.~~

~~Environmental benefit~~

~~Smaller sub-assemblies requiring less material.~~

~~Reference literature~~

~~[122, UBA, 2003]~~

4.4.2.3 Embedded passives

~~Description~~

~~Embedded passives is a technology which enables the manufacture of smaller boards with more functionality and improved high frequency performance. The principle is to remove the discrete resistors and capacitors from the surface and embed them in the inner layers of a PCB.~~

~~There are several different technologies available for embedded passives, from thin laminate type of materials to various kinds of paste solutions."~~

~~Reference literature~~

~~[159, TWG, 2004]~~

4.4.3 Porcelain (vitreous) enamelling of metals

4.4.3.1 Adherence without NiO and CoO

Description

Adherence of enamel on both carbon steel and stainless steel could be achieved by applying an inorganic primer on the substrate just before enamelling. The primer contains a mixture of metal oxides, metal salts, metals, metallates and glasses. None of the components used contain nickel or cobalt. All adherence-promoting components, together with rheological additives, are brought into suspension in water and the formed slip can be applied as a thin coating by spraying (conventional or with electrostatic support- ESTA), dipping, flow coating, or coil coating.

Reference literature

pei_24th_enamellers+congress_papers.pdf page 57

5 DRAFT BEST AVAILABLE TECHNIQUES (BAT) CONCLUSIONS FOR THE SURFACE TREATMENT OF METALS AND PLASTICS

[This chapter has been completely rewritten compared to the 2006 STM BREF.]

Scope

These BAT conclusions concern the following activities specified in Annex I to Directive 2010/75/EU as amended by Directive (EU) 2024/1785:

2.6. Surface treatment of metals or plastic materials using an electrolytic or chemical process where the volume of the treatment vats exceeds 30 m^3.

6.11 Independently operated treatment of waste water not covered by Directive 91/271/EEC[11], provided that the main pollutant load originates from the activities covered by these BAT conclusions.

These BAT conclusions cover the porcelain (vitreous) enamelling of metals and also the following:

- The manufacturing of semiconductors covered by the activity description in point 6.7 of Annex I to Directive 2010/75/EU as amended by Directive (EU) 2024/1785.
- The combined treatment of waste water from different origins, provided that the main pollutant load originates from the activities covered by these BAT conclusions and that the waste water treatment is not covered by Directive 91/271/EEC[1].
- Combustion processes directly associated with the activities covered by these BAT conclusions provided that the gaseous products of combustion are put into direct contact with material.

These BAT conclusions do not cover the following:

- Waste water from indirect cooling systems. This may be covered by the BAT conclusions for Industrial Cooling Systems (ICS).
- On-site combustion plants generating hot gases that are not used for direct contact heating, drying or any other treatment of objects or materials. These may be covered by the BAT conclusions for Large Combustion Plants (LCP) or by Directive (EU) 2015/2193 of the European Parliament and of the Council[12].

Other BAT conclusions and reference documents which could be relevant for the activities covered by these BAT conclusions are the following:

- Surface Treatment Using Organic Solvents (STS);
- Waste Treatment (WT);
- Monitoring of Emissions to Air and Water from IED Installations (ROM);
- Economics and Cross-Media Effects (ECM);
- Emissions from Storage (EFS);
- Energy Efficiency (ENE).

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[11] Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment (OJ L 135, 30.5.1991, p. 40).

[12] Directive (EU) 2015/2193 of the European Parliament and of the Council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants (OJ L 313, 28.11.2015, p. 1).

These BAT conclusions apply without prejudice to other relevant Union legislation, e.g. on the registration, evaluation, authorisation and restriction of chemicals (REACH), on classification, labelling and packaging of substances and mixtures (CLP), on energy efficiency (energy efficiency first principle), or on the European Union emissions trading system.

Definitions

For the purposes of these BAT conclusions, the following definitions apply:

[Note to the TWG: please consider proposing additional definitions if needed for a proper understanding of these BAT conclusions]

General terms	
Term used	**Definition**
Benchmarks	Benchmarks as defined in point 13b of Article 3 of Directive 2010/75/EU as amended by Directive (EU) 2024/1785.
Channelled emissions	Emissions of pollutants into the environment through any kind of duct, pipe, stack, etc.
Class 1	Refers to the cleanliness classification of a semiconductor manufacturing facility or specific clean room. The classification system is based on the number of particles per cubic metre of air in a specific size range, as defined by the International Organization for Standardization (ISO) and SEMI standards. Class 1 represents the highest level of cleanliness, with a maximum of 10 particles (0.1 µm or larger) per cubic metre of air.
Continuous measurement	Measurement using an automated measuring system permanently installed on site.
Diffuse emissions	Non-channelled emissions to air. Diffuse emissions include both fugitive and non-fugitive emissions. Fugitive emissions are non-channelled emissions to air caused by loss of tightness of equipment which is designed or assembled to be tight. Non-fugitive emissions may arise from atmospheric vents, bulk storage, or loading/unloading systems for example.
Direct discharge	Discharge to a receiving water body without further downstream waste water treatment.
E-coating	Coating process where paint particles dispersed in a water-based solution are deposited on immersed substrates under the influence of an electric field (electrophoretic deposition).
Existing plant	A plant that is not a new plant.
Hazardous waste	Hazardous waste as defined in point 2 of Article 3 of Directive 2008/98/EC⁽¹⁾.
Hazardous substances	Hazardous substances as defined in point 18 of Article 3 of Directive 2010/75/EU as amended by Directive (EU) 2024/1785.
Indirect discharge	A discharge that is not a direct discharge (e.g. a discharge of waste water to a sewer with or without pretreament).
Major plant upgrade	A major change in the design or technology of a plant with major adjustments or replacements of the process and/or abatement technique(s) and associated equipment.
New plant	A plant first permitted at the site of the installation following the publication of these BAT conclusions or a complete replacement of a plant following the publication of these BAT conclusions.
Periodic measurement	Measurement at specified time intervals using manual or automated methods.
Plant	All parts of an installation that carry out the activities covered by the scope of these BAT conclusions and any other directly associated activities which have an effect on environmental performance (e.g. consumption) and/or emissions. Plants may be new plants or existing plants. Different process lines may be part of the same plant.
Process chemicals	Substances and/or mixtures as defined in Article 3 of Regulation EC/1907/2006⁽²⁾ and used in the process(es). Process chemicals may contain hazardous substances.
Residue	Substance or object generated by the activities covered by the scope of these BAT conclusions as waste or by-product.
Surface run-off water	Water from precipitation that flows over land or impervious surfaces, such as paved streets, storage areas and rooftops, and does not soak into the ground.
Valid hourly (or half-hourly) average	An hourly (or half-hourly) average is considered valid when there is no maintenance or malfunction of the automated measuring system.

(1) Directive 2008/98/EC on waste and repealing certain Directives.
(2) Regulation EC/1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC (OJ L 396, 30.12.2006, p. 1).

Pollutants and parameters	
Term used	**Definition**
Ag	The sum of silver and its compounds, dissolved or bound to particles, expressed as Ag.
Al	The sum of aluminium and its compounds, dissolved or bound to particles, expressed as Al.
Sb	The sum of antimony and its compounds, dissolved or bound to particles, expressed as Sb.
AOX	Adsorbable organically bound halogens, expressed as Cl, include adsorbable organically bound chlorine, bromine and iodine.
As	The sum of arsenic and its compounds, dissolved or bound to particles, expressed as As.
B	The sum of boron and its compounds, dissolved or bound to particles, expressed as B.
BOD_5	Biochemical oxygen demand. Amount of oxygen needed for the biochemical oxidation of organic and/or inorganic matter in 5 (BOD_5) days.
Cd	The sum of cadmium and its compounds, dissolved or bound to particles, expressed as Cd.
CMR	Carcinogenic, mutagenic, toxic for reproduction. This includes CMR substances of categories 1A, 1B and 2, in accordance with Annex I to Regulation (EC) No 1272/2008 as amended[13].
CO	Carbon monoxide.
Co	The sum of cobalt and its compounds, dissolved or bound to particles, expressed as Co.
COD	Chemical oxygen demand. Amount of oxygen needed for the total chemical oxidation of the organic matter to carbon dioxide using dichromate. COD is an indicator for the mass concentration of organic compounds.
Cu	The sum of copper and its compounds, dissolved or bound to particles, expressed as Cu.
Cr	The sum of chromium and its compounds, dissolved or bound to particles, expressed as Cr.
Cr(VI)	The sum of chromium(VI) and its compounds, dissolved or bound to particles, expressed as Cr(VI) (in water). The sum of chromium(VI) and its compounds, expressed as Cr(VI) (in air).
Cyanide	Free cyanide, expressed as CN^-.
Dust	Total particulate matter (in air).
EDTA	Ethylenediaminetetraacetic acid.
HCl	All inorganic gaseous chlorine compounds, expressed as HCl.
HF	All inorganic gaseous fluorine compounds, expressed as HF.
Fe	The sum of iron and its compounds, dissolved or bound to particles, expressed as Fe.
Fluorides	Dissolved fluoride, expressed as F.
HCN	Hydrogen cyanide.
GHG	Greenhouse gases.
HOI	Hydrocarbon oil index. The sum of compounds extractable with a hydrocarbon solvent (including long-chain or branched aliphatic, alicyclic, aromatic or alkyl-substituted aromatic hydrocarbons).
Hg	The sum of mercury and its compounds, dissolved or bound to particles, expressed as Hg.

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[13] Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006 (OJ L 353, 31.12.2008, p. 1).

Pollutants and parameters	
Term used	**Definition**
NH_3	Ammonia.
Ni	The sum of nickel and its compounds, dissolved or bound to particles, expressed as Ni (in water). The sum of nickel and its compounds, expressed as Ni (in air).
NO_X	The sum of nitrogen monoxide (NO) and nitrogen dioxide (NO_2), expressed as NO_2.
Pb	The sum of lead and its compounds, dissolved or bound to particles, expressed as Pb (in water). The sum of lead and its compounds, expressed as Pb (in air).
Phenol index	The sum of phenolic compounds, expressed as phenol concentration and measured according to EN ISO 14402.
PFAS	Per- and polyfluoroalkyl substances.
Se	The sum of selenium and its compounds, dissolved or bound to particles, expressed as Se (in water).
Sn	The sum of tin and its compounds, dissolved or bound to particles, expressed as Sn (in water).
SOx	The sum of sulphur dioxide (SO_2), sulphur trioxide (SO_3), and sulphuric acid aerosols, expressed as SO_2.
Sulphides	The sum of dissolved sulphides and of those undissolved sulphides that are easily released upon acidification, expressed as S^{2-}.
TOC	Total organic carbon, expressed as C (in water), includes all organic compounds.
Total nitrogen	Total nitrogen, expressed as N, includes free ammonia and ammonium nitrogen (NH4-N), nitrite nitrogen (NO2-N), nitrate nitrogen (NO3-N) and organically bound nitrogen.
Total phosphorus	Total phosphorus, expressed as P, includes all inorganic and organic phosphorus compounds, dissolved or bound to particles.
TSS	Total suspended solids. Mass concentration of all suspended solids (in water), measured via filtration through glass fibre filters and gravimetry.
TVOC	Total volatile organic carbon, expressed as C (in air).
VOC	Volatile organic compound as defined in Article 3(45) of Directive 2010/75/EU as amended by Directive (EU) 2024/1785.
Zn	The sum of zinc and its compounds, dissolved or bound to particles, expressed as Zn.

Acronyms

For the purposes of these BAT conclusions, the following acronyms apply.

Acronym	**Definition**
CMS	Chemicals management system.
EMS	Environmental management system.
ET	Emerging technique as defined in Article 3(14) of Directive 2010/75/EU as amended by Directive (EU) 2024/1785.
IED	Industrial Emissions Directive (2010/75/EU) as amended by Directive (EU) 2024/1785.
OTNOC	Other than normal operating conditions.
PCB	Printed circuit board.

General considerations

Best Available Techniques and Emerging Techniques

The best available techniques (BAT) and emerging techniques (ET) listed and described in these BAT conclusions are neither prescriptive nor exhaustive. Other techniques may be used that ensure at least an equivalent level of environmental protection including human health and climate protection.

Unless otherwise stated, the BAT conclusions are generally applicable.

[NOTE: Whilst cross-references are provided to other parts of this document in order to aid the work of the TWG, they will not be included in the final BAT conclusions themselves. Such cross-references are consequently displayed in italics in square brackets.]

[NOTE: In order to avoid repetition, this section contains general considerations that are essential to the understanding of the BAT conclusions taken as a stand-alone document, such as:

- *reference conditions for emissions to air (e.g. dry gas, standard temperature/pressure);*
- *averaging periods;*
- *sampling times;*
- *conversions to reference conditions;*
- *units in which environmental performance levels are expressed.]*

Emission levels associated with the best available techniques (BAT-AELs)

Emission levels associated with the best available techniques (BAT-AELs) for emissions to air

The BAT-AELs for emissions to air given in these BAT conclusions refer to concentrations (mass of emitted substances per volume of waste gas) under the following standard conditions: dry gas at a temperature of 273.15 K and a pressure of 101.3 kPa, without correction to a reference oxygen level, and expressed in the unit mg/Nm^3.

For averaging periods of BAT-AELs for channelled emissions to air, the following definitions apply:~~.~~

Type of measurement	Averaging period	Definition
Continuous	Daily average	Average over a period of 1 day based on valid hourly or half-hourly averages.
Periodic	Average over the sampling period	Average value of three consecutive samplings/measurements of at least 30 minutes each (1).

(1) For any parameter where, due to sampling or analytical limitations and/or due to operational conditions (e.g. batch processes), a 30-minute sampling/measurement and/or an average of three consecutive samplings/measurements is inappropriate, a more representative sampling/measurement procedure may be employed.

When the waste gases of two or more sources are discharged through a common stack, the BAT-AELs apply to the combined discharge from the stack.

Emission levels associated with the best available techniques (BAT-AELs) for emissions to water

The BAT-AELs for emissions to water given in these BAT conclusions refer to concentrations (mass of emitted substances per volume of water), expressed in mg/l or µg/l.

The BAT-AELs for emissions to water refer to either of the following averaging periods:

Type of discharge	Averaging period	Definition
Continuous	Daily average	24-hour flow-proportional composite samples.
Batch	Average over the release duration	Average value over the release duration taken as a flow-proportional composite sample or, provided that the effluent is appropriately mixed and homogeneous, a spot sample taken before discharge.

Time-proportional composite samples can be used provided that sufficient flow stability is demonstrated. Alternatively, spot samples may be taken, provided that the effluent is appropriately mixed and homogeneous.

The BAT-AELs apply at the point where the emission leaves the installation.

Environmental performance levels associated with the best available techniques (BAT-AEPLs) and benchmarks

BAT-AEPLs and benchmarks for specific net energy consumption

The BAT-AEPLs and benchmarks for specific net energy consumption refer to yearly averages calculated using the following equation:

$$\text{specific net energy consumption} = \frac{\text{energy consumption rate}}{\text{activity rate}}$$

where:

energy consumption rate: total amount of heat (generated from primary energy sources) and electricity consumed by the relevant process(es) expressed in kWh/year; and

activity rate: either:

- total amount of workpieces treated expressed in t/year, or
- total surface of treated surface expressed in m^2/year, or
- total surface of wafer expressed in m^2/year,

depending on the sector.

BAT-AEPLs and benchmarks for specific net water consumption

The BAT-AEPLs and benchmarks for specific net water consumption refer to yearly averages calculated using the following equation:

$$\text{specific net water consumption} = \frac{\text{water consumption rate}}{\text{activity rate}}$$

where:

water consumption rate: total amount of water consumed by the plant or by a given process within, excluding:

- recycled and reused water, and
- cooling water used in once-through cooling systems, and
- water for domestic usage,

expressed in m^3/year; and

activity rate: either:

- total amount of workpieces treated expressed in t/year, or
- total surface of treated surface expressed in m^2/year, or
- total surface of wafer expressed in m^2/year,

depending on the sector.

Environmental management system (EMS)

The minimum requirements of the EMS are listed in Article 14a (2) of Directive 2010/75/EU as amended by Directive (EU) 2024/1785. In order to complement Article 14a (2) of the Directive, the additional elements of the EMS are given in Section 5.4 of these BAT conclusions.

5.1 Conclusions on general best available techniques and emerging techniques

5.1.1 Overall environmental performance

5.1.1.1 Emissions to soil and groundwater

BAT 1. In order to prevent or reduce emissions to soil and groundwater, BAT is to use all of the techniques given below.

	Technique	Description	Applicability
a.	Structuring and management of process areas and raw material storage areas	This includes techniques such as: • impermeable (e.g. cemented) floors for process and storage areas; • containment bunds for storage tanks; • double-walled storage tanks; • automated detection of possible leakages/spillages in retentions; • separate storage for various types of raw materials, close to the process lines; this can be achieved using, for example, compartments or boxes in the storage areas, bunkers.	Generally applicable.
b.	Prevention of contamination of surface run-off water	Process areas and/or areas where process chemicals, fuels, residues or waste are stored or handled are protected against surface run-off water. This is achieved by using at least the following techniques: • drainage channels and/or an outer kerb bund around the plant; • roofing with roof guttering of process and/or storage areas.	
c.	Collection of potentially contaminated surface run-off water	Surface run-off water from areas that are potentially contaminated is collected separately and only discharged after appropriate measures are taken, e.g. monitoring, treatment, reuse.	
d.	Safe handling and storage of process chemicals and other input materials	This includes the following: • Storage of chemicals in roofed and well ventilated areas with floors impermeable to the chemicals concerned. • Use of oil-tight trays or cellars for hydraulic stations and oil- or grease-lubricated equipment. • Immediate collection of spilled liquids. Materials used for spill cleaning that are contaminated with hazardous substances are handled as hazardous waste. • Loading/unloading areas, e.g. for fuels, process chemicals, lubricants, coatings, are designed and constructed in such a way that potential leaks and spillages are contained and either reused or sent to on-site treatment (see BAT 24) or off-site treatment. Facilities for loading/unloading of substances fulfilling the criteria referred to in Article 57 of Regulation (EC) No 1907/2006 are equipped with vapour recovery systems. • Acids are stored separately from alkalis and cyanides (to avoid generation of free cyanide). • Flammable chemicals are stored separately from oxidising agents. • Chemicals which are spontaneously combustible when damp, are stored in dry conditions . The loading and unloading areas, as well as process and	

Technique		Description	Applicability
		storage areas of these chemicals, are marked appropriately to avoid the use of water in fire-fighting. • Organic peroxides are stored separately from other materials such as acids, alkalis, amines, accelerators, combustible materials, metals, and reducing agents.	
e.	Good housekeeping	A set of measures to prevent or reduce the generation of emissions (e.g. regular maintenance and cleaning of equipment, work surfaces, floors and transport routes, containment and rapid clean-up of any spillages).	

[This BAT conclusion is based on information given in BREF Section 4.2.1.4]

5.1.1.2 Retention and handling of spent fire extinguishing material

BAT 2. In order to reduce emissions to soil and groundwater and to minimise the concentration of pollutants in waste water flows as well as the generation of hazardous waste, BAT is to collect and separately store spent fire extinguishing water and/or foam prior to appropriate handling.

Description

Equipment and procedures are in place for the separate collection of contaminated firefighting water and/or foam, its storage in watertight storage basins indoors or outdoors, and its appropriate handling (treatment or disposal). Firefighting water bulkheads are installed for sealing of process or storage areas and the capacity of the retention system is based on the volume of treatment vats and the estimated volume of firefighting water and/or foam.

[This BAT conclusion is based on information given in BREF Section 4.2.1.6]

5.1.1.3 Reduction of reworking

BAT 3. In order to reduce the consumption of raw materials, energy and water as well as to reduce the generation of residues, BAT is to define precise process specifications and implement rigorous process control.

Description

The right process specifications are defined and followed (e.g. according to quality and environmental management systems), to ensure that the production quality is as stable as possible. This is complemented by appropriate process control to achieve optimal production quality and avoid reworking.

[This BAT conclusion is based on information given in BREF Section 4.2.1.7]

5.1.2 Monitoring

5.1.2.1 Monitoring of environmental performance

BAT 4. BAT is to monitor the following parameters with a minimum monitoring frequency of once every year and expressed as yearly averages.

Parameter	Sector							
	Electrolytic & chemical plating / All processes	**Steel coil continuous coating**	**Aluminium coil, sheet conversion coating and anodising**	**Sheet processing for aluminium lithographic plates**	**Porcelain (vitreous) enamelling of metals**	**PCB manufacturing**	**Semiconductor manufacturing**	**Monitoring associated with**
Water consumption	m^3/m^2 of workpieces treated	m^3/t of coil coated	m^3/m^2 of treated surface			m^3/m^2 of final product	m^3/m^2 of wafer surface	BAT 13
Waste water discharge	m^3/m^2 of workpieces treated per rinsing cycle							
Energy consumption	kWh/m^2 of workpieces treated	kWh/t of coil coated	kWh/m^2 of treated surface			kWh/m^2 of final product	kWh/m^2 of wafer surface	BAT 10
Process chemicals consumption	kg/m^2 of workpieces treated	kg/t of coil coated	kg/m^2 of treated surface			kg/m^2 of final product	kg/m^2 of wafer surface	BAT 13
Materials recovered, recycled and/or reused								BAT 13 BAT 26
Waste sent to disposal	g/m^2 of workpieces treated	g/t of coil coated	g/m^2 of treated surface			g/m^2 of final product	g/m^2 of wafer surface	BAT 26
Residues generated	kg/m^2 of workpieces treated	kg/t of coil coated	Kg/m^2 of treated surface			kg/m^2 of final product	kg/m^2 of wafer surface	
CO_2 equivalent emissions generated	t CO_{2eq}/m^2 of workpieces treated	t CO_{2eq}/t of coil coated	t CO_{2eq}/m^2 of treated surface			t CO_{2eq}/m^2 of final product	t CO_{2eq}/m^2 of wafer surface	BAT 10

Description

Monitoring preferentially includes direct measurements. Calculations or recording, e.g. using suitable meters or invoices, can also be used. The monitoring is broken down to the most appropriate level (e.g. to process or plant level) and considers any significant changes in the process or plant.

[This BAT conclusion is based on information given in BREF Section 4.2.2.1]

Monitoring of emissions to air

BAT 5. BAT is to monitor channelled emissions to air with at least the frequency given below, and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

Sectors:
- **(A) Electrolytic or chemical plating**
- **(B) Aluminium coil / sheet conversion coating/anodising**
- **(C) Continuous steel coil coating**
- **(D) Porcelain (vitreous) enamelling**
- **(E) PCB manufacturing**
- **(F) Semiconductor manufacturing**

Substance/ Parameter		**Sector**	**Standard(s)**	**Minimum monitoring frequency (1)**	**Monitoring associated with**
NH_3 (2)		(A), (E), (F)	EN ISO 21877	Once every year	BAT 22 BAT 35 BAT 41
Acidic emissions (2)		(A), (B)	Various EN standards		-
Alkaline emissions (2)		(A), (B), (C)	Various EN standards		-
Dust (2)		(A), (B), (C), (F)	EN 13284-1		BAT 22 BAT 26 BAT 29 BAT 40
Gaseous chlorides, expressed as HCl (2)		(A), (C), (E), (F)	EN 1911		BAT 22 BAT 26 BAT 35 BAT 40
Gaseous fluorides, expressed as HF (2)		(A), (B)	ISO 15713/2006 EN/TS 17340		BAT 22 BAT 29
HCN (2)		(A)	No EN standards available		BAT 22
Metals	Cr (2)	(A), (B), (C)	EN 14385		BAT 22 BAT 26BAT 29
	Cr_(VI) (2)	(A)		Once every 6 months	BAT 22
	Cu (2)	(A)		Once every year	BAT 22
	Ni (2)	(A), (B), (C)			BAT 22 BAT 26BAT 29
	Zn (2)	(A), (C)			
NO_X		(A), (F)	EN 14792		BAT 23 BAT 41
SOx (2)		(A)	EN 14791		BAT 22
TVOC (2)		(A) (B)	EN 12619 EN ISO 13199		BAT 22 BAT 29
TVOC		(E), (F)			BAT 35 BAT 47

(1) To the extent possible, the measurements are carried out at the highest expected emission state under normal operating conditions.

(2) The monitoring only applies when the substance/parameter concerned is identified as relevant in the waste gas stream based on the inventory of inputs and outputs mentioned in Section 5.4.2.

[This BAT conclusion is based on information given in BREF Section 4.2.2.2]

5.1.2.2 Monitoring of emissions to water

BAT 6. BAT is to monitor emissions to water with at least the frequency given below, and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

Sectors:

- **(A) Electrolytic or chemical plating**
- **(B) Aluminium coil/sheet conversion coating/anodising**
- **(C) Continuous steel coil coating**
- **(D) Porcelain (vitreous) enamelling**
- **(E) PCB manufacturing**
- **(F) Semiconductor manufacturing**
- **(G) Sheet processing for aluminium lithographic plates**

Substance/ Parameter		**Sector**	**Standard(s)**	**Minimum monitoring frequency (1) (2)**	**Monitoring associated with**
BOD_5		(F)	EN 1899-2 EN ISO 5815	Once every 3 months	BAT 20
COD (3)		(A), (B), (C), (D), (E), (F), (G)	No EN standard available		
TOC (3)			EN 1484 EN ISO 9562		
TSS			EN 872		
Fluorides (4)			EN ISO 10304-1		
AOX (4)			EN ISO 9562		
Cyanides (free) (4)		(A), (B), (E), (F)	EN ISO 10304-1 EN ISO 10304-2		
HOI (4)		(A), (B), (C), (D), (E)	EN ISO 9377-2		
Metals and metalloids	Ag (4)	(A), (F)	Various EN standards available (e.g. EN ISO 11885, EN ISO 17294-2, EN ISO 17852)		
	Al (4)	(A)			
	As (4)	(B)			
	B (4)	(F)			
	Cd (4)	(A), (B), (C), (E), (F)			
	Co (4)	(A), (B), (E), (F)			
	Cu (4)	(A), (B), (C), (E), (F)			
	Cr (4)				
	Cr(VI) (4)	(A), (B), (C), (D), (E), (F), (G)			
	Fe (4)				
	Hg (4)	(A), (B), (C), (F)			
	Pb (4)	(A), (C), (E), (F)			
	Ni (4)	(A), (F)			
	Se (4)	(A), (B), (C), (E), (F)			
	Sn (4)	(A), (B), (C), (D), (E), (F), (G)			
	Zn (4)	(F)			
Total phosphorus (4)		(A), (B), (C), (E), (F)	EN ISO 11885 EN ISA 6878		
PFAS (4)		(A), (B), (C), (D), (G)	No EN standard available		
PFAS		(E), (F)			
Surfactants (4)		(A), (B), (C), (D), (E), (F), (G)	Various EN standards available (e.g. EN ISO 18857-1 and EN ISO 18857-2 for alkylphenol, EN 903 for anionic surfactants)		
Total nitrogen (4)			EN 12260 EN ISO 11905-1		

Sectors:
(A) Electrolytic or chemical plating
(B) Aluminium coil/sheet conversion coating/anodising
(C) Continuous steel coil coating
(D) Porcelain (vitreous) enamelling
(E) PCB manufacturing
(F) Semiconductor manufacturing
(G) Sheet processing for aluminium lithographic plates

Substance/ Parameter	Sector	Standard(s)	Minimum monitoring frequency (1) (2)	Monitoring associated with
Toxicity (4)		Various EN standards available (e.g. EN ISO 15088, EN ISO 6341, EN ISO 11348-1, EN ISO 11348-2, EN ISO 11348-3, EN ISO 20079, EN ISO 20227, EN ISO 8692, EN ISO 10253, and EN ISO 10710)	To be decided based on a risk assessment, after effluent characterisation	
Sulphides (4)		No EN standard available	Once every 3 months	

(1) In the case of batch discharge less frequent than the minimum monitoring frequency, monitoring is carried out once per batch.
(2) The minimum monitoring frequency may be reduced to once every year if the emission levels are proven to be sufficiently stable.
(3) Either COD or TOC is monitored. TOC monitoring is the preferred option because it does not rely on the use of very toxic compounds.
(4) The monitoring only applies when the substance/parameter is identified as relevant in the waste water stream based on the inventory of inputs and outputs mentioned in Section 5.4.2.

[This BAT conclusion is based on information given in BREF Section 4.2.2.3]

5.1.3 Energy efficiency

BAT 7. In order to increase the overall energy efficiency of the plant, BAT is to use all of the techniques given below.

Technique		Description	Applicability
Equipment selection and process optimisation			
a.	Use of general energy-saving techniques	This includes techniques such as: • burner maintenance and control; • use of energy-efficient equipment (e.g. motors, lights); • use of optimised steam and compressed air distribution systems; • regular inspection and maintenance of the steam distribution systems and of equipment in the electrical supply system; • use of process control systems and optimisation of process solutions; • use of variable speed drives; • use of optimised air conditioning and building heating; • minimisation of heat losses, e.g. thermal insulation of heated process treatment vats, pipe insulation, use of double-	Generally applicable.

Technique		Description	Applicability
		walled or pre-insulated containers, temperature control of heating treatment vats; • reduction of heat losses from the surface of process treatment vats using floating spheres or lids for example.	
b.	Optimised design and handling of voltage supply and current demands	Effective management of incoming supplies to ensure that they align with the production phases, minimising reactive energy losses during voltage reduction and efficiently meeting the current demand required in the process.	
c.	Process line optimisation	See Section 5.3.1.	
d.	Adjustment of electroplating current	Each workstation is equipped with its own current rectifier to regulate the electroplating current and adjust it to the process specifications.	
e.	Optimisation of process solution agitation, conductivity and composition	See Section 5.3.1.	
Heating and cooling techniques			
f.	Combined heat and power generation (cogeneration)	See Section 5.3.1.	Applicability may be restricted by the lack of a suitable heat demand.
g.	Heat recovery	See Section 5.3.1.	Generally applicable.
h.	Use of passive cooling systems	This includes: • ambient cooling using outside air in cold weather conditions (e.g. below 7 °C); • cooling using the thermal capacity of ground water.	Applicability may be limited due to the prevailing climatic conditions.
i.	Workspace temperature optimisation (1)	Optimisation of workspace temperature, e.g. lower temperature during winter period and higher during summer period.	Applicability may be restricted by product specifications.
Techniques promoting industrial symbiosis			
j. .	Use of excess heat in another plant or for district heating	This includes: • use of excess heat generated by one plant at another plant that requires heat; • use of excess heat generated for space heating and hot water supply in nearby buildings.	Applicability may be restricted by the lack of a suitable heat demand.
(1) This technique also contributes to decarbonisation.			

Further sector-specific techniques to increase energy efficiency are given in Sections 5.2.1.3, 5.2.2.3, 5.2.5.3, 5.2.6.4 and 5.2.7.3 of these BAT conclusions.

[This BAT conclusion is based on information given in BREF Section 4.2.3]

5.1.4 Water consumption and waste water discharge

BAT 8. In order to reduce water consumption and the amount of waste water generated as well as to improve water recyclability, BAT is to use all the techniques given below.

Technique		Description	Applicability
Equipment selection and process optimisation techniques			
a.	Segregation of water streams	Water streams are collected separately (see BAT 23), based on the pollutant content and on the required treatment (see BAT 20). Waste water streams that can be recycled without treatment are segregated (e.g. cooling water) from waste water streams that require treatment.	Generally applicable.
b.	Use of general water-saving techniques	This includes techniques such as: • automatic valves to prevent leaks; • use of high-pressure water cleaning systems; • recycling/reuse of spent process water; • advanced process monitoring and control systems (see Section 5.3.2); • automatic systems for the preparation and dosing of process chemicals (see Section 5.3.3); • process line optimisation (see Section 5.3.1).	
c.	Prevention of contamination of surface run-off water	See BAT 1 (c).	
d.	Structuring and management of process areas and raw material storage areas	See BAT 1 (b).	
e.	Water reuse and/or recycling	Water streams (e.g. process water, effluents from rinsing and wet scrubbing, cooling water) are reused and/or recycled in closed or semi-closed circuits, if necessary after treatment (see BAT 20). This may include: • recirculating rinsing water from etching and surface treatment to treatment vats (see Section 5.3.2); • reusing purified water from evaporation; • returning the rinse water from the first rinse to the process solution; • recycling of degreasing solutions for pH adjustment in rinsing; • using spent treatment solutions with high acidity or alkalinity for on-site physico-chemical waste water neutralisation; • using etching solution from the main etching tank for pre-etching.	The degree of water reuse and/or recycling is limited by the water balance of the plant, the content of impurities and/or the characteristics of the waste water streams.
f.	Drag-in reduction	See Section 5.3.2.	Generally applicable.
g.	Drag-out reduction		
h.	Rinsing optimisation	This includes: • using multiple rinsing with rinsing water recirculation (see Section 5.3.2); • using eco-rinse (pre-dip), (see Section 5.3.3); eco-rinse can be combined with other rinse stages to increase the effectiveness of the multiple rinsing system; • using spray rinsing; • using vacuum evaporation; • regenerating and reusing/recycling rinsing water.	
i.	Closing the loop	Closing the loop by applying at process/line	Applicability may be

Technique		Description	Applicability
		level: • reduction of drag-out (see technique (h) above); • optimising rinsing (see technique (i) above); • concentrating the returning drag-out or receiving solutions (using, for example, ion exchange, membrane filtration, evaporation).	restricted by the chemical composition of the process water.
Techniques to promote industrial symbiosis			
j.	Exchange of waste water among plants	The technique involves the sharing between different plants of specific waste water flows that are used in waste water treatment.	Generally applicable as long as the waste water sources and treatment facilities are compatible.

Further sector-specific techniques to reduce water consumption and waste water discharge are given in Sections 5.2.2.1 and 5.2.7.1 of these BAT conclusions.

[This BAT conclusion is based on information given in BREF Section 4.2.5]

5.1.5 Material efficiency

BAT 9. In order to increase material efficiency, to reduce the consumption of raw materials including chemicals and to reduce the amount of waste generated, BAT is to use an appropriate combination of the techniques given below.

Technique		Description	Applicability
Techniques relevant to raw materials inputs and storage			
a.	Prevention of corrosion and degradation of metal workpieces/substrates	This includes: • shortening of the storage time; • controlling the corrosivity of the atmosphere during storage and transport, e.g. by adjusting the humidity, temperature, composition and air ventilation; • using either an anticorrosion-coating or anticorrosion-packaging (e.g. use of oil and/or grease).	Use of corrosion-preventing coating or packaging may be restricted in the case of high-volume production.
b.	Timely use of process chemicals	Criteria associated for example with shortening the storage time of process chemicals are clearly established, and relevant parameters are monitored to avoid process chemicals perishing.	Generally applicable.
c.	Optimised packaging of chemicals	Process chemicals packaging is selected to facilitate its complete emptying (e.g. considering the size of the packaging aperture or the nature of the packaging material).	
d.	Return of unused process chemicals	Unused process chemicals (i.e. which remain in their original containers) are returned to their suppliers.	
Equipment selection and process optimisation techniques			

Technique		Description	Applicability
e.	Minimisation of the use of chemicals, especially those containing hazardous substances	This includes: • the use of alternatives to chemical cleaning treatment e.g. ultrasonic cleaning or mechanical pre-cleaning by centrifuging; • the substitution of chemicals containing hazardous substances (see BAT 14); • the use of solutions with a lower concentration of hazardous substances, e.g. chromium in passivation.	Applicability may be restricted by product specifications.
f.	Use of automatic system for the preparation and dosing of process chemicals	See Section 5.3.3.	Generally applicable.
g.	Advanced process monitoring and control systems	See Section 5.3.2.	
h.	Optimisation of process solution agitation, conductivity and composition	See Section 5.3.1.	
i.	Optimisation of degreasing	This includes the use of: • cascade (multiple) use of degreasing solution (see Section 5.3.3); • high-performance degreasing systems.	
j.	Maintenance of process solutions	This includes techniques such as: • filtration of process solutions, e.g. sulphuric acid and phosphate-containing solutions; • electrodialysis, e.g. for organic decomposition products in electroless nickel plating solutions; • retardation, e.g. acid resin sorption; • crystallisation of carbonates and metal sulphates; • anodising caustic etch recovery; • activated carbon treatment for organic decomposition products; • use of oil separator or ultrafiltration for degreasing solutions; • use of diffusion dialysis for pickling solutions.	
k.	Recovery of process metals	This includes techniques such as: • electrolytic recovery: an electric current is applied to electrodes submerged in the process solution, causing metal ions to deposit onto the cathode; • use of ion-exchange resins and filtration, e.g. for chromium plating treatment vats; • precipitation.	
l.	Recovery and use of leftover process chemicals	Residual process chemicals are recovered (e.g. by thoroughly purging pipes or completely emptying packaging) and used in the process.	Applicability may be restricted by the content of impurities and the perishability of the process chemicals.

Technique		Description	Applicability
m.	Collection of leakages or spills	Fixed and temporary pumps, hydraulic fluid systems and filters over mobile tanks or drip trays with sufficient capacity to retain leakage and spills are used. Pipe ends are kept over the process tank or drip trays. This enables liquid residues to be collected and returned to the correct process solutions or dealt with as a waste or waste water.	Generally applicable.
n.	Prolonging lifetime of ion-exchange resins	Regular (e.g. twice per year) chemical cleaning of the resins of the ion exchanger.	Applicability may be restricted by product specifications.
o.	Drag-in reduction	See Section 5.3.2.	Generally applicable.
p.	Drag-out reduction		
q.	Rinsing optimisation	This includes: • using multiple rinsing with rinsing water recirculation (see Section 5.3.2); • using eco-rinse (pre-dip) (see Section 5.1.5.2) can be combined with other rinse stages to increase the effectiveness of the multiple rinsing system (see Section 5.3.3); • using spray rinsing; • use of vaccum evaporation; • regeneration and reuse/recycling of rinsing water.	

Further sector-specific techniques to increase material efficiency are given in Sections 5.2.1.2, 5.2.2.2, 5.2.3.2, 5.2.5.2, 5.2.6.3 and 5.2.7.2 of these BAT conclusions.

[This BAT conclusion is based on information given in BREF Section 4.2.6]

5.1.6 Substitution of hazardous substances

BAT 10. In order to improve the overall environmental performance and to reduce the risks associated with the use of hazardous substances, BAT is to use technique (a) and an appropriate combination of techniques (b) to (g) given below.

	Technique	Description	Applicability
a.	Minimisation of the use of hazardous substances	This includes: • regularly reviewing the inventory of process chemicals (see Section 5.4.3) and optimising the formulation of chemicals used; • substitution of chemicals containing hazardous substances with non- or less hazardous ones (based on the analysis in Section 5.4.3, ii.d); • optimisation of the quantity of chemicals used (see BAT 9); • use of a closed loop to recover/reuse chemicals.	The substitution of chemicals containing hazardous substances may be restricted by the availability of a suitable alternative.
b.	Minimisation of the use of metallic salts	The anode consumption is regularly monitored and the anode is promptly renewed in Cu-, Sn-, Ni- and Ag-containing solutions, to avoid the addition of metallic salts.	Generally applicable.
c.	Substitution of Cr(VI) with non- or less hazardous	This includes: • use of Cr(III)-salts-based solutions such	Applicability may be restricted by

	Technique	Description	Applicability

	subtances and/or use of alternative processes	as chloride-based or sulphate-based solutions in passivation and plating;
		● use of Cr-free options, e.g.:
		  o use of potassium permanganate and phosphoric acid for plastic etching;
		  o zinc-based solution;
		  o tin-cobalt alloy;
		  o platinum-plated titanium anodes in pre-treatment, phosphating, passivation, plating, etching for example;
		  o use of electroplated nickel-tungsten, electroless nickel or nickel alloy deposits (NiL35) in plating;
		● use of alternative processes, e.g.:
		  o High Velocity Oxygen Fuel (HVOF) process;
		  o Physical Vapour Deposition (PVD);
		  o plasma nitriding;
		  o Laser Metal Deposition (LMD);
		  o Extreme High-speed Laser metal deposition (EHLA).
			product specifications.

d.	Substitution of cyanide with non- or less hazardous subtances	Use of cyanide-free solutions, e.g.: ● copper-based solutions in degreasing; ● alkaline silver-based solutions in plating.	
e.	Minimisation of the use of solvents containing hazardous substances	This includes techniques such as: ● use of aqueous degreasing solutions; ● use of solvents not containing hazardous substances, e.g. modified alcohol degreasing agents in closed systems to substitute tetrachloroethylene (PER).	
f.	Substitution of ethylenediaminetetraacetic acid (EDTA) with non- or less hazardous subtances	Use of gluconic-acid-based substances.	
g.	Use of PFAS-free surfactants	This includes: ● use of Cr(VI)-free processes that make the use of PFAS unnecessary, e.g. replacing chromium layers with nickel-based layers, alternative hardening techniques on steel instead of plating with chromium(VI), and alternative plastic etching using for example manganese (III)-based compounds; ● use of fluorine-free alternatives to substitute the current mist/fume suppressant 6:2 fluorotelomer sulphonic acid (6:2 FTS).	

[This BAT conclusion is based on information given in BREF Section 4.2.7]

5.1.7 Residues and circular economy

BAT 11. In order to reduce the amount of waste sent for disposal and to enhance circularity, BAT is to use technique (a) and an appropriate combination of the techniques (b) to (k) given below.

Technique		Description	Applicability
Process optimisation			
a.	Process line optimisation	See Section 5.3.6.	Generally applicable.
b.	Automatic systems for the preparation and dosing of process chemicals	See Section 5.3.6.	
c.	Advanced process monitoring and control systems	See Section 5.3.6.	
d.	Reduction, reuse and recycling of packaging	For product packaging, this includes techniques such as: • use of light and high-capacity packaging to reduce the specific consumption of packaging materials (e.g. high-expansion plastic films); • use of reusable packaging (e.g. reusable pallets, metal boxes); • use of recycled plastic films; • use of a reduced amount of printed plastic films (e.g. printed banderole) to facilitate downstream recycling. For the packaging of chemical substances and mixtures, this includes techniques such as: • storage, preferably in large containers; • reuse of packaging; • return to the supplier; • sending for material recycling.	
e.	Timely use of process chemicals	See BAT 9 (b).	
f.	Optimised sludge handling	This is achieved by, for example, reducing the discharges from rinsing and treatment vats so that the quantity of sludge generated is minimised, or by using sludge dewatering, drying or stabilisation.	
g.	Electrolytic recovery of metals	Metals are recovered by making use of their properties, e.g. selective recovery of metal zinc and iron chloride from spent pickling acids generated in galvanising processes.	
h.	Separate collection and storage of wastes contaminated with hazardous substances	Wastes containing hazardous substances are collected and stored separately, with special regard given to the substances fulfilling the criteria referred to in Article 57 of Regulation (EC) No 1907/2006 and substances addressed in restrictions referred to in Annex XVII to Regulation (EC) No 1907/2006 (e.g. sludges and filter cakes, aqueous rinsing liquids).	
i.	Contained areas for plating with hazardous substances	Areas where plating with hazardous substances (e.g. Cd, Cr(VI)) is taking place are contained to avoid cross-contamination. Waste water streams from these areas are collected separately and treated according to their content (see BAT 19).	Generally applicable.
Techniques promoting industrial symbiosis			
j.	External recovery of materials from waste	This includes the recovery of metals from metal-containing sludges (e.g. dewatered aluminium hydroxide sludge).	Generally applicable.
k.	Reuse of anodes	Spent anodes are reused, e.g. tin anodes in a hot-dip galvanizing plant.	

[This BAT conclusion is based on information given in BREF Section 4.2.11]

5.1.8 Emissions to air

5.1.8.1 Diffuse emissions to air

BAT 12. In order to prevent or, where that is not practicable, to reduce diffuse emissions to air from treatment vats and from internal transportation, BAT is to use all of the techniques given below.

	Technique	Description	Applicability
Prevention of emissions			
a.	Use of additives	Use of non-fluorinated additives in the treatment vat that can reduce the generation of gases and aerosols, e.g. Cr(VI) aerosols, HF, NO_X.	Only applicable when additives are compatible with the applied solution chemistry.
b.	Covered process treatment vats	Treatment vats generating gases and aerosols containing hazardous substances, not equipped with a fume exhaust system, are covered using lids for example and are maintained in negative pressure.	Generally applicable.
c.	Use of electric vehicle	Use of electric vehicles for on-site material transportation and handling, e.g. forklifts, trucks. Such equipment should be powered by electricity generated from fossil-free energy sources, if available.	Only applicable to new vehicles.
Collection of emissions			
d.	Extraction of emissions as close as possible to the emission source	Pollutant emissions from treatment vats are captured as close as possible to the emission source and extracted using, for example, enclosures, fixed or movable extraction hoods, centralised mechanical extraction. The collected off-gases may be treated by an abatement system before being released.	Generally applicable.

[This BAT conclusion is based on information given in BREF Section 4.2.8.1

5.1.8.2 Channelled emissions to air

BAT 13. In order to facilitate the reduction of channelled emissions to air, as well as to increase energy efficiency, BAT is to combine waste gas streams with similar characteristics, thus minimising the number of emission points.

Description

The combined treatment of waste gases with similar characteristics ensures more effective and efficient treatment compared to the separate treatment of individual waste gas streams. The combination of waste gases is carried out considering plant safety (e.g. avoiding concentrations close to the lower/upper explosive limit), technical (e.g. compatibility of the individual waste gas streams, concentration of the substances concerned), environmental (e.g. maximising recovery of materials or pollutant abatement) and economic factors (e.g. distance between different process units). Care is taken that the combination of waste gases does not lead to the dilution of emissions.

[This BAT conclusion is based on information given in BREF Section 4.2.8.2.1]

BAT 14. In order to reduce the total quantity of emissions to air, as well as to increase energy efficiency, BAT is to reduce the volume of extracted air.

Description
This includes techniques such as the reduction of the free surface area above vats, applying specific airflow above the process vats, enclosure of plating lines and adjustment of air extraction operating period.

[This BAT conclusion is based on information given in BREF Section 4.2.8.2.2]

BAT 15. In order to prevent or reduce emissions to air from thermal processes (e.g. treatment vat heating), BAT is to use either electric heating with electricity generated from fossil-free energy sources(1) or technique (a) and one or both of the techniques (b) and (c) given below.

Technique		Description	Applicability
a	Optimised combustion	See Section 5.3.4.	Generally applicable.
b	Fuel choice	The use of fuel (including support/ auxiliary fuel) with a low content of potential pollution-generating compounds (e.g. low sulphur, ash, nitrogen, fluorine or chlorine content in the fuel).	
c	Low-NO_X burners	See Section 5.3.4.	Applicability to existing plants may be restricted by furnace design and/or operational constraints.

(1) The use of electricity generated from fossil-free energy sources also contributes to decarbonisation.

Further sector-specific techniques to reduce emissions to air are given in Sections 5.2.1.4, 5.2.2.4, 5.1.1.1, 5.2.6.5 and 5.2.7.5 of these BAT conclusions.

[This BAT conclusion is based on information given in BREF Section 4.2.8.2.5]

5.1.9 Odour

BAT 16. BAT is to periodically perform odour monitoring.

Description
Odour can be monitored using the following:

- EN standards (e.g. dynamic olfactometry according to EN 13725 in order to determine the odour concentration and/or EN 16841-1 or -2 in order to determine the odour exposure).
- Alternative methods (e.g. estimation of odour impact) for which no EN standards are available. In such a case, ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality can be used.

The monitoring frequency is determined in the odour management plan (see Section 5.4.10).

Applicability

The applicability is restricted to cases where an odour nuisance at sensitive receptors is expected and/or has been substantiated.

[This BAT conclusion is based on information given in BREF Section 4.2.8.3]

5.1.10 Noise

BAT 17. In order to prevent or, where that is not practicable, to reduce noise emissions, BAT is to use one or a combination of the techniques given below.

Technique		Description	Applicability
a.	Appropriate location of equipment and buildings	Noise levels can be reduced by: • increasing the distance between the emitter and the receiver; • using buildings as noise screens; • relocating equipment and/or building openings (e.g. exits or entrances of the buildings).	For existing plants, the relocation of equipment and openings of the buildings may not be applicable due to a lack of space and/or excessive costs.
b.	Operational measures	This includes techniques such as: • inspection and maintenance of equipment; • closing of doors and windows of enclosed areas, if possible, or use of self-closing doors; • equipment operation by experienced staff; • avoidance of noisy activities at night, if possible; • provisions for noise control during production and maintenance activities, transport and handling of raw materials, e.g. reducing the number of material transfer operations, reducing the height from which pieces fall onto hard surfaces.	Generally applicable.
c.	Low-noise equipment	This includes direct drive motors; low-noise compressors, pumps and fans; low-noise transportation equipment.	
d.	Noise control equipment	This includes techniques such as: • use of noise reducers; • use of acoustic insulation of equipment; • enclosure of noisy equipment and processes (e.g. unloading of raw materials, fans); • use of building materials with good sound insulation properties (e.g. for walls, roofs, windows, doors).	Applicability to existing plants may be restricted by a lack of space.
e.	Noise abatement	Inserting obstacles between emitters and receivers (e.g. protection walls, embankments).	Only applicable to existing plants, as the design of new plants should make this technique unnecessary. For existing plants, the insertion of obstacles may not be applicable due to a lack of space.

[This BAT conclusion is based on information given in BREF Section 4.2.9]

5.1.11 Emissions to water

BAT 18. In order to reduce the amount of waste water generated, to prevent or reduce the pollutant loads directed to the waste water treatment and the emissions to water, BAT is to use an integrated strategy for waste water management and treatment that includes an appropriate combination of the techniques given below with the following order of priority:

- process-integrated techniques and techniques to recover and reuse process flows (see BAT 8 and BAT 9);
- separate collection of waste water streams containing pollutants that need dedicated treatment (see BAT 24); these waste water streams are either treated before being mixed with other waste water streams (see BAT 25) or handled as waste (see BAT 26);
- final waste water treatment techniques (see BAT 25).

Description

The integrated waste water management and treatment strategy is based on the information provided by the inventory of inputs and outputs (see Section 5.4.2).

[This BAT conclusion is based on information given in BREF Section 4.2.10]

BAT 19. In order to reduce emissions of hazardous substances, (e.g. toxic metals, free CN, PFAS) to water, BAT is to collect waste water streams containing hazardous substances separately and appropriately treat them before mixing with other waste water streams.

Description

Waste water streams containing hazardous substances (e.g. toxic metals, free CN, PFAS) are collected separately from other waste water streams and treated according to their content using, for example, chemical precipitation, chemical reduction, adsorption, filtration, ion exchange, before any mixing with other waste water streams.

[This BAT conclusion is based on information given in BREF Section 4.2.10]

BAT 20. In order to reduce emissions to water, BAT is to treat waste water using an appropriate combination of the techniques given below.

Technique (1)		Typical pollutants targeted
Preliminary, primary and general treatment, e.g.		
a.	Equalisation	All pollutants
b.	Neutralisation	Acids, alkalis
c.	Physical separation through, for example, screens, sieves, grit separators, grease separators, hydrocyclones, oil-water separators or primary settlement tanks	Gross solids, suspended solids, oil/grease
Physico-chemical treatment, e.g.		
d.	Adsorption (e.g. activated carbon, acid (resin) sorption)	Adsorbable dissolved non-biodegradable or inhibitory pollutants, e.g. hydrocarbons, mercury, AOX, 6:2 FTS or other PFAS
e.	Chemical oxidation (e.g. electrolytic/anodic, radiation-assisted)	CN, metals
f.	Chemical precipitation	Precipitable dissolved non-biodegradable or inhibitory pollutants, e.g. metals, fluorides

Technique (1)		Typical pollutants targeted
g.	Chemical reduction	Cr(VI)
h.	Crystallisation	Anions and cations
i.	Electrodialysis	Anions and cations
j.	Electrolysis	Anions and cations
k.	Evaporation (e.g. vacuum evaporation)	Soluble contaminants, e.g. salts
l.	Ion exchange (e.g. liquid/liquid or resins)	Metals, 6:2 FTS or other PFAS
m.	Nitrification/denitrification	Nitrogen
Biological treatment, e.g.		
m.	Activated sludge process	Biodegradable organic compounds
Solids removal, e.g.		
o.	Coagulation, flocculation and precipitation	Suspended solids and particulate-bound metals
p.	Sedimentation	Suspended solids and particulate-bound metals or non-biodegradable or inhibitory pollutants
q.	Filtration, e.g. gravel or sand filtration	Suspended solids and particulate-bound metals
r.	Membrane microfiltration, ultrafiltration, nanofiltration and reverse osmosis	
s.	Flotation	
(1) The descriptions of the techniques are given in Section 5.3.5.		

[This BAT conclusion is based on information given in BREF Section 4.2.10]

Table 5-1: BAT-associated emission levels (BAT-AELs) for water discharges

Sectors:

- **(A) Electrolytic or chemical plating**
- **(B) Aluminium coil/sheet conversion coating/anodising**
- **(C) Continuous steel coil coating**
- **(D) Porcelain (vitreous) enamelling**
- **(E) PCB manufacturing**
- **(F) Semiconductor manufacturing**

Substance/ parameter	Sector	BAT-AEL (Average over the sampling period)	Unit	Circumstances allowing the achievement of the strictest end of the BAT-AEL range
BOD_5	(F)	25 – 75 (1) (2)	mg/l	The strictest end of the range is typically achieved when using a combination of techniques including coagulation, flocculation and biological treatment.
COD	(A), (B), (C), (D), (E), (F)	30-150 (2) (3)		The strictest end of the range is typically achieved when using chemical reduction and neutralisation.
TOC	(A), (B), (C), (D), (E), (F)	10-50 (2) (3)		The strictest end of the range is typically achieved when using a combination of techniques including coagulation, flocculation and biological treatment.
TSS	(A), (B), (C), (D), (E), (F)	5 – 30 (2)		The strictest end of the range is typically achieved when using coagulation, flocculation and filtration.

Sectors:

- **(A) Electrolytic or chemical plating**
- **(B) Aluminium coil/sheet conversion coating/anodising**
- **(C) Continuous steel coil coating**
- **(D) Porcelain (vitreous) enamelling**
- **(E) PCB manufacturing**
- **(F) Semiconductor manufacturing**

Substance/ parameter		**Sector**	**BAT-AEL (Average over the sampling period)**	**Unit**	**Circumstances allowing the achievement of the strictest end of the BAT-AEL range**
Fluorides		(A), (B), (C), (D), (E), (F)	2-10 (4)		The strictest end of the range is typically achieved when using neutralisation.
AOX		(A), (B), (C), (D), (E), (F)	0.1 – 1 (4)		The strictest end of the range is typically achieved when using adsorption, chemical reduction and neutralisation.
Cyanides (free)		(A), (B), (E), (F)	0.05 - 0.2 (4)		The strictest end of the range is typically achieved when using a combination of techniques including adsorption, chemical oxidation, chemical reduction and neutralisation.
HOI		(A), (B), (C), (D), (E)	0.5 – 4 (4)		The strictest end of the range is typically achieved when using adsorption and coagulation.
Metals and metaloids	Ag	(A), (F)	0.05-0.1 (4)		The strictest end of the range is typically achieved when using ion-exchange resin, coagulation, flocculation and filtration.
	Al	(A)	0.5 – 2 (4)		
		(B)	1 – 5 (4)		
		(F)	0.1-0.2 (4)		
	As	(A), (B), (C), (E), (F)	0.005 – 0.03 (4)		
	B	(A), (B), (E), (F)	0.5-2 (4)		
	Cd	(A), (B), (C), (E), (F)	0.001-0.02 (4)		
	Co	(A), (B), (C), (E), (F)	0.001-0.01 (4)		
	Cu	(A), (B), (C), (D), (E), (F)	0.05-0.2 (4)		
	Cr	(A), (B), (C), (D), (E), (F)	0.05-0.2 (4)		
	Cr(VI)	(A), (B), (C), (F),	0.01-0.05 (4)		
	Fe	(A), (C), (E), (F)	0.5 – 2 (4)		
	Hg	(A), (F)	0.0005-0.005 (4)		
	Pb	(A), (B), (C), (E), (F)	0.02-0.1 (4)		
	Ni	(A), (B), (C), (D), (E), (F)	0.1-0.5 (4)		
	Se	(F)	0.001-0.01 (4)		
	Sn	(A), (B), (C), (E), (F)	0.1 – 1 (4)		
	Zn	(A)	0.2-1 (4)		
		(B)	0.2 - 0.5 (4)		
		(E), (F)	0.1-0.4 (4)		
Total PFAS		(A)	< 0.1 (4)	µg/l	-
Total PFAS		(E), (F)	< 0.1		
Total phosphorus		(A), (B), (C), (E), (F)	0.5 – 3 (2) (4)	mg/l	The strictest end of the range is typically achieved when using chemical reduction and chemical oxidation.

Sectors:

- **(A) Electrolytic or chemical plating**
- **(B) Aluminium coil/sheet conversion coating/anodising**
- **(C) Continuous steel coil coating**
- **(D) Porcelain (vitreous) enamelling**
- **(E) PCB manufacturing**
- **(F) Semiconductor manufacturing**

Substance/ parameter	Sector	BAT-AEL (Average over the sampling period)	Unit	Circumstances allowing the achievement of the strictest end of the BAT-AEL range

(1) No BAT-AEL applies for biochemical oxygen demand (BOD_5) for the sectors (A), (B), (C), (D) and (E). As an indication, for these sectors, the yearly average BOD_5 level in the effluent from a biological waste water treatment plant will generally be ≤ 20 mg/l.

(2) For indirect emissions to water, the upper end of the BAT-AEL range may be higher, without prejudice to the provisions of Article 15 (1) of Directive 2010/75/EU as amended by Directive (EU) 2024/1785.

(3) Either the BAT-AEL for COD or the BAT-AEL for TOC applies. The BAT-AEL for TOC is the preferred option because TOC monitoring does not rely on the use of very toxic compounds.

(4) The BAT-AEL only applies when the substance/parameter concerned is identified as relevant in the waste water stream based on the inventory of inputs and outputs mentioned in Section 5.4.2.

The associated monitoring is given in BAT 6.

5.2 Conclusions on sector-specific BAT and emerging techniques

5.2.1 BAT conclusions for electrolytic or chemical plating

The BAT conclusions in this section apply in addition to the general BAT conclusions given in Section 5.1.

5.2.1.1 Water consumption and waste water discharge

The environmental performance level for specific water consumption given below are associated with the general BAT conclusions described in Section 5.1.4.

Table 5-2: BAT-associated environmental performance levels (BAT-AEPLs) for specific water consumption at plant level for electrolytic or chemical plating

Unit	BAT-AEPL (Yearly average)
m^3/m^2 of workpieces treated	0.05 – 0.9

The associated monitoring is given in BAT 4.

5.2.1.2 Material efficiency

BAT 21. In order to reduce the quantity of materials used and the quantity of residues generated in electrolytic or chemical plating, BAT is to use all of the techniques given below.

	Technique	Description	Applicability
a.	Process-integrated automated plating	In large-scale plating of uniform cylindrical workpieces, the anode is shaped to fit around the workpiece and spin it rapidly, creating a high field intensity that allows fast plating. An automated sealed system delivers and removes the electrolyte, while a central processing system handles returned electrolytes, keeping the production line waste-free and minimising waste water.	Applicability may be restricted by product specifications.
b.	Switching the polarisation of the electrodes to minimise consumption	The polarisation of electrodes in electrolytic degreasing and in electrolytic pickling processes is switched at regular time intervals.	Only applicable in plants with bipolar electrodes.
c.	Reduction of drag-out in jig (rack) processing	Drag-out reduction, e.g. by: • optimised position of workpieces to avoid retention of process liquids; • adjustment of draining time when withdrawing the jigs; • regular inspection and maintenance of jigs to avoid fissures retaining process solution.	Generally applicable.
		Optimisation of workpieces to minimise spaces trapping process solution.	Applicability may be restricted by product specifications.

	Technique	Description	Applicability
d.	Reduction of drag-out in barrel processing	Drag-out reduction, e.g. by: • appropriate choice of barrel materials, e.g. hydrophobic plastic; • regular inspection and maintenance of barrels for worn areas, damage, recesses or bulges that may retain process solution; • withdrawing slowly to minimise the volume of liquid dragged out; • rotating intermittently; • rinsing using a pipe inside the barrel.	Generally applicable.
		Drag-out reduction, e.g. by: • ensuring the bores of holes in the barrel bodies have sufficient cross-sectional area in relation to the required thickness of the panels to minimise capillary effects; • ensuring that the proportion of holes in the barrel bodies is the highest for allowing drainage while retaining mechanical strength; • replacing holes with mesh plugs; • fitting drainage ledges between tanks canted back to the process tank; • inclining the barrel from one end.	Applicability may be restricted by product specifications.

5.2.1.3 Energy efficiency

The environmental performance level for specific net energy consumption given below are associated with the general BAT conclusions described in Section 5.1.3.

Table 5-3: BAT-associated environmental performance levels (BAT-AEPLs) for specific net energy consumption at plant level for electrolytic or chemical plating

Unit	BAT-AEPL (Yearly average)
kWh/m^2 of treated surface	25 - 200

The associated monitoring is given in BAT 4.

5.2.1.4 Emissions to air

BAT 22. In order to prevent or reduce emissions to air of NH_3, dust, HCl, HF, HCN, Cr, Cr(VI), Cu, Ni, Zn, SOx and TVOC in electrolytic or chemical plating, BAT is to collect the emissions using technique (a) and to treat the off-gases using an appropriate combination of the techniques (b) to (i) given below.

	Technique	Description	Typical substance/parameter targeted	Applicability
a	Off-gas extraction as close as possible to the emission source	Off-gas extraction using, for example, enclosure, edge or lip extraction.	All pollutants	Generally applicable
b	Adsorption	See Section	Organic compounds	Generally applicable

	Technique	Description	Typical substance/parameter targeted	Applicability
c	Aerosol/droplet separator	5.3.4.	Dust, aerosols, acidic/alkaline emissions	Generally applicable
d	Biofilter		Organic compounds	Generally applicable
e	Cyclone		Dust, particulate-bound metals	Generally applicable
f	Fabric filter		Dust and particulate-bound metals	Generally applicable
g	Demister (mist filter)		Particulate-bound metals, acidic/alkaline emissions	Generally applicable
h	Wet scrubber		Dust, particulate-bound metals, acidic/alkaline emissions	Generally applicable
i	Thermal oxidation		Organic compounds	Applicability may be restricted where the energy demand is excessive due to the low concentration of the compound(s) concerned in the process off-gases. Applicability of recuperative and regenerative thermal oxidation to existing plants may be restricted by design and/or operational constraints.

The associated emission levels for emissions to air given below are also associated with the general BAT conclusions described in Section 5.1.8.

Table 5-4: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of NH_3, dust, HCl, HF, HCN, Cr, Cr(VI), Cu, Ni, Zn, SO_X and TVOC for electrolytic or chemical plating

Substance/ parameter	Associated processes	BAT-AEL (Average over the sampling period) (1)	Unit	Circumstances allowing the achievement of the strictest end of the BAT-AEL range
NH_3	Degreasing, etching, pickling, plating, stripping, rinsing	0.3 – 2	mg/Nm³	The strictest end of the range is typically achieved when using a wet scrubber.
Dust	Abrasive blasting, degreasing, drying, etching, heat treatment, pickling, plating, stripping, rinsing	2 – 4	mg/Nm³	The strictest end of the range is typically achieved when using a wet scrubber or fabric filter.
Gaseous chlorides expressed as HCl	Degreasing, etching, pickling, plating, stripping, rinsing	2 – 10	mg/Nm³	The strictest end of the range is typically achieved when using a wet scrubber.
Gaseous fluorides expressed as HF		0.2 – 1		
HCN	Degreasing, drying, etching, pickling, plating, stripping, rinsing	0.1 – 0.5		
Cr	Abrasive blasting, degreasing, drying, etching, heat treatment, pickling, plating, stripping, rinsing	0.02 – 0.1		
Cr(VI)		0.01 – 0.05		

Substance/ parameter	Associated processes	BAT-AEL (Average over the sampling period) (1)	Unit	Circumstances allowing the achievement of the strictest end of the BAT-AEL range
Cu		0.01 – 0.1		
Ni				The strictest end of the range is typically achieved when using a wet scrubber or fabric filter.
Zn		0.1 – 0.5		
SO_x	Degreasing, etching, pickling, plating, stripping, rinsing	1 – 10		The strictest end of the range is typically achieved when using a wet scrubber.
TVOC	Drying, pickling, activation, degreasing	10 – 20	mgC/Nm³	The strictest end of the range is typically achieved when using thermal oxidation.
(1) The BAT-AEL only applies when the substance/parameter concerned is identified as relevant in the waste gas stream based on the inventory of inputs and outputs mentioned in Section 5.4.2.				

The associated monitoring is given in BAT 5.

BAT 23. In order to reduce NO_X emissions in waste gases while limiting CO emissions from the thermal treatment of off-gases in electrolytic or chemical plating, BAT is to use technique (a) or both of the techniques given below.

	Technique	Description	Applicability
a.	Optimised combustion	See Section 5.3.4.	Generally applicable
b.	Low-NO_X burner		Applicability to existing plants may be restricted by design and/or operational constraints.

Table 5-5: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of NO_X from the thermal treatment of off-gases in electrolytic or chemical plating

Parameter	Associated process	Unit	BAT-AEL (Daily average or average over the sampling period)	Circumstances allowing the achievement of the strictest end of the BAT-AEL range
NO_X	Thermal treatment of off-gases	mg/Nm³	20 – 100	The strictest end of the range is typically achieved when using low-NO_X burners

The associated monitoring is given in BAT 5.

5.2.2 BAT conclusions for continuous steel coil coating

The BAT conclusions in this section apply in addition to the general BAT conclusions given in Section 5.1.

5.2.2.1 Water consumption and waste water discharge

BAT 24. In order to reduce water consumption and the amount of waste water generated in continuous steel coil coating, BAT is to use all the techniques given below.

	Technique	Description	Applicability
a.	Recycling of quench water	To produce a bright finish on the product following flow melting in tin plating, the strip is cooled via a water quench. This water is recycled and reused until it is disposed of when the build-up of tin is too high.	Generally applicable.
b.	Use of condensate recovery steam pipes	Condensate recovery steam pipes are used in steam systems to collect and return condensed steam (condensate) back to the boiler for reuse.	Applicability may be restricted by the steam composition and temperature.
c.	Recirculation of rinsing water	In multiple rinsing, rinsing water from the subsequent rinsing steps is used in the previous rinsing steps.	Generally applicable.
d.	Recirculation of rinsing water from etching and surface treatment to the treatment baths	Rinsing water from etching and surface treatment is collected and undergoes treatment to remove contaminants. The treated water is then returned as water input to the treatment vats.	
e.	Use of closed cooling systems	See Section 5.3.2	

The environmental performance level for specific water consumption given below are also associated with the general BAT conclusions described in Section 5.1.5.

Table 5-6: BAT-associated environmental performance levels (BAT-AEPLs) for specific water consumption at plant level for continuous steel coil coating

Unit	BAT-AEPL (Yearly average)
m^3/t of coil coated	0.5 – 3

The associated monitoring is given in BAT 4.

5.2.2.2 Material efficiency

BAT 25. In order to reduce the quantity of materials used and the quantity of residues generated in continuous steel coil coating, BAT is to use all of the techniques given below.

	Technique	Description	Applicability
a.	Advanced process monitoring and control systems	See Section 5.3.2.	Generally applicable.
b.	Squeeze rolls	The remaining solutions or rinsing water on the steel strip are removed from the strip by squeezing the rolls before it leaves each section. This ensures that the drag-out of solution into the next section is minimised, as is the loss of chemicals and contamination of rinse water.	
c.	Electrolytic strip cleaning	Before coating, the strip must be perfectly clean. Oil from the previous step (temper mill) is removed by an electrolytic process. See also BAT 12 (j).	
d.	Use of ultrafiltration to regenerate degreasing solution	Electrolyte used for strip cleaning is recirculated in a closed loop; before reuse, the oil residues contained are filtrated. See also BAT 12 (j).	
e.	Cascade (multiple) use of degreasing solution	See Section 5.3.3. Strip degreasing typically involves 2 or 3 electrolytic cells. A shared electrolyte solution is utilised. Fresh electrolyte is introduced in the final cell and a backward counterflow mechanism enables its reuse in the preceding cells.	
f.	Control of the acidity in the pickling section	See also BAT 13 (g). This includes adjusting the concentration, temperature and flow rate of the acid solution.	
g.	Ultrasonic cleaning	Cleaning using high-frequency vibrations to loosen the adhered contamination.	The applicability may be restricted by the type of process, the substrate or equipment to be cleaned and the type of contamination.
h.	Control and management of electrolyte consumption	See also BAT 13 (g). In tin plating: Following the plating section, the strip passes through a rinsing section. To minimise the loss of electrolyte, the electrolyte is spray-rinsed with a dilute solution of PSA and tin. It is then returned to an electrolyte recirculation tank. An evaporator system is then used to condense the dilute electrolyte solution through evaporation, and it is then returned to the process for reuse. In acid zinc plating: An evaporator in a closed loop with a wet scrubber (for the plating cells), with the zinc electrolyte tanks and the plating rinse cells, concentrates the ions (Zn^{++}, $SO4^{--}$) in the residue and produces distilled water from the steam. The concentrated ions are reused and injected into the electrolyte while the distilled water is reused and injected into the different	Generally applicable.

	Technique	Description	Applicability
		processes.	
i.	Switching the polarisation of the electrodes in the electrolytic processes	See BAT 21 (c).	Only applicable in plants with bipolar electrodes.
j.	Optimisation of the anode-cathode gap	A mechanism of adjusting the gap as a function of the strip to be processed (width-thickness-flatness).	Generally applicable.
k.	Polishing the conductor roll	Oscillating abrasive blades continuously polish the conductor roll's surface, avoiding zinc and or nickel build-up.	
l.	Use of edge polishers	Removal of zinc dendrites formed at the strip edges in zinc electroplating cells equipped with low anode-cathode gaps.	
m.	Using edge masks	Edge masks move between the anode and the strip to avoid zinc dendrites and zinc overthrow (when plating one side only) at the strip edges.	Applicability may be restricted if the anode-cathode gap is not wide enough.
n.	Optimised use of oil	Use of covered electrostatic oilers where the anticorrosion or deep drawing oil is heated and electrostatically deposited on the surface. The splashed oil is collected and reused.	Applicability in existing plants may be restricted by a lack of space.
o.	Maintenance of process solutions	See also BAT 9 (j). This includes: • cleaning and recirculation of degreasing solutions; • continuous filtering (removal of iron) and reuse of the zinc solution; • cleaning and regeneration of the phosphate solution; • cleaning and regeneration of the chromate solution.	Generally applicable.
p.	Recovery of residual tin from recirculation tanks	The tin from the recirculation tanks can be recovered through the use of a filter press that separates tin sludge from electrolyte within the tin line operation. Separated tin sludge contains approximately 60% tin and can be recovered externally.	

5.2.2.3 Energy efficiency

The environmental performance level for specific net energy consumption given below are associated with the general BAT conclusions described in Section 5.1.3.

Table 5-7: BAT-associated environmental performance levels (BAT-AEPLs) for specific energy consumption at plant level for continuous steel coil coating

Unit	BAT-AEPL (Yearly average)
kWh/t of coil coated	100 – 400

The associated monitoring is given in BAT 4.

5.2.2.4 Emissions to air

BAT 26. In order to prevent or reduce emissions to air of dust, Cr, Ni, Zn and HCl in continuous steel coil coating, BAT is to collect the emissions using technique (a) and to treat the off-gases using one or a combination of the techniques (b) to (e) given below.

	Technique	**Description**	**Typical substance/parameter targeted**	**Applicability**
a.	Off-gas extraction as close as possible to the emission source	Off-gas extraction using, for example, enclosure, edge or lip extraction.	All pollutants	Generally applicable.
b.	Wet scrubber	See Section 5.3.4.	Dust and particulate-bound metals, acidic emissions	
c.	Demister (mist filter)		Particulate-bound metals, e.g. chromium, acidic/alkaline emissions	
d.	Cyclone		Dust and particulate-bound metals	
e.	Cartridge filter (fabric filter)			

The environmental performance levels for emissions to air given below are also associated with the general BAT conclusions described in Section 5.1.8.

Table 5-8: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of dust, Cr, Ni, Zn and HCl for steel continuous coil coating

Parameter	**Unit**	**Associated processes**	**BAT-AEL (Daily average or average over the sampling period) (1)**	**Circumstances allowing the achievement of the strictest end of the BAT-AEL range**
Dust	mg/Nm^3	Degreasing, drying, e-coating, pickling, plating, rinsing	2 – 4	The strictest end of the range is typically achieved when using a wet scrubber.
Cr		Drying, e-coating, plating, rinsing	0.02 – 0.06	
Ni		Degreasing, pickling, plating, rinsing	0.02 – 0.10	
Zn		Degreasing, e-coating, pickling, plating, rinsing	0.20 – 0.50	
HCl		Pickling, plating, rinsing	2 – 5	

(1) The BAT-AEL only applies when the substance/parameter concerned is identified as relevant in the waste gas stream based on the inventory of inputs and outputs mentioned in Section 5.4.2.

The associated monitoring is given in BAT 5.

5.2.3 BAT conclusions for aluminium coil, sheet conversion coating and anodising

The BAT conclusions in this section apply in addition to the general BAT conclusions given in Section 5.1.

5.2.3.1 Water consumption and waste water discharge

The environmental performance level for specific water consumption given below are associated with the general BAT conclusions described in Section 5.1.4.

Table 5-9: BAT-associated environmental performance levels (BAT-AEPLs) for specific water consumption at plant level for aluminium coil, sheet conversion coating and anodising

Unit	BAT-AEPL (Yearly average)
m^3/m^2 of treated surface	0.1 – 1

The associated monitoring is given in BAT 4.

5.2.3.2 Material efficiency

BAT 27. In order to reduce the quantity of materials used and the quantity of residues generated in aluminium coil, sheet conversion coating and anodising, BAT is to use all of the techniques given below.

	Technique	Description	Applicability
a.	Recovery of caustic etch solution	A regeneration system recirculates the etch solution continuously between the etch tank and a separate crystalliser tank, where the etch solution is seeded with alumina crystals in a separate crystalliser tank. It is then possible to regenerate the etch solution without scale building up. The hydrated alumina crystals formed in the crystalliser settle out in a settlement section. Regenerated etch solution, with reduced aluminium and increased free caustic levels, is returned to the etch vat directly from the top of the crystalliser. Alumina crystals are withdrawn periodically from the bottom of the crystalliser and dewatered in a vacuum filter.	May not be applicable in cases where the use of additives to achieve a specific surface specification interferes with the process or prevents the reuse of the alumina.
b.	Agitation of process solution	Agitation of process solution (e.g. with air injection or hydraulic turbulence).	Generally applicable.
c.	Automatic systems for the preparation and dosing of process chemicals	See Section 5.3.3.	

Energy efficiency

BAT 28. In order to reduce energy consumption in aluminium coil, sheet conversion coating and anodising, BAT is to use medium-temperature sealing systems for anodising of aluminium instead of using higher-temperature methods.

Description

The hot water sealing method typically operates at a temperature range of 90 °C to 100 °C, lower than some alternative sealing processes that require temperatures of up to 160 °C. In addition, it can be combined with the reuse of hot water available from other processes.

The environmental performance levels for specific net energy consumption given below are also associated with the general BAT conclusions described in Section 5.1.3.

Table 5-10: BAT-associated environmental performance levels (BAT-AEPLs) for specific energy consumption at plant level for aluminium coil, sheet conversion coating and anodising

Unit	BAT-AEPL (Yearly average)
kWh/m^2 of treated surface	50 - 200

The associated monitoring is given in BAT 4.

5.2.3.3 Emissions to air

BAT 29. In order to prevent or reduce emissions to air of dust, TVOC, HF, Cr and Ni in aluminium coil, sheet conversion coating and anodising, BAT is to collect the emissions using technique (a) and to treat the off-gases using one or a combination of the techniques (b) to (e) given below.

	Technique	Description	Typical substance/parameter targeted	Applicability
a.	Off-gas extraction as close as possible to the emission source	Off-gas extraction using, for example, enclosure, edge or lip extraction.	All pollutants	Generally applicable
b.	Adsorption	See Section 5.3.4.	TVOC	
c.	Demister (mist filter)		Particulate-bound metals, e.g. chromium, acidic/alkaline emissions	
d.	Aerosol/droplet separator		Dust, aerosols, acidic/alkaline emissions	
e.	Wet scrubber		Dust and particulate-bound metals, acidic/alkaline emissions	
f.	Fabric filter		Dust and particulate-bound metals	
g.	Cyclone			

The BAT-associated emission levels given below are also associated with the general BAT conclusions described in Section 5.1.8.

Table 5-11: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of dust, TVOC, HF, Cr and Ni for aluminium coil, sheet conversion coating and anodising

Parameter	Associated processes	Unit	BAT-AEL (Daily average or average over the sampling period) (1)	Circumstances allowing the achievement of the strictest end of the BAT-AEL range
Dust	Abrasive blasting, anodising, chemical milling, degreasing, drying, etching, lacquering, mechanical polishing, pickling, plating, rinsing	mg/Nm^3	2 – 5	The strictest end of the range is typically achieved when using a wet scrubber or fabric filter.
TVOC	Anodising, degreasing, drying, etching, heat treatment, plating, stripping	mgC/Nm^3	5 – 20	The strictest end of the range is typically achieved when using a wet scrubber.
HF	Anodising, degreasing, e-coating, etching, pickling, stripping.	mg/Nm^3	0.1 – 1	
Cr	Abrasive blasting, anodising, degreasing, e-coating, etching, pickling, stripping, plating, rinsing		0.02 – 0.1	The strictest end of the range is typically achieved when using a wet scrubber or fabric filter.
Ni	Abrasive blasting, anodising, degreasing, e-coating, etching, pickling, stripping, plating, rinsing		0.01 – 0.1	

(1) The BAT-AEL only applies when the substance/parameter concerned is identified as relevant in the waste gas stream based on the inventory of inputs and outputs mentioned in Section 5.4.2.

The associated monitoring is given in BAT 5.

5.2.4 BAT conclusions for sheet processing for aluminium lithographic plates

[TWG, please provide information on specific BAT that apply in this sector]

5.2.5 BAT conclusions for porcelain (vitreous) enamelling of metals

The BAT conclusions in this section apply in addition to the general BAT conclusions given in Section 5.1.

5.2.5.1 Water consumption and waste water discharge

The benchmark for specific waste water consumption given below are associated with the general BAT conclusions described in Section 5.1.4.

Table 5-12: Benchmark for specific water consumption at plant level for porcelain (vitreous) enamelling of metals

Unit	Benchmark (Yearly average)
m^3/m^2 of treated surface	< 0.01

The associated monitoring is given in BAT 4.

5.2.5.2 Material efficiency

BAT 30. In order to reduce the quantity of materials used and the quantity of residues generated in porcelain (vitreous) enamelling of metals, BAT is to use all of the techniques given below.

	Technique	Description
a.	Optimisation of raw material consumption	This includes: • optimisation of the use of raw materials, such as enamel powder (minimising excess powder) and metal substrates; • use of recycled enamel; • optimisation of the metal surface preparation process.
b.	Optimisation of process control	This includes: • implementing advanced process control systems and monitoring including real-time data analysis; • predictive maintenance; • process automation. See BAT 12.
c.	Improvement of pickling efficiency	Agitation of process solution (e.g. with air injection or hydraulic turbulence).
d.	Optimisation of degreasing	See BAT 12 (i). This also includes the use of oil separators for the maintenance of degreasing solutions.
e.	Recovery of acids/alkalis	Spent treatment solutions with high acidity or alkalinity are recovered and used for on-site physico-chemical waste water neutralisation.

In addition, the following emerging technique to reduce the emissions of cobalt and nickel to air from porcelain (vitreous) enamelling of metals has been identified.

	Emerging technique	Description	Applicability
a.	Adherence without NiO or CoO	Adherence of enamel on both carbon steel and stainless steel is achieved by applying an inorganic primer on the substrate just before enamelling. The primer contains a mixture of metal oxides, metal salts, metals, metallates and glasses. None of the components used contain nickel or cobalt.	Applicability may be restricted by product specifications.

5.2.5.3 Energy efficiency

BAT 31. In order to increase energy efficiency in porcelain (vitreous) enamelling of metals, BAT is to use all of the techniques given below.

	Technique	Description	Applicability
a.	Selection of an energy-efficient type of furnace	See Section 5.3.1.	Only applicable to new plants and/or major plant upgrades.
b.	Furnace automation and control		Generally applicable.
c.	Techniques for maximising the thermal efficiency of furnaces		

5.2.6 BAT conclusions for printed circuit board manufacturing

The BAT conclusions in this section apply in addition to the general BAT conclusions given in Section 5.1.

5.2.6.1 Water consumption and waste water discharge

The environmental performance levels for specific water consumption given below are associated with the general BAT conclusions described in Section 5.1.5.

Table 5-13: Benchmark for specific water consumption at plant level for printed circuit board manufacturing

Unit	Benchmark (Yearly average)
m^3/m^2 of final product	1 – 5 (1)
(1) The upper end of the benchmark may be higher and up to 10 m^3/m^2 of final product in case of multi-layer PCB.	

The associated monitoring is given in BAT 4.

5.2.6.2 Material efficiency

BAT 32. In order to reduce the quantity of materials used and the quantity of residues generated in printed circuit board manufacturing, BAT is to use all of the techniques given below.

	Technique	Description	Applicability
a.	Optimisation of dry resist development	Monitoring and control of the concentration and temperature of the developer solution. When necessary, the developer solution is replenished by adding fresh solution.	Generally applicable.
b.	Optimisation of PCB electroplating	Use of direct air injection, combined with oscillation and vibration of the boards. The panel is fixed in the lower part of the bath to ensure an optimum exchange of electrolytes inside the holes. The individual baths are served by automatic carriers.	

	Technique	Description	Applicability
c.	Optimisation of dry resist development	Control of the concentration of the developer solution by regularly checking its conductivity, and conducting laboratory analysis. When necessary replenish it by adding fresh solution.	
d.	Optimised oxide processes using less chemicals in the manufacturing of inner layers	Use of the brown oxide process that consists of hydrogen peroxide, organic additives and chloride running at 30 °C.	
e.	Use of oxide-alternative techniques in the manufacturing of inner layers	This includes techniques such as direct metallisation, sputtering, pulse reverse plating, and atomic layer deposition.	Applicability may be restricted by process and product specifications.
f.	Etching optimisation	This includes: • online monitoring of acidic etchant and adjustment of HCl concentration; • recirculation of the rinsing water of the first cascade into the etching solution while the etching parameters are kept at a constant level.	Generally applicable.
g.	Laser direct imaging	A highly focused laser beam is used to directly expose the photoresist, creating the pattern without the need for a photomask or film.	
h.	High-density interconnects (HDIs)	HDI technology produces PCBs with a higher wiring density per unit area than traditional PCBs using sequential lamination and laser drilling to form the microvias (tiny interlayer connections).	
i.	Embedded passives	The technology includes the direct integration of resistors, capacitors and inductors into the PCB layers or structure using techniques such as laser direct imaging, additive manufacturing or plating processes.	Applicability may be limited due to product specifications (e.g. for complex or high-density designs).
j.	Recycling of alkali etchants online with copper recovery	The alkaline ammonia etching solution is regenerated and the dissolved copper is recovered on site in a closed loop.	Only applicable in systems using alkali copper etchants.
k.	Tin recovery from stripping of etch tin resist	Recovery of tin contained in the precipitated sludge that results from the treatment of rinsing water and the concentrate.	Generally applicable.

5.2.6.3 Energy efficiency

BAT 33. In order to increase energy efficiency in printed circuit board manufacturing, BAT is to use all of the techniques given below.

	Technique	Description	Applicability
a.	Selection of an energy-efficient type of furnace	See Section 5.3.1.	Only applicable to new plants and/or major plant upgrades.
b.	Furnace automation and control		Generally applicable.
c.	Techniques for maximising the thermal efficiency of furnaces		

The environmental performance levels for specific net energy consumption given below are also associated with the general BAT conclusions described in Section 5.1.3.

Table 5-14: BAT-associated environmental performance levels (BAT-AEPLs) for specific energy consumption at plant level for printed circuit board manufacturing

Unit	BAT-AEPL (Yearly average)
kWh/m^2 of final product	100 – 1 000

The associated monitoring is given in BAT 4.

5.2.6.4 Emissions to air

BAT 34. In order to prevent or reduce emissions to air of TVOC, HCl and NH_3 in printed circuit board manufacturing, BAT is to:

- **use technique (a);**
- **collect the emissions using technique (b); and**
- **treat the off-gases using one or a combination of the techniques (c) to (e) given below.**

	Technique	Description	Typical substance/parameter targeted	Applicability
a.	Substitution of high-VOC resins in the application of solder mask	Substitution of high-VOC resins with alternatives that have low VOC - high solid content or are VOC-free.	TVOC	Generally applicable
b.	Optimisation of solvent emissions from the application of solder mask	Use of lacquer systems with high solid content or the treatment of off gases using, for example, condensation, thermal oxidation or biofiltration.	TVOC	
c.	Off-gas extraction as close as possible to the emission source	Off-gases are extracted using, for example, full enclosure, edge or lip extraction.	All pollutants	
d.	Wet scrubber	See Section 5.3.4..	Dust and particulate-bound metals, acidic/alkaline emissions	
e.	Biofilter		TVOC	
f.	Adsorption			

The BAT-associated emission levels given below are also associated with the general BAT conclusions described in Section 5.1.8.

Table 5-15: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of TVOC, HCl and NH_3 for printed circuit board manufacturing

Parameter	Associated processes	Unit	BAT-AEL (Daily average or average over the sampling period)	Circumstances allowing the achievement of the strictest end of the BAT-AEL range
TVOC	Cleaning, conditioning, degreasing, photoresist application, solder mask application, plating, photo developing, heat treatment	mg C/Nm^3	3 – 10	The strictest end of the range is typically achieved when using low-VOC or VOC-free alternatives, or when using a wet scrubber.
Gaseous chlorides expressed as HCl	Descaling, etching, pickling, plating	mg/Nm^3	2 – 5 (1)	The strictest end of the range is typically achieved when using a wet scrubber.
NH_3	Degreasing, descaling, etching, pickling, plating		3 – 10 (1)	
(1) The BAT-AEL only applies when the substance/parameter concerned is identified as relevant in the waste gas stream based on the inventory of inputs and outputs mentioned in Section 5.4.2.				

The associated monitoring is given in BAT 5.

5.2.7 BAT conclusions for semiconductor manufacturing

The BAT conclusions in this section apply in addition to the general BAT conclusions given in Section 5.1.

5.2.7.1 Water consumption and waste water discharge

BAT 35. In order to reduce water consumption and the quantity of waste water generated in semiconductor manufacturing, BAT is to use both of the techniques given below.

	Technique	Description
a.	Reuse of spent ultra-pure water	Reuse of spent ultra-pure water in other processes as cooling water (e.g. in chillers, pumps and other heat-generating processes).
b.	Use of closed cooling systems	See Section 5.3.2. Water or a water-glycol mixture is circulated through a series of heat exchangers, chillers and cooling towers without the need for external water sources.

The environmental performance levels for specific water consumption given below are also associated with the general BAT conclusions described in Section 5.1.5.

Table 5-16: BAT-associated environmental performance levels (BAT-AEPLs) for specific water consumption at plant level for semiconductor manufacturing

Unit	BAT-AEPL (yearly average)
m^3/m^2 of wafer	50 – 130

The associated monitoring is given in BAT 4.

5.2.7.2 Material efficiency

BAT 36. In order to reduce the quantity of materials used and the quantity of residues generated in semiconductor manufacturing, BAT is to use all of the techniques given below.

	Technique	Description
a.	Process optimisation	This includes: • optimisation of cleaning processes to reduce the consumption of acids and ammonia; • optimisation of etching processes to reduce the consumption of acids; • optimisation of polishing processes to reduce the generation of slurries; • optimisation of physical vapour deposition (PVD) processes to reduce the consumption of gases and liquids; • optimisation of stripping processes to reduce the consumption of strippers; • automatic systems for the preparation and dosing of process chemicals.
b.	Maintenance of process solutions	See BAT 9 (j).
c.	Recovery of process metals	See BAT 9 (k).

5.2.7.3 Energy efficiency

BAT 37. In order to increase energy efficiency in semiconductor manufacturing, BAT is to use sealed containers.

Description

Use of specialised sealed containers (front-opening unified pods or standard mechanical interface) to transfer and store silicon wafers in enclosed clean conditions (class 1) without being exposed to the surrounding airflow. In this way, less energy is needed compared to maintaining the entire surrounding environment at class 1 conditions.

The environmental performance levels for specific net energy consumption given below are also associated with the general BAT conclusions described in Section 5.1.3.

Table 5-17: BAT-associated environmental performance levels (BAT-AEPLs) for specific energy consumption at plant level for semiconductor manufacturing

Unit	BAT-AEPL (Yearly average)
MWh/m^2 wafer	1 - 9

The associated monitoring is given in BAT 4.

5.2.7.4 Substitution of hazardous substances

BAT 38. In order to reduce the environmental and health risks associated with the use of hazardous substances in semiconductor manufacturing, BAT is to use all of the techniques given below.

	Technique	Description	Applicability
a.	Use of lead-free alternatives	Lead-free solders typically containing tin (Sn), silver (Ag) and copper (Cu) as the primary components, with various additional elements such as bismuth (Bi), indium (In) and antimony (Sb), are used to improve properties like melting temperature, wetting and mechanical strength.	Applicability may be restricted by product specifications.
b.	Cyanide substitution	This includes the use of the following: • Thiourea(CH_4N_2S)-based processes. These involve the formation of soluble thiourea complexes, which can be easily separated from the metal ions and regenerated for reuse. • Thiosulphate-based processes. Sodium thiosulphate ($Na_2S_2O_3$) is used for the dissolution of gold and silver. The thiosulphate complexes can be reduced to elemental metal using a suitable reducing agent. • Ionic liquids. Room-temperature ionic liquids (RTILs) can be used as non-aqueous media for the dissolution of gold and silver. • Electrochemical processes, such as electroless deposition and electrodeposition. These involve the transfer of metal ions between an anode and cathode in an electrolyte solution, with the metal ions selectively deposited onto the cathode surface.	Generally applicable.
c.	Remote plasma chamber cleaning	A remote plasma is generated using an electric discharge in a chamber filled with NF_3 gas. The plasma breaks down the NF_3 molecules, generating highly reactive fluorine radicals that react with and remove organic and inorganic contaminants from the chamber surface.	

5.2.7.5 Emissions to air

BAT 39. In order to prevent or reduce emissions of dust, TVOC, HCl and NH_3 in semiconductor manufacturing, BAT is to collect the emissions using technique (a) and to treat the off-gases using one or a combination of the techniques (b) to (d) given below.

	Technique	Description	Typical substance/parameter targeted
a.	Off-gas extraction as close as possible to the emission source	Off-gases from various processes (e.g. solvent use, photoresist development) are extracted using local exhaust ventilation or general exhaust systems. Depending on their composition, extracted off-gases are treated separately (point-of-use abatement) and/or combined at a central abatement system.	All pollutants
b.	Wet scrubber	See Section 5.3.4.	Dust and particulate-bound metals, acidic/alkaline emissions
c.	Thermal oxidation		Organic compounds (e.g. TVOC, GHGs)
d.	Adsorption		TVOC

The BAT-associated emission levels given below are also associated with the general BAT conclusions described in Section 5.1.8.

Table 5-18: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of dust, TVOC, HCl and NH_3 for semiconductor manufacturing

Parameter	Associated process	Unit	BAT-AEL (Daily average or average over the sampling period)	Circumstances allowing the achievement of the strictest end of the BAT-AEL range
Dust	Back grinding, lithography, metal plating, wet etching	mg/Nm^3	1-3 (1)	The strictest end of the range is typically achieved when using a wet scrubber.
TVOC	Diffusion functional area, lithography, metal plating	$mg\ C/Nm^3$	5 – 15	The strictest end of the range is typically achieved when using thermal oxidation or a wet scrubber.
Gaseous chlorides expressed as HCl	Diffusion functional area, lithography, metal plating	mg/Nm^3	0.2 – 2 (1)	The strictest end of the range is typically achieved when using a wet scrubber.
NH_3	Chemical vapour deposition, diffusion functional area, lithography, metal plating, etching			

(1) The BAT-AEL only applies when the substance/parameter concerned is identified as relevant in the waste gas stream based on the inventory of inputs and outputs mentioned in Section 5.4.2.

The associated monitoring is given in BAT 5.

BAT 40. In order to reduce NO_X emissions in waste gases while limiting CO emissions from the thermal treatment of off-gases in semiconductor manufacturing, BAT is to use technique (a) or both of the techniques given below.

	Technique	Description	Applicability
a.	Optimised combustion	See Section 5.3.4.	Generally applicable.
b.	Use of low-NO_X burners		Applicability to existing plants may be restricted by design and/or operational constraints.

Table 5-19: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of NO_X for semiconductor manufacturing

Parameter	Associated process	Unit	BAT-AEL (Daily average or average over the sampling period)	Circumstances allowing the achievement of the strictest end of the BAT-AEL range
NO_X	Thermal treatment of off-gases	mg/Nm^3	20 – 100	The strictest end of the range is typically achieved when using a low-NO_X burner.

The associated monitoring is given in BAT 5.

5.3 Descriptions of techniques

5.3.1 Techniques to increase energy efficiency

Technique	Description
Furnace automation and control	The heating process is optimised by using a computer system controlling key parameters such as furnace and feedstock temperature, air to fuel ratio and the furnace pressure.
Cogeneration	Combined generation of heat and electricity where the heat (mainly from the steam that leaves the turbine) is used for producing hot water/steam to be used in industrial processes/activities or in a district heating/cooling network.
Heat recovery	This includes: • recovery of excess heat from cooling systems such as chillers and cooling towers to be used, for example, for space heating or evaporation of waste water; • recovery of excess heat from once-through cooling water to utilise the heat gained, for instance in rinsing prior to drying; • recovery of excess heat from processes (e.g. coating ovens) to be used to heat the building; • recovery of excess heat from exhaust gases (e.g. regenerative catalytic thermal oxidation) to be used used to preheat incoming off-gases. In aluminium anodising, the heat of spent sealing solutions can be used to heat the water used for a new sealing process, either by using a heat exchanger or by piping the incoming cold water through the hot sealing solution.
Optimisation of process solution agitation, conductivity and composition	This includes: • reducing the surface treatment duration by process solution agitation using, for example, hydraulic turbulence; • reducing the heating temperature by substituting chemicals, e.g. galvanic chemicals; • increasing the conductivity of the process solution by using additives or by process solution maintenance.
Process line optimisation	Optimisation of process line operation, i.e. calculating the inputs required and outputs generated (use of raw materials, energy and water; emissions to water and residues generation) and adjusting the process parameters appropriately. This may include the use of software modelling tools, e.g. software simulation for jigging or barrel processing.
Selection of an energy-efficient type of furnace	Furnace energy efficiency is taken into consideration for the furnace selection, e.g. furnaces that allow the preheating and drying of incoming charge prior to the melting zone.
Techniques for maximising the thermal efficiency of furnaces	Measures taken to maximise the efficiency of energy conversion furnaces while minimising emissions. This is achieved by applying a series of process optimisation measures according to the furnace type including optimisation of the temperature (e.g. efficient mixing of the fuel and combustion air) and residence time in the combustion zone, and use of furnace automation and control (see above).

5.3.2 Techniques to reduce water consumption and waste water discharge

Technique	Description
Advanced process monitoring and control systems	The regular monitoring and control of processes by collecting and analysing key process parameters to reach optimal process conditions (e.g. optimal uptake of process chemicals, electrolytic cleaning with pH control). This is carried out by, for example, on-line automated systems equipped with sensors and controllers and/or sampling and laboratory analysis. Key process parameters include: • level, pH, temperature and conductivity of the treatment vats; • chemical composition of the treatment vats.
Drag-in reduction	Techniques to reduce drag-in include the use of:

Technique	Description
	• eco-rinse (or pre-dip) technique (see Section 5.3.3); • air knives or wiper rollers to remove as much rinsing water as possible for sheet and coil substrates.
Drag-out reduction	Techniques to reduce drag-out include the use of: • eco-rinse (or pre-dip) technique (see Section 5.3.3); • evaporation using either the surplus internal energy released from the process tank or additional heat; • electrodialysis (electric dialysis); anions and cations are removed from solutions with an applied electric field in cells with alternating anion- and cation-permeable membranes; • reverse osmosis, a membrane process in which a pressure difference applied between the compartments separated by the membrane causes water to flow from the more concentrated solution to the less concentrated one; • closed loop system, e.g. for Cr(VI) and PFAS recycling in chromium plating (see Section 1.5.3); • compatible chemicals (use of same acid in pickling or activating the surface prior to an acid-based plating process); • proper arrangement of workpieces at the jigs; • specific processes in barrel processing, e.g. proper design of the perforated area, intermittent rotation of the barrel above the process tank while draining, application of draining ledges within the barrels, blowing excess solution out of the barrel while draining over the treatment vat.
Multiple rinsing with rinsing water recirculation	In multiple rinsing, rinsing water from the subsequent rinsing steps is used in the previous rinsing steps.
Recirculation of rinsing water from etching and surface treatment to the treatment vats	Rinsing water from etching and surface treatment is collected and undergoes treatment to remove contaminants. The treated water is then returned to the treatment vats.
Use of closed cooling systems	Closed cooling systems use a secondary system, such as refrigeration, for cooling the recirculating coolant in the primary system.

5.3.3 Techniques to increase material efficiency

Technique	Description
Automatic systems for the preparation and dosing of process chemicals	Automatic systems are used for weighing, dosing, dissolving, measuring and dispensing process chemicals.
Closed loop for Cr(VI) and PFAS recycling	Design and operation of hexavalent Cr(VI) plating as a closed loop system for chromium and PFAS recycling by using a combination of powerful exhaust air systems, cascade rinsing, ion exchange and spray tower evaporators.
Eco-rinse (or pre-dip)	Drag-out from process solutions working at (but not limited to) ambient temperature can be partially recovered through a single rinse station in which the workload is dipped before and after being processed.
Cascade (multiple) use and/or reuse of degreasing solution	Reuse of the degreasing solution, or use of the degreasing solution in a cascade mode, to extend its lifetime. The solution from the electrolytic degreasing section is reused once a certain oil level is reached, either in the spray section of coil lines, or in the first degreasing section of other lines. The spent degreasing solution of the spray section can be regenerated.

5.3.4 Techniques to reduce emissions to air

Technique	Description
Adsorption	The removal of pollutants from a process off-gas or waste gas stream by retention on a solid surface (activated carbon is typically used as the adsorbent). Adsorption may be regenerative or non-regenerative.

Technique	Description
Aerosol/droplet separator	A fill material is used to condense aerosols and droplets. Condensate is usually treated in a waste water treatment plant.
Biofilter	The waste gas stream is passed through a bed of organic material (such as peat, heather, compost, root wood, tree bark, softwood and different kinds of combinations) or some inert material (such as clay, activated carbon, and polyurethane), where it is biologically oxidised by naturally occurring microorganisms into carbon dioxide, water, inorganic salts and biomass.
Catalytic oxidation	Abatement technique which oxidises combustible compounds in a waste gas stream with air or oxygen on a catalyst bed. The catalyst enables oxidation at lower temperatures and in smaller equipment compared to thermal oxidation. The typical oxidation temperature is between 200 °C and 600 °C.
Optimised combustion	Good design of the combustion chambers, burners and associated equipment/devices is combined with optimisation of combustion conditions (e.g. the temperature and residence time in the combustion zone, efficient mixing of the fuel and combustion air) and regular planned maintenance of the combustion system according to suppliers' recommendations.
Cyclone	Equipment for the removal of dust from an off-gas stream based on imparting centrifugal forces, usually within a conical chamber. Cyclones are mainly used as a pretreatment before further dust abatement or abatement of organic compounds. Multic~~C~~yclones may also be used.~~ can be applied alone or as multicyclones.~~
Demister	Demisters are filter devices that remove entrained liquid droplets from a gas stream. They consist of a woven structure of metal or plastic wires, with a high specific surface area. Through their momentum, small droplets present in the gas stream impinge against the wires and coalesce into bigger drops.
Fabric filter	Fabric filters, often referred to as bag filters, are constructed from porous woven or felted fabric through which gases are passed to remove particles. Fabric filters can be in the form of sheets, cartridges or bags with a number of individual fabric filter units housed together in a group. The use of a fabric filter requires the selection of a fabric suitable for the characteristics of the waste gas and the maximum operating temperature.
Furnace automation and control	See Section 5.3.1.
Low-NO_X burner	The technique (including ultra-low-NO_X burners) is based on the principles of reducing peak flame temperatures. The air to fuel ratio adjustment reduces the availability of oxygen and reduces the peak flame temperature, thus retarding the conversion of fuel-bound nitrogen to NO_X and the formation of thermal NO_X, while maintaining high combustion efficiency.
Selection of an appropriate furnace type	Selection of an appropriate furnace type(s) based on the level of emissions and technical criteria, e.g. type of process such as continuous or batch production, furnace capacity, type of castings, availability of raw materials, flexibility depending on raw materials' cleanliness and alloy change. The energy efficiency of the furnace is also considered (see technique 'Selection of an energy-efficient type of furnace' in Section 5.3.1).
Thermal oxidation	Abatement technique which oxidises combustible compounds in a waste gas stream by heating it with air or oxygen to above its auto-ignition point in a combustion chamber and maintaining it at a high temperature long enough to complete its combustion to carbon dioxide and water. The typical combustion temperature is between 800 °C and 1 000 °C. Several types of thermal oxidation are operated: • Straight thermal oxidation: thermal oxidation without energy recovery from the combustion. • Recuperative thermal oxidation: thermal oxidation using the heat of the waste gases by indirect heat transfer. • Regenerative thermal oxidation: thermal oxidation where the incoming waste gas stream is heated when passing through a ceramic-packed bed before entering the combustion chamber. The purified hot gases exit this chamber by passing through one (or more) ceramic-packed bed(s) (cooled by an incoming waste gas stream in an earlier combustion cycle). This reheated packed bed then begins a new combustion cycle

Technique	Description
	by preheating a new incoming waste gas stream.
Wet scrubber	The removal of gaseous or particulate pollutants from a process off-gas or waste gas stream via mass transfer to a suitable liquid, often water or an aqueous solution. It may involve a chemical reaction (e.g. in an acid or alkaline scrubber).

5.3.5 Techniques to reduce emissions to water

Technique	Description
Activated sludge process	In the activated sludge process, the microorganisms are maintained as a suspension in the waste water and the whole mixture is mechanically aerated. The activated sludge mixture is sent to a separation facility from which the sludge is recycled to the aeration tank.
Adsorption	The removal of soluble substances (solutes) from the waste water by transferring them to the surface of solid, highly porous particles (typically activated carbon).
Chemical oxidation	Chemical oxidation is the conversion of pollutants by chemical-oxidising agents other than oxygen/air or bacteria into similar but less harmful or hazardous compounds and/or to short-chained and more easily degradable or biodegradable organic components. Ozone is one example of a chemical-oxidising agent applied.
Chemical precipitation	The conversion of dissolved pollutants into an insoluble compounds by adding chemical precipitants. The solid precipitates formed are subsequently separated by sedimentation, air flotation or filtration. If necessary, this may be followed by microfiltration or ultrafiltration. Multivalent metal ions (e.g. calcium, aluminium, iron) are used for phosphorus precipitation.
Chemical reduction	The conversion of pollutants by chemical reducing agents into similar but less harmful or hazardous compounds. The reduction of Cr(VI) is achieved at pH values under 2.5. The most common reducing agent is sodium hydrogen sulphite (bisulphite).
Coagulation and flocculation	Coagulation and flocculation are used to separate suspended solids from waste water and are often carried out in successive steps. Coagulation is carried out by adding coagulants with charges opposite to those of the suspended solids. Flocculation is carried out by adding polymers, so that collisions of microfloc particles cause them to bond to produce larger flocs.
Crystallisation	Waste water treatment technique used to separate and remove dissolved solids by converting them into solid crystals. It involves controlled cooling, evaporation, or chemical reactions to promote the formation of crystals, which are removed from the water through filtration or sedimentation
Electrodialysis	Use of electric potential difference properties to transport salt ions from one solution to another solution through ion-exchange membranes.
Electrolysis	Passage of a direct electric current through an ionic substance, resulting in chemical reactions at the electrodes. The ionic substance is either molten or dissolved in a suitable solvent.
Equalisation	Balancing of flows and pollutant loads at the inlet of the final waste water treatment by using central tanks. Equalisation may be decentralised or carried out using other management techniques.
Evaporation	Evaporation of waste water is a distillation process where water is the volatile substance, leaving the concentrate as bottom residue to be handled (e.g. recycled or disposed of). The aim of this operation is to reduce the volume of waste water or to concentrate mother liquors. The volatile steam is collected in a condenser and the condensed water is, if necessary after subsequent treatment, recycled. There are many types of evaporators: natural circulation evaporators; short-tube vertical evaporators; basket-type evaporators; falling film evaporators; agitated thin film evaporators. Typical pollutants targeted are soluble contaminants (e.g. salts).
Filtration	The separation of solids from waste water by passing them through a porous medium, e.g. sand filtration, microfiltration and ultrafiltration.

Flotation	The separation of solid or liquid particles from waste water by attaching them to fine gas bubbles, usually air. The buoyant particles accumulate at the water surface and are collected with skimmers.
Ion exchange	The retention of ionic pollutants from waste water and their replacement by more acceptable ions using an ion-exchange resin. The pollutants are temporarily retained and afterwards released into a regeneration or backwashing liquid.
Membrane bioreactor (MBR)	A MBR consists of the combination of a membrane process (e.g. microfiltration or ultrafiltration) with a suspended growth bioreactor. In a MBR system for biological waste water treatment, the secondary clarifier and the tertiary filtration step of a traditional aerated sludge system are replaced by membrane filtration (the separation of sludge and suspended solids).
Nitrification/denitrification	Part of the organic nitrogen is transformed into ammonium. Ammonium is oxidised by nitrifying bacteria into nitrite and nitrate. By applying anaerobic periods, the nitrate can be transformed into N_2 in the presence of organic carbon. In a secondary basin, the sludge settles, with part of it being reused in the aeration basin. The residue can be used as fertiliser (composted or not) after concentration.
Nanofiltration	A filtration process in which membranes with pore sizes of approximately 1 nm are used.
Neutralisation	The adjustment of the pH of waste water to a neutral level (approximately 7) by the addition of chemicals. Sodium hydroxide (NaOH) or calcium hydroxide ($Ca(OH)_2$) is generally used to increase the pH, whereas sulphuric acid (H_2SO_4), hydrochloric acid (HCl) or carbon dioxide (CO_2) is generally used to decrease the pH. The precipitation of some substances may occur during neutralisation.
Physical separation	The separation of gross solids, suspended solids or metal particles from the waste water using for example screens, sieves, grit separators, grease separators, hydrocyclones, oil-water separation or primary settlement tanks.
Reverse osmosis	A membrane process in which a pressure difference applied between the compartments separated by the membrane causes water to flow from the more concentrated solution to the less concentrated one.
Sedimentation	The separation of suspended particles and suspended material by gravitational settling.
Segregation of water streams	Water streams (e.g. surface run-off water, process water) are collected separately, based on the pollutant content and on the required treatment techniques. Waste water streams that can be recycled without treatment are segregated from waste water streams that require treatment.

5.3.6 Techniques to reduce waste generation and promote circular economy

Technique	Description
Process line optimisation	See Section 5.3.1.
Automatic systems for the preparation and dosing of process chemicals	See Section 5.3.3.
Advanced process monitoring and control systems	See Section 5.3.2.

5.4 Content of the Environmental Management System (EMS)

According to Articles 14a (1) and 14a (2) of the Industrial Emissions Directive, the EMS shall include the following elements and shall comply with relevant BAT conclusions that determine aspects to be covered in the EMS:

(a) environmental policy objectives for the continuous improvement of the environmental performance and safety of the installation, which shall include measures to:
  (i) prevent the generation of waste;
  (ii) optimise resource and energy use and water reuse;
  (iii) prevent or reduce the use or emissions of hazardous substances;
(b) objectives and performance indicators in relation to significant environmental aspects, which shall take into account benchmarks set out in the relevant BAT conclusions;
(c) for installations covered by the obligation to conduct an energy audit or implement an energy management system pursuant to Article 8 of Directive 2012/27/EU, inclusion of the results of that audit or implementation of the energy management system pursuant to Article 8 of and Annex VI to that Directive and of the measures to implement their recommendations;
(d) a chemicals inventory of the hazardous substances present in or emitted from the installation as such, as constituents of other substances or as part of mixtures, with special regard given to the substances fulfilling the criteria referred to in Article 57 of Regulation (EC) No 1907/2006 and substances addressed in restrictions referred to in Annex XVII to Regulation (EC) No 1907/2006, and a risk assessment of the impact of such substances on human health and the environment, as well as an analysis of the possibilities for substituting them with safer alternatives or reducing their use or emissions;
(e) measures taken to achieve the environmental objectives and avoid risks for human health or the environment, including corrective and preventive measures where needed;
(f) a transformation plan as referred to in Article 27d.

The aspects in the following sections are to be covered in the EMS, in addition to the elements listed above.

According to Article 14a (3), the level of detail of the EMS shall be consistent with the nature, scale and complexity of the installation, and the range of environmental impacts it could have. Where elements required to be included in the EMS, including objectives, performance indicators or measures, have already been developed in accordance with other relevant Union legislation and comply with this Article 14a, a reference in the EMS to the relevant documents shall be sufficient.

5.4.1 General aspects

The following general aspects are to be covered in the environmental management system (EMS):

i. Commitment, leadership, and accountability of the management, including senior management, for the implementation of an effective EMS.
ii. An analysis that includes the determination of the organisation's context, the identification of the needs and expectations of interested parties, the identification of characteristics of the installation that are associated with possible risks for the environment and human health as well as of the applicable legal requirements relating to the environment and human health.

iii. Determination of structures, roles and responsibilities in relation to environmental aspects and objectives and provision of the financial and human resources needed.
iv. Ensuring the necessary competence and awareness of staff whose work may affect the environmental performance of the installation (e.g. by providing information and training).
v. Internal and external communication on the environmental performance of the installation.
vi. Fostering employee involvement in good environmental management practices.
vii. Establishing and maintaining a management manual and written procedures to control activities with significant environmental impact as well as relevant records.
viii. Effective operational planning and process control.
ix. Implementation of appropriate maintenance programmes.
x. Emergency preparedness and response protocols, including the prevention and/or mitigation of the adverse (environmental) impacts of emergency situations.
xi. When (re)designing a (new) installation or a part thereof, consideration of its environmental impacts throughout its life, which includes construction, maintenance, operation and decommissioning.
xii. Implementation of a monitoring and measurement programme; if necessary, information can be found in the Reference Report on Monitoring of Emissions to Air and Water from IED Installations.
xiii. Application of sectoral benchmarking on a regular basis.
xiv. Following and taking into account the development of cleaner techniques.

5.4.1.1 Benchmarks for the surface treatment of metals and plastics industry

Benchmarks for the surface treatment of metals and plastics industry are included in **Table 5-12** and **Table 5-13**.

5.4.2 Inventory of inputs and outputs

In order to improve the overall environmental performance, an inventory of inputs and outputs is set-up, implemented and regularly reviewed. The inventory of inputs and outputs incorporates at least the following features:

- (i) information about the production processes, including:
  - (a) simplified process flow sheets that show the origin of the emissions to air, water and soil and the associated emission point(s);
  - (b) descriptions of process-integrated techniques and waste water/waste gas treatment techniques to prevent or reduce emissions, including their performance (e.g. abatement efficiency);
- (ii) information about the quantity and characteristics of raw materials and fuels used;
- (iii) information about water consumption and usage (e.g. flow diagrams and water mass balances);
- (iv) information about energy consumption and usage;
- (v) information about the characteristics of the waste water streams, such as:
  - (a) average values and variability of flow, pH, temperature and conductivity;
  - (b) average concentration and mass flow values of relevant substances/parameters (e.g. total suspended solids, TOC or COD, hydrocarbon oil index, metals) and their variability;
  - (c) presence of substances classified as CMR 1A, CMR 1B or CMR 2; the presence of such substances may for example be assessed according to the criteria of Regulation (EC) No 1272/2008 on classification, labelling and packaging (CLP);
- (vi) information about the quantity and characteristics of the process chemicals used (e.g. PFAS):

  - (a) the identity and the characteristics of process chemicals, including properties with adverse effects on the environment and/or human health;
  - (b) the quantities of process chemicals used and the location of their use;
- (vii) information about the characteristics of the waste gas streams, such as:
  - (a) average values and variability of flow and temperature;
  - (b) average concentration and mass flow values of relevant substances (e.g. dust, alkaline:acidic emissions, NO_X, SO_X, metals) and their variability;
  - (c) presence of other substances that may affect the waste gas treatment system (e.g. oxygen, nitrogen, water vapour) or installation safety;
  - (d) information about the quantity and origin of greenhouse gas (GHG) emissions;
  - (e) presence of substances classified as CMR 1A, CMR 1B or CMR 2; the presence of such substances may for example be assessed according to the criteria of Regulation (EC) No 1272/2008 on classification, labelling and packaging (CLP);
- (viii) information about the quantity and characteristics of residues generated.

5.4.3 Chemicals management system

In order to improve the overall environmental performance, a chemicals management system (CMS) is set-up, implemented and regularly reviewed. The CMS incorporates at least the following features:

i. Information about the quantity and characteristics of the process chemicals used:
   - (a) the identity and the characteristics of the process chemicals, including properties with adverse effects on the environment and/or human health;
   - (b) the quantities of the process chemicals used and the location of their use.

ii. A policy to reduce the consumption of and risks associated with process chemicals, including a procurement policy to select less harmful process chemicals and their suppliers with the aim of minimising the use of and risks associated with hazardous substances, with special regard given to the substances fulfilling the criteria referred to in Article 57 of Regulation (EC) No 1907/2006 and substances addressed in restrictions referred to in Annex XVII to Regulation (EC) No 1907/2006, as well as to avoid the procurement of an excess amount of process chemicals. The selection of process chemicals is based on:
   - a) the comparative analysis of their bioeliminability/biodegradability, eco-toxicity and potential to be released into the environment in order to reduce emissions to the environment;
   - b) the characterisation of the risks associated with the process chemicals, based on the chemicals' hazard classification, pathways through the plant, potential release and level of exposure and including the requirements of Article 14a 2 (d);
   - c) the potential for recovery and reuse (see BAT 13);
   - d) the regular (e.g. annual) analysis of the potential for substitution with the aim to identify potential new available and safer alternatives to the use of hazardous substances; this may be achieved by changing process(es) or using other process chemicals with no or lower impacts on the environment and/or the human health (see BAT 13) and including the requirements of Article 14a 2 (d);
   - e) the anticipatory monitoring of regulatory changes related to hazardous substances, and the safeguarding of compliance with applicable legal requirements.

   The inventory of process chemicals (see Section 5.4.2 vii.) may be used to provide and keep the information needed for the selection of process chemicals.

iii. Goals and action plans to avoid or reduce the use of and risks associated with hazardous substances.

iv. Development and implementation of procedures for the procurement, handling, storage and use of process chemicals, disposal of waste containing process chemicals and return of unused process chemicals, to prevent or reduce emissions to the environment (e.g. see BAT 1).

5.4.4 Risk-based OTNOC management plan

In order to improve the overall environmental performance, a risk management plan is set-up, implemented and regularly reviewed. The risk-based OTNOC management plan includes at least the following features:

i. identification of potential OTNOC (e.g. failure of equipment critical to the protection of the environment ('critical equipment')), of their root causes and of their potential consequences;
ii. appropriate design of critical equipment (e.g. off-gas treatment, waste water treatment);
iii. set-up and implementation of an inspection plan and preventive maintenance programme for critical equipment (see Section 5.4.1 ix.);
iv. monitoring (i.e. estimating or, where possible, measuring) and recording of emissions during OTNOC and of associated circumstances;
v. periodic assessment of the emissions occurring during OTNOC (e.g. frequency of events, duration, amount of pollutants emitted) and implementation of corrective actions if necessary;
vi. regular review and update of the list of identified OTNOC under point i. following the periodic assessment of point v.;
vii. implementation of backup systems (where appropriate) and regular testing of them.

5.4.5 Plan for the prevention and control of leaks and spillages

In order to improve the overall environmental performance, a plan for the prevention and control of leaks and spillages is set-up, implemented and regularly reviewed. The plan for prevention and control of leaks and spillages includes at least the following features:

- site incident plans for small and large spillages;
- identification of the roles and responsibilities of persons involved;
- ensuring staff are environmentally aware and trained to prevent and deal with spillage incidents;
- identification of areas at risk of spillage and/or leaks of hazardous materials and substances, and ranking them according to the risk;
- identification of suitable spillage containment and clean-up equipment and regularly ensuring it is available, in good working order and close to points where these incidents may occur;
- waste management guidelines for dealing with waste arising from spillage control;
- prompt repair of leaks from valves, glands, flanges, etc.;
- regular inspections (at least on a monthly basis) of storage and handling areas, testing and calibration (at least on an annual basis) of leak detection equipment and prompt repair of leaks from valves, glands, flanges, etc.

5.4.6 Energy efficiency plan

In order to improve the overall environmental performance, an energy efficiency plan is set-up, implemented and regularly reviewed. The energy efficiency plan entails defining and monitoring the specific energy consumption/usage of the plant/process (e.g. kWh/t of workpieces treated), setting objectives in terms of energy efficiency and implementing actions to achieve these objectives.

5.4.7 Residues management plan

In order to improve the overall environmental performance, a residues management plan is set-up, implemented and regularly reviewed. The residues management plan entails defining and monitoring the quantity and characteristics of residues generated by the plant/process (e.g. kg/t of workpieces treated).

The residues management plan comprises a set of measures aiming to:

- minimise the generation of residues;
- optimise the reuse, recycling and/or recovery of residues;
- ensure the proper disposal of waste.

5.4.8 Water management plan

In order to improve the overall environmental performance, a water management plan is set-up, implemented and regularly reviewed. The water management plan entails defining and monitoring the specific water consumption/usage of the plant/process (e.g. m^3/t of workpiece treated) and incorporates at least the following features:

- flow diagrams and water mass balances of the plant as part of the inventory of inputs and outputs mentioned in Section 5.4.2;
- establishment of water efficiency objectives;
- implementation of water optimisation techniques (e.g. control of water usage, reuse/recycling, detection and repair of leaks).

5.4.9 Noise management plan

As part of the EMS and in order to improve the overall environmental performance, a noise management plan is set up, implemented and regularly reviewed. The noise management plan includes at least the following features:

- a protocol containing appropriate actions and timelines;
- a protocol for monitoring of noise emissions;
- a protocol for responding to identified noise events, e.g. managing complaints and/or taking corrective actions;
- a noise reduction programme designed to identify the source(s), to measure/estimate noise exposure, to characterise the contributions of the sources to the overall noise emissions and to implement prevention and/or reduction measures.

Applicability
The applicability is restricted to cases where a noise nuisance at sensitive receptors is expected and/or has been substantiated.

5.4.10 Odour management plan

As part of the EMS and in order to improve the overall environmental performance, an odour management plan is set up, implemented and regularly reviewed. An odour management plan includes at least the following features:

- A protocol containing appropriate actions and timelines.
- A protocol for conducting odour monitoring. The protocol may be complemented by measurement/estimation of odour exposure or estimation of odour impact.
- A protocol for response to identified odour incidents, e.g. managing complaints and/or taking corrective actions.
- An odour prevention and reduction programme designed to identify the source(s); to measure/estimate odour exposure; to characterise the contributions of the sources; and to implement prevention and/or reduction measures.

Applicability
The applicability is restricted to cases where an odour nuisance at sensitive receptors is expected and/or has been substantiated.

6 CONCLUDING REMARKS AND RECOMMENDATIONS FOR FUTURE WORK

[This chapter will be completed after the Final TWG meeting.]

7 ANNEXES

[Note to the TWG: several annexes from the existing BREF have been removed..]

7.1 List of plants that participated in the data collection

Plant-code	Name of the plant	City	Country	Activity
AT_001	AT&S Leoben	Leoben	AT	Printed circuit boards
AT_002	AT&S Fehring	Fehring	AT	Printed circuit boards
AT_003	Collini GmbH	Hohenems	AT	Plating
AT_004	Collini GmbH	Wien	AT	Plating
AT_005	Doka GmbH	Amstetten	AT	Plating
AT_006	Henkel Beiz- & Elektropoliertechnik Betriebs GmbH	Waidhofen	AT	Plating
AT_007	Lahner KG	Brunn am Gebirge	AT	Plating
AT_008	MACO- Mayder und Co Beschläge GmbH	Salzburg	AT	Plating
AT_009	MACO- Mayder und Co Beschläge GmbH	Trieben	AT	Plating
AT_010	Miba Gleitlager Austria GmbH	Laakirchen	AT	Plating
AT_011	OTN Galvanotechnik GmbH	Elsbethen	AT	Plating
AT_012	Stiefler GmbH	Krems an der Donau	AT	Plating
AT_013	Voestalpine Stahl GmbH	Linz	AT	Continuous steel coil coating
AT_014	Austria Email AG	Knittelfeld	AT	Vitreous enamelling
AT_015	voestalpine Rotec GmbH	Krieglach	AT	Plating
AT_016	Collini GmbH	St. Pantaleon	AT	Plating
AT_020	Umdasch Store Makers Leibnitz GmbH	8430 Leibnitz	AT	Plating
AT_021	Doka GmbH	3376 Ennsbach	AT	Plating
BE_001	Alvance Aluminium Duffel (vm Aleris Aluminium)	Duffel	BE	Plating
BE_002	ArcelorMittal Belgium- Sikel	Genk	BE	Continuous steel coil coating
BE_003	Kanigen Works Benelux	Genk	BE	Plating
BE_004	ACB	Dendermonde	BE	Printed circuit boards
BE_005	Cevema Surface Treatments	Lummen	BE	Plating
BE_010	Packo Inox	Diksmuide	BE	Plating
BE_015	Tenneco Automotive Europe	Sint-Truiden	BE	Plating
BE_017	Voestalpine Sadef	Hooglede	BE	Plating
BE_018	Volvo Cars Gent	Gent	BE	Plating
BE_020	Kopal	Kortemark	BE	Plating
BE_031	Electrocoat	Genk	BE	Plating
BE_040	Sobinco	Zulte	BE	Plating
BG_004	Palfinger Productiontehnik EOOD	Tenevo	BG	Plating
BG_006	Ideal Standart Vidima AD	Sevlievo	BG	Plating
BG_013	Sofia Med AD	Sofia	BG	Plating
CZ_001	GO Steel a.s.	Frýdek-Místek	CZ	Continuous steel coil coating
CZ_002	TK Galvanoservis s.r.o.	Prague	CZ	Plating
CZ_003	GALVA s.r.o.	Držovice	CZ	Plating
CZ_006	ZF Automotive CZ	Jablonec nad Nisou	CZ	Plating

Plant-code	Name of the plant	City	Country	Activity
CZ_007	CVP Galvanika s.r.o.	Příbram	CZ	Plating
CZ_010	Iveco Czech Republic, a.s.	Vysoké Mýto	CZ	Plating
CZ_011	Czech Airlines Technics	Prague	CZ	Plating
CZ_012	F.X.Meiller Slaný s.r.o	Slaný	CZ	Plating
CZ_014	ŽĎAS, a.s.	Žďár nad Sázavou	CZ	Plating
DE_001	ALBEA Metall-Oberflächentechnik GmbH	Friesenheim-Schuttern	DE	Plating
DE_002	Alutecta GmbH & Co. KG	Kirchberg	DE	Plating
DE_003	AnodiTec Sontra GmbH & Co. KG	Sontra	DE	Plating
DE_005	Diedrich Sandersfeld GmbH & Co. KG	Bremen	DE	Plating
DE_006	EKO-Dekor Oberflächenveredelungs GmbH	Surwold	DE	Plating
DE_007	Elox Gerhard Gotta GmbH & Co. KG Aluminiumveredelung	Rödermark	DE	Plating
DE_008	ESP Südeloxal GmbH	Stephanskirchen	DE	Plating
DE_009	Gartner Extrusion GmbH	Gundelfingen	DE	Plating
DE_010	Hydro Extrusion Deutschland GmbH	Rackwitz	DE	Plating
DE_012	Kühl Eloxal GmbH	Bochum	DE	Plating
DE_018	Rudolph Clauss	Mülheim an der Ruhr	DE	Plating
DE_019	Anke GmbH	Essen	DE	Plating
DE_023	Chrom-Schmitt	Baden-Baden	DE	Plating
DE_024	Galvano Röhrig	Solingen	De	Plating
DE_025	Zeschky Galvanik Gmbh & Co. KG	Wetter (Ruhr)	DE	Plating
DE_031	Tata Steel	Düsseldorf	DE	Continuous steel coil coating
DE_033	BIA	Solingen	DE	Plating
DE_034	thyssen krupp Rasselstein	Andernach	DE	Continuous steel coil coating
DE_036	Hansgrohe SE	Offenburg	DE	
DE_037	Hansgrohe SE	Schiltach	DE	Plating
DE_038	Sedus Stoll AG	Dogern	DE	Plating
DE_040	Würth Elektronik	Niedernhall	DE	Printed circuit boards
DE_041	Gretsch-Unitas GmbH	Ditzingen	DE	Plating
DE_045	Gerhardi Galvanotechnik Werdohl GmbH	Altena	DE	Plating
DE_048	HDO Druckguß- u. Oberflächentechnik GmbH	Paderborn	DE	Plating
DE_054	WHW Langenfeld GmbH & Co. KG	Langenfeld (Rhld.)	DE	Plating
DE_059	Holder	Laichingen	DE	Plating
DE_060	ZF Friedrichshafen	Friedrichshafen	DE	Plating
DE_062	Wilhelm Bauer GmbH & Co KG	Hannover-Anderten	DE	Plating
DE_066	Schweizer Electronic	Schramberg	DE	Printed circuit boards
DE_068	Texas Instruments Deutschland GmbH	Freising	DE	Semiconductor manufacturing
DE_072	Infineon Technologies Dresden GmbH & Co. KG	Dresden	DE	Semiconductor manufacturing
DE_073	Infineon Technologies Regensburg	Regensburg	DE	Semiconductor manufacturing
DE_074	Robert Bosch Semiconductor Manufacturing Dresden GmbH	Dresden	DE	Semiconductor manufacturing

Plant-code	Name of the plant	City	Country	Activity
DE_076	Robert Bosch GmbH	Reutlingen	DE	Semiconductor manufacturing
DE_077	Continental AG	Rheinböllen	DE	Plating
DE_078	ANCOA Oberflächenveredelung GmbH	Kurtscheid	DE	Plating
DE_079	Walter Werner GmbH Metallveredelung	Birkenfeld		Plating
DK_001	Midtjydsk Fornikling, Herning	Herning	DK	Plating
ES_001	EXTRUSIONES DE TOLEDO S.A. (EXTOL)	Toledo	ES	Plating
ES_002	GALOL	L'Olleria	ES	Plating
ES_003	SRG GLOBAL IBI	Ibi	ES	Plating
ES_004	GONVARRI TARRAGONA	Tarragona	ES	Plating
ES_005	GONVARRI BARCELONA	Castellbisbal	ES	Plating
ES_006	ARCELOR PACKAGING INTERNATIONAL ESPAÑA, S.L. (FABRICA DE ETXEBARRI)	Basauri	ES	Continuous steel coil coating
ES_007	ARCELORMITTAL ESPAÑA, S.A.- Sagunto	Sagunto	ES	Continuous steel coil coating
ES_008	ARCELORMITTAL ESPAÑA- PLANTA SIDERÚRGICA DE AVILÉS Y GIJÓN	Gijón, Corvera de Asturias, Avilés, Carreño and Gozón	ES	Continuous steel coil coating
ES_009	HITACHI ASTEMO BUELNA, S. L.U.(antes: CHASSIS BRAKES INTERNATIONAL SPAIN S.L.U. (Nueva Braking Systems))	San Felices de Buelna	ES	Plating
ES_010	ALUDEC GALVANIC S.A_2	Pontevedra	ES	Plating
ES_012	ALUMINIOS CORTIZO	Lugar da Matanza, Padrón	ES	Plating
ES_013	CROMADOS ESTEVEZ, S.L.	Lugo	ES	Plating
ES_014	GESTAMP VIGO S.A.	Porriño	ES	Plating
ES_016	ANODIAL ESPAÑOLA, S.L.	Arrúbal	ES	Plating
ES_019	ITESAL LACADOS, S.L.	Pina de Ebro	ES	Plating
ES_020	EXTRUSIONADOS Y TRATAMIENTOS DEL COLOR, S.L. (EXTRUCOLOR)	Abanilla	ES	Plating
ES_021	INTEC-AIR, S.L.	Cádiz	ES	Plating
ES_023	KYB SUSPENSIONS EUROPE	Ororbia	ES	Plating
ES_024	ACABADO DE SUPERFICIES BOLGUI, S.L	Yeles	ES	Plating
ES_030	ALUDEC GALVANIC S.A_1	Pontevedra	ES	Plating
ES_031	ITP Aero/ INDUSTRIA DE TURBO PROPULSORES, S.A.	Zamudio	ES	Plating
FI_002	ASSA Abloy Oy	Joensuu	FI	Plating
FI_003	Oras Oy	Rauma	FI	Plating
FI_004	Purso Oy	Nokia	FI	Plating
FI_005	Aurajoki Oy	Turku	FI	Plating
FR_004	ARCELORMITTAL FRANCE	Indre	FR	Continuous steel coil coating
FR_006	Sovab	Batilly	FR	Plating
FR_007	STELLANTIS SOCHAUX (ex PSA PEUGEOT)	Sochaux	FR	Plating
FR_009	Bretagne Chrome SA	Pluvigner	FR	Plating
FR_011	GALVANOPLAST (ex Frantz Electrolyse)	Villeneuve la Garenne	FR	Plating

Plant-code	Name of the plant	City	Country	Activity
FR_012	GRAINDORGE	SENS	FR	Plating
FR_014	MITHIEUX	CHAMBERY	FR	Plating
FR_015	PEM Siaugues Ste Marie	SIAUGUES STE MARIE	FR	Plating
FR_016	PROTEC INDUSTRIE (EX SEPROJA)	BEZONS	FR	Plating
FR_017	SEVELNORD	Saint Amand	FR	Plating
FR_018	QUALIPAC AURILLAC (ex. AURIPLAST)	AURILLAC	FR	Plating
FR_019	SAFRAN AIRCRAFT ENGINES (ex SNECMA)	EVRY COURCOURONNES	FR	Plating
FR_023	CONSTELLIUM NEUF BRISACH	Biesheim	FR	Plating
FR_024	OVAKO	Redon	FR	Plating
FR_029	HYDRO EXTRUSION PUGET	PUGET SUR ARGENS	FR	Plating
FR_030	STMicroelectronics Rousset	Rousset	FR	Semiconductor manufacturing
FR_031	STMicroelectronics Tours	Tours	FR	Semiconductor manufacturing
FR_032	Airbus Atlantic	Saint Nazaire	FR	Plating
FR_033	REVIMA	Rives sur Seine	FR	Plating
FR_034	CONSTELLIUM Nuits Saint Georges	Nuits Saint Georges	FR	Plating
FR_035	EATON SOURIAU	Champagné	FR	Plating
FR_036	ASSA Abloy	Longué-Jumelles	FR	Plating
IE_001	Intel	Leixlip, Co Kildare	IE	Semiconductor manufacturing
IT_001	GALVANICA NOBILI Srl	MARANO SUL PANARO (Modena)	IT	Plating
IT_002	TOBALDINI Spa	ALTAVILLA VICENTINA (Vicenza)	IT	Plating
IT_004	BURELLO Srl	PAVIA DI UDINE (Udine)	IT	Plating
IT_006	TRAME Srl	ZOLA PREDOSA (Bologna)	IT	Plating
IT_008	EVEREST Srl	MIANE (Treviso)	IT	Plating
IT_009	GALVANICA RIVA Srl	SOLARO (Milano)	IT	Plating
IT_010	CROMOULDS Srl	CORTE FRANCA (Brescia)	IT	Plating
IT_011	MOREX Spa	PIEVE DEL GRAPPA (Treviso)	IT	Plating
IT_012	Z.A.G. Snc	MOLINELLA (Bologna)	IT	Plating
IT_013	C.R.S. Srl	GALLARATE (Varese)	IT	Plating
IT_019	EREDI DI BONACINA MARIO	Caravaggio (BG)	IT	Plating
IT_020	GASER BOLOGNA	Cadriano (BO)	IT	Plating
IT_022	STM MICROELETTRONICS	Agrate Brianza (MB)	IT	Semiconductor manufacturing
IT_023	STM MICROELETTRONICS	Catania	IT	Semiconductor manufacturing
IT_025	Ovako Group	MOLINELLA (Bologna)	IT	Plating
IT_029	IAMET			Plating
IT_030	LaGalvanina			Plating
IT_031	GDZ			Plating

Plant-code	**Name of the plant**	**City**	**Country**	**Activity**
IT_032	Desalto			Plating
IT_033	ADI			Plating
MT_001	STMICROELETTRONICS	Kirkop	MT	Semiconductor manufacturing
NL_001	Waelbers	Ruinerwold	NL	Plating
NL_002	TATA STEEL	Ijmuiden	NL	Continuous steel coil coating
NL_003	NXP	Nijmegen	NL	Semiconductor manufacturing
PL_001	Gränges Konin S.A.	Konin	PL	Plating
PT_002	Salemo & Merca, Lda	Palmela	PT	Plating
PT_012	LAUAK Aerostrutures Grândola, S.A.	Grândola	PT	Plating
SE_002	Hydro Extrusion Sweden AB	Vetlanda	SE	Plating
SE_003	Hydro Extrusion Sweden AB	Vetlanda	SE	Plating
SE_004	Ovako	Hallstahammar	SE	Plating
SE_005	GKN Aerospace	Trollhättan	SE	Plating
SE_006	Calamo	Molkom	SE	Plating
SK_001	U.S.Steel Košice, s.r.o.	Košice	SK	Continuous steel coil coating

GLOSSARY

Note to the TWG: Glossary will be updated at a later stage

General Glossary

1. General terms, abbreviations, acronyms and substances

ENGLISH TERM	MEANING
A	
A	ampere
ABS	any of the class of plastics based on acrylonitrile-butadiene-styrene copoloymers
A/dm^2, A/m^2	amperes per square decimetre, amperes per square metre. A measure of current density at the electrode.
AC	alternating current
acid	proton donor. A substance that, more or less readily, gives off hydrogen ions in a water solution
ACGHI	American Conference of Governmental Industrial Hygienists. This organisation produces various standards for industrial hygiene/workplace safety
achieved environmental benefits (See Chapter 4)	main environmental impact(s) to be addressed by the technique (process or abatement), including emission values achieved and efficiency performance. Environmental benefits of the technique in comparison with others
acute effect	an adverse effect on any living organism in which severe symptoms develop rapidly and often subside after the exposure stops.
acute pollution	pollution arising from infrequent events, unplanned events or accidents (see also: chronic pollution)
acute toxicity	adverse effects that result from a single dose or single exposure of a chemical; any poisonous effect produced within a short period, usually less than 96 hours. This term is normally used to describe effects in experimental animals.
aeration	the act of mixing a liquid with air (oxygen).
aerobic	a biological process that occurs in the presence of oxygen
air knife	a machine using low pressure, high volume air emitted through precision slits, giving a laminar air curtain. Components can be passed through this curtain, either manually or on a conveyor belt, or as a coil. The air heats up due to compression and movement in the system, and this warms oils and greases, assisting their removal. Both the air movement and the temperature facilitates drying of components. Also used in other industries, such as for finishing chocolates
alkali	proton acceptor. A substance that, more or less readily, takes up hydrogen ions in a water solution.
anaerobic	a biological process that occurs in the absence of oxygen.
anion	a negatively charged ion; an ion that is attracted to towards the anode in electrochemical reactions
anode	positive electrode
anodising (GB) anodizing (US)	anodic oxidation. Electrolytic process in which the surface layer of a metal, such as aluminium, magnesium or zinc is converted to a coating, usually an oxide, having protective, decorative or functional properties [101, CEN, 2000]
AOCl	adsorbable organic chlorine compounds
AOX	adsorbable organic halogen compounds. The total concentration in

ENGLISH TERM	MEANING
	milligrams per litre, expressed as chlorine, of all halogen compounds (except fluorine) present in a sample of water that are capable of being adsorbed on activated carbon.
APE	alkyl phenol ethoxylates
applicability (see Chapter 4)	Consideration of the factors involved in applying and retrofitting the technique (e.g. space availability, process specific)
aquifer	a water-bearing layer of rock (including gravel and sand) that will yield water in usable quantity to a well or spring.
assimilative capacity	the ability of a natural body of water to receive waste waters or toxic materials without harmful effects and without damage to aquatic life
ATBC	acetyl tributyl citrate
autocatalytic plating	deposition of a metallic coating by a controlled chemical reduction that is catalysed by the metal or alloy being deposited [101, CEN, 2000]
B	
bactericide	a pesticide used to control or destroy bacteria
barrel	Also called or translated as drum. A rotating container used to contain workpieces when they are treated in bulk:
barrel processing	surface treatment activities carried out using barrels. For example, barrel cleaning, barrel electroplating
BAT	best available techniques
bath	a solution of chemicals for a specific surface treatment activity, e.g. pickling bath. Also refers to the relevant vat or workstation in a process sequence
BF	batch wise flocculation
big bag, or bulk bag	large bag for containing and/or delivering solids. Usually contains approximately one tonne depending on the material density and is designed to be compatible with pallet handing systems
biodegradable	that can be broken down physically and/or chemically by micro-organisms. For example, many chemicals, food scraps, cotton, wool and paper are biodegradable.
BOD	biochemical oxygen demand: the quantity of dissolved oxygen required by micro-organisms in order to decompose organic matter. The unit of measurement is mg O_2/l. In Europe, BOD is usually measured after 3 (BOD_3), 5 (BOD_5) or 7 (BOD_7) days.
BREF	BAT reference document
bulk bag	see big bag
C	
caroat	potassium monopersulphate
CASS	copper accelerated salt spray test. A standard corrosion test
cathode	negative electrode
cation	a positively charged ion: an ion that is attracted towards the cathode in electrochemical reactions
CF	continuous flocculation
CNC	computer numeric control
COD	chemical oxygen demand: the amount of potassium dichromate, expressed as oxygen, required to oxidise chemically, at about 150 °C, substances contained in waste water. However, CODCr also includes any inorganic reducing agents present.. High Chloride (>1000mg/l also interferes with the results. The ISO standard for COD is ISO 15705:2002. TOC is also a measure of organic compounds in waste water
CPI	corrugated plate interceptor- oil separation device utilizing inclined

ENGLISH TERM	MEANING
	corrugated plates to separate free non-emulsified oil and water based on their density difference
chelating agent	a compound capable of chelation with metal ions.
chelation	the formation of a closed ring of atoms by the attachment of compounds or radicals to a central polyvalent metal ion (occasionally non-metallic).
chronic pollution	pollution occurring from regular or continuous events, such as effluent discharge (see acute pollution)
coil processing	processing of continuous coils of substrate. The largest scale activities are for steel (up to 2080 mm wide) or aluminium, although copper, brass, nickel, and zinc are also processed in coils. Coils can also be on a smaller scale (a few mm wide) for decorative trim
complexing agent	see chelating agent
containment, contained area	(secondary) containment refers to additional protection against storage tank releases over and above the inherent protection provided by the tank container itself. There are two major types of secondary containment for leakages, namely those that are part of the tank construction, such as, double tank bottoms (only for aboveground tanks), double skinned and double walled tanks and impervious barriers which are placed upon the soil surface below the tanks [90, COM 2020]
corrosion	surface chemical reaction especially on metals, by the action of moisture, air or chemicals.
cross-media effects (See Chapter 4)	Any side-effects and disadvantages caused by implementation of the technique. Details on the environmental problems of the technique in comparison with others
D	
DAF	dissolved air flotation
DC	direct current (electrical supply)
DDC	dithiocarbamate
deburring	removal of burrs or sharp edges by electropolishing, grinding, linishing or pickling
DEA	Data envelope analysis; a method of benchmarking and/or analysing data
de-embrittlement	a specific type of embrittlement of a metal or alloy caused by absorption of atomic hydrogen, for example, during electroplating, cathodic cleaning, or pickling processes and manifested by delayed fracture, brittle fracture or a reduction of ductility [101, CEN, 2000]
description (see Chapter 4)	Technical description of the technique
dialysis	a separation technique: the separation of colloids in solution from other dissolved substances by selective diffusion through a membrane
diffuse emission	emissions arising from direct contact of volatile or light dusty substances with the environment (atmosphere, under normal operating circumstances). These can result from: • inherent design of the equipment (e.g. filters, driers, etc.) • operating conditions (e.g. during transfer of material between containers) • type of operation (e.g. maintenance activities), or • from a gradual release to other media (e.g. to cooling water or waste water). Fugitive emissions are a subset of diffuse emissions.
diffuse sources	sources of similar diffuse or direct emissions which are multiple and distributed inside a defined area
displacement	see immersion coating

ENGLISH TERM	MEANING
coating	
DNC	direct or distributed numeric control. A system where a NC program is sent from a PC to a CNC machine.
DOS	dioxyl sebacate
drag-in	liquid (from a previous bath) carried into a bath by the workpieces or substrate introduced during treatment
drag-out	liquid carried out of a bath by the workpieces or substrate during treatment
driving force for implementation (see Chapter 4)	reasons for implementation of the technique (e.g. other legislation, improvement in production quality)
DS	dry solids (content). The mass of a material remaining after drying by the standard method of test
DSA	dimensionally stable anodes. Metal anodes that are not consumed during use as graphite anodes are, hence dimensionally stable.
E	
EC50	effect concentration 50. The concentration at which effects are observed in 50 % of the test population after administering a single dose. Effects include the immobilisation of daphnia, inhibition of growth, cell division or biomass production, or the production of chlorophyll by algae.
ECCS	electro-chemical chromium plating
Economics (see Chapter 4)	information on costs (investment and operation) and any possible savings (e.g. reduced raw material consumption, waste charges) also as related to the capacity of the technique
EDT	
EDTA	ethylenediaminetetraacetic acid. An important chelating agent
EDDS	ethylene diamine disuccinate
eco rinse	a static rinse tank where workpieces are passed through before and after plating, allowing the collected drag-out to be re-used as drag-in
effluent	physical fluid (air or water together with contaminants) forming an emission
EIPPCB	European IPPC Bureau
electrode	a conductor by which an electric current enters or leaves an electrolyte in an electro-chemical reaction (or an electric arc or a vacuum tube) [101, CEN, 2000], See anode and cathode
electrogalvanising	a term often used to translate the German *galvanische Metallabscheidung,* or similar terms from other languages. Should not be used in English, as it is easily confused with *hot dip galvanising.*
electroless plating	see autocatalytic plating. Use of this term discouraged [CEN, 2000 #101
electrolyte	a substance that is capable of conducting an electric current in solution or fused state
electroplating	electrodeposition of an adherent metallic coating upon an electrode for the purpose of securing a surface with properties or dimensions different from those of the base metal (see electrogalvanising, galvanising. German = galvanische Metallabscheidung). Note: plating alone cannot be used in this sense. [101, CEN, 2000]
electropolishing	smoothing and brightening of a metal surface by making it anodic in an appropriate solution [101, CEN, 2000]
emerging techniques	Novel techniques that are relevant to the document (see the BREF outline and Guide). The name of the standard chapter in BREFs where novel techniques are identified.
emission	the direct or indirect release of substances, vibrations, heat or noise from individual or diffuse sources in the installation into the air, water

ENGLISH TERM	MEANING
	or land
consumption and emission levels associated with the use of BAT	
emission limit values	the mass, expressed in terms of certain specific parameters, concentration and/or level of an emission, which may not be exceeded during one or more periods of time
EMS	environmental management system
end-of-pipe technique	a technique that reduces final emissions or consumptions by some additional process but does not change the fundamental operation of the core process. Synonyms: "secondary technique", "abatement technique". Antonyms: "process-integrated technique", "primary technique" (a technique that in some way changes the way in which the core process operates thereby reducing raw emissions or consumptions)
ENSA	ethoxylated alpha-naphthol sulphonic acid
EOP, EoP, eop	end-of-pipe
EP	electrostatic precipitator
etching	In general, the removal of part of a metal surface by the action of acid or alkali. This can be used to describe the removal of the top surface of metal, together with dirt and oxides, etc, prior to subsequent treatment. Used before anodising, etching employs an alkaline solution where micro galvanic activity at the alloy surface leads to the development of a matt appearance. [118, ESTAL, 2003]
EU-15	the 15 Member States at 26 June 2002. Most of the data in this document pre-dates the EU-25. Data from the new Member States is indicated where it is provided.
eutrophication	the pollution of a body of water by sewage, fertilisers washed from the land, and industrial wastes (inorganic nitrates and phosphates). These compounds stimulate the growth of algae, reducing the oxygen content in the water, and so killing animals with a high oxygen requirement.
example plants (see Chapter 4)	reference to a plant where the technique is reported to be used
existing installation	an installation in operation or, in accordance with legislation existing before the date on which this Directive is brought into effect, an installation authorized or in the view of the competent authority the subject of a full request for authorisation, provided that that installation is put into operation no later than one year after the date on which this Directive is brought into effect
F	
flight bar	the assembly used both to move the jigs through the core process steps and (where the processes depends on electrical current) to carry the electrical current to the jig
flocculation	the coagulation of finely divided particles into particles of greater mass [39, 1993]
fugitive emission	emission caused by non-tight equipment/leak: emission into the environment resulting from a gradual loss of tightness from a piece of equipment designed to contain an enclosed fluid (gaseous or liquid). Fundamentally caused by a difference of pressure and a resulting leak. Examples of fugitive emissions: leak from a flange, a pump, a sealed or tightened equipment…
G	
galvanising	In UK English: hot dip metal coating (German: Schelztauchüberzug; French: galvanisation à chaud).

ENGLISH TERM	MEANING
	A term often used to wrongly translate the German *galvanische Metallabscheidung,* or similar words from other languages. This term should be translated into English by electroplating
global warming	greenhouse effect: The short wave solar radiation passes through the Earth's atmosphere but after being reradiated by its surface as infrared radiation, some of it is absorbed by gases in the atmosphere causing a rise in temperature (known as global warming. It is calculated that 55 % of global warming is caused by absorption of energy by CO_2. The remaining 45 % is caused mainly by energy absorption by methane and damage to the ozone layer as a result of the use of various VOX
H	
HC	Hydrocarbon
HDI	High density interconnects. A type of printed circuit board with multiple layers and a high density of interconnections between the layers.
I	
IEF	Information Exchange Forum (informal consultation body in the framework of the IPPC Directive)
immersion coating	metal produced by a replacement reaction in which one metal is replaced by another from the solution [101, CEN, 2000]. For example: $Fe + Cu^{2+} \rightarrow Cu + Fe^{2+}$ (also known as displacement coating)
installation	in the IPPC Directive, a stationary technical unit where one or more activities listed in Annex I are carried out, and any other directly associated activities which have a technical connection with the activities carried out on that site and which could have an effect on emissions and pollution
IPPC	integrated pollution prevention and control
J	
Jig, or rack	a frame for suspending workpieces during surface treatment activities. In electrochemical activities, the rack also carries current to the workpieces
JIT	just-in-time; a manufacturing management technique, when components are delivered for the next stage of assembly just as they are needed, and not held in stock
jobbing shop, job shop	specialist surface treatment company operating as a sub-contractor in the engineering industries
K	
Knoop	Knoop units are a measure of hardness
L	
LAS	linear alkylbenzene sulphonate
LC50	lethal concentration 50. The lowest concentration of a substance in water or ambient air in milligrams per litre sufficient to cause death in 50 % of the test population within a defined period (e.g. 96 hours for fish, 48 hours for daphnia).
LD50	lethal dose 50. The lowest dose of a substance administered to species such as mice and rats sufficient to cause death in 50 % of the test population within a defined period (no more than 14 days), expressed in

ENGLISH TERM	MEANING
	milligrams of test substance per kilogram of bodyweight.
legionella (English)	a genus of gram-negative bacilli that includes species that cause Legionnaires' disease (légionellose, French; Legionärskrankheit, German, legionela sometimes in Spanish)
linishing	directional grinding of flat surfaces by means of an abrasive bonded to an endless flexible belt (US: graining) [101, CEN, 2000]
looper unit	unit in coil coating that contains loops of the continuous substrate. In entry loopers the length of the loops is decreased, allowing the end of the substrate to remain motionless when attaching a new coil; in exit loopers the loops are increased in length while holding the receiving coil motionless while cutting the end of a completed roll
LPG	liquified petroleum gas. A mixture of petroleum gases, usually propane and butane, that is stored under pressure as a liquid
M	
MAC	maximum allowable concentration
macrothrowing power	ability of an electroplating solution to produce a coating with a surface smOther than that of the substrate. cf. throwing power [101, CEN, 2000]
metallizing metallising	application of a metallic coating to the surface of non-metallic material Note: It is recommended to restrict the term metallizing to this meaning and in particular not to use it as a synonym for metal spraying or in the sense of depositing a metallic layer on a metallic substrate [101, CEN, 2000]
microelectronics	the brand of electronics that deals with miniature components
microrough	microscopic irregularities in the surface of a material
microthrowing power	ability of an electroplating solution under a specific set of conditions to deposit metal in pores or scratches Note: Good microthrowing power does not necessarily imply good macrothrowing power [101, CEN, 2000]
MLB	Mulit-layer board. A printed circuit board with more than one layer.
monitoring	process intended to assess or to determine the actual value and the variations of an emission or another parameter, based on procedures of systematic, periodic or spot surveillance, inspection, sampling and measurement or another assessment methods intended to provide information about emitted quantities and/or trends for emitted pollutants
MSA	methane sulphonic acid
MTO	metal turnover. The number of times the original quantity of metal in a bath is replenished (or turned over) by additions
multi-media effects	where effects can apply to more than one media, e.g. to air and water. See *cross-media effects*
N	
n/a	not applicable OR not available (depending on the context)
NC	numerically controlled
n/d	no data
NO_x	oxides of nitrogen
NPE	nonyl phenyl ethoxylate
NTA	nitriloacetic acid
O	
O&M	operations and maintenance in this document. (May also mean organisation and methods, relating to work planning)
OEM	original equipment manufacturer. a company that supplies equipment to

ENGLISH TERM	MEANING
	other companies to resell or incorporate into another product using the reseller's brand name, e.g. the manufacturer of components to major automotive manufacturers
operational data (see Chapter 4)	performance data on emissions/wastes and consumption (raw materials, water and energy). Any other useful information on how to operate, maintain and control the technique, including safety aspects, operability constraints of the technique, output quality, etc.
operator	any natural or legal person who operates or controls the installation or, where this is provided for in national legislation, to whom decisive economic power over the technical functioning of the installation has been delegated
OSPAR	the 1992 OSPAR Convention, combined the 1972 Oslo Convention on dumping of waste at sea and PARCOM (see below). The work under the Convention is managed by the OPSAR Commission
P	
PARCOM	the 1974 Paris Convention on land-based sources of marine pollution. The PARCOM Commission was the forum through which the Contracting Parties cooperated. It has now been superceded by the 1992 OSPAR Convention (see above)
Pcb, PCB	(i) printed circuit board. An electronic circuit in which the wiring between components and certain fixed components themselves are printed on an insulating board. (Notes: 1. This is the main use in this document. 2. Flexible films and other substrates can be instead of insulating board) [39, 1993] (ii) polychlorinated biphenyl. Chlorinated derivatives of biphenyl. Bioaccumulable toxic compounds use din synthetic resins and as electrical insulators. The only use in this document is discussing chemicals potentially used in installations of this sector (see Section 4.1.1.1) [39, 1993]
PFOS	Perfluorooctane sulphonate: a surfactant.
pickling	for metal: removal of oxides or other compounds from a metal surface by chemical or electrochemical action [101, CEN, 2000] for plastic: a mixture of chromic and sulphuric acid applied to ABS-type plastic surfaces to oxidise and dissolve the butadiene component, thus generating a microrough surface as part of the preparation for autocatalytic plating (German: Beizen, although Dekapieren seems to fit the same description)
plant	machinery or factory. A large item of equipment or an assembly of equipment, e.g. a plant for sub-contact surface treatment, a plant for chromium electroplating
plating	A widely used abbreviation of ‘electroplating’, which is the more correct term
PSA	phenyl sulphonic acid
PI	process-integrated
polishing, mechanical	smoothing of a metal surface by action of abrasive particles
pollutant	individual substance or group of substances which can harm or affect the environment
primary measure/technique	a technique that in some way changes the way in which the core process operates thereby reducing raw emissions or consumptions (see *end-of-pipe technique)*

ENGLISH TERM	MEANING
profiles, architectural	workpieces and substrate manufactured to specific cross-sectional dimensions and cut to size for assembly and use in the building construction industry. For example, door and window frames
PS	presensitised; used in this document with lithographic plates which are surface treated with a photosensitive coating as part of the manufacturing process, and prior to distribution.
PTFE	polytetrafluoroethylene
pth	plating through hole. This is a technique for Printed Circuit Boards. Plating through the holes provides electrically conductive connections between the conductor tracking planes on both sides of a double sided board or between the multiple tracking planes of Multi layer Boards (MLBs) **Note**: do not confuse with through hole construction, which is a type of PCB construction where the wires of components are placed through holes drilled through the board. This has now largely been superseded by surface mounted components.
Q	
QAC	quaternary ammonium compound
QMS	quality management system
R	
rack, or jig	frame for suspending workpieces during surface treatment activities. In electrochemical activities, the rack also carries current to the workpieces
reference conditions	conditions that are specified, e.g. in connection with operating a process, collecting samples, etc.
reflow	the melting of an electroplated tin coating to give a bright finish
rectification	Rectification is the reworking of products with reject quality surface treatment to the required specification. In practice, the terms reworking and stripping are sometimes confused and may be used to indicate both activities.
rinse criterion	Rinse ratio of contaminant to solvent, usually water, to be achieved
Rz	Measure of roughness of a surface
S	
secondary measure/technique	see *end-of-pipe technique*
sequestration	The process of ‘locking up’ metal ions in co-ordination compounds to make them ineffective. the sequestering agents used for this purpose are usually chelating agents
SME	small and medium enterprise(s), see [61, EC, 2002]
solubility product	the product of the concentrations of the ions of a dissolved electrolyte when in equilibrium with undissolved substance
specific emission	emission related to a reference basis, such as production capacity, or actual production (e.g. mass per tonne or per unit produced)
SPC	statistical process control; a process management technique. Regular measurements of process parameters (such as bath temperature, pH, concentration of key process components) are analysed on a continuous basis to ensure compliance within statistical parameters (such as 3 x the standard deviation) to control the quality of the process
SS	suspended solids (content) (in water) (See also TSS)
strip, stripping	process or solution used for the removal of a coating from a base metal

ENGLISH TERM	MEANING
	or undercoat. See *rectification*
STM	surface treatment of metals and plastics. Refers to topics within the scope of this document
T	
TA Luft	German Federal Regulation for control of pollution to air
TDS	total dissolved solids
throwing power	improvement of coating (usually metal) distribution over that given by the primary current distribution on an electrode (usually a cathode) in a given solution, under specified conditions. Note: the term may also be used for anodic processes for which the term is analogous such as: macrothrowing power [101, CEN, 2000]
TOC	total organic carbon: a measure of organic compounds in waste waters. Does not include other reducing agents in the determination (unlike CODCr). The European Standard method for total organic carbon (TOC) is; EN 1484
TS	total solids (content). Solid content before drying of the material
TSS	total suspended solids (content) (in water) (See also SS)
tumbling	bulk processing in barrels in either the presence of abrasives or burnishing shot for the purpose of improving the surface finish
TWG	technical working group
U	
unplanned release	an emission that is not planned for, and is therefore not authorised by a permit. For example, a spillage of a liquid that travels to surface or groundwater, or a discharge to a waste water treatment plant that exceeds the planned capacity of the treatment. It may be acute (i.e. happening in a short period of time, often called an accidental emission, such as a spillage) or chronic (i.e. happening over a long period of time, such as leak from a tank)
US	(i) American English (ii) United States of America
uv	ultraviolet light
V	
valorise	to get the value from, or add value to, something,. For example, valorise a sludge containing metals by using the sludge as a raw material in a metallurgical plant (a smelter), and recovering the metals
VHN	Vickers Hardness Number (measurement of hardness)
vs.	versus: used to compare two ideas or sets of data, etc.
V.I.	viscosity index
VOC	volatile organic compounds (includes VOX and non-VOX compounds)
VOX	volatile organic halogenated compounds
W	
WHB	waste heat boiler
WWTP	waste water treatment plant
weak emulsion solution	a weakly emulsifying solution used for degreasing. The oils in the solution can be easily removed enabling the cleaned solution to be re-used ((*demulgen* is one trade name)
wetting agent	substance that reduces the surface tension of a liquid. This allows the liquid to spread more easily and more uniformly on a solid surface
X	

ENGLISH TERM	MEANING
Y	
Z	

2. Common units, measurements and symbols

TERM	MEANING
A	ampere
AC	Alternating current
ACkWh	kilowatt-hours (alternating current)
amp	ampere
A/dm², A/m²	amperes per square decimetre, amperes per square metre. A measure of current density at the electrode.
atm	normal atmosphere (1 atm = 101325 N/m²)
bar	bar (1013 bar = 1 atm)
barg	bar gauge (bar + 1 atm)
°C	degree Celsius
cgs	centimetre gram second. A system of measurements now largely replaced by SI.
cm	centimetre
cSt	centistokes = 10^{-2} stokes
d	day
DC	direct current
g	gram
GJ	gigajoule
Hz	hertz
h	hour
ha	hectare (10^4 m²) (=247105 acres)
J	Joule
K	kelvin (0 °C = 273.15 K)
kA	kiloamp(ere)
kcal	kilocalorie (1 kcal = 4.19 kJ)
kg	kilogram (1 kg = 1000 g)
kJ	kilojoule (1 kJ = 0.24 kcal)
kPa	kilopascal
kt	kilotonne
kWh	kilowatt-hour (1 kWh = 3600 kJ = 3.6 MJ)
l	Litre
m	metre
m^2	square metre
m^3	cubic metre
mg	milligram (1 mg = 10^{-3} gram)
MJ	megajoule (1 MJ = 1000 kJ = 10^6 joule)
ml	millilitre
mm	millimetre (1 mm = 10^{-3} m)
m/min	metres per minute
Mt	megatonne (1 Mt = 10^6 tonne)
Mt/yr	megatonnes per year
mV	millivolts
MW_e	megawatts electric (energy)
MW_{th}	megawatts thermal (energy)
ng	nanogram (1 ng = 10^{-9} gram)
Nm^3	normal cubic metre (101325 kPa, 273 K)
Pa	pascal
Poise	viscosity measurement: 1 Poise = 0.1 Pascal second
ppb	parts per billion
ppm	parts per million (by weight)
ppmv	parts per million (by volume)

TERM	MEANING
s	second
S	siemens, the SI unit measure of conductance
St	stokes. An old, cgs unit of kinematic viscosity. 1 St = 10^{-6} m^2/s
t	metric tonne (1000 kg or 10^6 gram)
t/d	tonnes per day
t/yr	tonne(s) per year
V	volt
vol-%	percentage by volume. (Also % v/v)
W	watt (1 W = 1 J/s)
wt-%	percentage by weight. (Also % w/w)
yr	year
val/l	valency per litre
~	around; more or less
ΔT	increase of temperature
µm	micrometre (1 µm = 10^{-6} m)
Ω	ohm, unit of electrical resistance
Ω cm	ohm centimetre, unit of specific resistance
% v/v	percentage by volume. (Also vol-%)
% w/w	percentage by weight. (Also wt-%)

3. List of chemical elements

NAME	SYMBOL	NAME	SYMBOL
actinium	Ac	mercury	Hg
aluminium	Al	molybdenum	Mo
americium	Am	neodymium	Nd
antimony	Sb	neon	Ne
argon	Ar	neptunium	Np
arsenic	As	nickel	Ni
astatine	At	niobium	Nb
barium	Ba	nitrogen	N
berkelium	Bk	nobelium	No
beryllium	Be	osmium	Os
bismuth	Bi	oxygen	O
boron	B	palladium	Pd
bromine	Br	phosphorus	P
cadmium	Cd	platinum	Pt
calcium	Ca	plutonium	Pu
californium	Cf	polonium	Po
carbon	C	potassium	K
cerium	Ce	praseodymium	Pr
caesium	Cs	promethium	Pm
chlorine	Cl	protactinium	Pa
chromium	Cr	radium	Ra
cobalt	Co	radon	Rn
copper	Cu	rhenium	Re
curium	Cm	rhodium	Rh
dysprosium	Dy	rubidium	Rb
einsteinium	Es	ruthenium	Ru
erbium	Er	rutherfordium	Rf
europium	Eu	samarium	Sm
fermium	Fm	scandium	Sc
fluorine	F	selenium	Se
francium	Fr	silicon	Si
gadolinium	Gd	silver	Ag
gallium	Ga	sodium	Na
germanium	Ge	strontium	Sr
gold	Au	sulphur	S
hafnium	Hf	tantalum	Ta
helium	He	technetium	Tc
holmium	Ho	tellurium	Te
hydrogen	H	terbium	Tb
indium	In	thallium	Tl
iodine	I	thorium	Th
iridium	Ir	thulium	Tm
iron	Fe	tin	Sn
krypton	Kr	titanium	Ti
lanthanum	La	tungsten	W
lawrencium	Lr	uranium	U
lead	Pb	vanadium	V
lithium	Li	xenon	Xe
lutetium	Lu	ytterbium	Yb
magnesium	Mg	yttrium	Y
manganese	Mn	zinc	Zn
mendlevium	Md	zirconium	Zr

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