



## JRC SCIENCE FOR POLICY REPORT

# Best Available Techniques (BAT) Reference Document for Common Waste Gas Management and Treatment Systems in the Chemical Sector

*Industrial Emissions Directive  
2010/75/EU  
(Integrated Pollution  
Prevention and Control)*

Daginnus, K., Marty, T., Trotta, N. V., Brinkmann, T.,  
Whitfield, A., Roudier, S.

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#### Contact information

Name: European IPPC Bureau, JRC Directorate B - Fair and Sustainable Economy, European Commission  
Address: Edificio Expo, c/ Inca Garcilaso 3, E-41092 Seville, Spain  
Email: [JRC-B5-FIPPCB@ec.europa.eu](mailto:JRC-B5-FIPPCB@ec.europa.eu)  
Tel.: +34 95 4488 284

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## **Abstract**

The Best Available Techniques (BAT) Reference Document (BREF) for Common Waste Gas Management and Treatment Systems in the Chemical Sector is part of a series of documents presenting the results of an exchange of information between EU Member States, the industries concerned, non-governmental organisations promoting environmental protection, and the Commission, to draw up, review and – where necessary – update BAT reference documents as required by Article 13(1) of Industrial Emissions Directive 2010/75/EU. This document is published by the European Commission pursuant to Article 13(6) of the Industrial Emissions Directive 2010/75/EU.

The BREF for Common Waste Gas Management and Treatment Systems in the Chemical Sector covers the management and treatment of channelled and diffuse emissions to air arising from a variety of sources associated with the chemical production processes listed in points 4.1 to 4.6 of Annex I to the Industrial Emissions Directive 2010/75/EU.

The BREF consists of six main chapters. General information of the chemical industry in Europe (industrial and economic development, geographical distribution) and the relevant air pollutants emitted from the chemical sector are presented in Chapter 1. Chapter 2 gives an overview of the current emission levels related to channelled and diffuse air emissions from the chemical production processes covered by the present BREF. Chapter 3 outlines the general techniques to be considered in the determination of BAT for reducing channelled and diffuse emissions to air (i.e. techniques widely applied) in chemical production processes. Chapter 4 presents the BAT conclusions as defined in Article 3(12) of the Industrial Emissions Directive (2010/75/EU), including BAT that apply generally to the chemical sector covered by this BREF and, when appropriate, sector-specific BAT. Chapter 5 does not include any information on emerging techniques (no exchange of information took place on this topic). Concluding remarks and recommendations for future work are presented in Chapter 6.

## Acknowledgements

This report was produced by the European Integrated Pollution Prevention and Control Bureau (EIPPCB) at the European Commission's Joint Research Centre – Directorate B: Fair and Sustainable Economy under the supervision of Serge Roudier (Head of the EIPPCB), Alejandro Villanueva (Deputy Head of the Circular Economy and Sustainable Industry Unit) and Mikel Alvarez Lanbadaso (Acting Head of the Circular Economy and Sustainable Industry Unit).

The authors of this BREF were Klaus Daginnus, Thibaut Marty, Nicoletta Valeria Trotta, Thomas Brinkmann, Aidan Whitfield and Serge Roudier.

This report was drawn up in the framework of the implementation of the Industrial Emissions Directive (2010/75/EU) and it is the result of the exchange of information provided for in Article 13 of the Directive.

Major contributors of information were:

- among EU Member States: Austria, Belgium, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, the Netherlands, Poland, Portugal, Slovakia, Spain, Sweden and the United Kingdom (until 31/01/2020);
- among EEA countries: Norway;
- among industry: CEFIC (European Chemical Industry Council), ACCESSA (Association for the Catalytic Control of Emissions from Stationary Sources to Air), BUSINESS EUROPE (Confederation of European Business), CEMBUREAU (European Cement Association), EIGA (European Industrial Gases Association), ePURE - European Renewable Ethanol, EUCOPRO (European association for co-processing), EUROMETAUX (European non-ferrous metals association), FERTILIZERS EUROPE, FETSA (Federation of European Tank Storage Associations), FUELSEUROPE (European petroleum refining industry), ORGALIM - Europe's Technology Industries, ESA (European Sealing Association);
- among environmental non-governmental organisations: EEB (European Environmental Bureau).

Sonia Fereres and Ioannis Stamou from the EIPPCB contributed to the editing of the final document. Eric Aries, George Chronopoulos and Martin Weiss contributed significantly to the internal discussions and task force sessions for the development of this document while working at the EIPPCB.

The whole EIPPCB team provided contributions and peer reviewing.

This report was edited by Anna Atkinson and formatted by Carmen Ramirez, Carlos Javier Muñoz Crespo and Daniela Antonova.



This document is one from the series of documents listed below (at the time of writing, the following documents have been drafted):

<b>Reference Document on Best Available Techniques (BREF)</b>	<b>Code</b>
Ceramic Manufacturing Industry	CER
<i>Common Waste Gas Management and Treatment Systems in the Chemical Sector</i>	WGC
Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector	CWW
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
<b>Reference Document (REF)</b>	
Economics and Cross-media Effects	ECM
Monitoring of Emissions to Air and Water from IED Installations	ROM

Electronic versions of draft and finalised documents are publicly available and can be downloaded from <http://eippcb.jrc.ec.europa.eu/>.



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## PREFACE

### 1. Status of this document

Unless otherwise stated, references to ‘the Directive’ in this document refer to Directive 2010/75/EU of the European Parliament and the Council on industrial emissions (integrated pollution prevention and control) (Recast).

This BAT reference document for Common Waste Gas Management and Treatment Systems in the Chemical Sector forms part of a series presenting the results of an exchange of information between EU Member States, the industries concerned, non-governmental organisations promoting environmental protection and the Commission, to draw up, review and, where necessary, update BAT reference documents as required by Article 13(1) of the Directive. This document is published by the European Commission pursuant to Article 13(6) of the Directive.

As set out in Article 13(5) of the Directive, the Commission Implementing Decision 2022/2427/EU on the BAT conclusions contained in Chapter 4 was adopted on 06/12/2022 and published on 12/12/2022<sup>1</sup>.

### 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 the European IPPC Bureau (of the Commission's Joint Research Centre).

### 3. Structure and contents of this document

Chapter 1 provides general information on the chemical industry in Europe and its environmental relevance for emissions to air as well as general information on waste gases and waste gas treatment systems used within the chemical industry.

Chapter 2 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 emission levels. In particular, this chapter describes the main techniques used to reduce emissions to air and the associated emission levels.

Chapter 3 describes in more detail the techniques to prevent or, where this is not practicable, to reduce emissions to air of operating installations in the chemical industry that were considered in determining the BAT. This information includes, where relevant, the environmental performance levels (e.g. emission and consumption levels) which can be achieved by using the waste gas treatment techniques, the associated monitoring and the costs and the cross-media issues associated with the techniques.

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<sup>1</sup> OJ L 318, 12.12.2022, p. 157

Chapter 4 presents the BAT conclusions as defined in Article 3(12) of the Directive.

Chapter 5 does not include any information on ‘emerging techniques’ as defined in Article 3(14) (no exchange of information took place on this topic).

Concluding remarks and recommendations for future work are presented in Chapter 6.

#### **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 collated and assessed by the European IPPC Bureau (of the Commission's Joint Research Centre) who led the work on determining Best Available Techniques (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 available data 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 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 the European IPPC Bureau 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 3. 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.

### Contact information

All comments and suggestions should be made to the European IPPC Bureau at the Joint Research Centre (JRC) at the following address:

European Commission  
JRC Directorate B – Fair and Sustainable Economy  
European IPPC Bureau  
Edificio Expo  
c/Inca Garcilaso, 3  
E-41092 Seville, Spain  
Telephone: +34 95 4488 284  
E-mail: [JRC-B5-EIPPCB@ec.europa.eu](mailto:JRC-B5-EIPPCB@ec.europa.eu)  
Internet: <http://eippcb.jrc.ec.europa.eu>

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# Best Available Techniques Reference Document for Common Waste Gas Management and Treatment Systems in the Chemical Sector

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## SCOPE

This BREF concerns the following activity specified in Annex I to Directive 2010/75/EU: 4. Chemical industry (i.e. all production processes included in the categories of activities listed in points 4.1 to 4.6 of Annex I, unless specified otherwise).

More specifically, this BREF focuses on emissions to air from the aforementioned activity.

This BREF does not address the following:

1. Emissions to air from the production of chlorine, hydrogen, and sodium/potassium hydroxide by the electrolysis of brine. This is covered by BREF for the Production of Chlor-alkali (CAK).
2. Channelled emissions to air from the production of the following chemicals in continuous processes where the total production capacity of those chemicals exceeds 20 kt/yr:
  - lower olefins using the steam cracking process;
  - formaldehyde;
  - ethylene oxide and ethylene glycols;
  - phenol from cumene;
  - dinitrotoluene from toluene, toluene diamine from dinitrotoluene, toluene diisocyanate from toluene diamine, methylene diphenyl diamine from aniline, methylene diphenyl diisocyanate from methylene diphenyl diamine;
  - ethylene dichloride (EDC) and vinyl chloride monomer (VCM);
  - hydrogen peroxide.

This is covered by the BREF for the Production of Large Volume Organic Chemicals (LVOC).

However, channelled emissions to air of nitrogen oxides (NO<sub>x</sub>) and carbon monoxide (CO) from thermal treatment of waste gases (i.e. using thermal or catalytic oxidation) originating from the aforementioned production processes are included in the scope of this BREF.

3. Emissions to air from the production of the following inorganic chemicals:

- ammonia;
- ammonium nitrate;
- calcium carbide;
- calcium chloride;
- calcium ammonium nitrate;
- calcium nitrate;
- carbon black;
- ferrous chloride;
- ferrous sulphate (i.e. copperas and related products, such as chloro-sulphates);
- hydrofluoric acid;
- inorganic phosphates;
- nitric acid;
- nitrogen-, phosphorus- or potassium-based fertilisers (simple or compound fertilisers);
- phosphoric acid;



- 
- precipitated calcium carbonate;
  - sodium carbonate (i.e. soda ash);
  - sodium chlorate;
  - sodium silicate;
  - sulphuric acid;
  - synthetic amorphous silica;
  - titanium dioxide and related products;
  - urea;
  - urea-ammonium nitrate.

This may be covered by the BREFs for the Production of Large Volume Inorganic Chemicals (LVIC).

4. Emissions to air from steam reforming as well as from the physical purification and reconcentration of spent sulphuric acid provided that these processes are directly associated with a production process listed under the aforementioned points 2 or 3.
5. Emissions to air from the production of magnesium oxide using the dry process route. This may be covered by the BREF for the Production of Cement, Lime and Magnesium Oxide (CLM).
6. Emissions to air from the following:
  - Combustion units other than process furnaces/heaters. This may be covered by the BREF for Large Combustion Plants (LCP), the BREF for the Refining of Mineral Oil and Gas (REF) and/or by Directive (EU) 2015/2193 of the European Parliament and of the Council<sup>2</sup>.
  - Process furnaces/heaters with a total rated thermal input below 1 MW.
  - Process furnaces/heaters used in lower olefins, ethylene dichloride and/or vinyl chloride monomer production referred to in point 2 above. This is covered by the BREF for the production of Large Volume Organic Chemicals (LVOC).
7. Channelled and diffuse emissions to air from waste incineration plants. This may be covered by the BREF for Waste Incineration (WI).
8. Emissions to air from the storage, transfer and handling of liquids, liquefied gases and solids, where these are not directly associated with the activity specified in Annex I to Directive 2010/75/EU: 4. Chemical industry. This may be covered by the BREF for Emissions from Storage (EFS).

However, emissions to air from the storage, transfer and handling of liquids, liquefied gases and solids are included in the scope of this BREF when these processes are directly associated with the chemical production processes specified in the scope of this BREF.
9. Emissions to air from indirect cooling systems. This may be covered by the BREF for Industrial Cooling Systems (ICS).

---

<sup>2</sup> 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).

## Scope

---

The BREF for Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (CWW) is complementary for the activities covered by this BREF.

Other reference documents which could be relevant for the activities covered by this BREF are the following:

- Production of Chlor-alkali (CAK);
- Manufacture of Large Volume Inorganic Chemicals – Ammonia, Acids and Fertilisers (LVIC-AAF);
- Manufacture of Large Volume Inorganic Chemicals – Solids and Others Industry (LVIC-S);
- Production of Large Volume Organic Chemicals (LVOC);
- Manufacture of Organic Fine Chemicals (OFC);
- Production of Polymers (POL);
- Production of Speciality Inorganic Chemicals (SIC);
- Refining of Mineral Oil and Gas (REF);
- Economics and Cross-media Effects (ECM);
- Emissions from Storage (EFS);
- Energy Efficiency (ENE);
- Industrial Cooling Systems (ICS);
- Large Combustion Plants (LCP);
- Monitoring of Emissions to Air and Water from IED installations (ROM);
- Waste Incineration (WI);
- Waste Treatment (WT).

The scope of this BREF does **not** include matters that only concern safety in the workplace or the safety of products because these matters are not covered by the Industrial Emissions Directive (2010/75/EU). They are discussed only where they affect matters within the scope of the Industrial Emissions Directive (2010/75/EU).

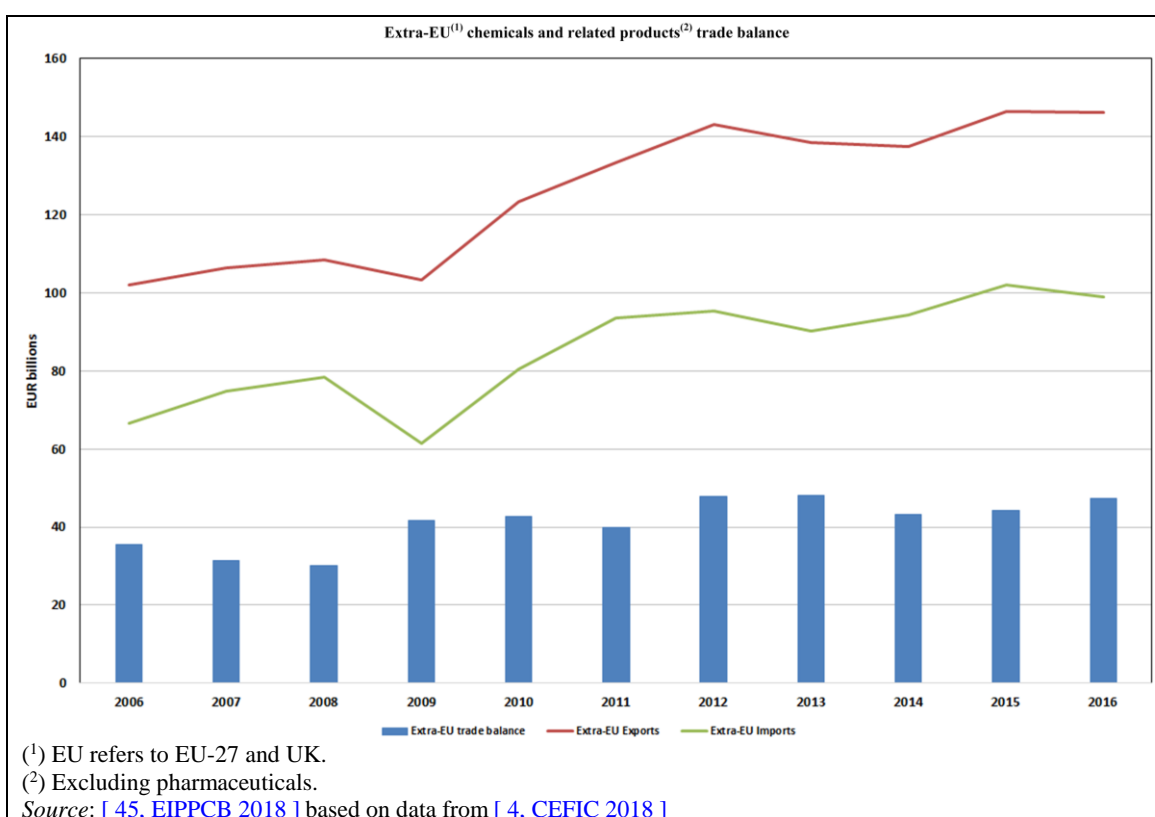


# 1 GENERAL INFORMATION

## 1.1 The chemical industry in Europe

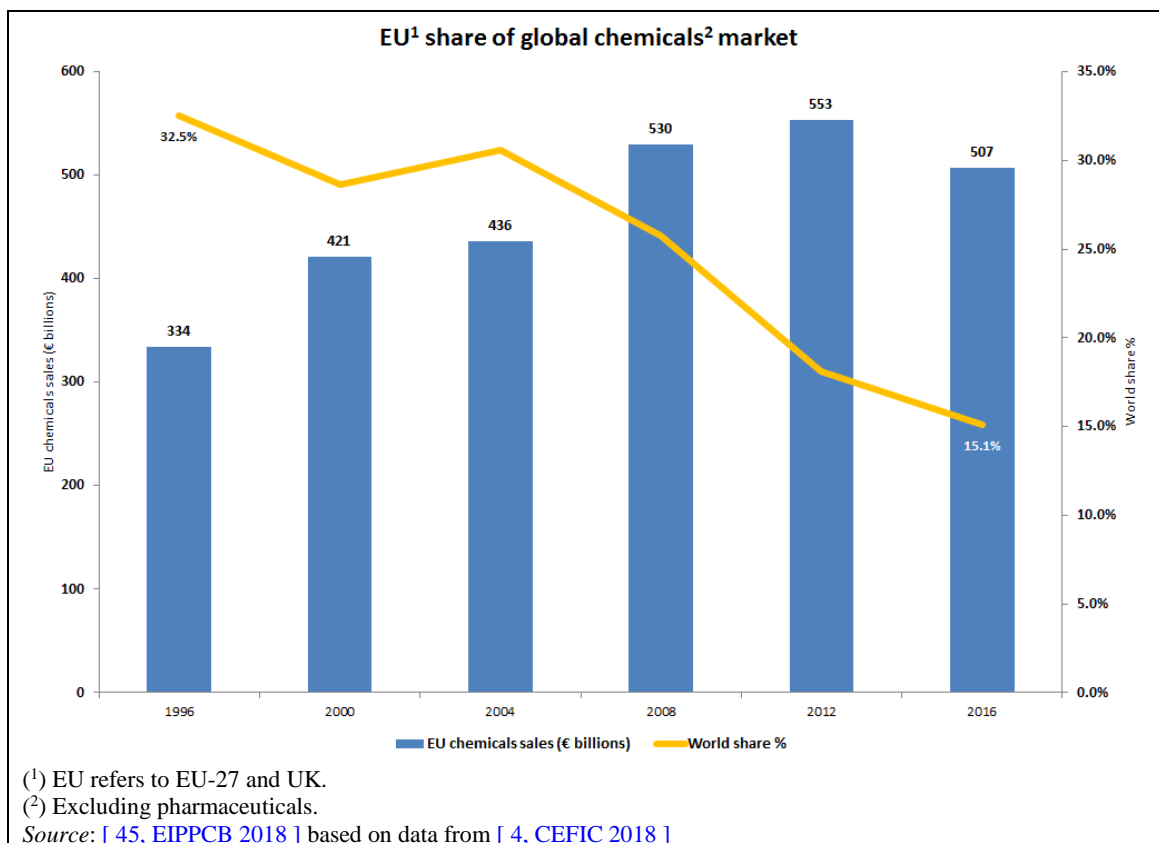
### 1.1.1 Industrial and economic development

The EU chemical industry provides a significant contribution to the EU economy. It is one of its most international and competitive industries, connected to a wide field of processing and manufacturing activities. Its output covers a wide range of chemical products, and supplies virtually all sectors of the economy. Figure 1.1 shows that the EU-27 and United Kingdom chemical industry registered a significant trade surplus in the last decade, representing EUR 47.3 billion in 2016 (the production of pharmaceuticals is not included) [4, CEFIC 2018]. Including the production of pharmaceuticals, the EU trade surplus amounts to EUR 56.7 billion [27, Eurostat 2018].



**Figure 1.1: Extra-EU chemicals and related products trade balance**

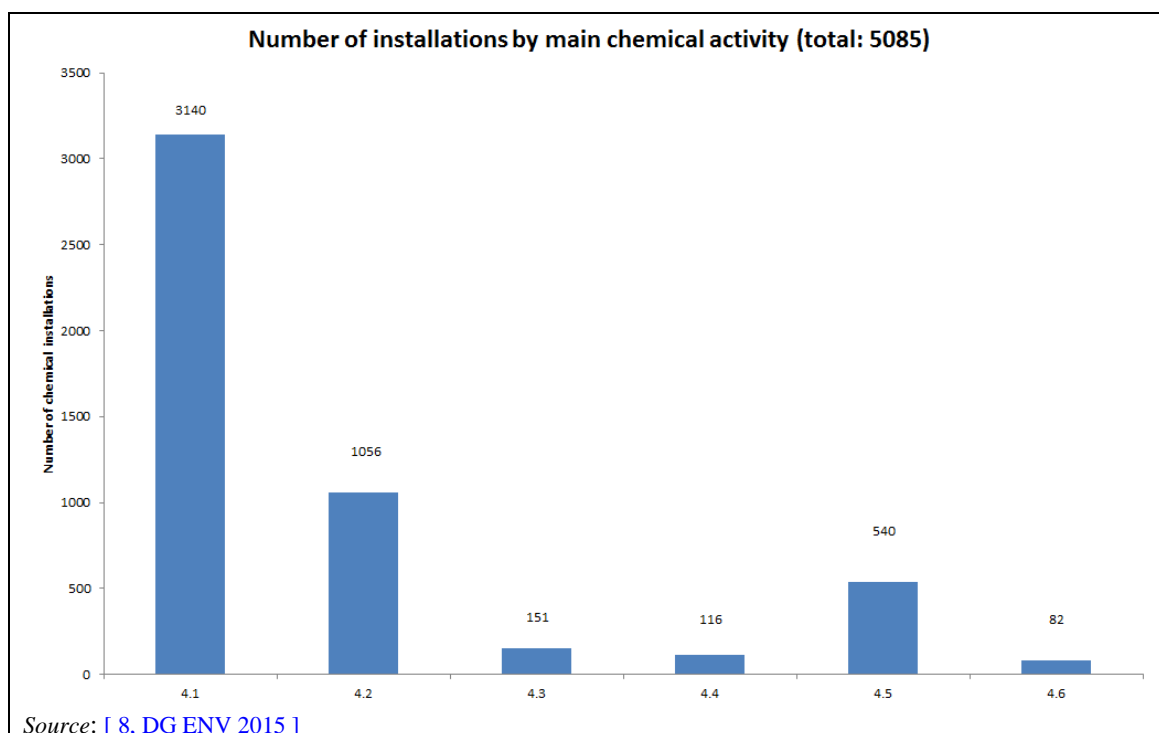
Figure 1.2 shows that the chemical market in Europe and the United Kingdom grew continuously from 1996 to 2012 (and decreased by 8 % in 2016). In 2016, the total chemical sales (excluding pharmaceuticals) in the EU-27 and United Kingdom amounted to EUR 507 billion. With 15.1 % of the global sales in terms of value, the chemical industry in Europe and the United Kingdom ranks second, followed by the United States (14.2 %), but after China which holds the top ranking in sales (39.6 %) [4, CEFIC 2018].



**Figure 1.2: EU share of global markets**

The chemical sector in the EU-27 and United Kingdom employed a total staff of about 1.14 million people in 2016. This number has been relatively stable since 2010. Direct employment even increased slightly (+0.4 %) between 2015 and 2016 [4, CEFIC 2018 ].

As shown in Figure 1.3, the production of organic chemicals accounts for the largest number of chemical installations, followed by the production of inorganic chemicals and pharmaceuticals.

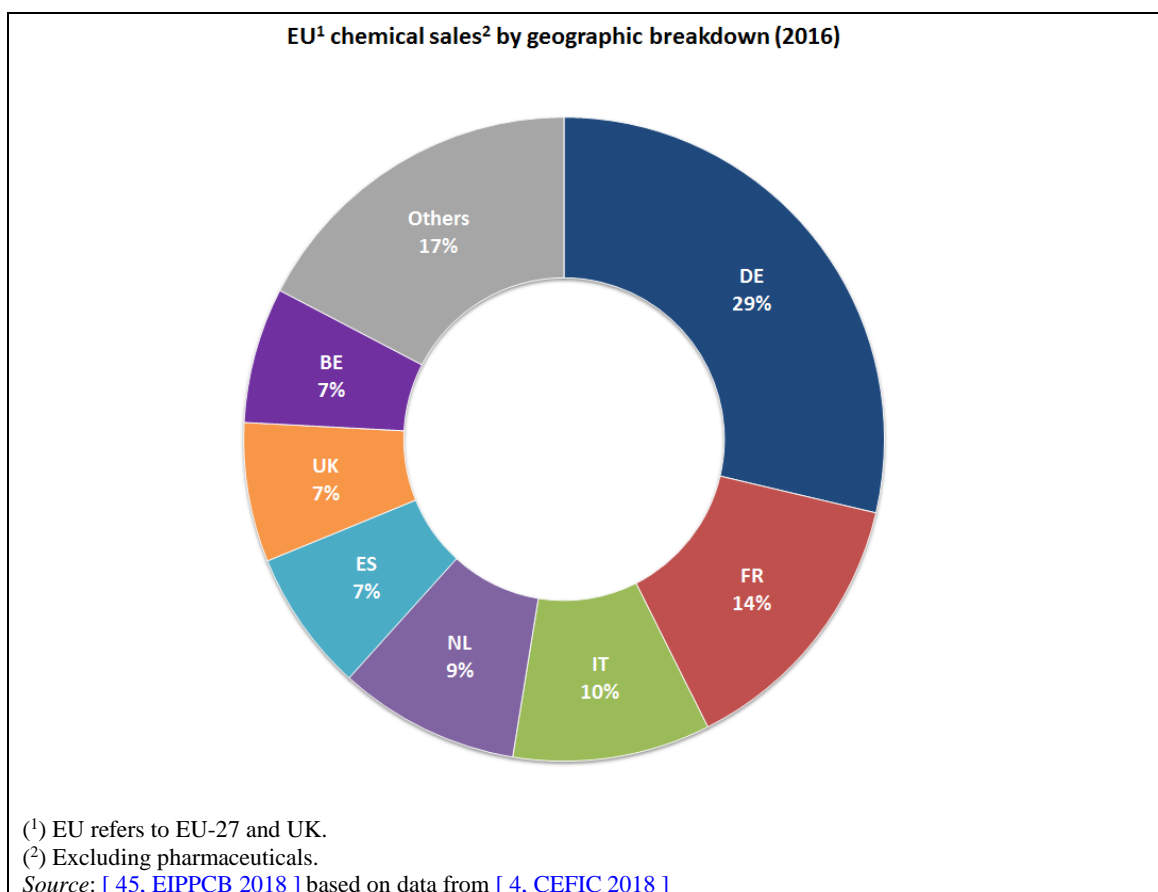


**Figure 1.3: EU-27 and UK: number of chemical installations by IED category**

## 1.1.2 Geographic distribution

Germany and France are the two largest chemical producers in Europe with regards to chemical sales, followed by Italy and the Netherlands. These four countries together accounted for 61.7 % of European chemical sales in 2016, valued at EUR 312.8 billion.

The share rises to 82.6 %, or EUR 419 billion, when including Spain, the United Kingdom and Belgium. The remaining EU Member States accounted for 17.4 % of European chemical sales in 2016, valued at EUR 88 billion. Poland and Austria are the two largest contributors to that Member States bloc.



**Figure 1.4: EU chemical industry sales by geographic breakdown**

Germany has the largest number of chemical installations, followed by the UK, Italy, France and Spain.

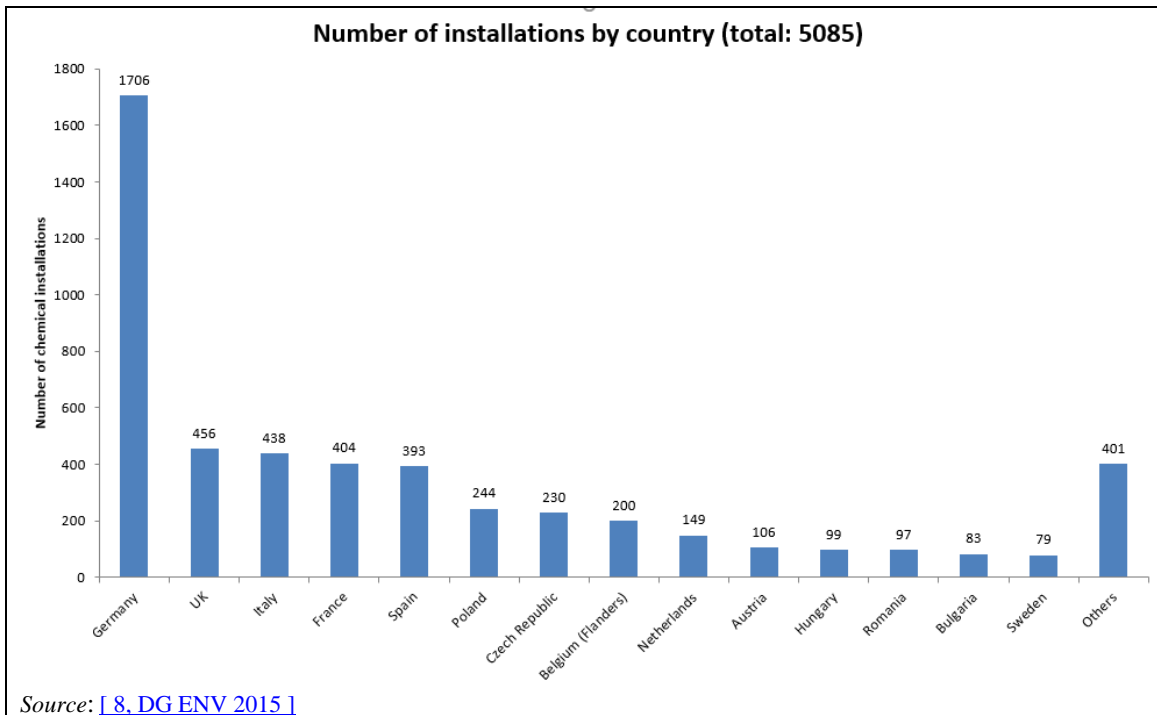


Figure 1.5: Number of chemical installations in the 14 top producing countries

## 1.2 Environmental relevance of the chemical industry for emissions to air

### 1.2.1 Key environmental issues

At the eighth IED Article 13 Forum meeting, the European Commission proposed four criteria for defining key environmental issues (KEIs) [\[ 46, DG ENV 2015 \]](#):

- a. environmental relevance of pollution caused by the activity or process, i.e. whether it may cause an environmental problem;
- b. significance of activity (number of installations, geographical spread, contribution to total industrial emissions in Europe);
- c. potential of BREF review for identifying new or additional techniques that would further significantly reduce pollution;
- d. potential of BREF review for BAT-AELs that would significantly improve the level of environmental protection from current emission levels.

Criteria c. and d. are not applicable to the WGC BREF as this is a new BREF and not the review of an existing document.

For the WGC BREF, two additional criteria were considered in the definition of KEIs:

- the availability of emission data;
- the availability of standardised emission monitoring methods.

KEI candidates were taken from various sources, such as substances covered by the European air quality standards, substances covered by the Stockholm Convention, greenhouse gases as listed in Annex II to Directive 2003/87/EC, ozone-depleting substances covered by Regulation (EC) No 1005/2009, substances covered by other chemical BREFs and substances proposed by members of the technical working group.

The following substances/parameters were defined as KEIs for the WGC BREF [\[ 6, EIPPCB 2017 \]](#):

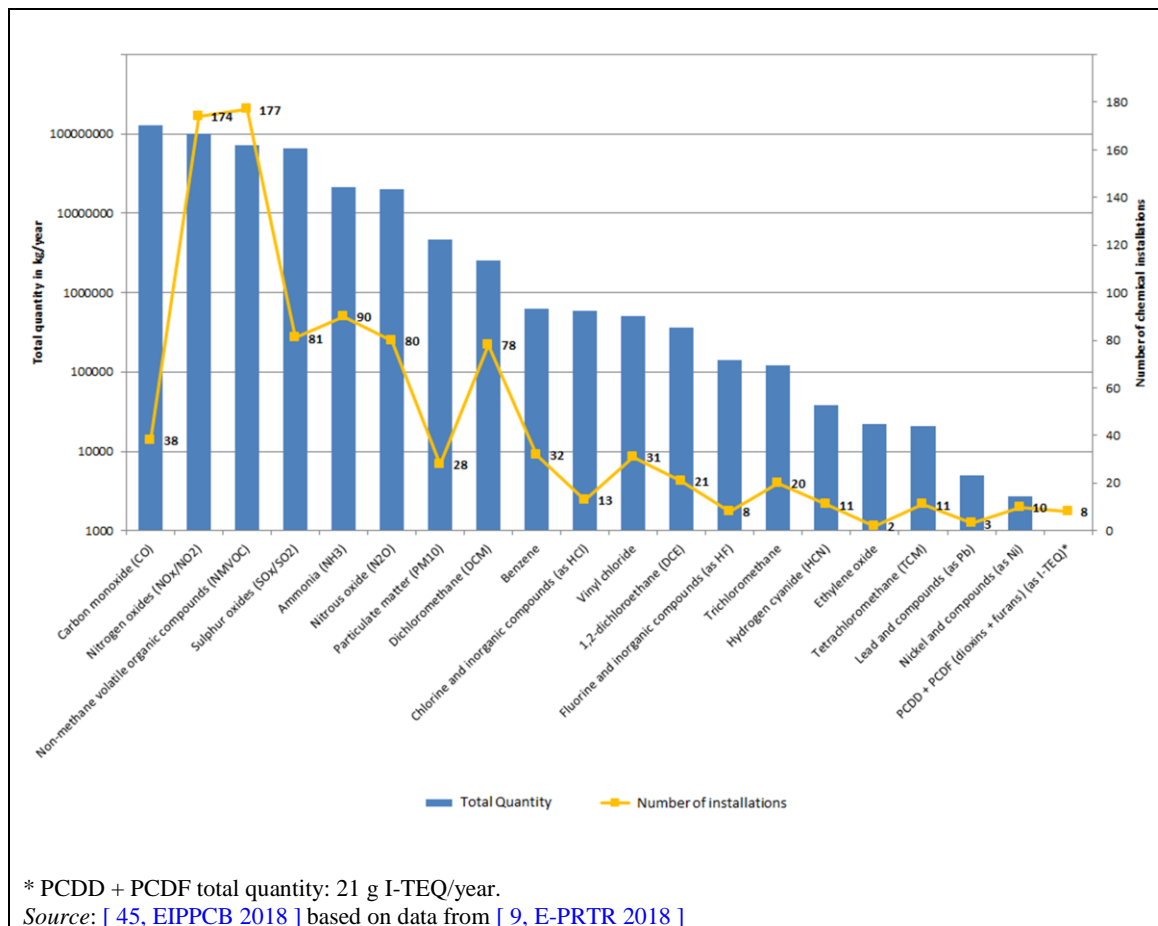
- substances covered by the European air quality standards: benzene, carbon monoxide, dust, nitrogen oxides, lead and its compounds, nickel and its compounds and sulphur oxides;
- substances covered by the Stockholm Convention: PCDD/F (dioxins and furans);
- greenhouse gases: nitrous oxide;
- ozone-depleting substances: tetrachloromethane;
- volatile organic compounds (VOCs): 1,3butadiene, chloromethane, dichloromethane, ethylene dichloride, ethylene oxide, formaldehyde, propylene oxide, toluene, trichloromethane and vinyl chloride monomer;
- other gases: ammonia, carbon disulphide, elemental chlorine, gaseous chlorides, gaseous fluorides, hydrogen sulphide and hydrogen cyanide.

Most of the data presented in this section were taken from the European Pollutant Release and Transfer Register (E-PRTR) which covers large industrial installations. It also includes fugitive and non-fugitive emissions to air from industrial facilities [\[ 9, E-PRTR 2018 \]](#).

The E-PRTR contains annual data (releases to air, water and land as well as off-site transfers of waste and pollutants in waste water) reported by more than 30 000 industrial facilities, covering 65 economic activities within 9 industrial sectors. The definition of the chemical industry in the E-PRTR is the same as in the Directive [\[ 25, EU 2010 \]](#). However, the E-PRTR only lists the main IED activity of each facility, so any other potential IED activities of the facility –

including other chemical activities – are not listed. Installations do not report their emissions to the E-PRTR if those emissions are below the E-PRTR reporting threshold.

Out of the 21 571 facilities of the dataset referring to emissions to air from the EU-27 and United Kingdom plus Norway and Serbia in 2016, 1 437 reported chemical production as their main activity [9, E-PRTR, 2018]. Figure 1.6 gives an overview of emissions to air reported by those facilities.



**Figure 1.6: Overview of emissions to air by chemical substances**

The range of reported quantities is extremely wide and depends on the substance, going from over one megatonne per year, e.g. in the case of nitrogen oxides and NMVOCs, to lower orders of magnitude between one kilotonne and one megatonne per year, e.g. in the case of benzene or chlorine and its inorganic compounds, or even lower down to a gram, e.g. in the case of dioxins and furans.

The number of reporting facilities reporting chemical production as their main activity, ranging between 2 (for ethylene oxide) and 177 (for NMVOC), indicates that the E-PRTR reporting threshold is often not met by the chemical industry.

The E-PRTR does not include all relevant pollutants listed in Annex II to the Directive [25, EU 2010], in particular some substances which have been proved to possess carcinogenic or mutagenic properties or properties which may be toxic for reproduction, e.g. formaldehyde or 1,3-butadiene. However, information was made regionally available for some polluting substances (see Sections 1.2.6.2, 1.2.6.8 and 1.2.6.9).

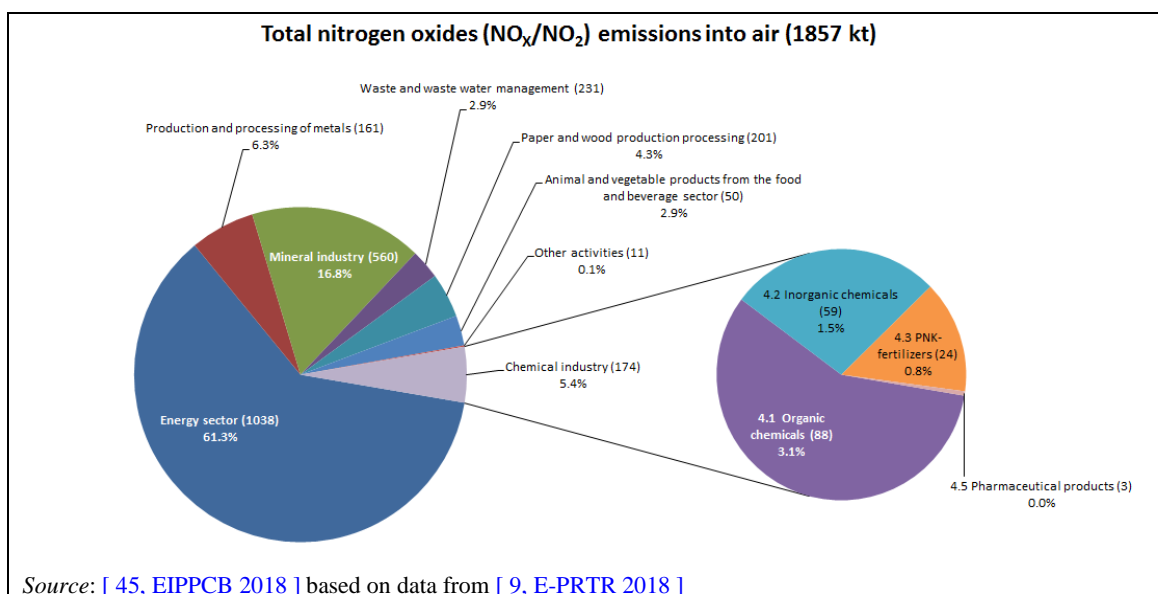
## 1.2.2 European air quality standards substances

Human health can be adversely affected by exposure to pollutants in ambient air. In response, the EU has developed an extensive body of legislation which establishes health-based standards and objectives for pollutants in ambient air:

- Limit values for benzene, carbon monoxide, dusts as fine particles (PM<sub>2.5</sub>) or particulate matter (PM<sub>10</sub>), lead, nitrogen dioxide and sulphur dioxide.
- Target values for arsenic, cadmium, nickel, ozone and polycyclic aromatic hydrocarbons (PAHs). Ground-level ozone (or tropospheric ozone) is typically not emitted directly by industrial processes, but rather formed by the effect of the sunlight on hydrocarbons and nitrogen oxides present in the air. Ozone formation is therefore controlled by reducing the emissions of hydrocarbons and nitrogen oxides.

### 1.2.2.1 Nitrogen oxides (NO<sub>x</sub>)

Emissions of nitrogen oxides to air by industrial sector are shown in Figure 1.7. In 2016, 174 installations of the chemical industry emitted around 100 kilotonnes of nitrogen oxides to air, representing 5.4 % of the total amount of nitrogen oxides emitted to air by all installations covered by the E-PRTR. The largest share of nitrogen oxide emissions originated from the energy sector. Within the chemical industry, the production of basic organic chemicals was responsible for almost 60 % of all nitrogen oxide emissions.



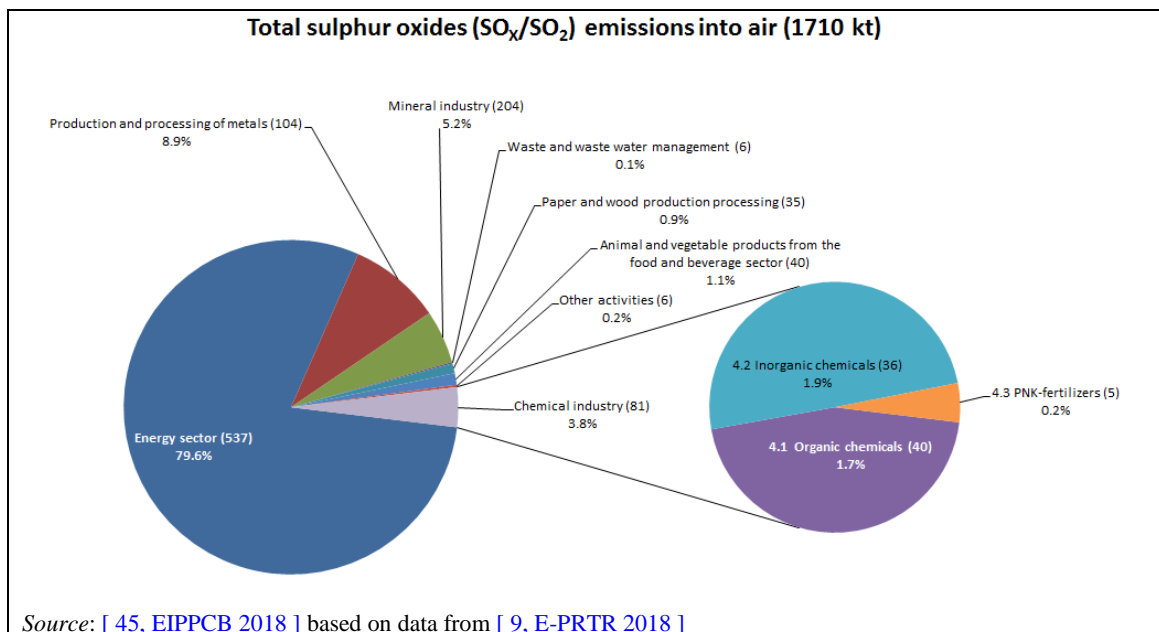
**Figure 1.7: Emissions of nitrogen oxides to air by industrial sector/activity in Europe 2016 (EU-27 and UK)**

NO<sub>x</sub> emissions from all sources occurring in the territory of the Member States are also addressed by the emission reduction commitments established by Directive 2016/2284.

### 1.2.2.2 Sulphur oxides (SO<sub>x</sub>)

Emissions of sulphur oxides to air by industrial sector are shown in Figure 1.8. In 2016, 81 installations of the chemical industry emitted around 65 kilotonnes of sulphur oxides to air, representing 3.8 % of the total amount of sulphur oxides emitted to air by all installations

covered by the E-PRTR. The largest share of sulphur oxide emissions originated from the energy sector. Within the chemical industry, the production of basic organic and inorganic chemicals were together responsible for approximately 95 % of all sulphur oxide emissions.



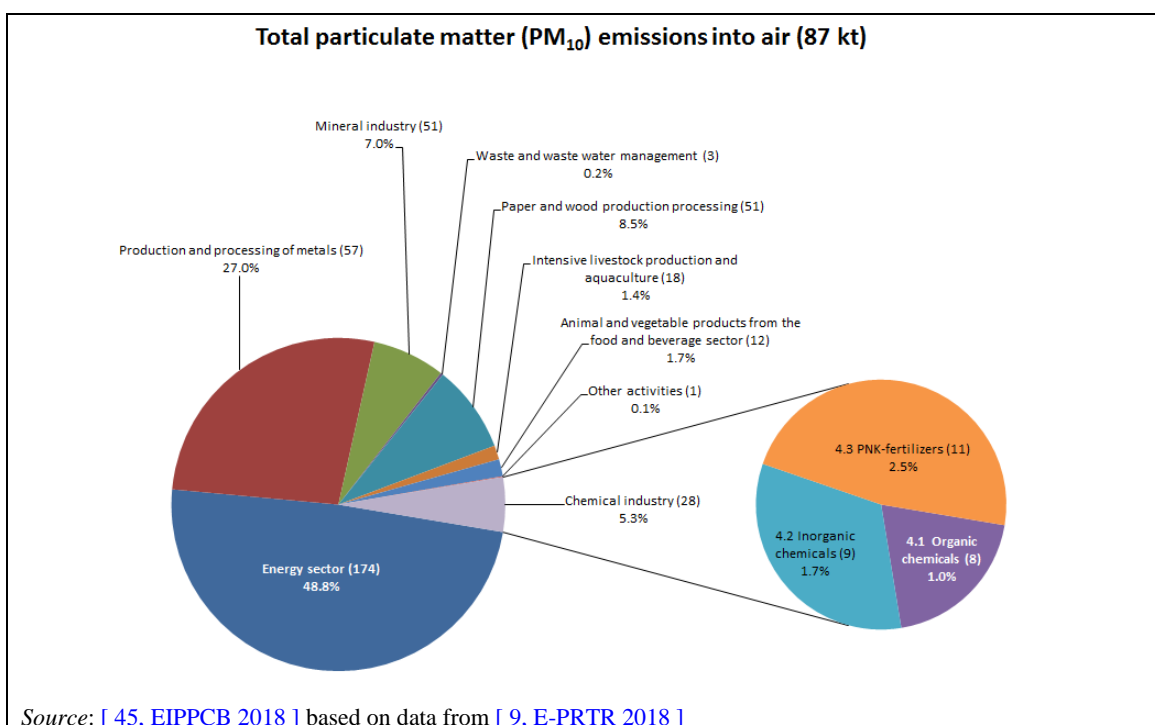
**Figure 1.8: Emissions of sulphur oxides to air by industrial sector/activity**

SO<sub>x</sub> emissions from all sources occurring in the territory of the Member States are also addressed by the emission reduction commitments established by Directive 2016/2284.

### 1.2.2.3 Dust (particulate matter)

Emissions of particulate matter to air by industrial sector are shown in Figure 1.9. In 2016, 28 installations of the chemical industry emitted around 4.6 kilotonnes of particulate matter to air, representing 5.3 % of the total amount of particulate matter emitted to air by all installations covered by the E-PRTR. The largest share of particulate matter emissions originated from the energy sector. Within the chemical industry, the production of NPK fertilisers was responsible for approximately 50 % of all particulate matter emissions.



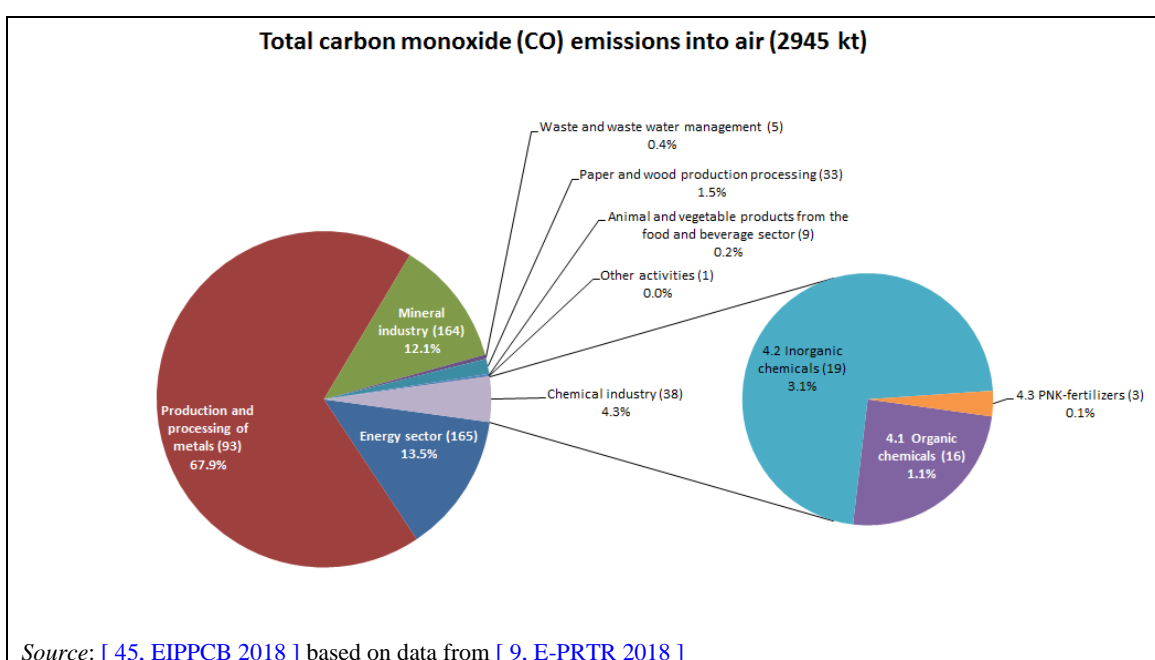


**Figure 1.9: Emissions of particulate matter to air by industrial sector/activity**

Dust emissions from all sources occurring in the territory of the Member States are also addressed by the emission reduction commitments established by Directive 2016/2284.

#### 1.2.2.4 Carbon monoxide (CO)

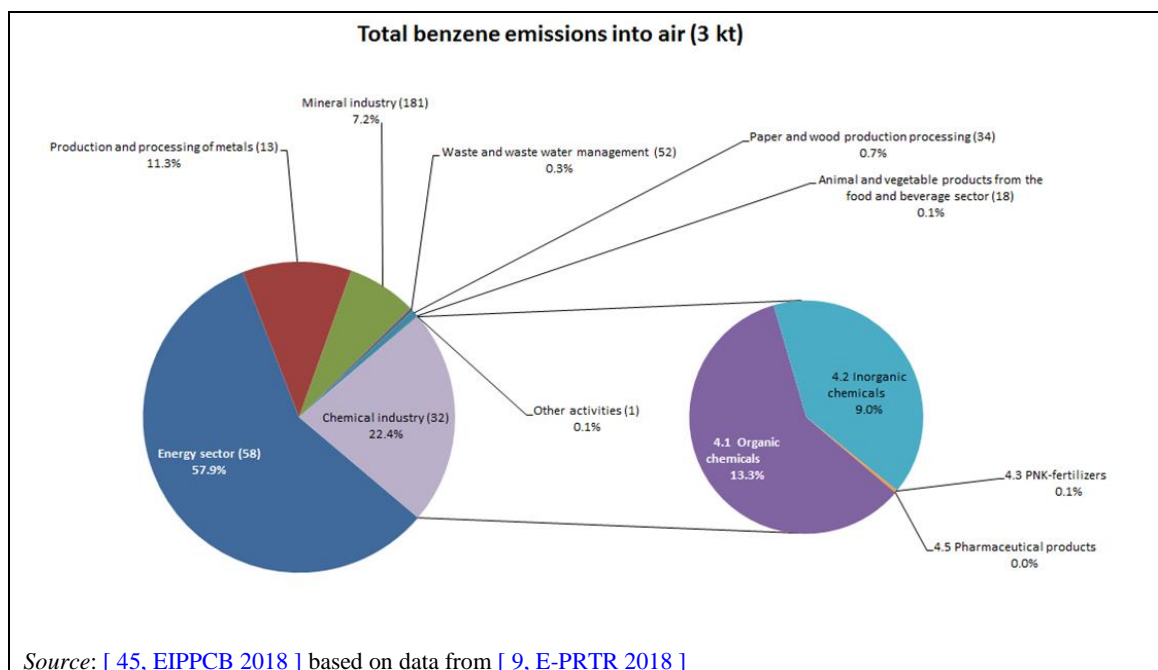
Emissions of carbon monoxide to air by industrial sector are shown in Figure 1.10. In 2016, 38 installations of the chemical industry emitted around 127 kilotonnes of carbon monoxide to air, representing 4.3 % of the total amount of carbon monoxide emitted to air by all installations covered by the E-PRTR. The largest share of carbon monoxide emissions originated from the production and processing of metals. Within the chemical industry, the production of inorganic chemicals was responsible for approximately 70 % of all carbon monoxide emissions.



**Figure 1.10: Emissions of carbon monoxide to air by industrial sector/activity**

### 1.2.2.5 Benzene

Emissions of benzene to air by industrial sector are shown in Figure 1.11. In 2016, 32 installations of the chemical industry emitted around 672 tonnes of benzene to air, representing 22.4 % of the total amount of benzene emitted to air by all installations covered by the E-PRTR. The largest share of benzene emissions originated from the energy sector. Within the chemical industry, the production of organic and inorganic chemicals was responsible for approximately 99 % of all benzene emissions.



**Figure 1.11: Emissions of benzene to air by industrial sector/activity**

### 1.2.2.6 Lead and its compounds (as Pb)

Emissions of lead and its compounds to air by industrial sector are shown in Figure 1.12. In 2016, 3 installations of the chemical industry emitted around 5 kilotonnes of lead and its compounds to air, representing 1.8 % of the total amount of lead and its compounds emitted to air by all installations covered by the E-PRTR. The largest share of emissions of lead and its compounds originated from the sector of production and processing of metals. Within the chemical industry, the production of organic chemicals was responsible for approximately 80 % of the emissions of lead and its compounds.

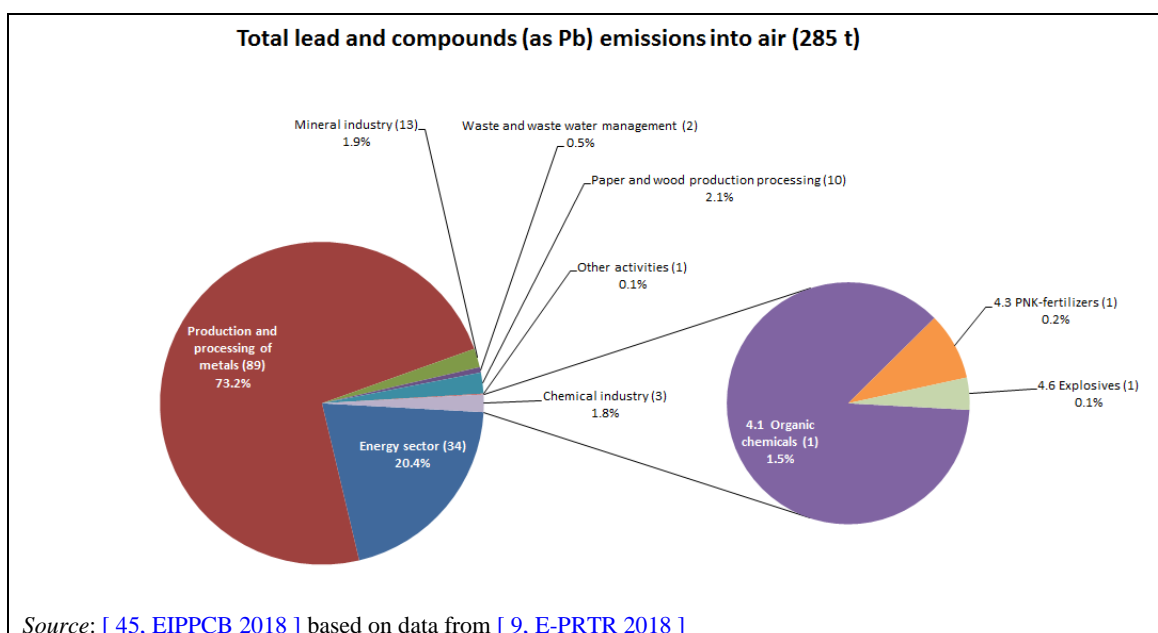


Figure 1.12: Emissions of lead and its compounds to air by industrial sector/activity

### 1.2.2.7 Nickel and its compounds (as Ni)

Emissions of nickel and its compounds to air by industrial sector are shown in Figure 1.13. In 2016, 10 installations of the chemical industry emitted around 2.7 tonnes of nickel and its compounds to air, representing 1.8 % of the total amount of nickel and its compounds emitted to air by all installations covered by the E-PRTR. The largest share of emissions of nickel and its compounds originated from the energy sector. Within the chemical industry, the production of organic and inorganic chemicals was responsible for approximately 80 % of the emissions of nickel and its compounds.

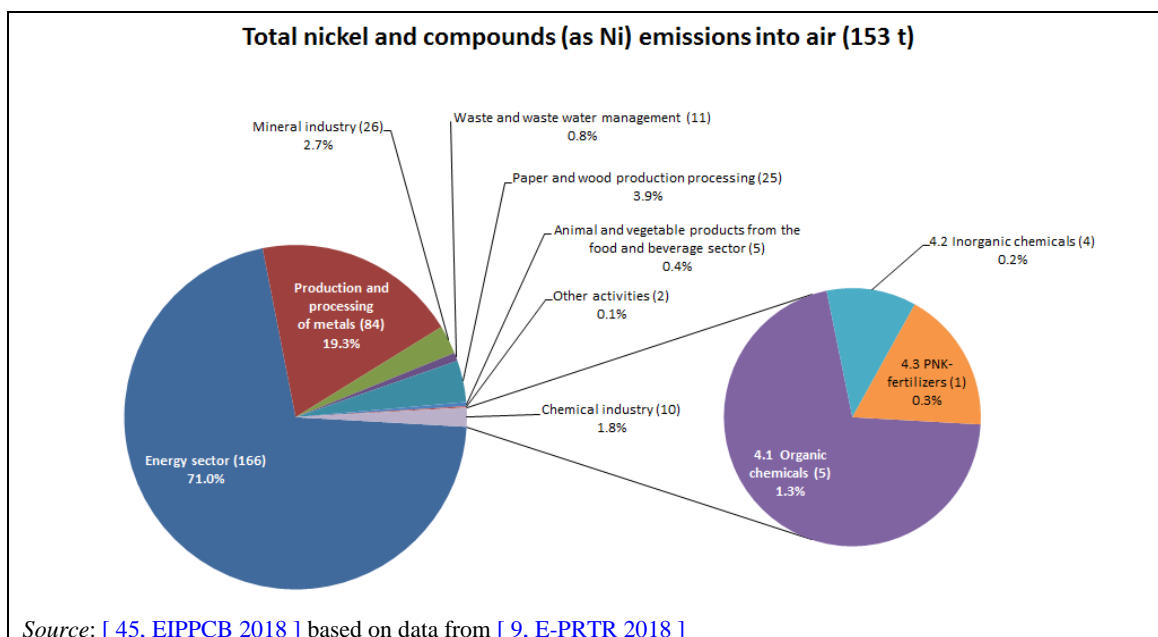


Figure 1.13: Emissions of nickel and its compounds to air by industrial sector/activity

### 1.2.3 Stockholm Convention substances

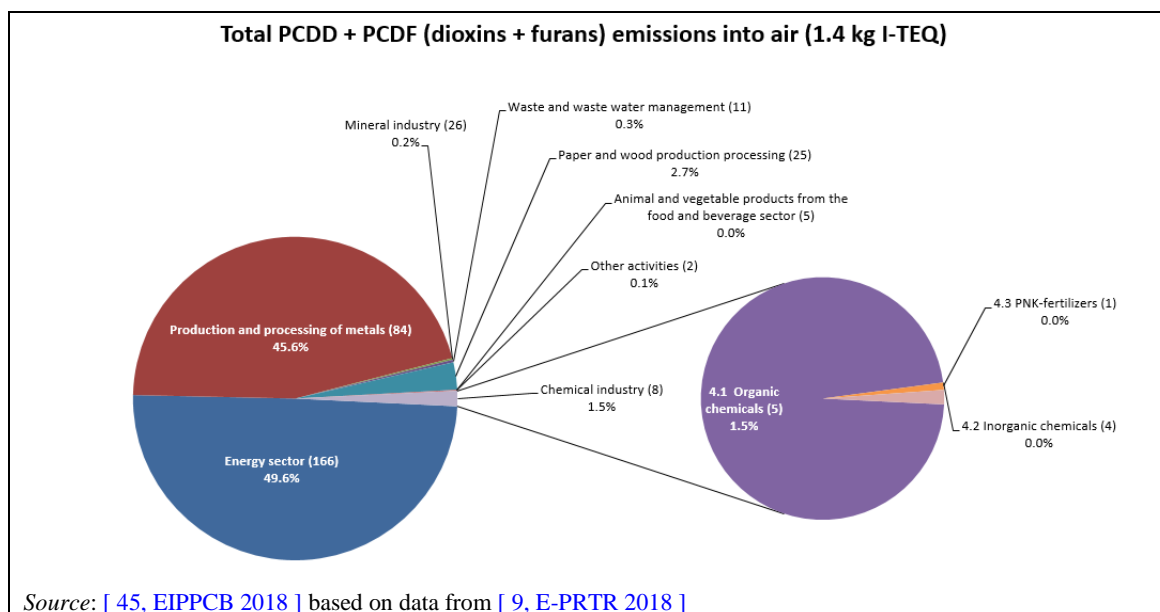
Under the Stockholm Convention on Persistent Organic Pollutants, Parties shall promote in some cases, and require in others, the use of best available techniques as well as the application of best environmental practices.

Parties must take measures to reduce unintentional releases of chemicals listed under Annex C with the goal of continuing minimisation and, where feasible, ultimate elimination of targeted chemicals. These include polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs) and dioxin-like PCBs among other chemicals.

Emissions to air of Stockholm Convention substances are outside the scope of this document except for PCDD/F.

#### 1.2.3.1 PCDD/F (dioxins and furans)

Emissions of PCDD/F to air by industrial sector are shown in Figure 1.14. In 2016, 8 installations of the chemical industry emitted around 21 g TEQ of PCDD/F to air, representing 1.5 % of the total amount of PCDD/F emitted to air by all installations covered by the E-PRTR. The largest share of PCDD/F emissions originated from the sector of energy and from production and processing of metals. Within the chemical industry, the production of organic chemicals was responsible for more than 99 % of the emissions of PCDD/F.



**Figure 1.14: Emissions of PCDD/F to air by industrial sector/activity**

### 1.2.4 Greenhouse gases

According to Article 9(1) of the Directive [ 25, EU 2010 ], the permit shall not include an emission limit value for direct emissions of greenhouse gas originating from activities listed in Annex I to Directive 2003/87/EC (greenhouse gas emission allowance trading scheme). Consequently, BAT-AELs may not be set for the following activities in this document as regards greenhouse gas emissions:

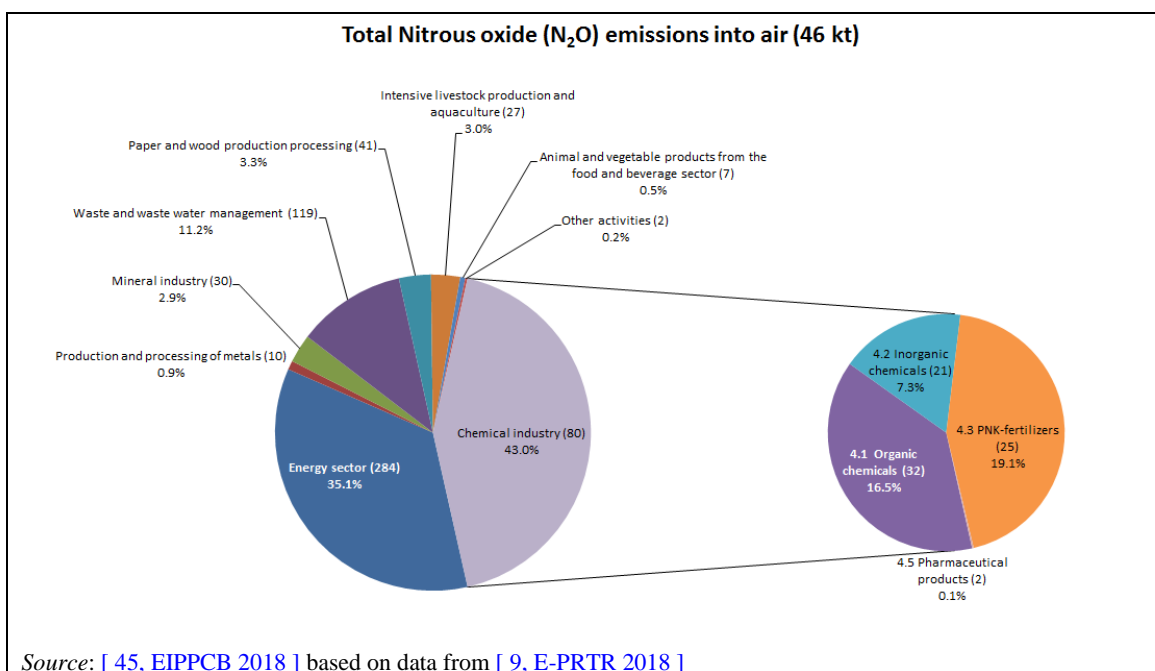
- the production of adipic acid, glyoxal and glyoxylic acid;

- the production of bulk organic chemicals by cracking, reforming partial or full oxidation or by similar processes with a production capacity exceeding 100 tonnes per day;
- the production of hydrogen and synthesis gas by reforming or partial oxidation with a production capacity exceeding 25 tonnes per day.

Substances listed as greenhouse gases in Directive 2003/87/EC, other than nitrous oxide, are outside the scope of this document [ 6, EIPPCB 2017 ].

#### 1.2.4.1 Nitrous oxide (N<sub>2</sub>O)

Emissions of nitrous oxide to air by industrial sector are shown in Figure 1.15. In 2016, 80 installations of the chemical industry emitted around 20 kilotonnes of nitrous oxide to air, representing 43 % of the total amount of nitrous oxide emitted to air by all installations covered by the E-PRTR. The largest share of nitrous oxide emissions originated from the chemical industry. A major part of these emissions is outside the scope of this document (e.g. the production of NPK fertilisers). Within the chemical industry, the production of organic chemicals and the production NPK fertilisers were responsible for more than 80 % of nitrous oxide emissions.



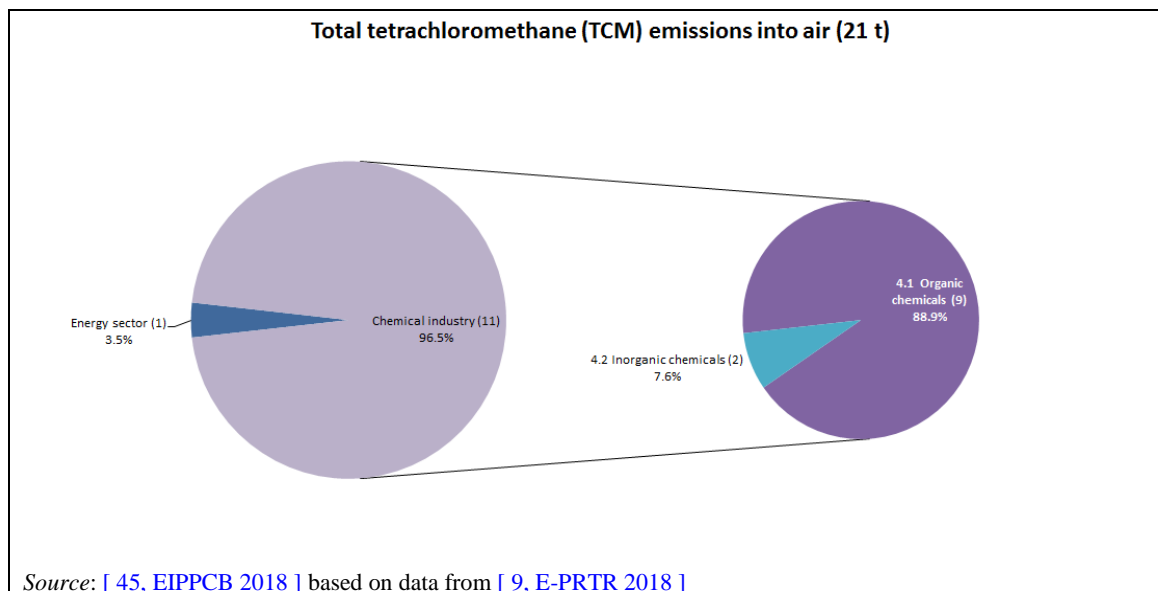
**Figure 1.15: Emissions of nitrous oxide to air by industrial sector/activity**

#### 1.2.5 Ozone-depleting substances

Ozone-depleting substances are controlled by Regulation (EC) No 1005/2009. The Regulation contains two derogations that are relevant for the WGC BREF: the use of controlled substances as feedstock for chemical processes (Article 7) and as process agents (Article 8). Controlled substances were produced in 2015 almost exclusively for feedstock use inside the EU or as an unintended by-product, which is subsequently destroyed. Unlike the other ozone depleting substances, tetrachloromethane remains an important issue, globally and in the EU, and was included in the data collection.

### 1.2.5.1 Tetrachloromethane (CCl<sub>4</sub>)

Emissions of tetrachloromethane to air by industrial sector are shown in Figure 1.16. In 2016, 11 installations of the chemical industry emitted around 20 tonnes of tetrachloromethane to air, representing 96.5 % of the total amount of tetrachloromethane emitted to air by all installations covered by the E-PRTR. The largest share of tetrachloromethane emissions originated from the chemical industry. Within the chemical industry, the production of organic chemicals was responsible for more than 90 % of tetrachloromethane emissions.

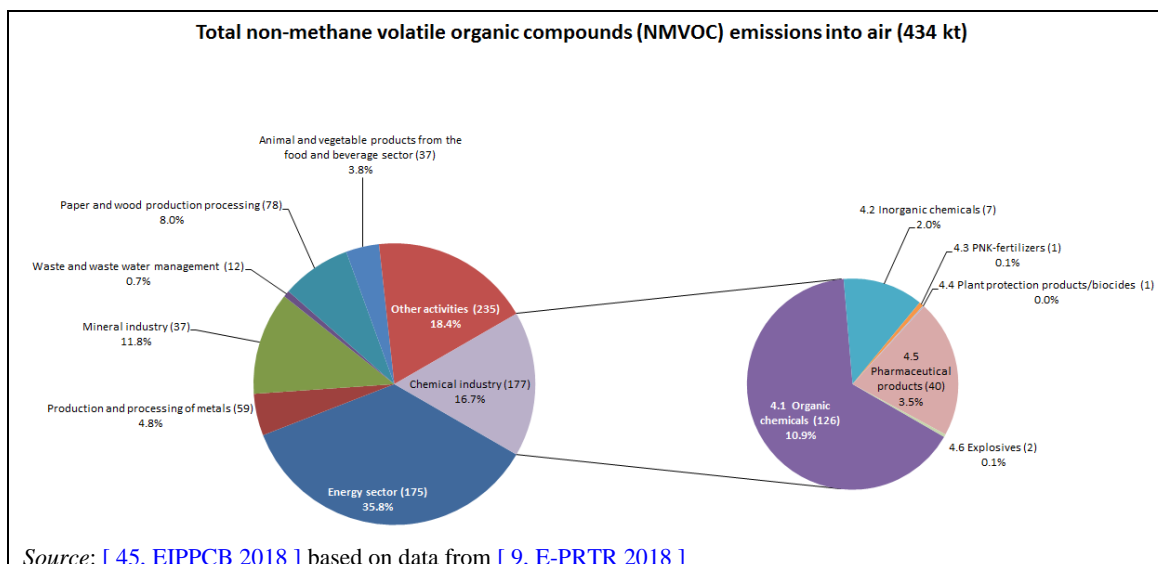


**Figure 1.16: Emissions of tetrachloromethane to air by industrial sector/activity**

## 1.2.6 Other organic substances

### 1.2.6.1 Volatile organic compounds (VOCs)

Emissions of volatile organic compounds to air by industrial sector are shown in Figure 1.17. In 2016, 177 installations of the chemical industry sector emitted around 72 kilotonnes of volatile organic compounds to air, representing 16.7 % of the total amount of volatile organic compounds emitted to air by all installations covered by the E-PRTR (where the reporting threshold for NMVOC is 100 t/yr). Half of the emissions of volatile organic compounds originated from the energy sector and the chemical industry. Within the chemical industry, the production of organic chemicals and the production of pharmaceuticals were responsible for more than 85 % of volatile organic compounds emissions.



**Figure 1.17: Emissions of volatile organic compounds to air by industrial sector/activity**

### 1.2.6.2 Formaldehyde

Formaldehyde is not included in the list of E-PRTR pollutants, but is included in Annex II to the Directive [ 25, EU 2010 ] because of its carcinogenic properties [ 10, ECHA 2019 ].

Formaldehyde is one of the organic substances most frequently measured in Germany [ 37, UBA 2016 ]. Emissions to air are measured in the production of organic chemicals, and more particularly, the production of plastic materials.

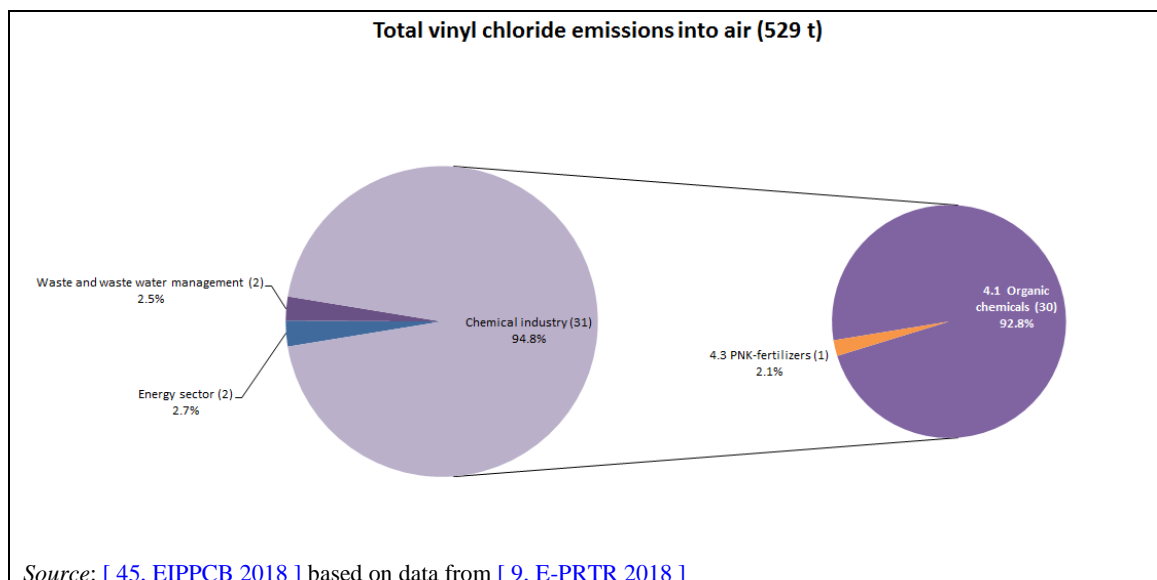
Formaldehyde emissions are also reported from industrial sites, including chemical installations, in Belgium [ 29, FluxSense 2010 ] [ 28, FluxSense 2016 ]:

- Port of Antwerp (21 sites): 61 kg formaldehyde/h;
- Zwijndrecht (7 sites): 5 kg formaldehyde/h.

The data indicate that emissions of this substance seemed to be in a similar range to CMR substances reported in the E-PRTR such as benzene (see Section 1.2.2.5) and ethylene oxide (see Section 1.2.6.7).

### 1.2.6.3 Vinyl chloride

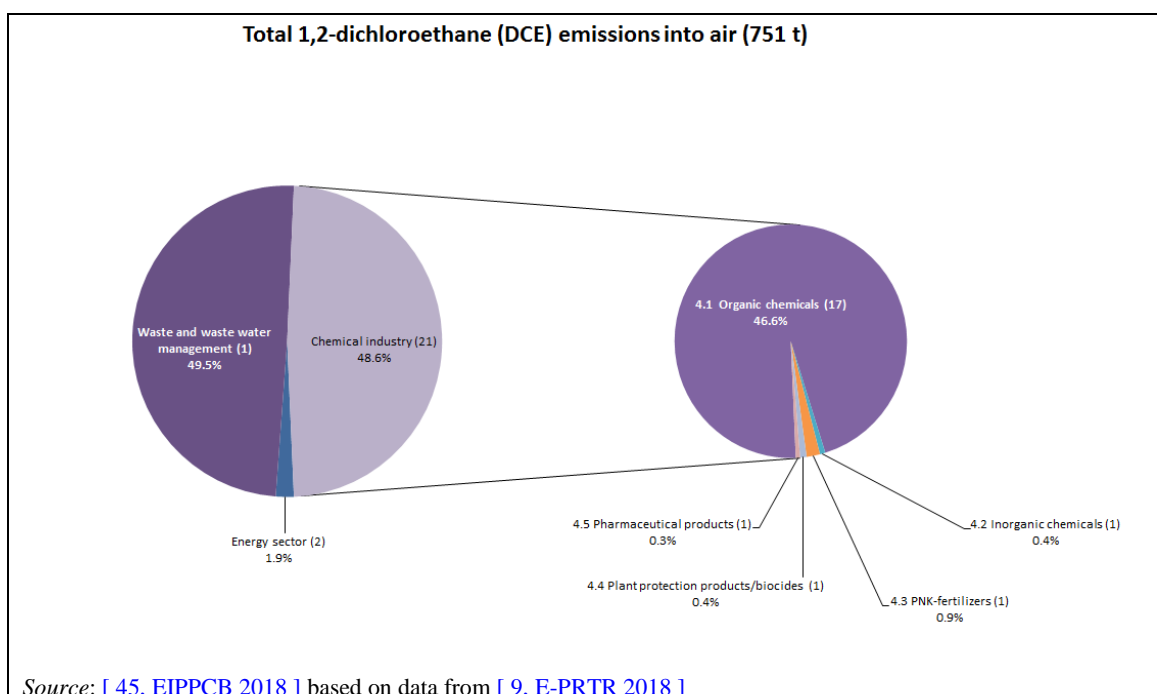
Emissions of vinyl chloride to air by industrial sector are shown in Figure 1.18. In 2016, 31 installations of the chemical industry emitted around 500 tonnes of vinyl chloride to air, representing 94.8 % of the total amount of vinyl chloride emitted to air by all installations covered by the E-PRTR. The largest share of vinyl chloride emissions originated from the chemical industry. Within the chemical industry, the production of organic chemicals was responsible for more than 90 % of vinyl chloride emissions.



**Figure 1.18: Emissions of vinyl chloride to air by industrial sector/activity**

#### 1.2.6.4 Ethylene dichloride (EDC)

Emissions of ethylene dichloride to air by industrial sector are shown in Figure 1.19. In 2016, 21 installations of the chemical industry emitted around 365 tonnes of ethylene dichloride to air, representing 48.6 % of the total amount of ethylene dichloride emitted to air by all installations covered by the E-PRTR. Almost half of ethylene dichloride emissions originated from the chemical industry. Within the chemical industry, the production of organic chemicals was responsible for more than 95 % of ethylene dichloride emissions.

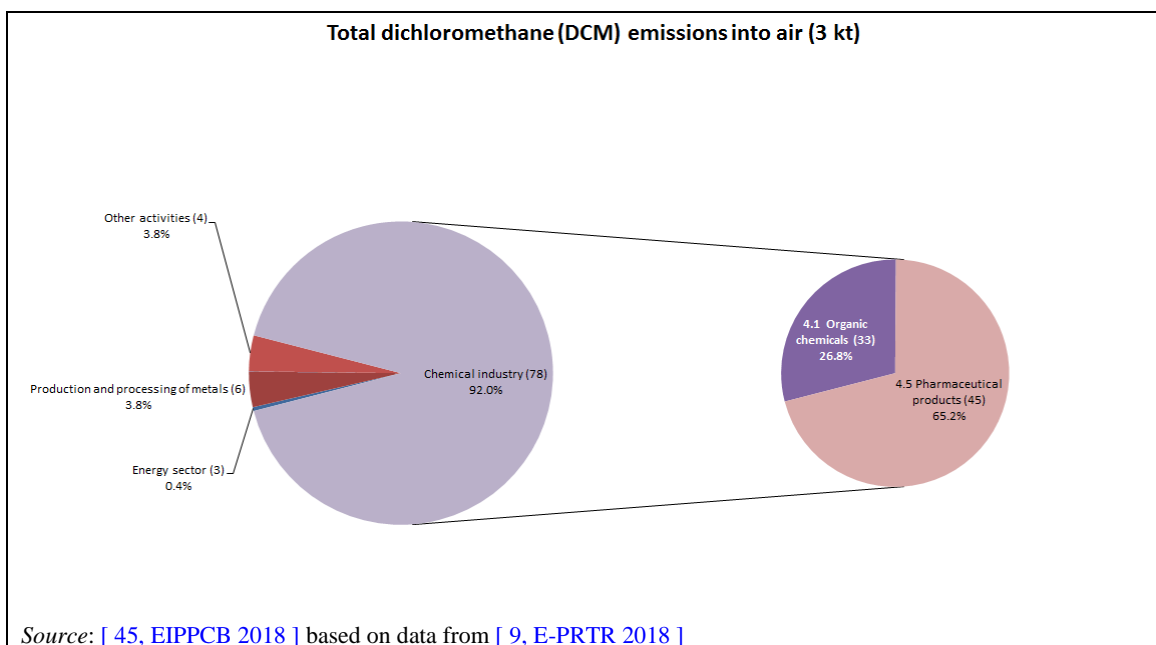


**Figure 1.19: Emissions of ethylene dichloride to air by industrial sector/activity**



### 1.2.6.5 Dichloromethane (DCM)

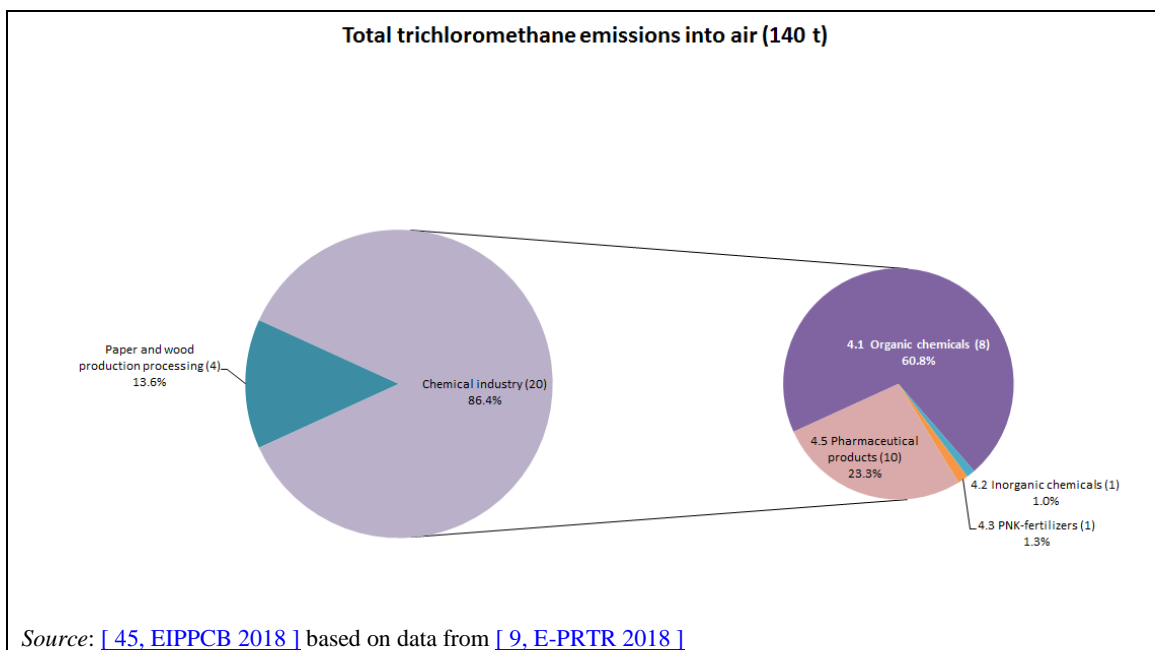
Emissions of dichloromethane to air by industrial sector are shown in Figure 1.20. In 2016, 78 installations of the chemical industry emitted around 2.8 tonnes of dichloromethane to air, representing 92 % of the total amount of dichloromethane emitted to air by all installations covered by the E-PRTR. The largest share of dichloromethane emissions originated from the chemical industry. Within the chemical industry, the production of pharmaceuticals was responsible for 65 % of dichloromethane emissions.



**Figure 1.20: Emissions of dichloromethane to air by industrial sector/activity**

### 1.2.6.6 Trichloromethane

Emissions of trichloromethane to air by industrial sector are shown in Figure 1.21. In 2016, 20 installations of the chemical industry emitted around 120 tonnes of trichloromethane to air, representing 86.4 % of the total amount of trichloromethane emitted to air by all installations covered by the E-PRTR. The largest share of trichloromethane emissions originated from the chemical industry. Within the chemical industry, the production of organic chemicals was responsible for 70 % of trichloromethane emissions.

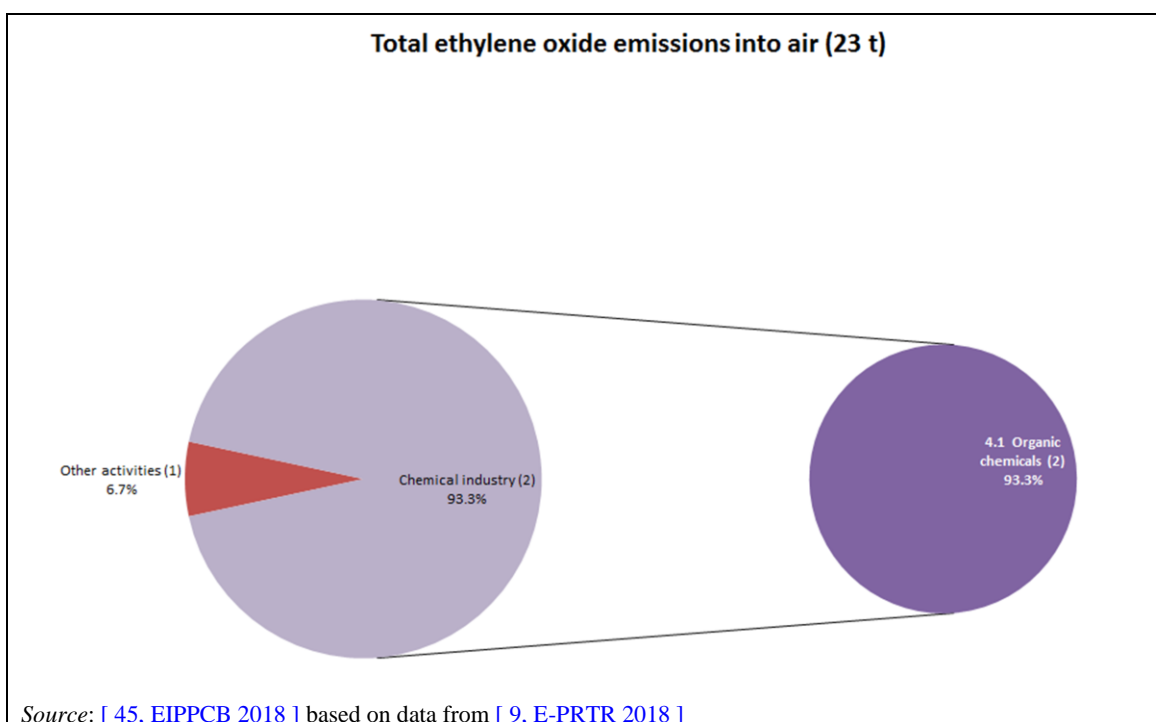


**Figure 1.21: Emissions of trichloromethane to air by industrial sector/activity**

### 1.2.6.7 Ethylene oxide

Emissions of ethylene oxide to air by industrial sector are shown in Figure 1.22. In 2016, two installations of the chemical industry emitted around 23 tonnes of ethylene oxide to air, representing 93.3 % of the total amount of ethylene oxide emitted to air by all installations covered by the E-PRTR. Those two installations belong to the sector of organic chemicals production.

Ethylene oxide is one of the organic substances most frequently measured in Germany [37, UBA 2016]. The reported data show that, after waste gas treatment, the measured ethylene oxide emissions to air are far below the E-PRTR threshold of 1 000 kg/year. All reported measurements of emissions to air of were carried out in the sectors of organic chemicals and production of plastic materials.



**Figure 1.22: Emissions of ethylene oxide to air by industrial sector/activity**

### 1.2.6.8 Toluene

Toluene is not included in the list of E-PRTR pollutants.

Toluene is one of the organic substances most frequently measured in Germany, [37, UBA 2016]. All reported measurements of emissions to air were carried out in the sector of organic chemicals. Toluene is used in the manufacture of chemicals and as a solvent [34, Kirk-Othmer 2014].

### 1.2.6.9 1,3-Butadiene

1,3-Butadiene is not included in the list of E-PRTR pollutants, but is included in Annex II to the Directive [25, EU 2010] because of its carcinogenic and mutagenic properties [11, ECHA 2019].

France [30, FR 2017] reported emissions of 75.5 tonnes of 1,3-butadiene in 2015 from the eight French chemical facilities for which emissions were above the French declaration threshold of 15 tonnes/year.

The data indicate that the emissions of 1,3-butadiene and the emissions of other CMR substances reported in the E-PRTR like benzene (see Section 1.2.2.5) and ethylene oxide (see Section 1.2.6.7) seem to be in a similar range.

## 1.2.7 Other gases

### 1.2.7.1 Ammonia (NH<sub>3</sub>)

Emissions of ammonia to air by industrial sector are shown in Figure 1.23. In 2016, 90 installations of the chemical industry emitted around 21 kilotonnes of ammonia to air, representing 9.7 % of the total amount of ammonia emitted to air by all installations covered by

the E-PRTR. The largest share of ammonia emissions originated from intensive livestock production and aquaculture. An important part of these emissions is outside the scope of this document (e.g. the production of NPK fertilisers). Within the chemical industry, the production of organic chemicals and the production of NPK fertilisers were responsible for more than 90 % of ammonia emissions.

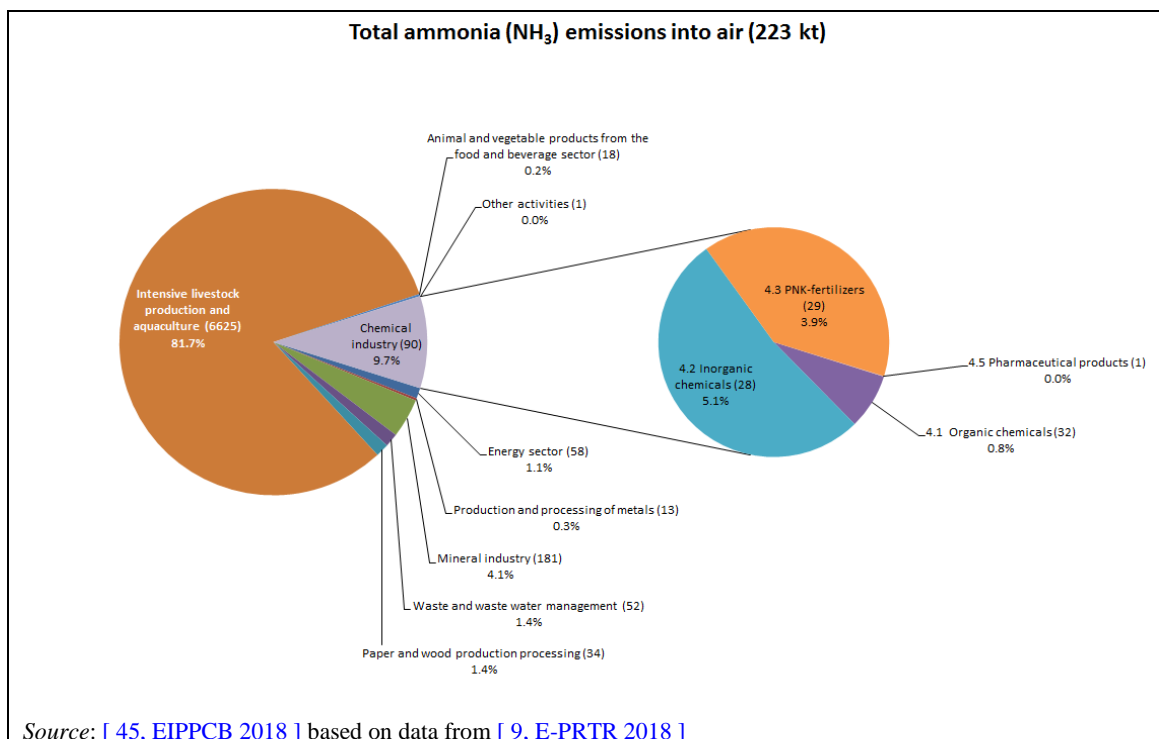
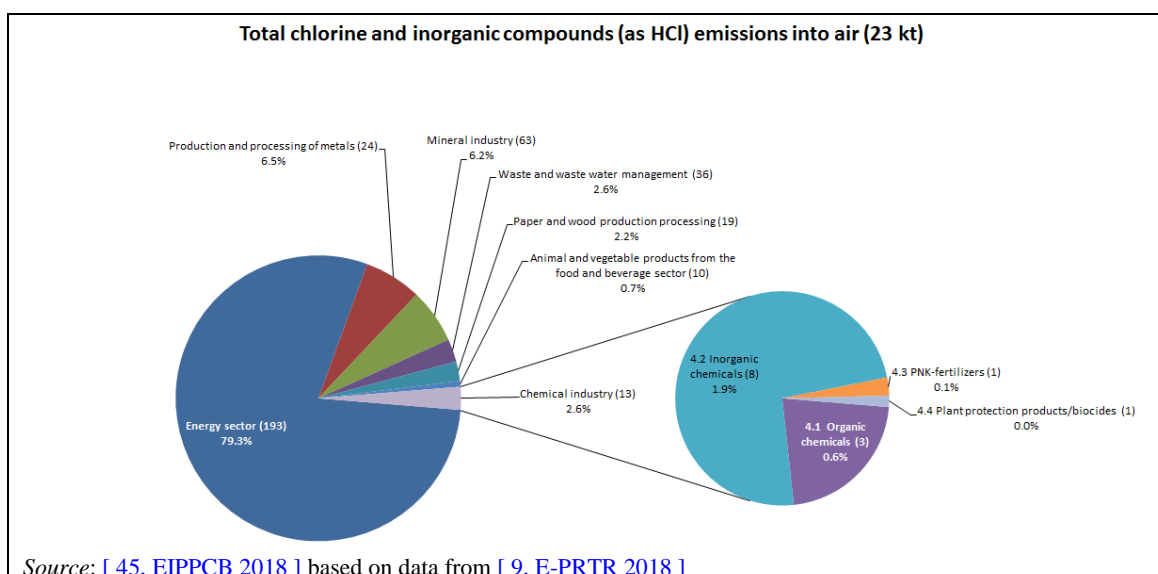


Figure 1.23: Emissions of ammonia to air by industrial sector/activity

Ammonia emissions from all sources occurring in the territory of the Member States are also addressed by the emission reduction commitments established by Directive 2016/2284.

### 1.2.7.2 Gaseous chlorides

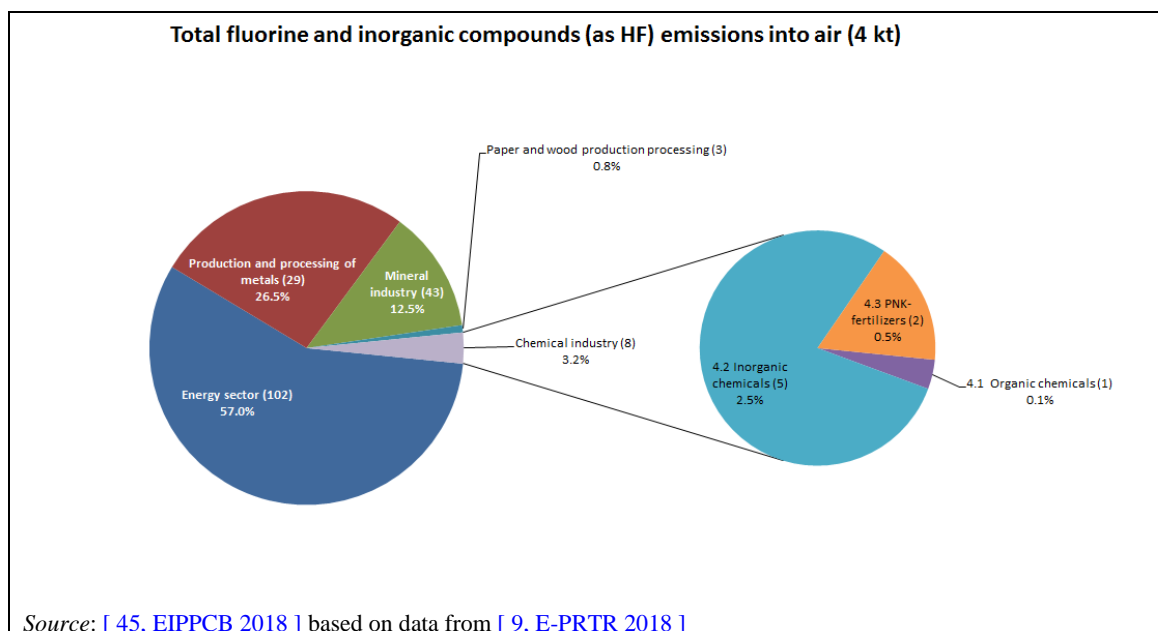
Emissions of gaseous chlorides to air by industrial sector are shown in Figure 1.24. In 2016, 13 installations of the chemical industry emitted around 600 tonnes of gaseous chlorides to air, representing 2.6 % of the total amount of gaseous chlorides emitted to air by all installations covered by the E-PRTR. The largest share of gaseous chlorides emissions originated from the energy sector. Within the chemical industry, the production of organic chemicals was responsible for more than 70 % of gaseous chlorides emissions.



**Figure 1.24: Emissions of gaseous chlorides to air by industrial sector/activity**

### 1.2.7.3 Gaseous fluorides

Emissions of gaseous fluorides to air by industrial sector are shown in Figure 1.25. In 2016, 8 installations of the chemical industry emitted around 128 tonnes of gaseous fluorides to air, representing 3.2 % of the total amount of gaseous fluorides emitted to air by all installations covered by the E-PRTR. The largest share of gaseous fluorides emissions originated from the energy sector. Within the chemical industry, the production of inorganic chemicals was responsible for almost 80 % of gaseous fluorides emissions.



**Figure 1.25: Emissions of gaseous fluorides to air by industrial sector/activity**

### 1.2.7.4 Hydrogen cyanide (HCN)

Emissions of hydrogen cyanide to air by industrial sector are shown in Figure 1.26. In 2016, 11 installations of the chemical industry emitted around 38 tonnes of hydrogen cyanide to air, representing 19.7 % of the total amount of hydrogen cyanide emitted to air by all installations

covered by the E-PRTR. The largest share of hydrogen cyanide emissions originated from the energy sector. Within the chemical industry, the production of organic chemicals was responsible for almost 80 % of hydrogen cyanide emissions.

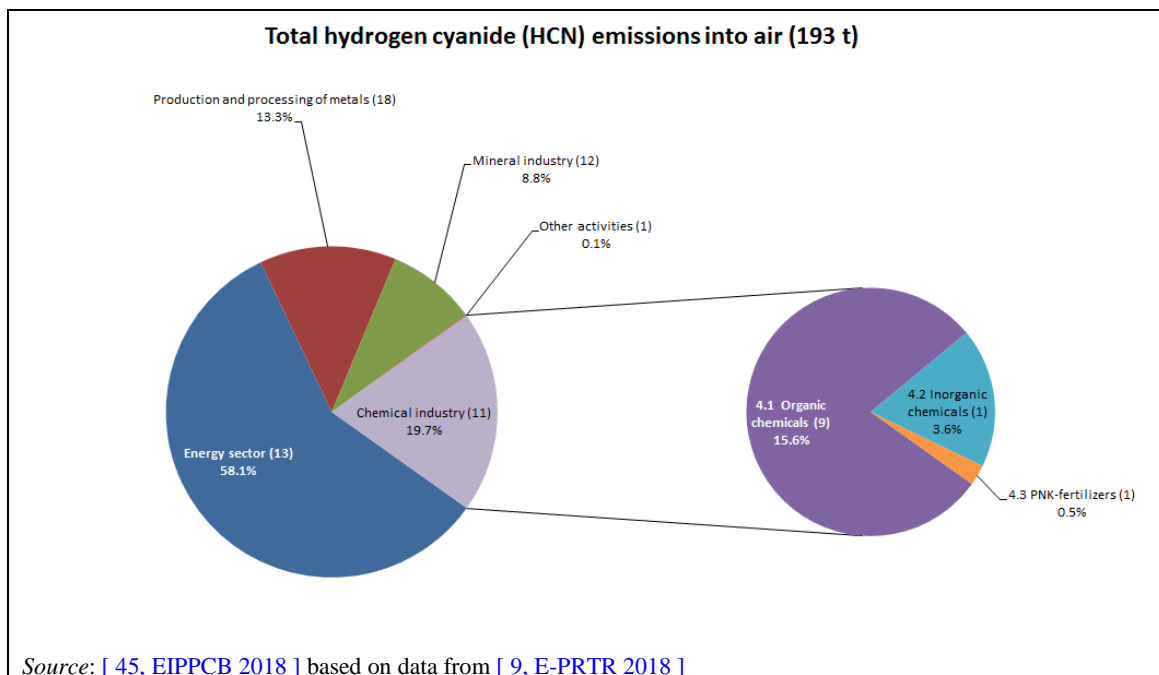


Figure 1.26: Emissions of hydrogen cyanide to air by industrial sector/activity

### 1.3 Waste gas in the chemical industry

The characteristics and scale of emissions from chemical plants are highly variable. Emissions may depend on factors such as raw material composition, product type, nature of intermediates, use of auxiliary materials, process operating conditions, type of process-integrated techniques to prevent or reduce emissions and type of end-of-pipe treatment.

Waste gas streams can be roughly divided into ducted (channelled) and non-ducted (diffuse) emissions. Capturing diffuse emissions and subsequent treatment can often be carried out in order to minimise pollution.

Emissions to air in the chemical industry include the following:

- Channelled emissions, such as:
  - process emissions released through a vent pipe by process equipment and inherent to the running of the plant;
  - flue-gases from energy-providing units, such as process furnaces, steam boilers, combined heat and power units, gas turbines and gas engines;
  - waste gases from emission control equipment, such as filters, incinerators/oxidisers or adsorbers, likely to contain unabated pollutants or pollutants generated in the abatement system;
  - tail gases from reaction vessels and condensers;
  - waste gases from catalyst or solvent regeneration;
  - waste gases from vents, storage and handling (transfers, loading and unloading) of products, raw materials and intermediates;
  - exhaust air from vents or captured diffuse emissions, e.g. sources of diffuse emissions installed within an enclosure or a building.
  
- Diffuse emissions arising from point, linear, surface or volume sources [[3, CEFIC 2000](#)], such as:
  - process emissions from the process equipment inherent in running the plant, released from a large surface or through openings e.g. ‘working losses’ and ‘breathing losses’, when not captured and channelled);
  - non-channelled emissions from storage equipment and during handling operations (e.g. the filling of drums, trucks or containers);
  - non-routine emissions resulting from other than normal operating conditions (OTNOC) including emissions during start-up or shutdown and during maintenance;
  - secondary emissions resulting from the handling or disposal of waste (e.g. volatile material from sewers, waste water handling facilities or cooling water);
  - fugitive emissions, typically due to equipment leaks from pumps and compressors, seals, valves, flanges, connectors and other piping items, or other equipment such as drain or vent plugs or seals.

As far as diffuse emissions are concerned, the objective of waste gas management is generally their prevention and/or minimisation.

Some Member States (e.g. Belgium, France and Germany) have implemented more specific measures in their general binding rules for diffuse emissions. These measures include the following for example:

- Periodic monitoring (monitoring campaigns), quantification of diffuse emissions and application of a leak detection and repair programme (LDAR). The frequency

requirements may vary depending on the type of chemical activity, the hazardous properties and the quantity of VOCs emitted.

- A quality assurance system (product certification, assembly procedures, staff training, etc.).

Depending on the chemical sector, the share of diffuse emissions in the total emissions may be significantly higher than the share of channelled emissions. France reported that 83 % of total NMVOC emissions<sup>3</sup> in 2015 were diffuse emissions, for the 10 operators of chemical sector facilities reporting the highest levels of NMVOC emissions in the French pollutant release register [31, FR 2017]. France also reported, from calculations based on the data collection, that the proportion of diffuse and channelled emissions can be estimated at 86 % for diffuse emissions and 14 % for channelled emissions [54, FR 2019]. The share of diffuse emissions may be even higher for specific substances like benzene, for which diffuse emissions accounted for 91 % of the total emissions in 2015, or even 1,3-butadiene for which 100 % of the emissions were diffuse.

An evaluation of total VOC emissions carried out by the Flemish competent authority of Belgium [35, Lucht et al. 2014] shows that the total VOC emissions in Flanders had been reduced by 67 % in 2012 since the implementation of LDAR programmes according to the Flemish general binding rules.

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<sup>3</sup> NMVOC emissions from the ten main French contributors of the chemical sector.



## 1.4 Waste gas treatment technology

### 1.4.1 Overview

The number of different sources of emissions, the variety of the contaminants, their physical state (liquid, gaseous or solid) and their load make the implementation of a system of techniques to prevent, control and/or reduce emissions inevitable. The system is designed according to the complexity of the production and based on management decisions. Such a system consists of:

- process-integrated techniques (see Section 1.4.2);
- end-of-pipe treatment (individual and/or central facilities, see Section 1.4.3).

### 1.4.2 Process-integrated techniques

Advanced environmental protection is shifting more and more from end-of-pipe techniques (see Section 1.4.3) to process-integrated or production-integrated techniques. Process-integrated techniques are a source of significant environmental improvement in both new and existing plants. They are intended to reduce, or even prevent, the production of residues directly at the source before they become a discharge. Often these ‘process improvements’ help decrease the cost of additional treatment measures, as well as increase the economic efficiency by increasing production yield and/or decreasing raw material input including water usage. Disposal costs and the limitations of end-of-pipe treatment can influence this shift toward process-integrated techniques. Although the prevention of waste gas, and thus the implementation of process-integrated techniques, is becoming increasingly significant, waste gas treatment techniques will remain essential contributors to the control of emissions into the environment, mainly when process-integrated techniques are not feasible for existing production plants.

Proper process-integrated environmental protection uses all possible physical, chemical, biological and engineering techniques for the prevention, reduction and recycling of residues. This includes for example:

- creation of new synthesis pathways;
- use of purer or even different feedstocks and process agents;
- use of purer or different fuels;
- optimisation of process steps;
- improvement of plant technology, process control and reaction sequence;
- technical adaptations to the process;
- improvement of the use of catalysts and/or solvents;
- recycling of auxiliaries (e.g. washing water, inert gases, solvents, and catalysts);
- immediate recycling of residues during the process;
- use of residues as raw materials for other production processes (product integration on-or off-site);
- use of residues for energy generation.

Obviously, the development and implementation of completely new pathways for syntheses in existing plants will remain an exception, mostly for economic reasons, and will therefore be mostly carried out in processes used to manufacture bulk products or products of high economic value. In practice, production-integrated environmental protection will progress continuously as the sum of many individual, and possibly small, improvements over time.

Though, strictly speaking, process-integrated techniques for the reduction of the pollutant discharge via waste gas are part of the scope of the other chemical BREFs they are nevertheless mentioned in this document as long as they are generally applicable in chemical production processes and when they refer to certain polymer production processes (see Section 3.5). They are in any case elements of good management practice and worthy of consideration when implementing an environmental management system, including a waste gas management system for channelled emissions to air and a management system for diffuse emissions.

### 1.4.3 End-of-pipe techniques

Because it is not always possible to prevent pollution at the source, end-of-pipe techniques are those that treat the waste streams arising from a process, a storage unit or an area to reduce its pollutant content.

Waste gas treatment techniques in general are involved in the reduction of:

- particulate matter;
- vapours of volatile liquid substances;
- gaseous air contaminants;
- odour.

Waste gas treatment normally takes place directly at the source. Only rarely can waste gas streams with different characteristics be treated simultaneously in one central treatment unit. One main reason is that treatment units are normally specifically designed for a particular waste gas composition. Another important reason is that special attention must be paid to the release of toxic and hazardous compounds and their impact on the surroundings as well as on the safety of the plant. In the chemical industry, safety is a crucial issue given the toxicity and/or hazardous characteristics of many compounds and the generally large volumes that are handled and processed. Moreover, facilities needed to transport waste gases through a whole site require significant investments and can be technically challenging.

A selection of techniques by working principles, pollutant and waste gas volume flow rate is given in Table 1.1.

**Table 1.1: Working principles/techniques, pollutant and waste gas volume flow rate**

Working principle/ technique	Dust	VOC	NH <sub>3</sub>	HCl	HF	NO <sub>x</sub>	SO <sub>x</sub>	Other inorganic gaseous compounds	Volume flow rate (Nm <sup>3</sup> /h)	Reference
Absorption (Scrubbing)	+	X	X	X	X	X	X	X	1-400 000	See Section 3.3.2.1
Adsorption		X	X	X		X	X		1-300 000	See Section 3.3.2.2
Bioprocesses		X	X					X	100- 500 000	See Sections 3.5.1.3.1 and 3.5.1.3.2 in the CWW BREF
Cold oxidation		X	X						20- 200 000	See Sections 3.5.1.3.7 and 3.5.1.3.8 in the CWW BREF
Condensation		X	X	X					1-100 000	See Section 3.3.2.5
Dust scrubbing	X	+	X	+	+		+	+	720- 170 000	See Section 3.3.2.1
Electrostatic precipitation	X								900- 800 000	See Section 3.3.2.7
Filtration	X								2- 5 000 000	See Sections 3.3.2.8, 3.3.2.9 and 3.3.2.10
Gravitational separation	X								5-300 000	See Section 3.3.2.6
Membrane Separation		X							< 3 000	See Section 3.5.1.2.1 in the CWW BREF
Reduction						X			1 500- 50 000	See Sections 3.3.2.16 and 3.3.2.17
Catalytic or thermal oxidation	+	X		+				X	100- 150 000	See Sections 3.3.2.14 and 3.3.2.15

NB: If a technique's primary goal is not the removal of a specific pollutant, but this pollutant is (partly) removed by the technique, this is indicated by a '+'.  
Source: [13, COM 2016] [43, TWG 2021]

#### 1.4.4 Cross-media effects of waste gas treatments and their interdependencies

Because of fundamental conservation laws, most treatment technologies can have, in addition to their purging abilities, negative impacts on the environment. Examples of these cross-media effects are waste generated by filters (see Sections 3.3.2.8, 3.3.2.9 and 3.3.2.10) and waste water generated by scrubbers (see Section 3.3.2.1). Waste gas oxidation (see in particular Sections 3.3.2.14 and 3.3.2.15) discharges a flue-gas containing gaseous contaminants that were not present in the original input and might require further waste gas treatment. This is briefly reviewed in Table 1.2.

Other relevant points of concern are the energy consumption, the sludge generation and the water consumption, the latter being an essential issue under certain climatic conditions.

A life cycle assessment according to EN 14040 may assist the implementation of an integrated waste gas management and treatment strategy and the selection of waste gas treatment techniques. An example was provided by the plant DE\_290.

**Table 1.2: Potential effect of waste gas treatment facilities on the environment**

<b>Environmental medium</b>	<b>Potential effect/emission</b>
Air	<ul style="list-style-type: none"><li>• In principle (and primarily), significant reduction of contaminant emissions.</li><li>• However, VOCs can be converted into flue-gas contaminants, such as carbon oxides, hydrogen halides, sulphur dioxide, nitrogen oxides or dioxins, in the case of thermal and catalytic oxidation.</li></ul>
Water	<ul style="list-style-type: none"><li>• Absorption (scrubbing) transfers contaminants from the air to the water medium.</li><li>• However, some treatment techniques (e.g. scrubbing, water-run condensation) increase water consumption and waste water generation.</li></ul>
Waste	<ul style="list-style-type: none"><li>• Generation of sludge from secondary treatment of waste water, initially originating from waste gas treatment.</li><li>• Generation of residues from waste gas treatment facilities (e.g. separated solids, condensed liquid not recycled, spent adsorbent, spent catalyst).</li></ul>
Other	<ul style="list-style-type: none"><li>• Waste gas treatment facilities normally consume energy.</li><li>• Consumption of auxiliary chemicals (e.g. ammonia for selective non-catalytic reduction (SNCR), alkaline agents for scrubbing solutions).</li></ul>

In addition to waste gas treatment systems, a large number of safety facilities can be found in the chemical industry. The main purpose of these facilities is to reduce the environmental impact and/or increase the safety of the plant operation.

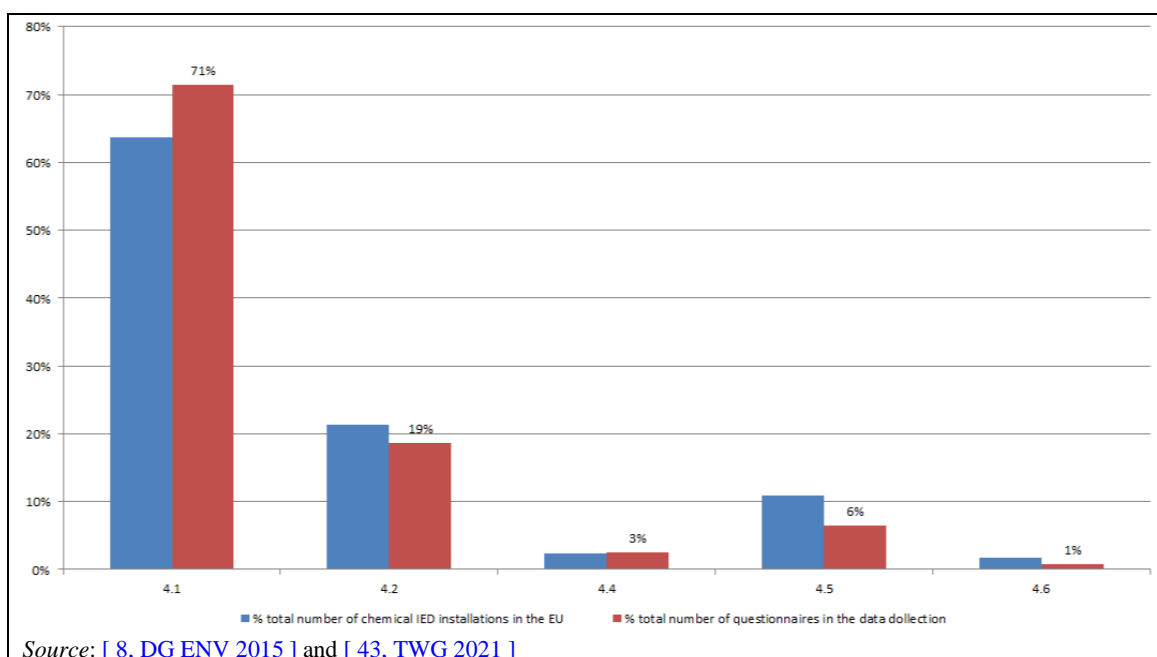
## 2 CURRENT EMISSION LEVELS

### 2.1 General information on the chemical sector

#### 2.1.1 Overview

This chapter summarises the installation-specific data gathered during the data collection carried out over the course of the BREF drawing-up process (see schedule in Table 6.1).

Figure 2.1 gives an overview of the share of chemical installations in the EU-27 and United Kingdom by categories of activities listed in points 4.1 to 4.6 of Annex I to the IED compared to the share of questionnaires in the data collection by same chemical activity. Please note that to cover all relevant emission points, some installations required filling out additional questionnaires.



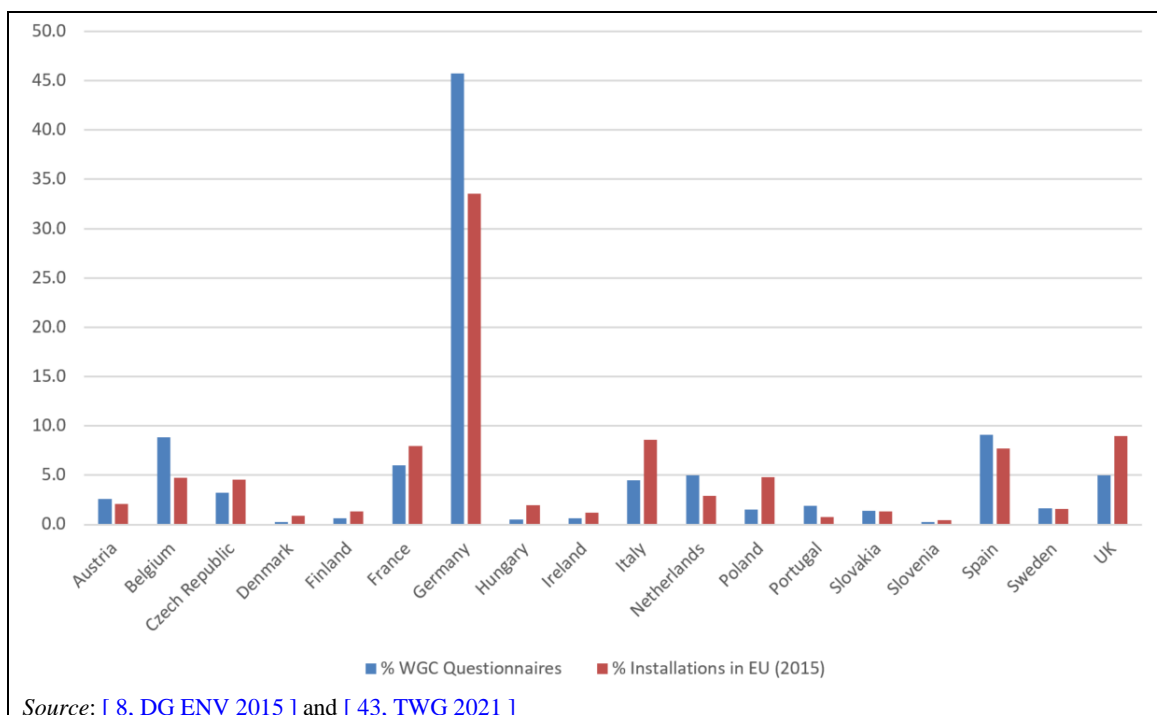
**Figure 2.1: Share of IED installations in EU-27 and UK by IED chemical activity versus share of questionnaires by IED chemical activity**

The data collection for the WGC BREF focused on the following information using a standardised questionnaire:

- Identification and description of the plant:
  - plant name, company name, country and city;
  - start of operation (year), substantial changes having a significant effect on emissions to air;
  - description of the waste gas treatment system.
- Channelled emissions to air (emission points):
  - category of IED activity, type of product, type of process, process operating time, range of production capacity;
  - number of associated process furnaces/heaters;
  - other information such as external treatment of channelled emissions.
- Channelled emissions to air and associated waste gas treatment systems:
  - monitored substances;

- type of monitoring (periodic or continuous);
- waste gas treatment techniques applied (possibility to report up to five techniques including the case when no waste gas treatment is applied);
- information on emissions to air after the final treatment, including measured concentrations and contextual information on the measurement(s);
- information on the hazardous properties of groups of substances monitored, such as dust and TVOC.
- Waste gas treatments techniques, e.g. absorption, filtration, thermal oxidation:
  - substance(s) removed by the technique, removal efficiency;
  - information on the type of equipment;
  - waste gas properties, such as volume flow and temperature;
  - operational information, such as energy consumption and other consumables.
- Information on waste gases when no treatment technique is applied.
- Particular polymer production: polyolefins, PVC, solution-polymerised rubbers, viscose:
  - type of product;
  - type of process;
  - process-integrated techniques;
  - recovery techniques;
  - specific loads.
- Process furnaces/heaters:
  - type of product;
  - type of process furnace/heater, e.g. combustion scenario and primary techniques to prevent emissions;
  - operational information, e.g. type of fuel, total rated input and process temperature.
- Diffuse emissions to air:
  - contextual information around the monitoring of diffuse emissions to air;
  - annual quantities of diffuse emissions to air.
- Fugitive emissions to air:
  - information on the monitoring of fugitive emissions to air, such as monitoring criteria, methods to prevent, estimate, calculate or measure fugitive emissions;
  - information on the application of a leak detection and repair (LDAR) programme;
  - annual quantities of fugitive emissions to air.
- Non-fugitive emissions to air:
  - information on the type of equipment monitored;
  - information on monitoring methods;
  - annual quantities of non-fugitive emissions to air.
- Information on the use of a solvent management plan.

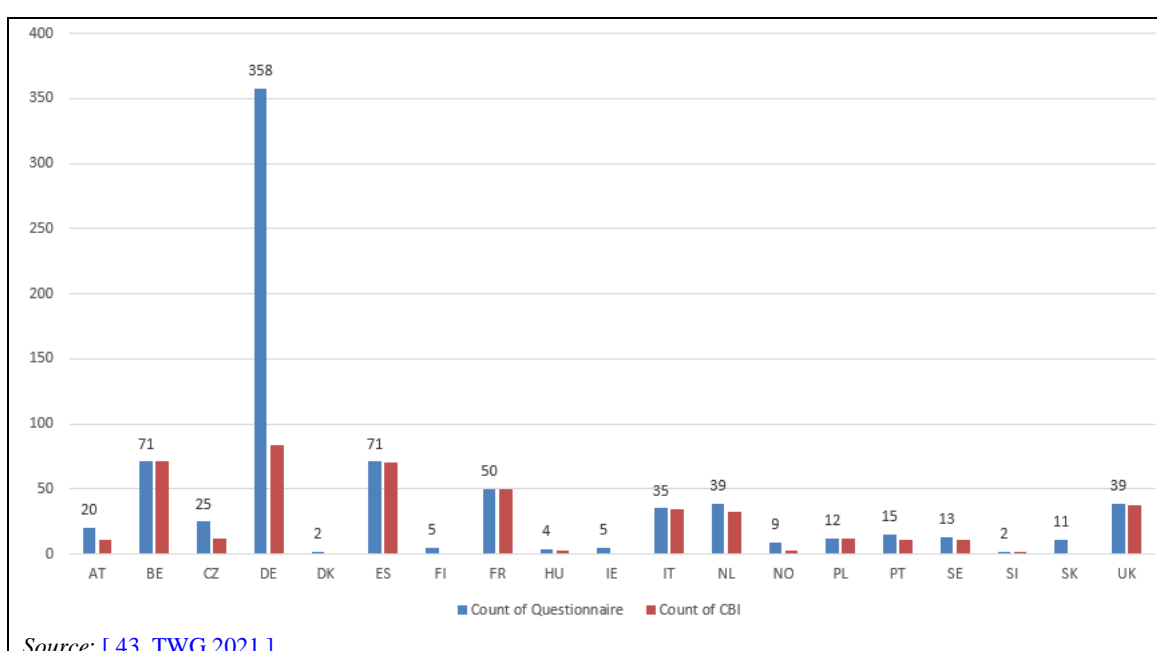
Figure 2.2 gives an overview of the share of questionnaires in the data collection compared to the IED chemical installations (for all chemical activities) per country.



**Figure 2.2: Share of IED chemical installations in EU-27 and UK versus share of questionnaires**

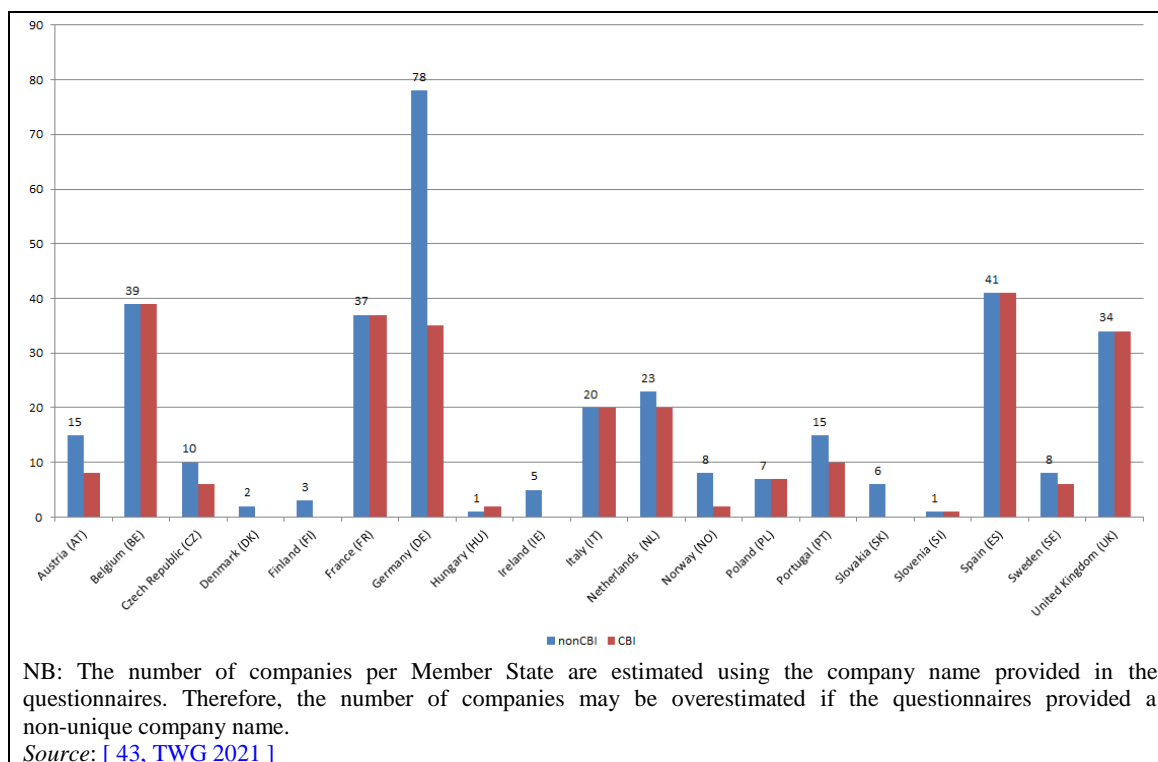
The total number of questionnaires received was 784. Of these 784, a total of 443 contained confidential business information.

Figure 2.3 shows the number of questionnaires for the versions containing non-confidential business information (non-CBI versions), or submitted by email to the EIPPCB for the versions containing confidential business information (CBI versions).



**Figure 2.3: Number of questionnaires submitted by country**

Figure 2.4 gives an overview of the number of IED chemical companies by country. The total number of companies that provided a non-CBI questionnaire is 353 and the total number of companies that provided a CBI version is 268.



**Figure 2.4:** Number of companies by country

## 2.1.2 Total emissions to air

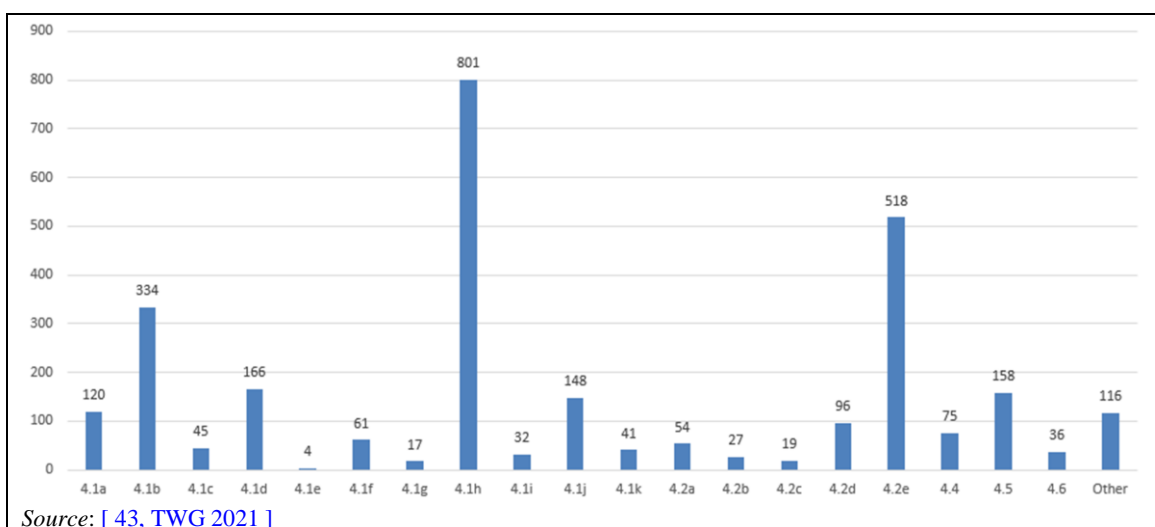
Waste gas streams can roughly be divided into ducted (channelled) and non-ducted (diffuse) emissions. In practice, only ducted emissions can be treated. As far as diffuse emissions are concerned, the objective of waste gas management is to prevent or minimise them, or to capture them and carry out subsequent treatment.

According to the data collection, the share of diffuse emissions is significantly higher than the share of channelled emissions. This is the case, for example, for volatile organic substances monitored as TVOC (83.1 %), for CMR substances such as 1,3-butadiene (99.5 %) and benzene (90.6 %). However, the data collection also shows high variability in the range of reported diffuse emissions due to the complexity and diversity of the chemical plants.

### 2.1.2.1 Channelled emissions to air

Figure 2.5 gives an overview of the number of channelled emission points reported in the questionnaires per main IED chemical activity. The total number sums up to 2 911 channelled emission points. The data collection covers all IED chemical activities. However, according to the scope of this BREF, there are fewer questionnaires in the case of the production of inorganic acids (IED category 4.1a), bases (IED category 4.2b) and no questionnaire at all in the case of fertilisers (IED category 4.3). For some emission points, the main IED chemical activity was not specified: those emission points do not appear on the graph.

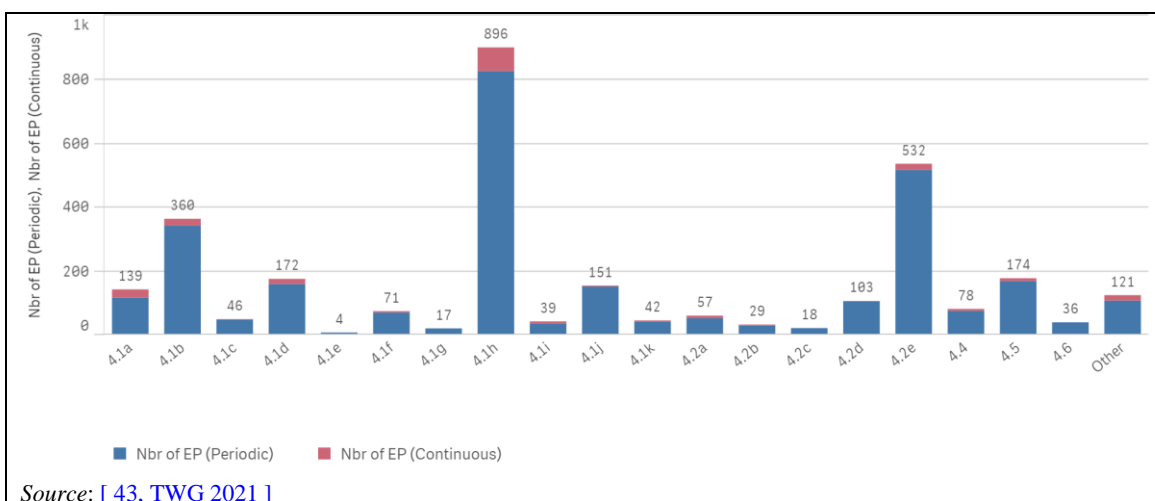




**Figure 2.5:** Number of channelled emission points reported by IED category

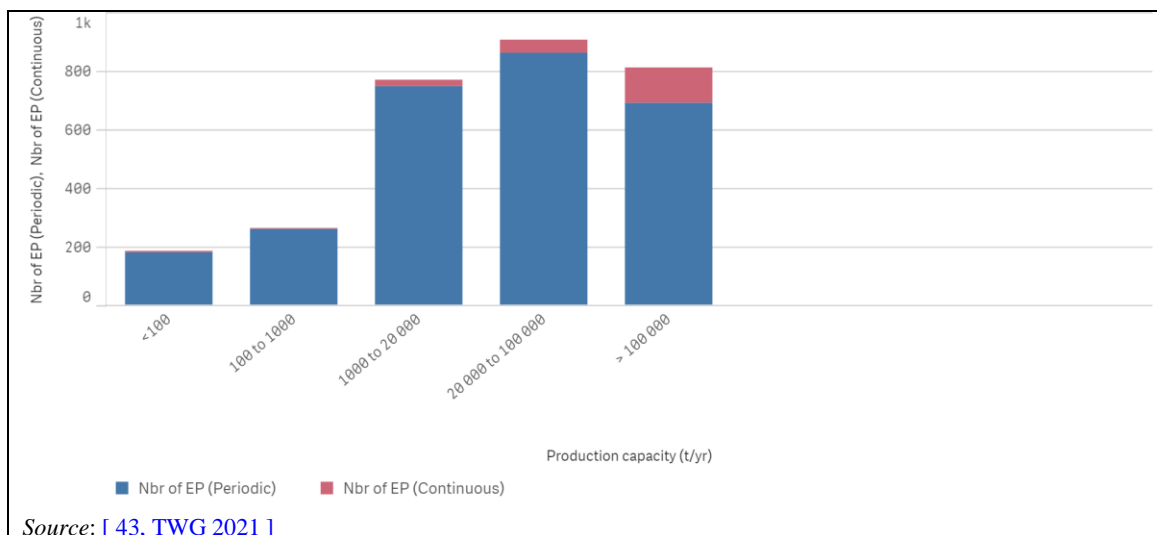
Channelled emission points are mainly monitored periodically as show in Figure 2.6:

- total number of emission points where periodic monitoring is applied: 2 812;
- total number of emission points where continuous monitoring is applied: 192.
- When several substances/parameters are monitored at the same emission point, both periodic and continuous monitoring are sometimes applied depending on the substance/parameter.
- A total of 226 emission points reported monitoring substances/parameters that are not considered key environmental issues (KEIs) for this BREF. Those emission points do not appear in the graphs presented in this section.



**Figure 2.6:** Number of emission points where periodic or continuous monitoring is applied by IED category

Figure 2.7 gives an overview of the annual production capacity ranges associated with the emission points reported in the data collection, depending on the type of monitoring applied (periodic or continuous).



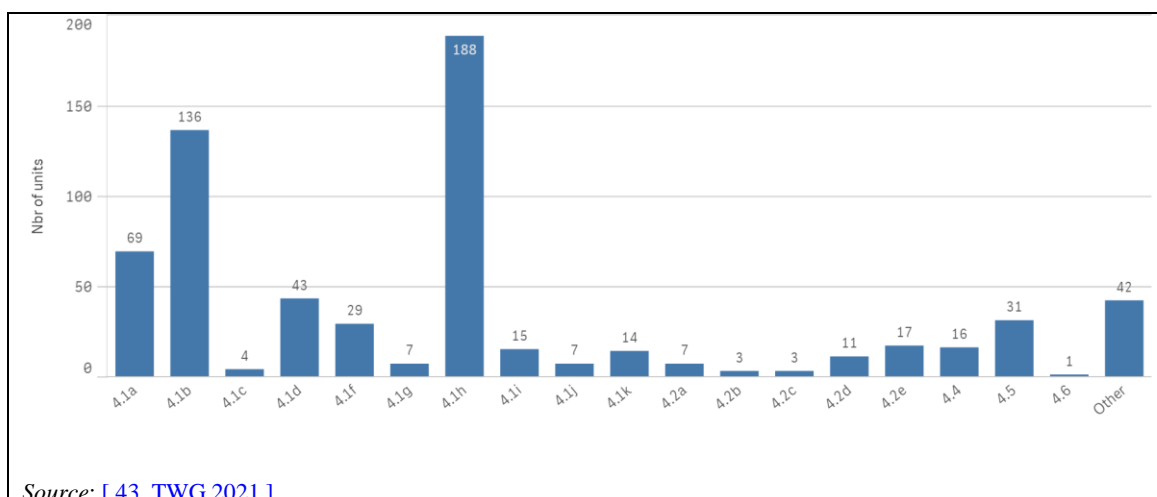
**Figure 2.7: Production capacity ranges**

### 2.1.2.2 Diffuse emissions to air

For the purpose of the data collection on diffuse emissions, the term ‘unit’ was defined as an installation, or a part thereof, for which diffuse emissions are monitored, as required by the IED permit or any other national regulation or standard (e.g. if the permit requires the monitoring of diffuse emissions from a tank farm or a particular production unit, this tank farm or production unit can be considered as a unit regarding diffuse emissions).

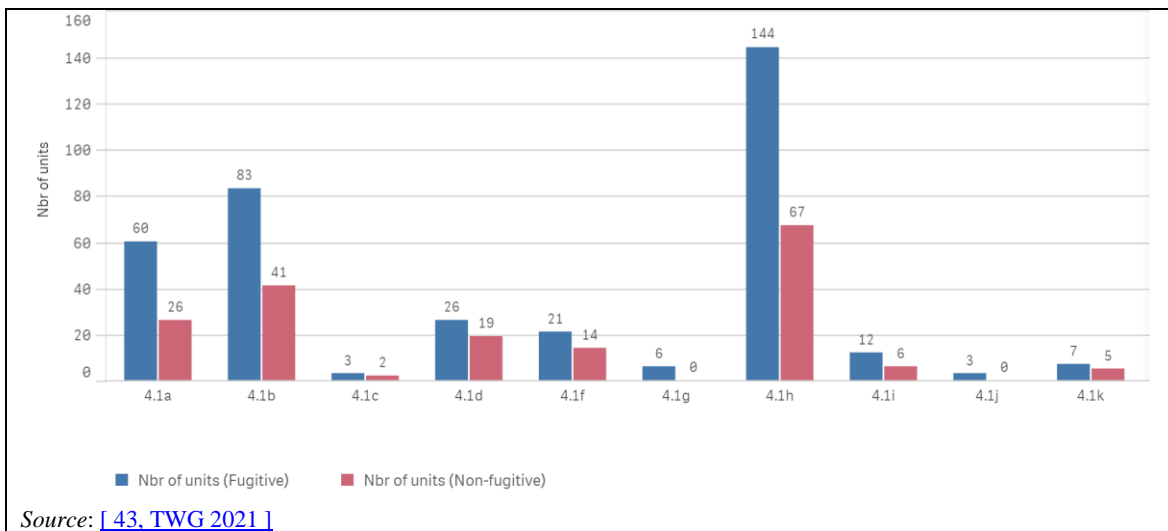
In this chapter, and more particularly in Sections 2.4, 2.4.2.1, 2.6 and 2.7, the term ‘unit’ shall have the abovementioned meaning.

Figure 2.8 gives an overview of the number of units for which diffuse emissions were collected per main IED chemical activity (covered by Section 4 of Annex I to the IED). The total number sums up to 643 units.



**Figure 2.8: Number of units reported for diffuse emissions by IED category**

Figure 2.9 gives an overview of the number of units for which fugitive and non-fugitive emissions were collected per main IED chemical activity. The total number sums up to 430 (fugitive) and 239 (non-fugitive).



**Figure 2.9: Number of units reported for fugitive and non-fugitive emissions by IED category**

## 2.2 Main techniques to reduce channelled emissions to air

The waste gas treatment working principles/techniques generally reported in the data collection are shown in Table 2.1.

**Table 2.1: Waste gas treatment working principles/techniques**

Working principle/technique	Share of total number of EP
Absorption	26.0 %
Adsorption	4.1 %
Bioprocess	0.3 %
Condensation	5.0 %
Dust scrubbing	3.6 %
Electrostatic precipitation	0.5 %
Filtration	26.1 %
Gravitational separation	3.6 %
Membrane separation	0.0 % <sup>(1)</sup>
Reduction (SCR or SNCR)	0.8 %
Thermal treatment	9.8 %
No waste gas treatment	20.1 %
<sup>(1)</sup> The use of membrane separation was reported in one questionnaire for one emission point. Source: [43, TWG 2021]	

For each working principle/technique applied, a specific type could be reported in the questionnaire. Table 2.2 shows the most reported waste gas treatment techniques in the data collection.

**Table 2.2: Most reported waste gas treatment techniques**

Technique	No of emission points
Packed-bed scrubber	392
Spray tower	154
Fixed bed adsorber	95
Condenser	129
Cryogenic condensation	34
Wet dust scrubber	66
Venturi scrubber	22
Absolute filter (HEPA)	65
Fabric filter / Bag filter	777
High-efficiency air filter (HEAF)	127
Cyclone	150
Catalytic oxidiser	47
Recuperative thermal oxidiser	35
Regenerative thermal oxidiser	42
Straight thermal oxidiser	112
Source: [43, TWG 2021]	

The complete waste gas treatment system is usually a combination of the above-mentioned individual waste gas treatment techniques. For example, the waste gas treatment technique that is most commonly used to reduce emissions to air of organic compounds is the straight thermal oxidiser. Absorption, adsorption and condensation may be used to increase resource efficiency and to reduce the load of organic compounds sent to the straight thermal oxidiser. In order to reduce emissions to air of inorganic compounds (e.g.  $\text{NO}_x$ ,  $\text{SO}_x$ ) and PCCD/F, additional techniques may be applied.

## 2.3 Channelled emissions to air

### 2.3.1 General

The following sections present data reported for the pollutants identified as KEIs (e.g. monitoring, removal efficiency, concentration and mass flows of emitted pollutants). The graphs contained in this section exclusively refer to channelled emissions to air reported in the data collection for the WGC BREF. Data were gathered from the last three monitoring campaigns between the reference years 2008 and 2018. However, the majority of the data was reported for the years 2015, 2016 and 2017.

In general, the concentrations and the mass flows presented in the graphs from this section are given as average values, obtained as described in Annex 7.1.

It should be underlined that, although the data collection covered emissions from EPs linked to a chemical activity in the scope of the WGC BREF, the diversity and the complexity of the plants' characteristics (e.g. in terms of layout, type of process (continuous vs batch), type of technique applied or absence of waste gas treatment techniques) did not allow a precise differentiation between minor and major contributors to channelled emissions. Therefore, for each KEI addressed in the following specific sections, the reference mass flow value used to filter the data shown in the graphs should be considered as an 'example value' to guide the reader towards a possible distinction between major and minor emission types.

### 2.3.2 Organic substances

#### 2.3.2.1 Total volatile organic carbon (TVOC)

Data for TVOC and NMVOC were collected. The data collected shows that concentrations of NMVOC and concentrations of TVOC are in the same ranges. In particular, there is generally no indication that concentrations of NMVOC significantly differ from concentrations of TVOC. Thus, the remainder of this document does not differentiate between TVOC and NMVOC.

##### 2.3.2.1.1 Sectors

TVOC is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.10.

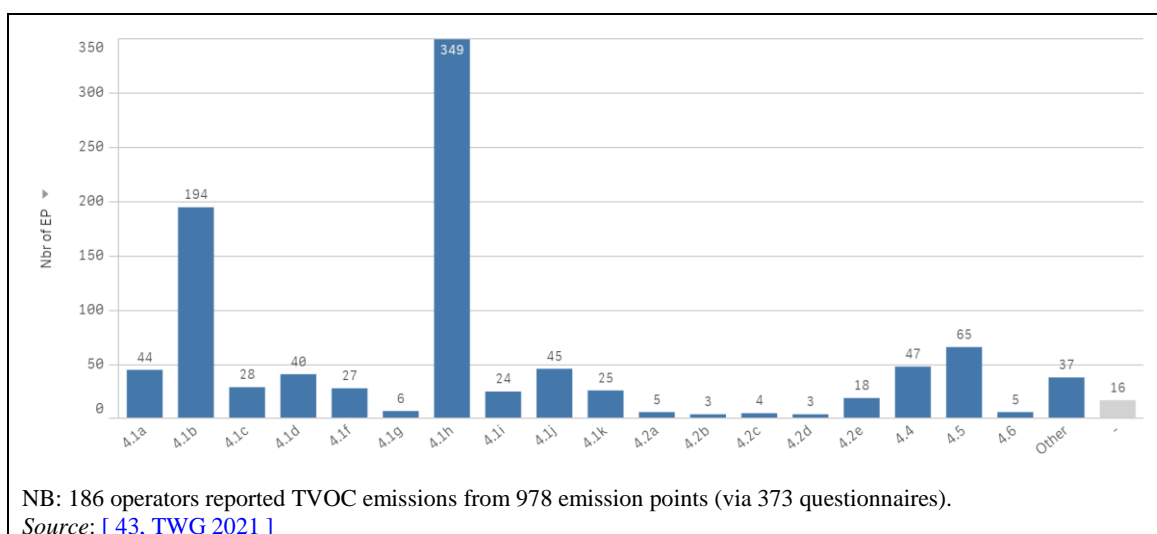


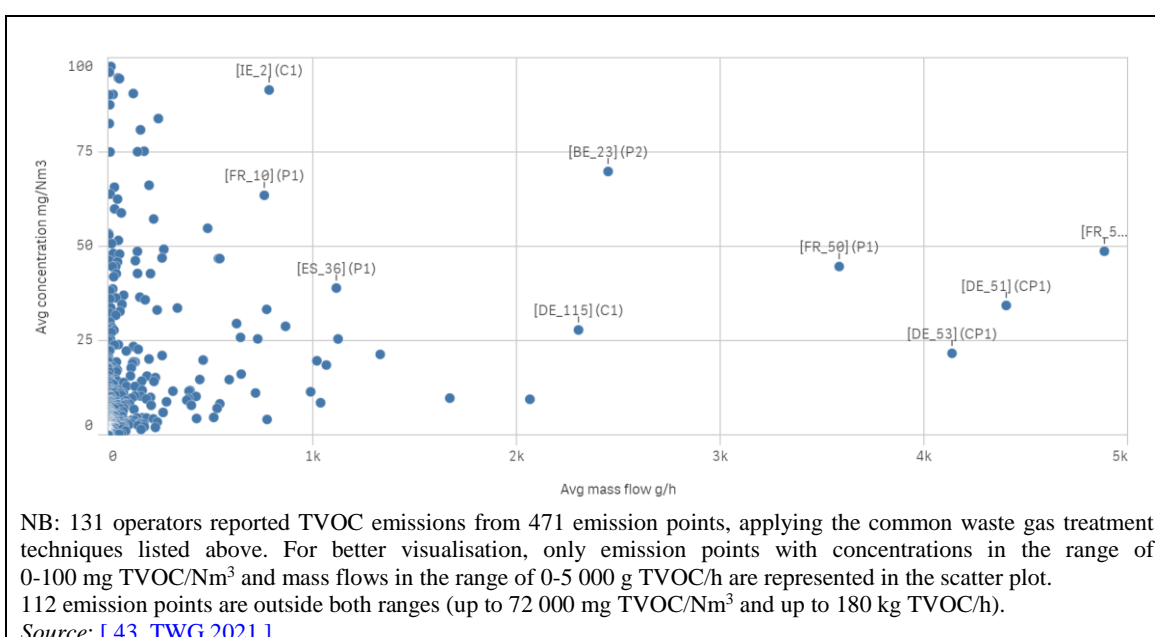
Figure 2.10: Number of emission points for TVOC emissions to air by IED category

### 2.3.2.1.2 Treated emissions

TVOC is generally treated with at least one waste gas treatment technique. The typical emission levels of TVOC after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.11.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are:

- absorption;
- adsorption;
- bioprocess;
- condensation;
- thermal or catalytic oxidation.



**Figure 2.11: TVOC emissions after waste gas treatment**

2.3.2.1.3 Untreated emissions

The typical emission levels of TVOC when no waste gas treatment is applied are shown, in concentration and mass flow, in the scatter plot of Figure 2.12.

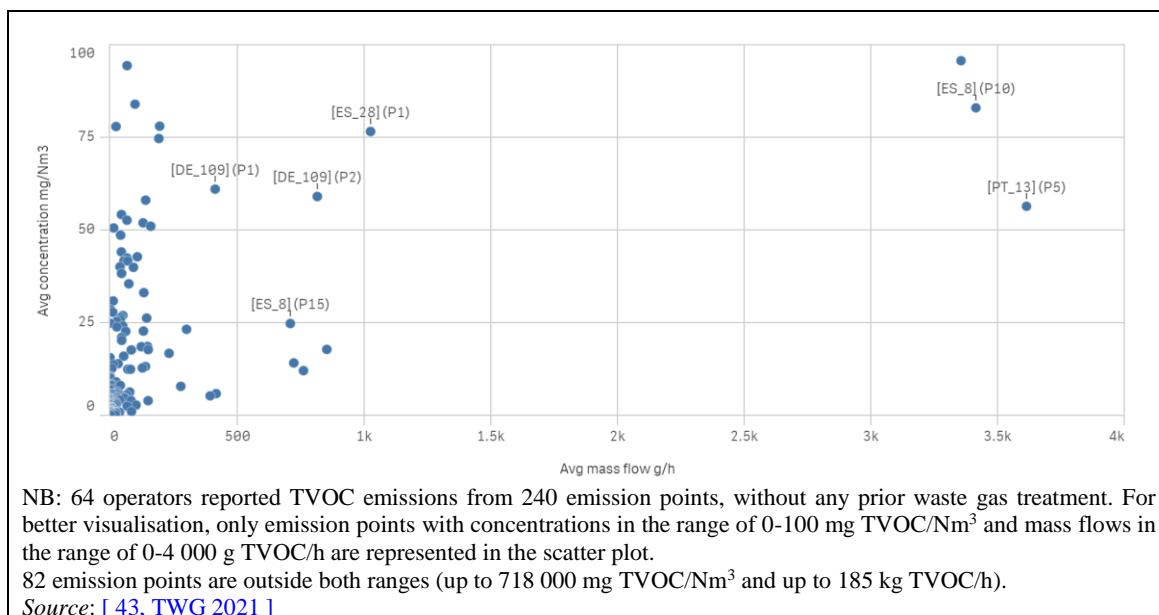


Figure 2.12: TVOC emission points with no waste gas treatment

2.3.2.1.4 Monitoring

Periodic monitoring is more common than continuous monitoring: 1 758 instances of periodic monitoring and 117 of continuous monitoring were reported. Typical frequencies for the periodic monitoring of channelled TVOC emissions are shown in the bar chart of Figure 2.13.

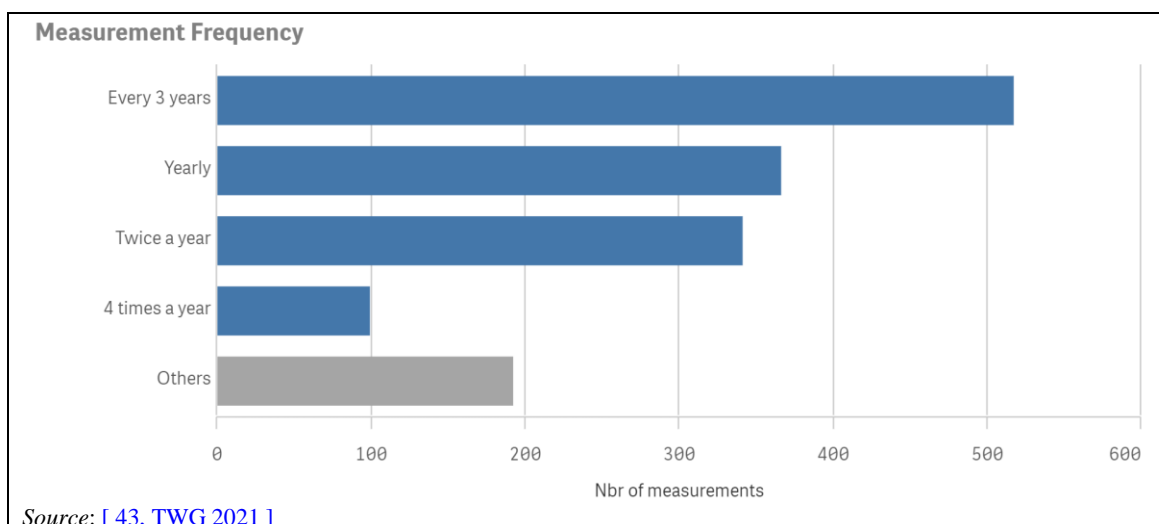


Figure 2.13: Reported measurement frequencies for periodic TVOC monitoring



Percentiles of reported limits of quantification and limits of detection for TVOC measurements are shown in Table 2.3.

**Table 2.3: Reported limits of quantification and detection for TVOC**

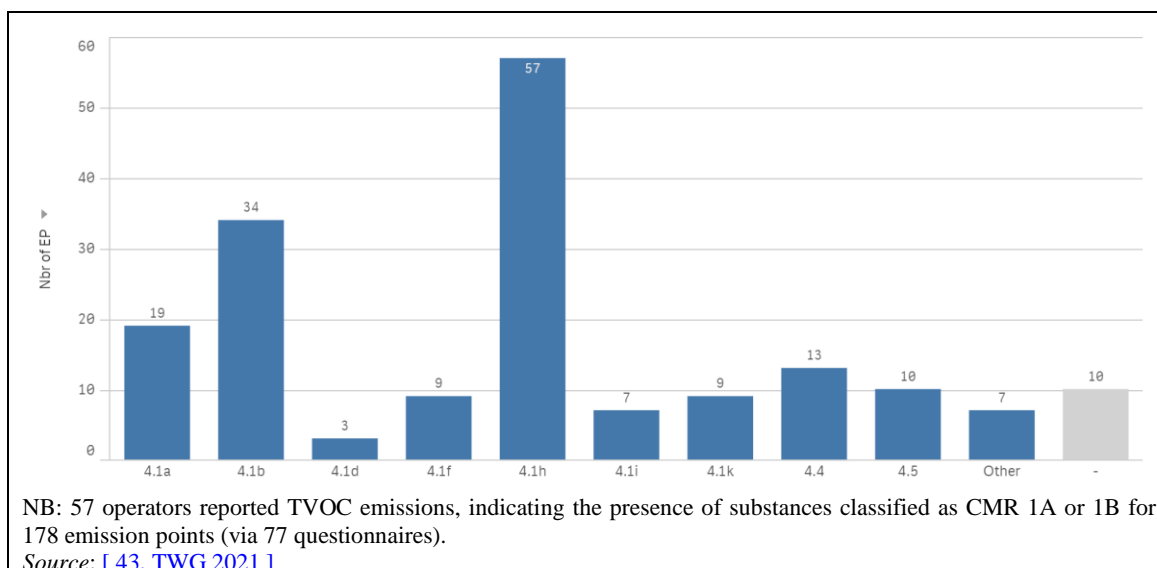
Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.5	0.2
50 <sup>th</sup>	1.0	0.5
80 <sup>th</sup>	3.0	1.6

NB: The numbers of instances reported for the limits of quantification and detection are 495 and 516, respectively.  
Source: [43, TWG 2021]

### 2.3.2.2 Total volatile organic carbon (TVOC) containing substances classified as CMR 1A or 1B

#### 2.3.2.2.1 Sectors

TVOC containing substances classified as CMR 1A or 1B are typically emitted by chemical sectors as shown in the bar chart of Figure 2.14.



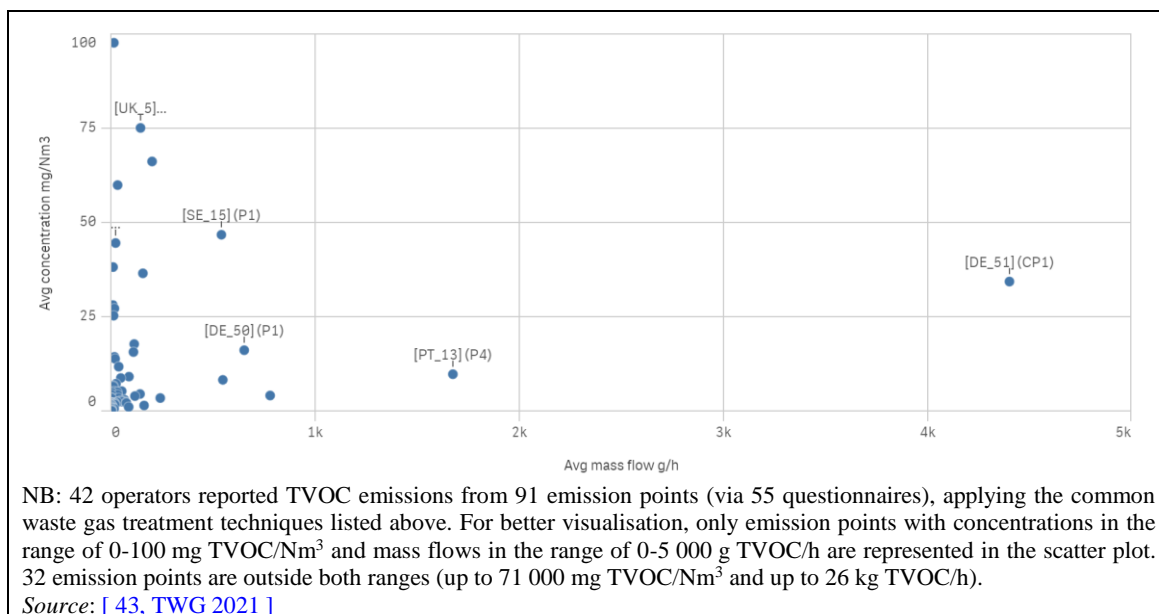
**Figure 2.14: Number of emission points for TVOC emissions containing substances classified as CMR 1A or 1B by IED category**

#### 2.3.2.2.2 Emissions

TVOC containing substances classified as CMR 1A or 1B is generally treated with at least one waste gas treatment technique. The typical emission levels of TVOC containing substances classified as CMR 1A or 1B after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.15.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are:

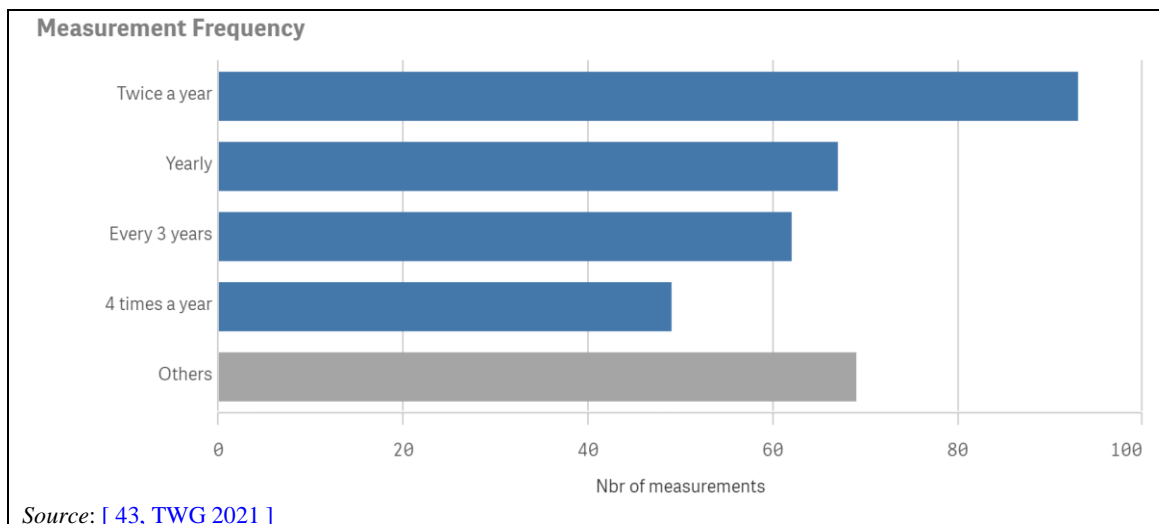
- absorption;
- adsorption;
- bioprocess;
- condensation;
- thermal or catalytic oxidation.



**Figure 2.15: Emissions of TVOC containing substances classified as CMR 1A or 1B after waste gas treatment**

### 2.3.2.2.3 Monitoring

Periodic monitoring is more common than continuous monitoring: 422 instances of periodic monitoring and 25 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled emissions of TVOC containing substances classified as CMR 1A or 1B are shown in the bar chart of Figure 2.16.



**Figure 2.16: Reported measurement frequencies for periodic monitoring of TVOC containing substances classified as CMR 1A or 1B**

Percentiles of reported limits of quantification and limits of detection for TVOC containing substances classified as CMR 1A or 1B are shown in Table 2.4.

**Table 2.4: Reported limits of quantification and detection for TVOC containing substances classified as CMR 1A or 1B**

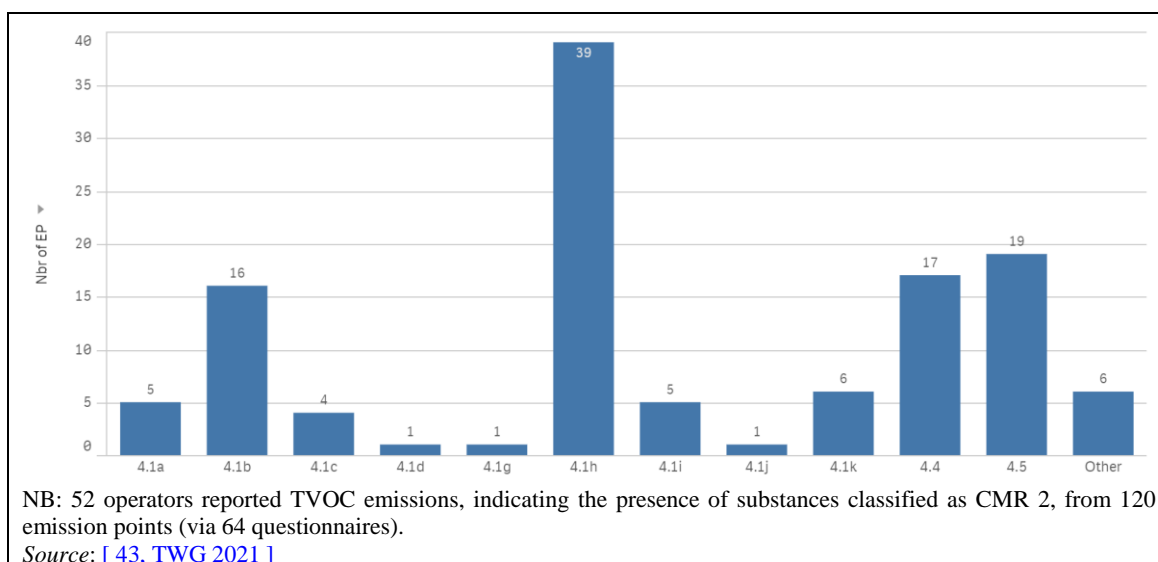
Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.6	0.2
50 <sup>th</sup>	1.6	1.0
80 <sup>th</sup>	3.3	3.0

NB: The numbers of instances reported for the limits of quantification and detection are 137 and 152, respectively.  
Source: [43, TWG 2021]

### 2.3.2.3 Total volatile organic carbon (TVOC) containing substances classified as CMR 2

#### 2.3.2.3.1 Sectors

TVOC containing substances classified as CMR 2 is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.17.



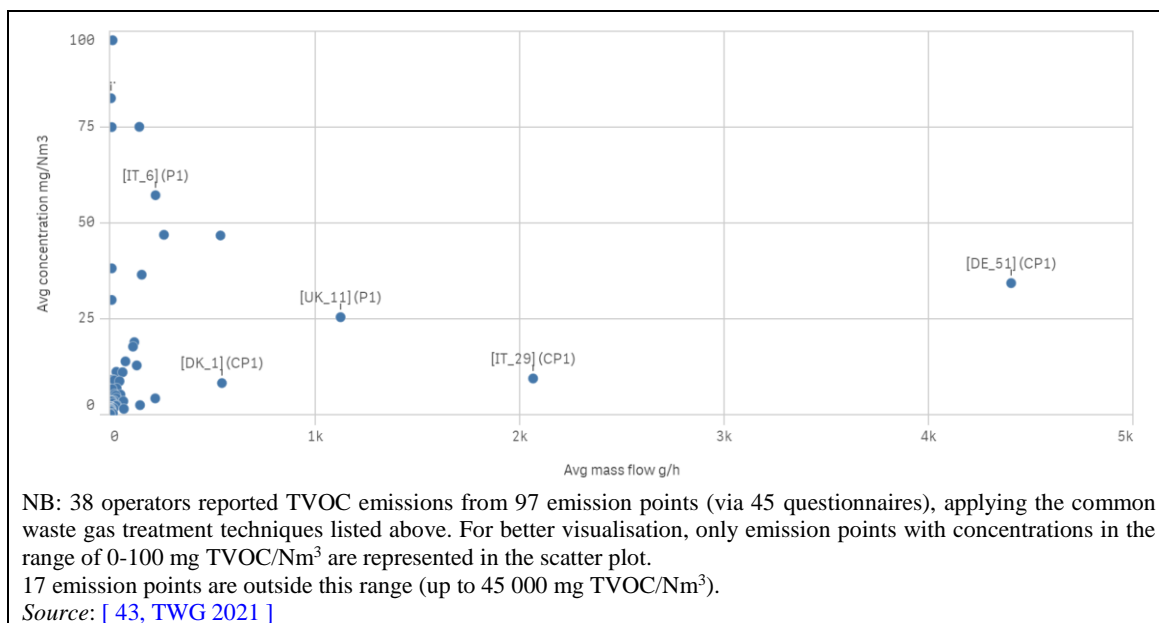
**Figure 2.17: Number of emission points for TVOC containing substances classified as CMR 2 by IED category**

#### 2.3.2.3.2 Emissions

TVOC containing substances classified as CMR 2 is generally treated with at least one waste gas treatment technique. The typical emission levels of TVOC containing substances classified as CMR 2 after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.18.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

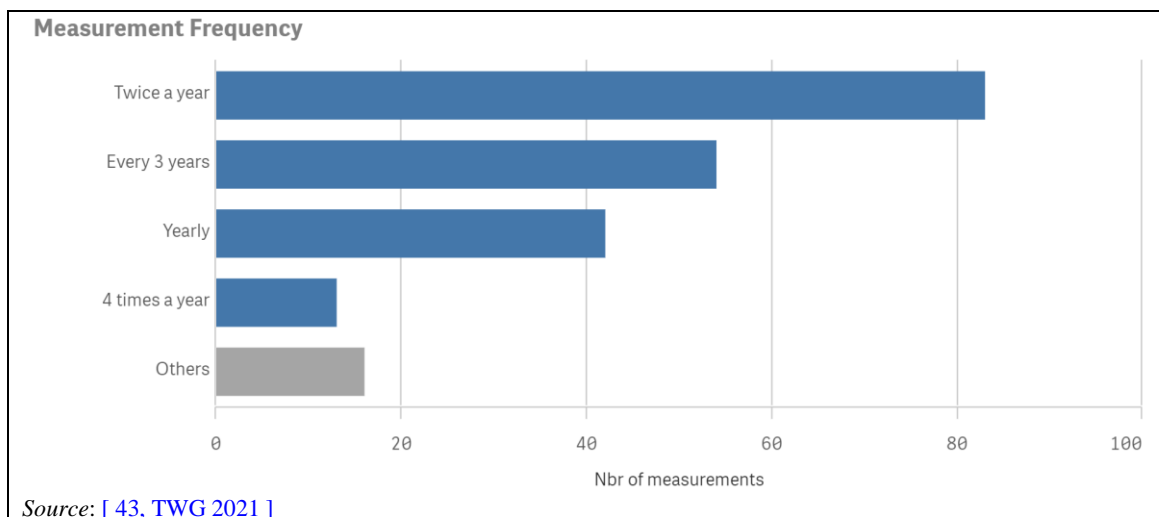
- absorption;
- adsorption;
- bioprocess;
- condensation;
- thermal or catalytic oxidation.



**Figure 2.18: Emissions of TVOC containing substances classified as CMR 2 after waste gas treatment**

### 2.3.2.3.3 Monitoring

Periodic monitoring is more common than continuous monitoring: 254 instances of periodic monitoring and 24 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled emissions of TVOC containing substances classified as CMR 2 are shown in the bar chart of Figure 2.19.



**Figure 2.19: Reported measurement frequencies for periodic monitoring of TVOC containing substances classified as CMR 2**

Percentiles for reported limits of quantification and limits of detection for TVOC containing substances classified as CMR 2 are shown in Table 2.5.

**Table 2.5: Reported limits of quantification and detection for TVOC containing substances classified as CMR 2**

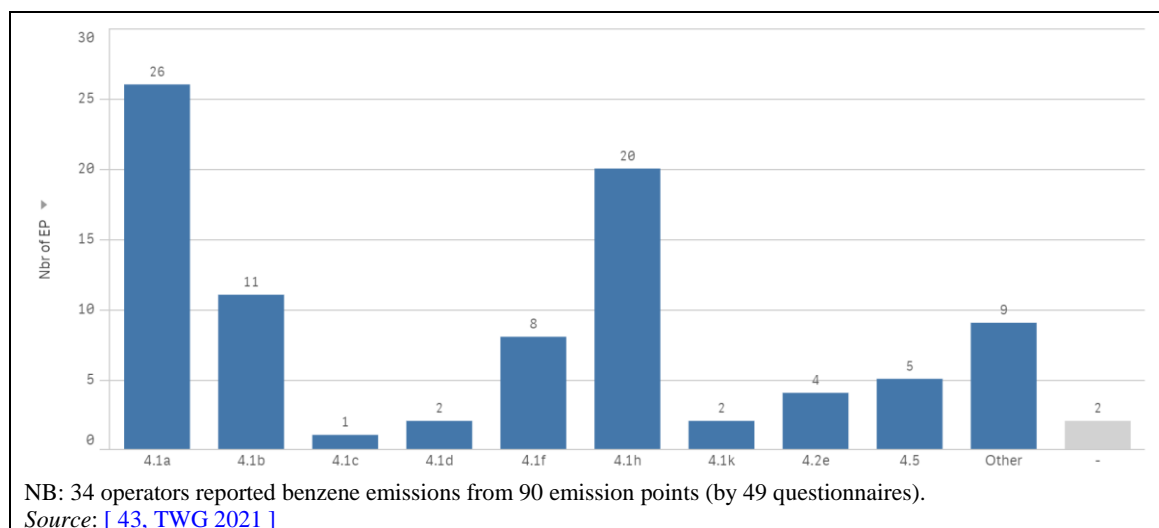
Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.3	0.2
50 <sup>th</sup>	0.7	0.3
80 <sup>th</sup>	1.0	1.0

NB: The numbers of instances reported for the limits of quantification and detection are 70 and 93, respectively.  
Source: [43, TWG 2021]

### 2.3.2.4 Benzene

#### 2.3.2.4.1 Sectors

Benzene is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.20.



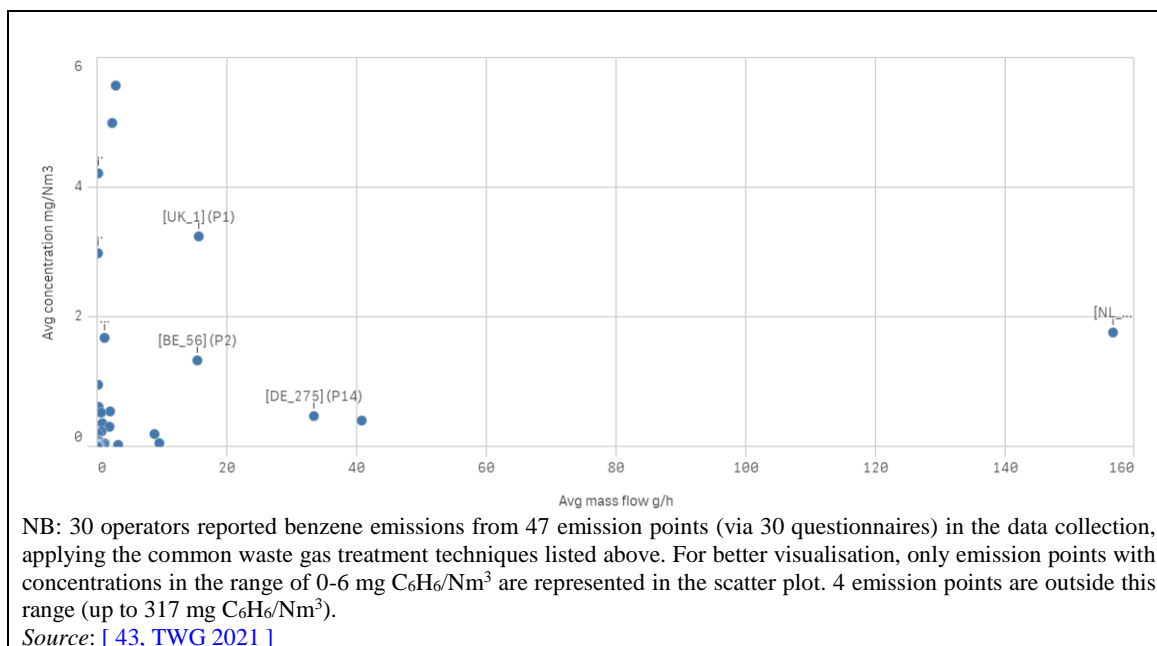
**Figure 2.20: Number of emission points for benzene by IED category**

#### 2.3.2.4.2 Treated emissions

Benzene is generally treated with at least one waste gas treatment technique. The typical emission levels of benzene after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.21.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

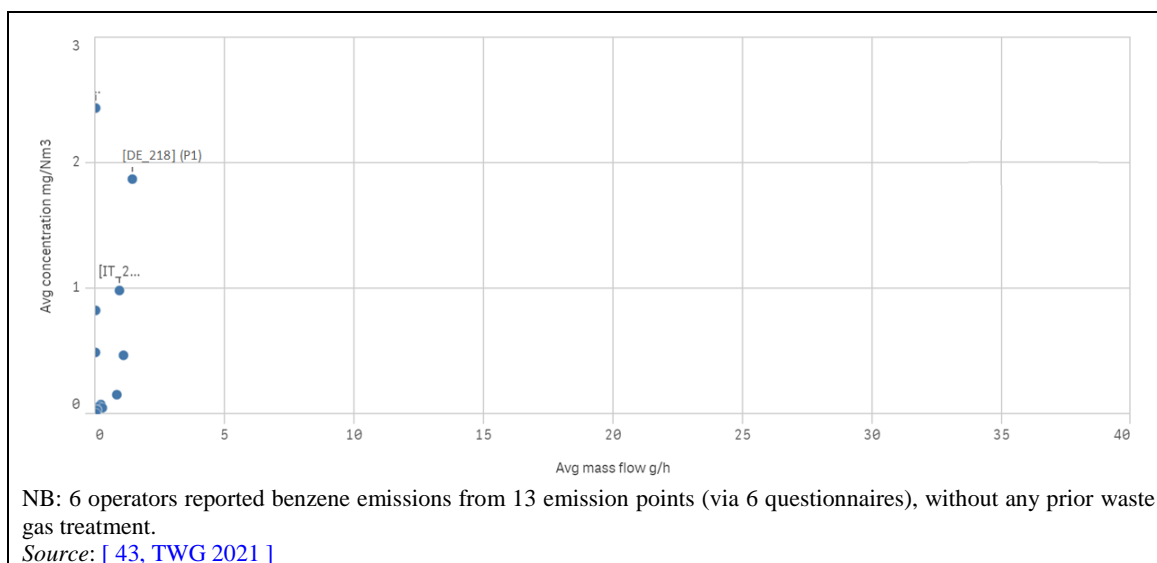
- absorption;
- adsorption;
- bioprocess;
- condensation;
- thermal or catalytic oxidation.



**Figure 2.21: Benzene emissions after waste gas treatment**

### 2.3.2.4.3 Untreated emissions

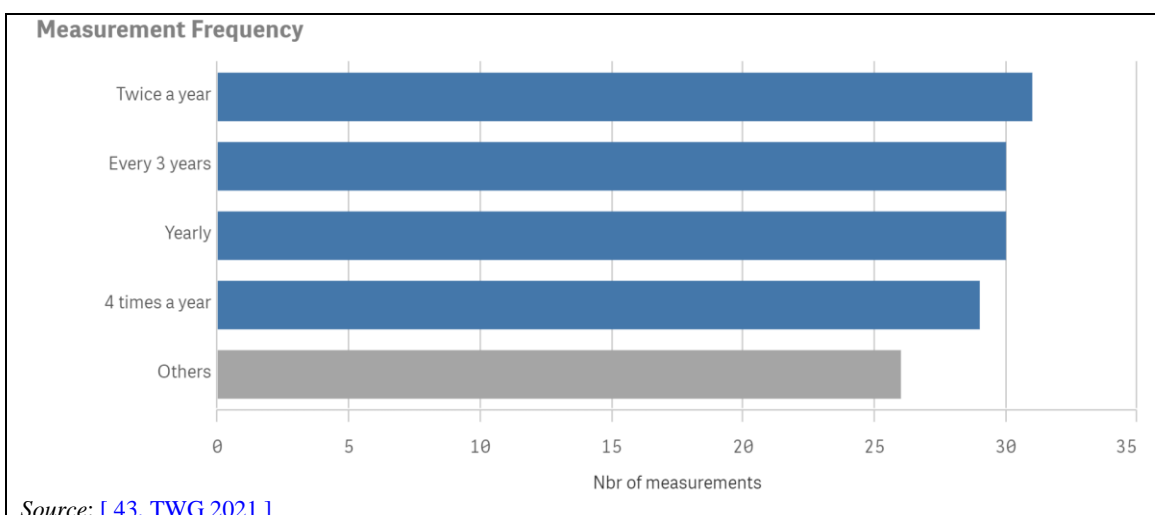
The typical emission levels of benzene when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.22.



**Figure 2.22: Benzene emission points with no waste gas treatment technique**

### 2.3.2.4.4 Monitoring

Periodic monitoring is more common than continuous monitoring: 173 instances of periodic monitoring and 3 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled benzene emissions are shown in the bar chart of Figure 2.23.



**Figure 2.23: Reported measurement frequencies for periodic benzene monitoring**

Percentiles for reported limits of quantification and limits of detection for benzene measurements are shown in Table 2.6.

**Table 2.6: Reported limits of quantification and detection for benzene**

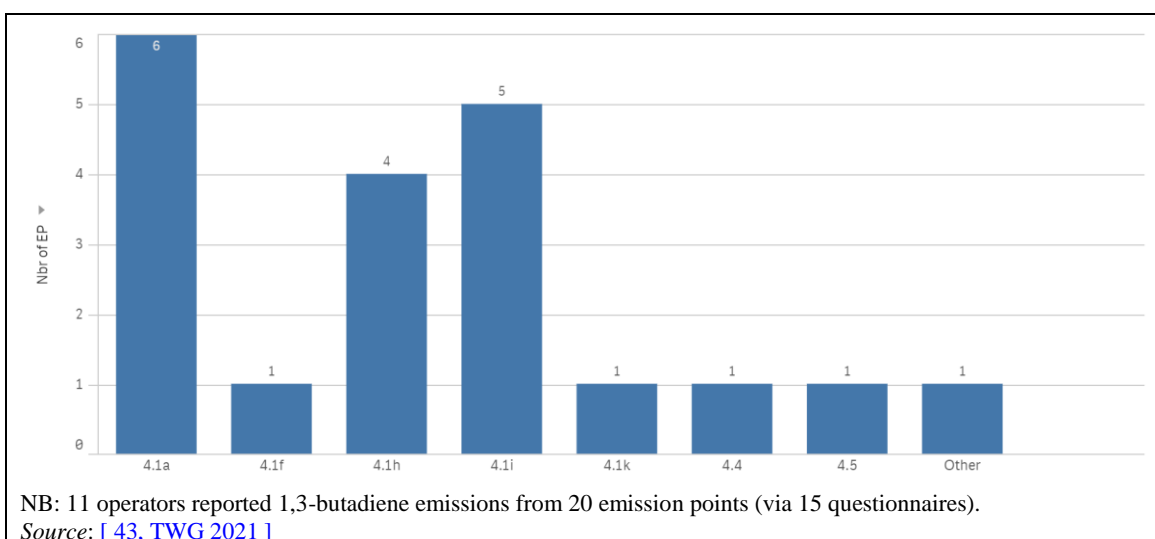
Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.01	0.03
50 <sup>th</sup>	0.05	0.05
80 <sup>th</sup>	0.50	0.16

NB: The numbers of instances reported for the limits of quantification and detection are 92 and 73, respectively.  
Source: [43, TWG 2021]

### 2.3.2.5 1,3-Butadiene

#### 2.3.2.5.1 Sectors

1,3-Butadiene is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.24.



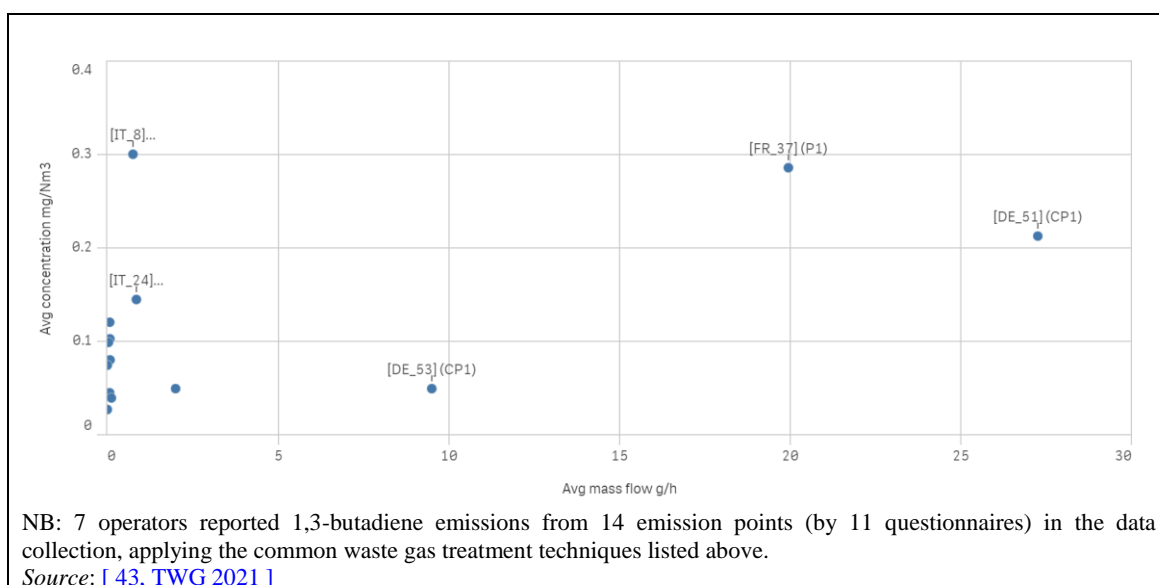
**Figure 2.24: Number of emission of points for 1,3-butadiene by IED category**

2.3.2.5.2 Treated emissions

1,3-Butadiene is generally treated with at least one waste gas treatment technique. The typical emission levels of 1,3-butadiene after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.25.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

- absorption;
- adsorption;
- bioprocess;
- condensation;
- thermal or catalytic oxidation.



NB: 7 operators reported 1,3-butadiene emissions from 14 emission points (by 11 questionnaires) in the data collection, applying the common waste gas treatment techniques listed above.

Source: [43, TWG 2021]

Figure 2.25: 1,3-Butadiene emissions after waste gas treatment



### 2.3.2.5.3 Untreated emissions

The typical emission levels of 1,3-butadiene when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.26.

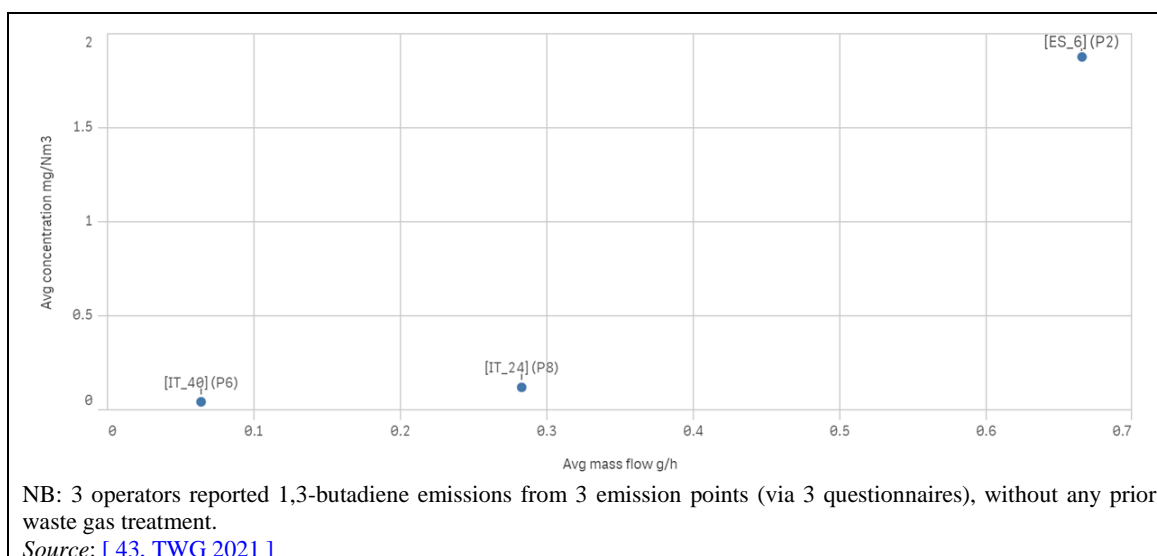


Figure 2.26: 1,3-Butadiene emission points with no waste gas treatment technique

### 2.3.2.5.4 Monitoring

Only periodic monitoring was reported (45 instances). Typical frequencies for the monitoring of channelled 1,3-butadiene emissions are shown in the bar chart of Figure 2.27.

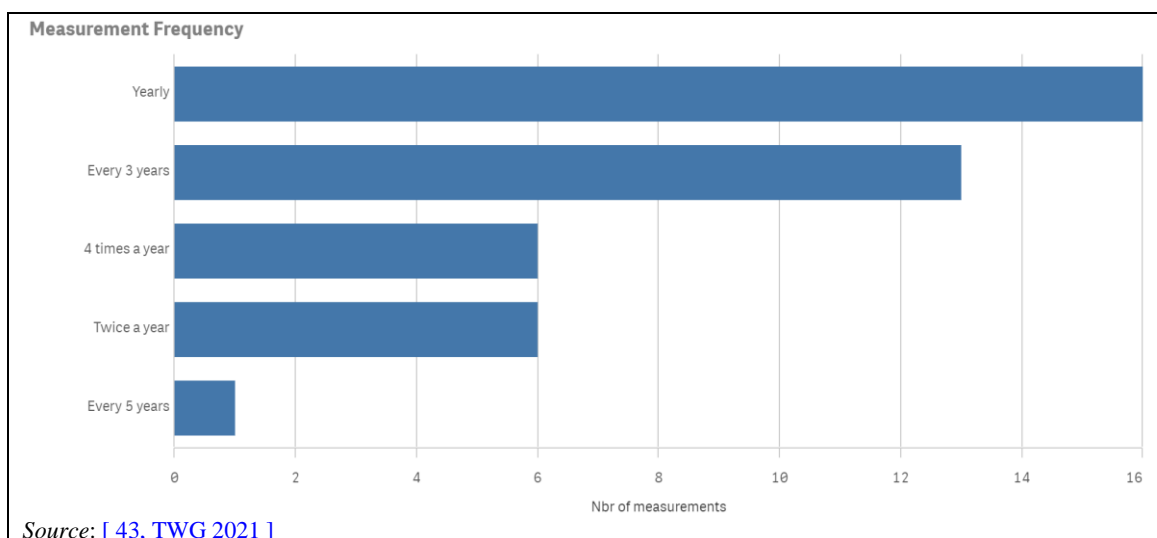


Figure 2.27: Reported measurement frequencies for periodic 1,3-butadiene monitoring

Percentiles for reported limits of quantification and limits of detection for 1,3-butadiene measurements are shown in Table 2.7.

**Table 2.7: Reported limits of quantification and detection for 1,3-butadiene**

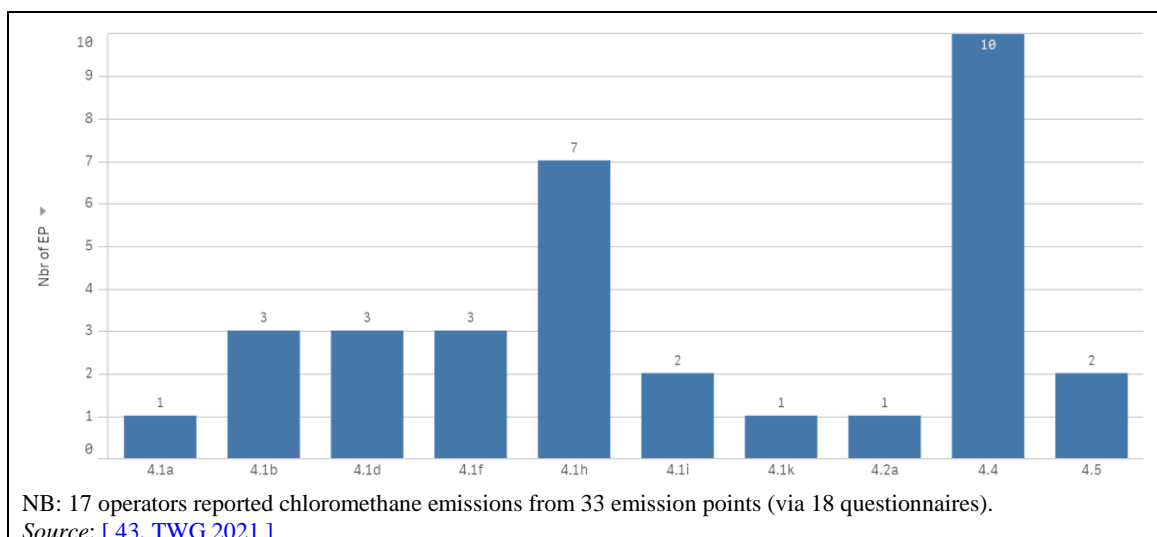
Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.05	0.05
50 <sup>th</sup>	0.07	0.06
80 <sup>th</sup>	0.50	0.10

NB: The numbers of instances reported for the limits of quantification and detection are 19 and 26, respectively.  
 Source: [43, TWG 2021]

### 2.3.2.6 Chloromethane

#### 2.3.2.6.1 Sectors

Chloromethane is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.28.



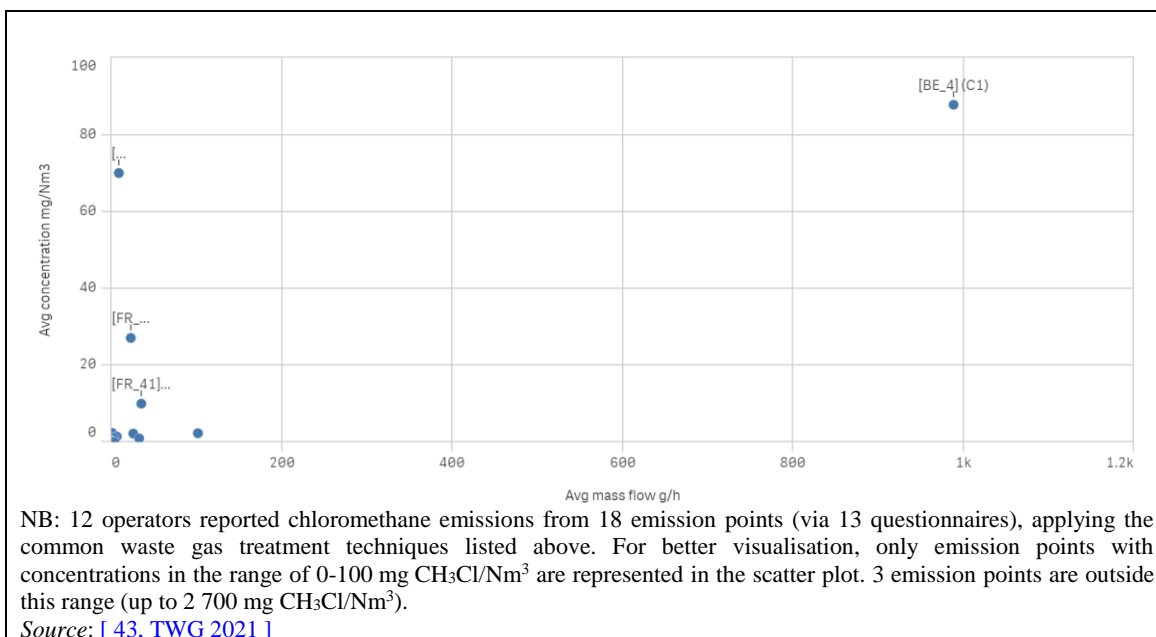
**Figure 2.28: Number of emission points for chloromethane by IED category**

#### 2.3.2.6.2 Treated emissions

Chloromethane is generally treated with at least one waste gas treatment technique. The typical emission levels of chloromethane after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.29.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

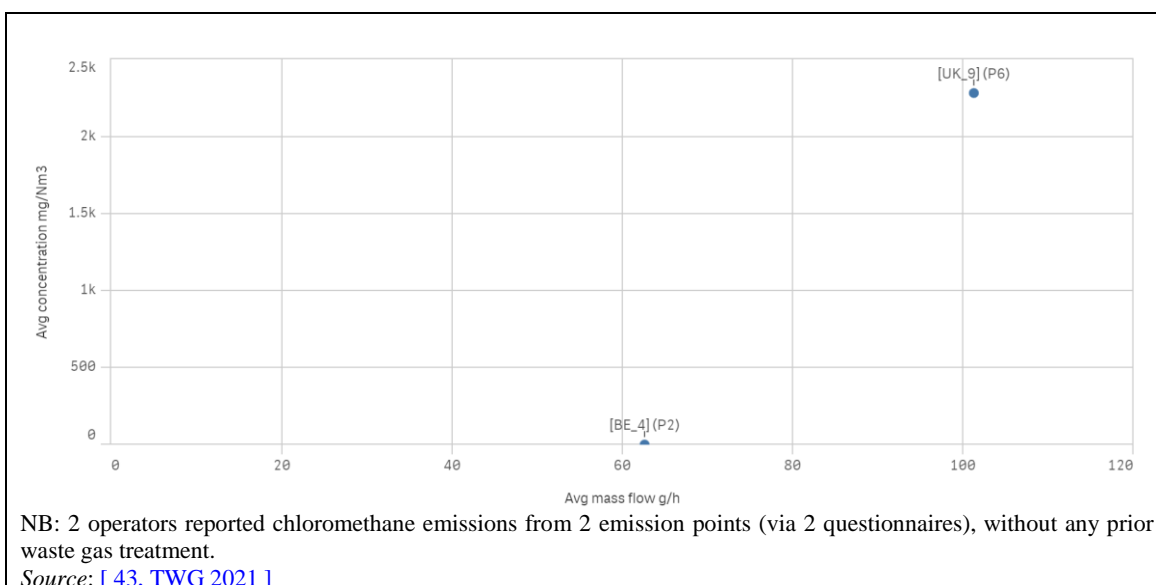
- absorption;
- adsorption;
- bioprocess;
- condensation;
- thermal or catalytic oxidation.



**Figure 2.29: Chloromethane emissions after waste gas treatment**

### 2.3.2.6.3 Untreated emissions

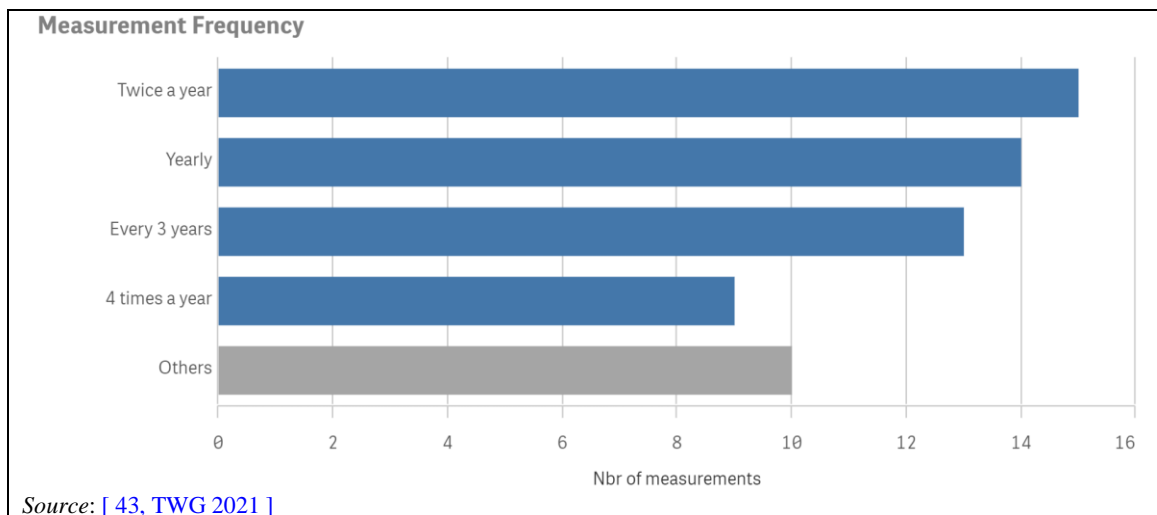
The typical emission levels of chloromethane when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.30.



**Figure 2.30: Chloromethane emission points with no waste gas treatment technique**

## 2.3.2.6.4 Monitoring

Periodic monitoring is more common than continuous monitoring: 66 instances of periodic monitoring and 3 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled chloromethane emissions are shown in the bar chart of Figure 2.31.



**Figure 2.31: Reported measurement frequencies for periodic chloromethane monitoring**

Percentiles for reported limits of quantification and limits of detection for chloromethane measurements are shown in Table 2.8.

**Table 2.8: Reported limits of quantification and detection for chloromethane**

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.1	0.04
50 <sup>th</sup>	10.0	2.2
80 <sup>th</sup>	45.0	15.0

NB: The numbers of instances reported for the limits of quantification and detection are 29 and 28, respectively.  
Source: [43, TWG 2021]

### 2.3.2.7 Dichloromethane

#### 2.3.2.7.1 Sectors

Dichloromethane is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.32.

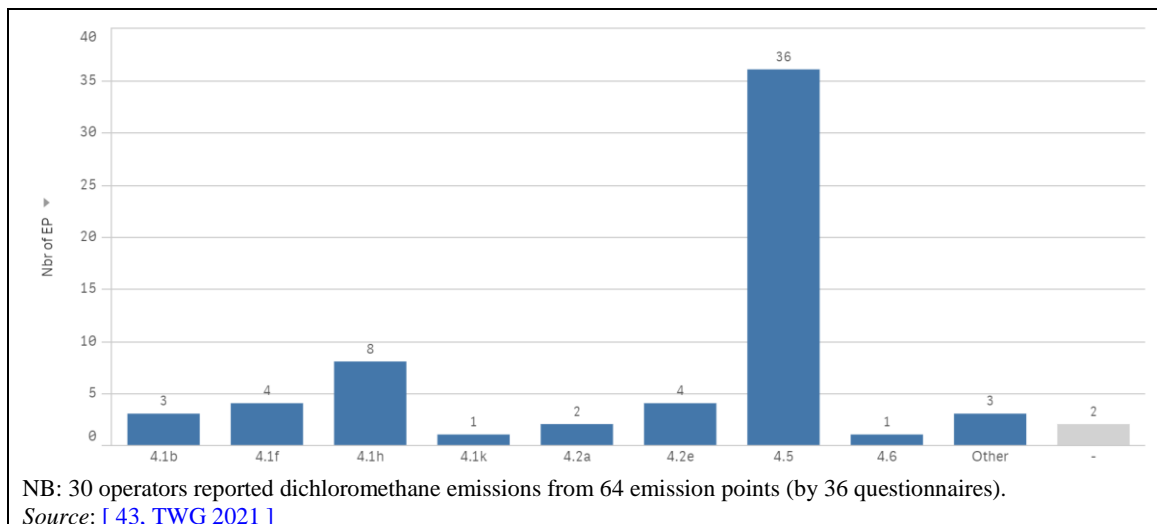


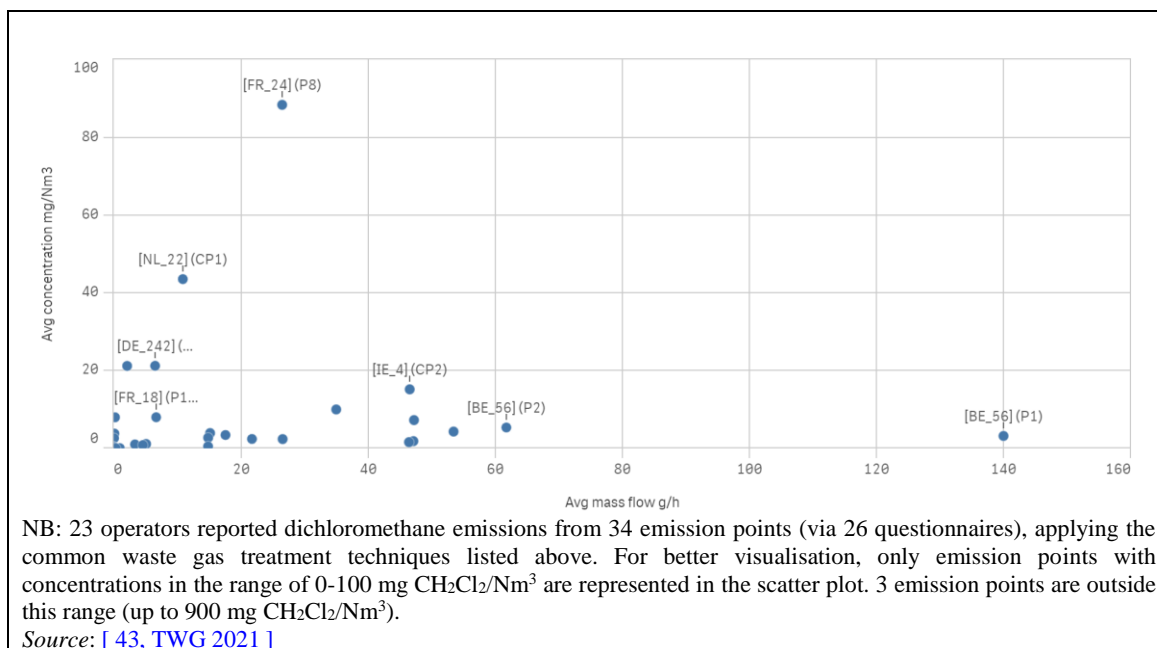
Figure 2.32: Number of emission points for dichloromethane by IED category

#### 2.3.2.7.2 Treated emissions

Dichloromethane is generally treated with at least one waste gas treatment technique. The typical emission levels of dichloromethane after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.33.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

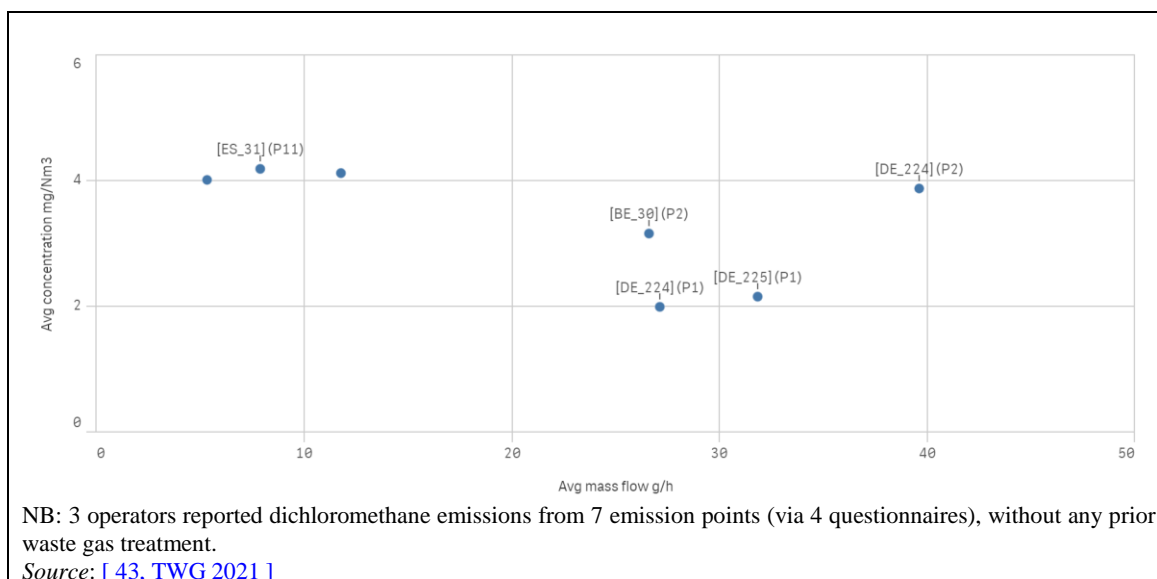
- absorption;
- adsorption;
- condensation;
- thermal or catalytic oxidation.



**Figure 2.33: Dichloromethane emissions after waste gas treatment**

### 2.3.2.7.3 Untreated emissions

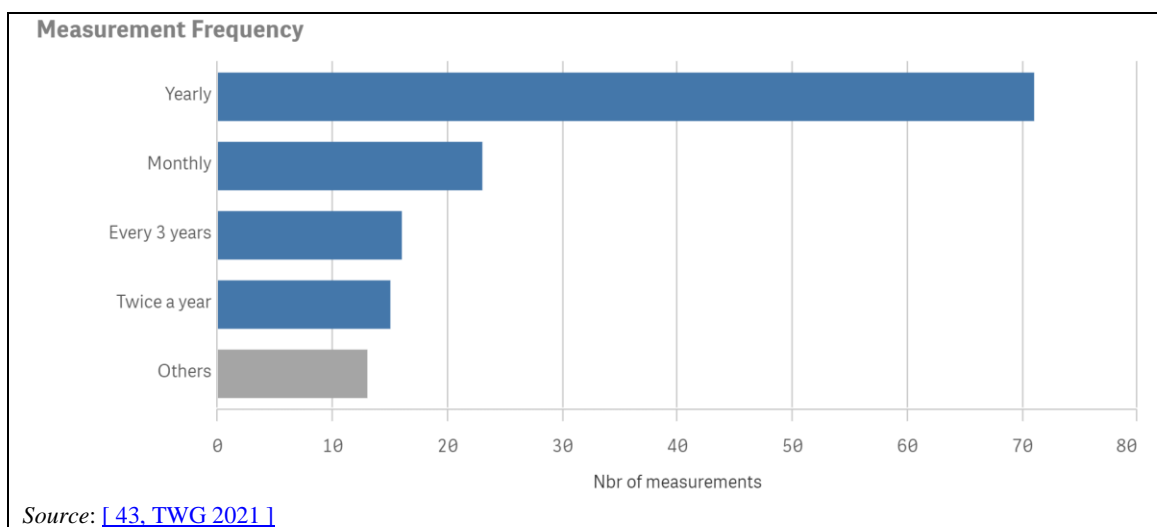
The typical emission levels of dichloromethane when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.34.



**Figure 2.34: Dichloromethane emission points with no waste gas treatment technique**

### 2.3.2.7.4 Monitoring

Only periodic monitoring was reported (143 instances). Typical frequencies for the monitoring of channelled dichloromethane emissions are shown in the bar chart of Figure 2.35.



**Figure 2.35: Reported measurement frequencies for periodic dichloromethane monitoring**

Percentiles for reported limits of quantification and limits of detection for dichloromethane measurements are shown in Table 2.9.

**Table 2.9: Reported limits of quantification and detection for dichloromethane**

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.05	0.02
50 <sup>th</sup>	1.0	0.1
80 <sup>th</sup>	2.0	0.2

NB: The numbers of instances reported for the limits of quantification and detection are 50 and 26, respectively.

Source: [43, TWG 2021]

### 2.3.2.8 Ethylene dichloride

#### 2.3.2.8.1 Sectors

Ethylene dichloride is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.36.

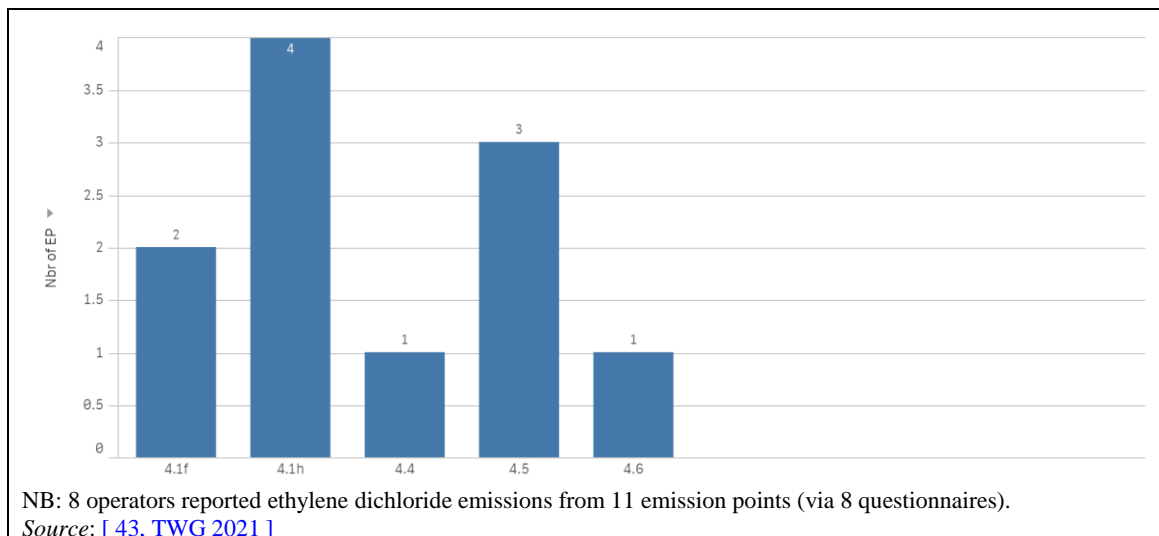


Figure 2.36: Number of emission points for ethylene dichloride by IED category

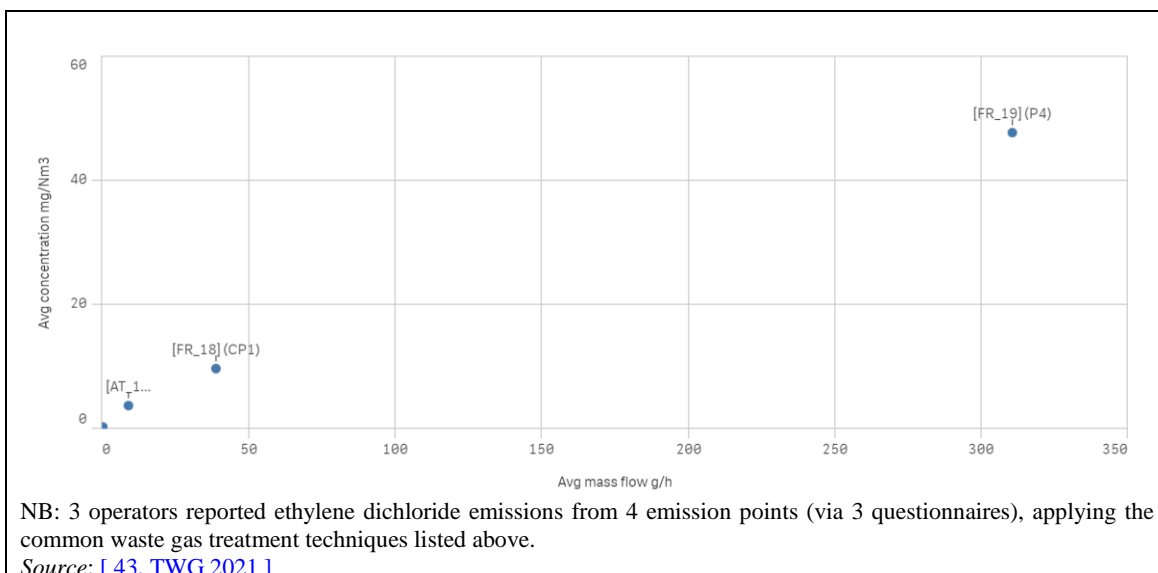
#### 2.3.2.8.2 Treated emissions

Ethylene dichloride is generally treated with at least one waste gas treatment technique. The typical emission levels of ethylene dichloride after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.37.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

- adsorption;
- condensation;
- thermal or catalytic oxidation.

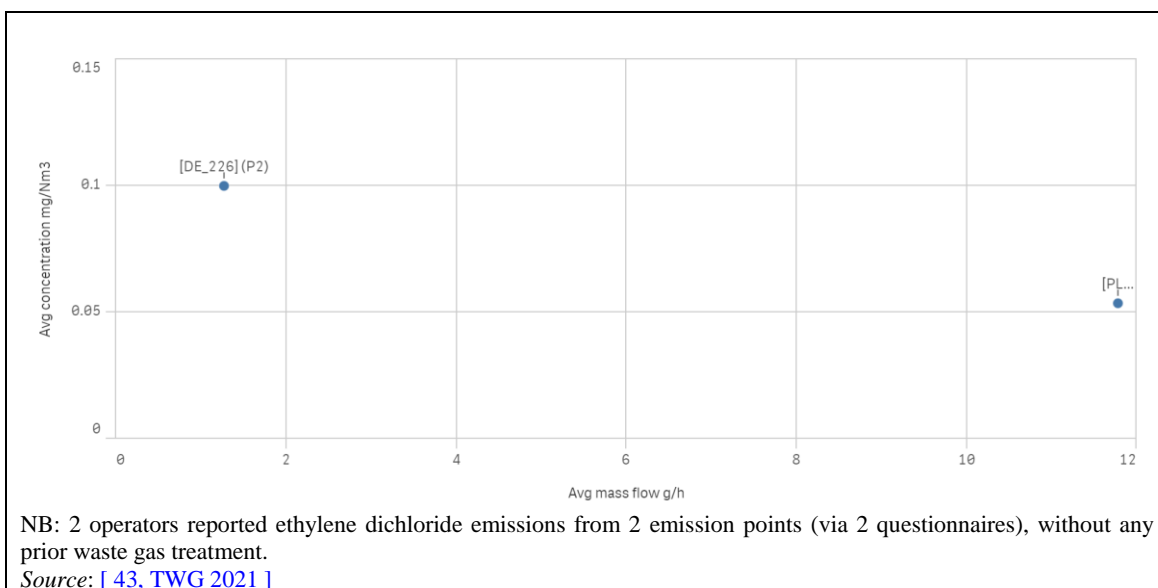




**Figure 2.37: Ethylene dichloride emissions after waste gas treatment**

### 2.3.2.8.3 Untreated emissions

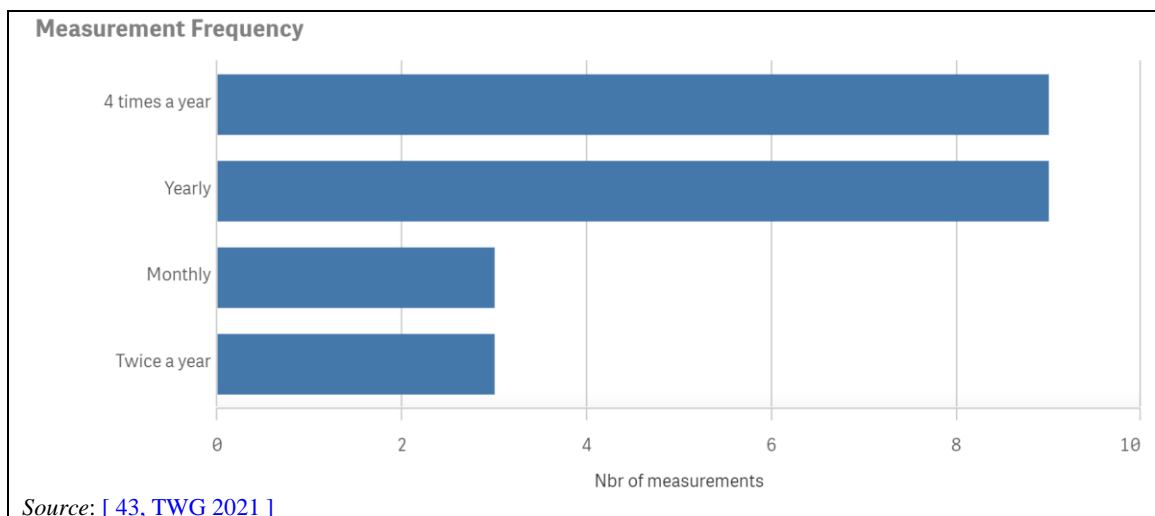
The typical emission levels of ethylene dichloride when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.38.



**Figure 2.38: Ethylene dichloride emission points with no waste gas treatment technique**

## 2.3.2.8.4 Monitoring

Only periodic monitoring was reported (24 instances). Typical frequencies for the monitoring of channelled ethylene dichloride emissions are shown in the bar chart of Figure 2.39.



**Figure 2.39: Reported measurement frequencies for periodic ethylene dichloride monitoring**

Percentiles for reported limits of quantification and limits of detection for ethylene dichloride measurements are shown in Table 2.10.

**Table 2.10: Reported limits of quantification and detection for ethylene dichloride**

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.07	0.02
50 <sup>th</sup>	0.10	0.07
80 <sup>th</sup>	0.83	0.23

NB: The numbers of instances reported for the limits of quantification and detection are 11 and 8, respectively.  
Source: [43, TWG 2021]

### 2.3.2.9 Ethylene oxide

#### 2.3.2.9.1 Sectors

Ethylene oxide is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.40.

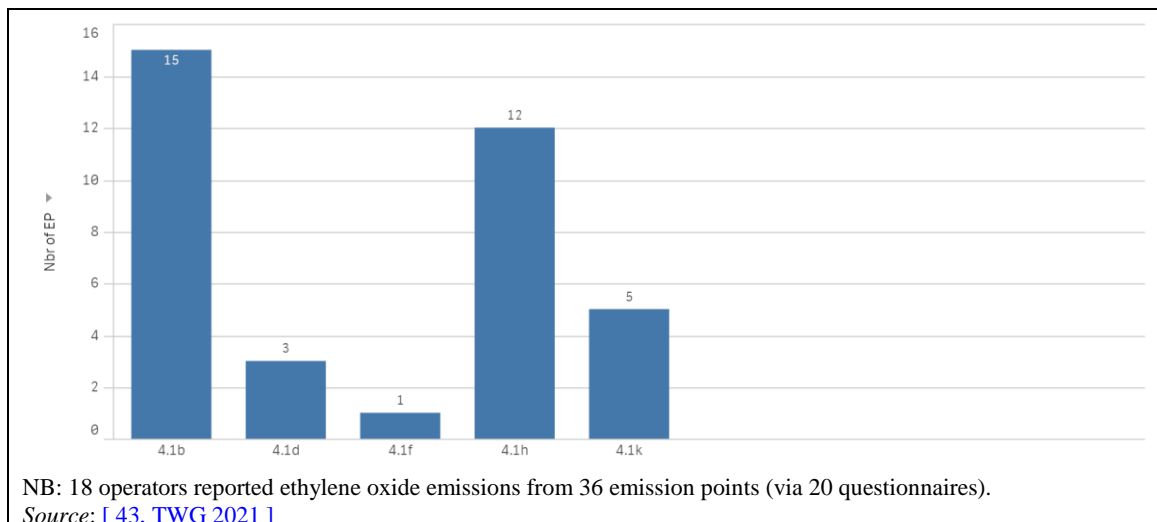


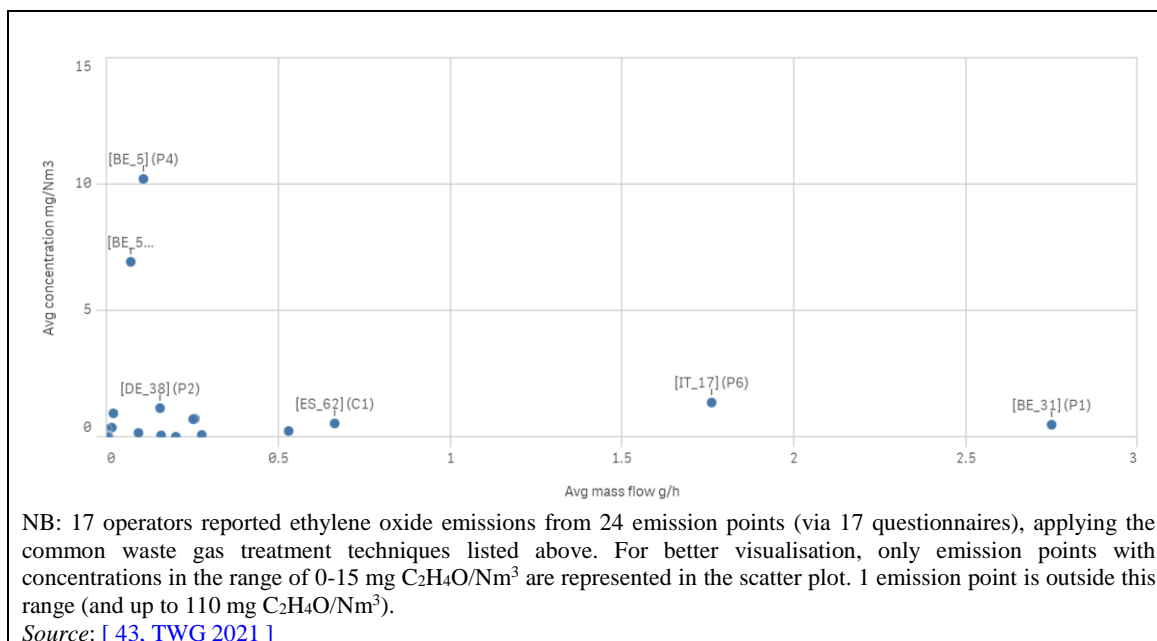
Figure 2.40: Number of emission points for ethylene oxide by IED category

#### 2.3.2.9.2 Treated emissions

Ethylene oxide is generally treated with at least one waste gas treatment technique. The typical emission levels of ethylene oxide after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.41.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

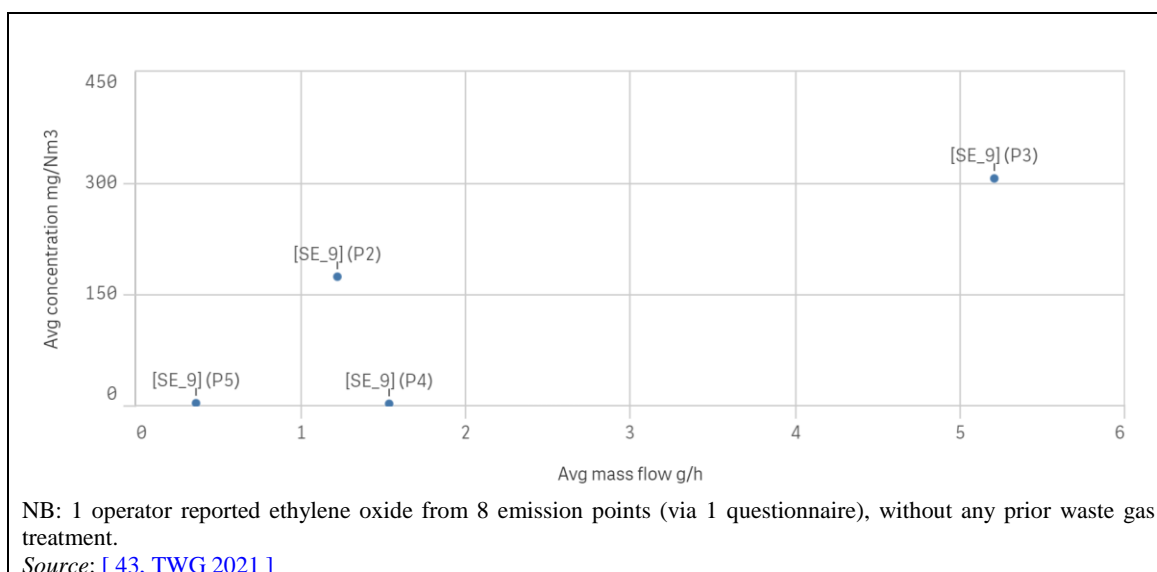
- absorption;
- condensation;
- thermal or catalytic oxidation.



**Figure 2.41: Ethylene oxide emissions after waste gas treatment**

### 2.3.2.9.3 Untreated emissions

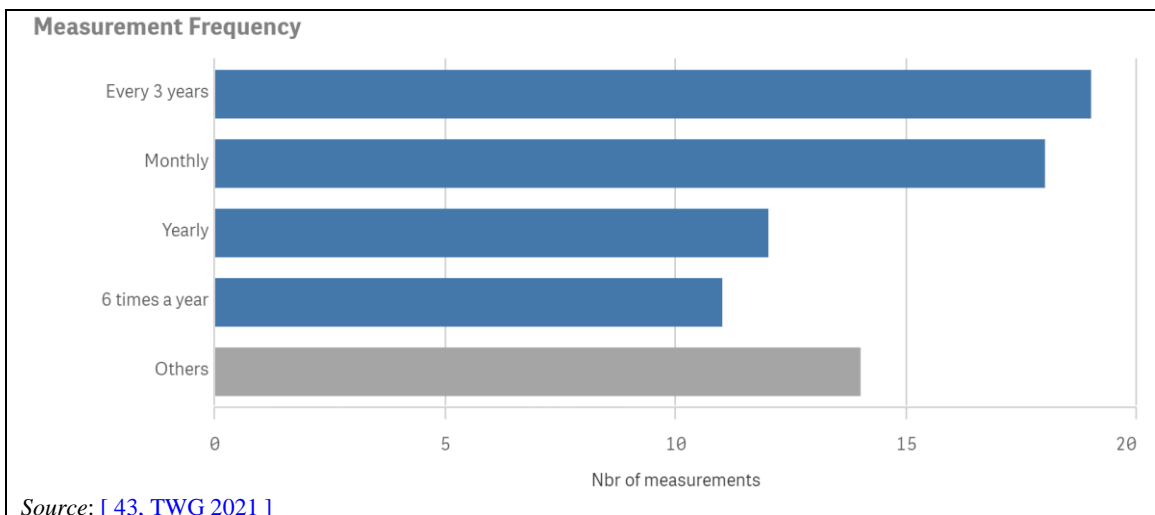
The typical emission levels of ethylene oxide when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.42.



**Figure 2.42: Ethylene oxide emission points with no waste gas treatment technique**

### 2.3.2.9.4 Monitoring

Periodic monitoring is more common than continuous monitoring: 79 instances of periodic monitoring and 3 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled ethylene oxide emissions are shown in the bar chart of Figure 2.43.



**Figure 2.43: Reported measurement frequencies for periodic ethylene oxide monitoring**

Percentiles for reported limits of quantification and limits of detection for ethylene oxide measurements are shown in Table 2.11.

**Table 2.11: Reported limits of quantification and detection for ethylene oxide**

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.02	0.02
50 <sup>th</sup>	0.08	0.10
80 <sup>th</sup>	0.50	0.35

NB: The numbers of instances reported for the limits of quantification and detection are 10 and 19, respectively.  
Source: [43, TWG 2021]

### 2.3.2.10 Formaldehyde

#### 2.3.2.10.1 Sectors

Formaldehyde is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.44.

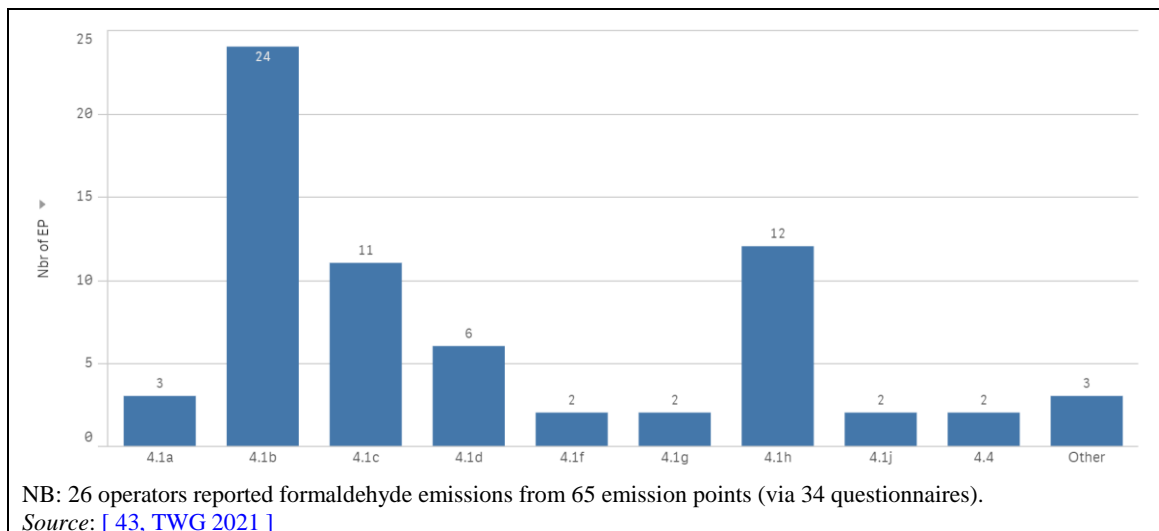


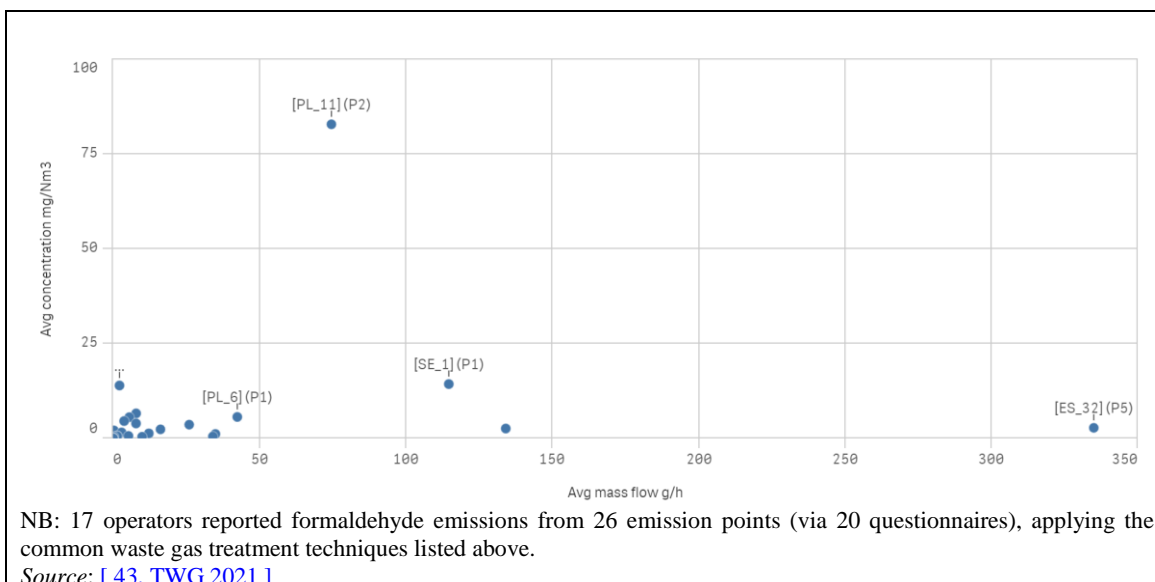
Figure 2.44: Number of emission points for formaldehyde by IED category

#### 2.3.2.10.2 Treated emissions

Formaldehyde is generally treated with at least one waste gas treatment technique. The typical emission levels of formaldehyde after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.45.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

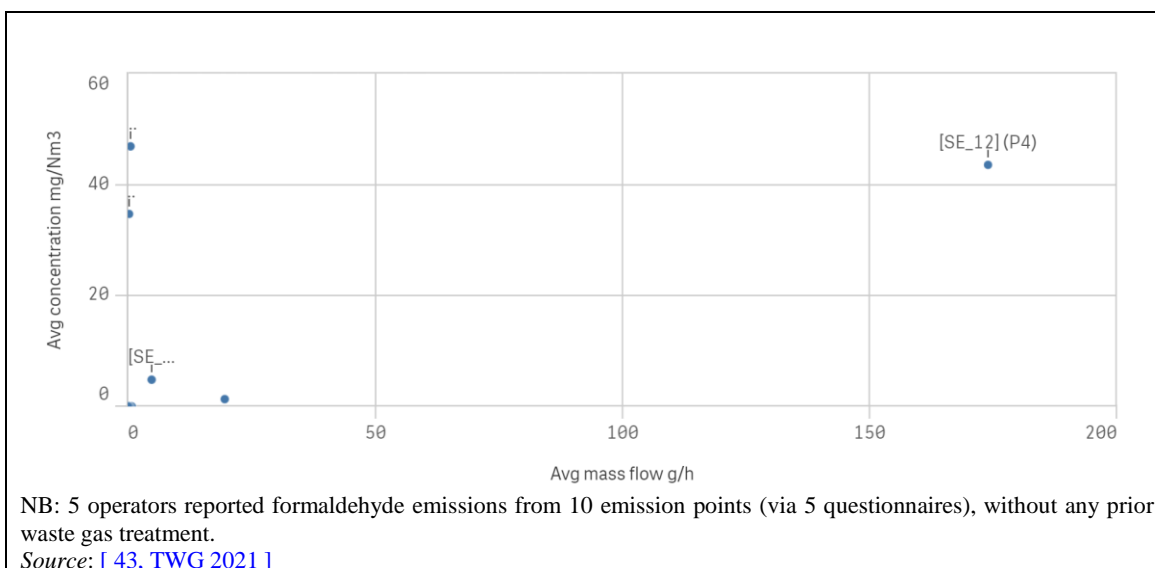
- absorption;
- adsorption;
- bioprocess;
- condensation;
- thermal or catalytic oxidation.



**Figure 2.45: Formaldehyde emissions after waste gas treatment**

### 2.3.2.10.3 Untreated emissions

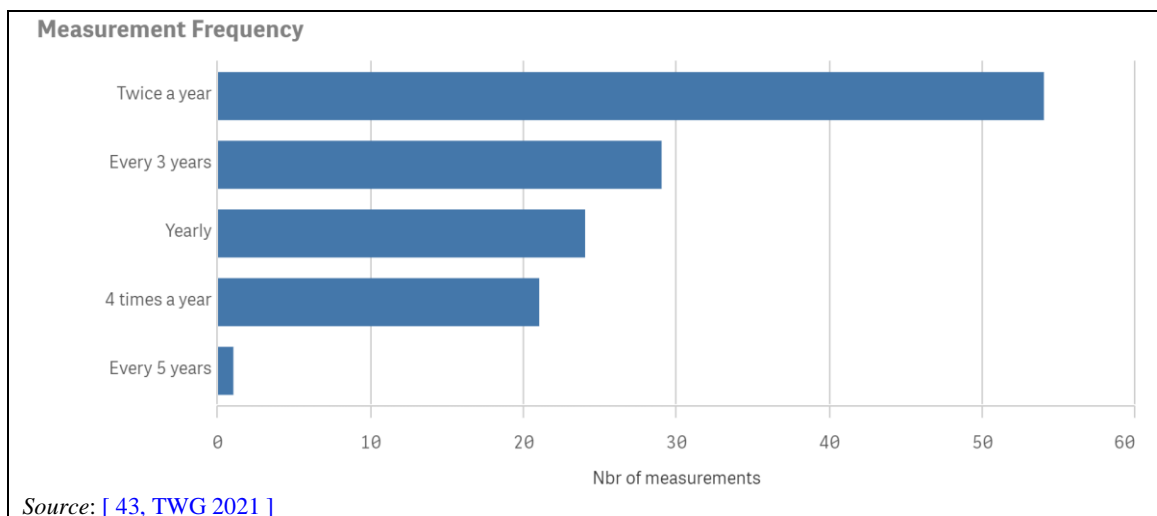
The typical emission levels of formaldehyde when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.46.



**Figure 2.46: Formaldehyde emission points with no waste gas treatment technique**

## 2.3.2.10.4 Monitoring

Only periodic monitoring was reported (119 instances). Typical frequencies for the monitoring of channelled formaldehyde emissions are shown in the bar chart of Figure 2.47.



**Figure 2.47: Reported measurement frequencies for periodic formaldehyde monitoring**

Percentiles for reported limits of quantification and limits of detection for formaldehyde measurements are shown in Table 2.12.

**Table 2.12: Reported limits of quantification and detection for formaldehyde**

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.04	0.004
50 <sup>th</sup>	0.06	0.025
80 <sup>th</sup>	1.20	1.50

NB: The numbers of instances reported for the limits of quantification and detection are 36 and 20, respectively.  
Source: [43, TWG 2021]



### 2.3.2.11 PCDD/F

#### 2.3.2.11.1 Sectors

PCDD/F is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.48.

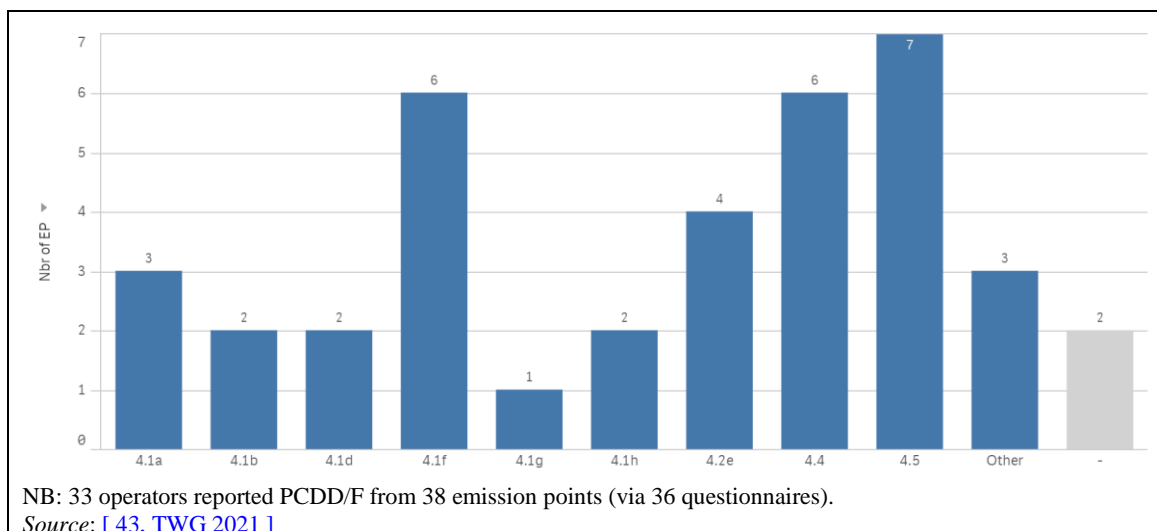


Figure 2.48: Number of emission points for PCDD/F by IED category

#### 2.3.2.11.2 Emissions

Emissions of PCDD/F mainly originate from the use of catalytic or thermal oxidation. The typical emission levels of PCDD/F after catalytic or thermal oxidation are shown as concentration and mass flow in the scatter plot of Figure 2.49.

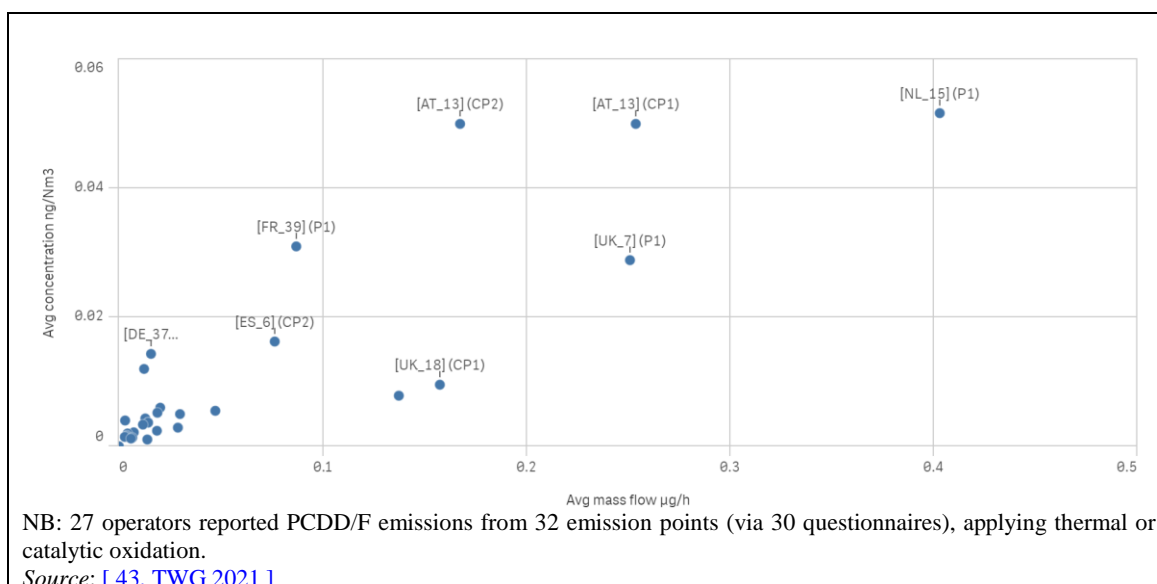


Figure 2.49: PCDD/F emissions after waste gas treatment

2.3.2.11.3 Monitoring

Only periodic monitoring was reported (82 instances). Typical frequencies for the monitoring of channelled PCDD/F emissions are shown in the bar chart of Figure 2.50.

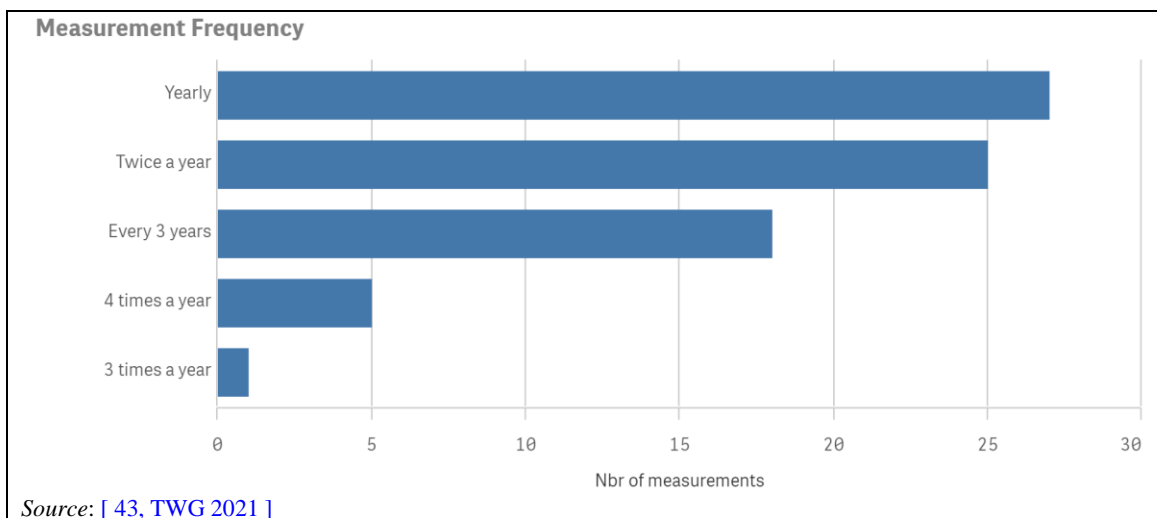


Figure 2.50: Reported measurement frequencies for periodic PCDD/F monitoring

Percentiles for reported limits of quantification and limits of detection for PCDD/F measurements are shown in Table 2.13.

Table 2.13: Reported limits of quantification and detection for PCDD/F

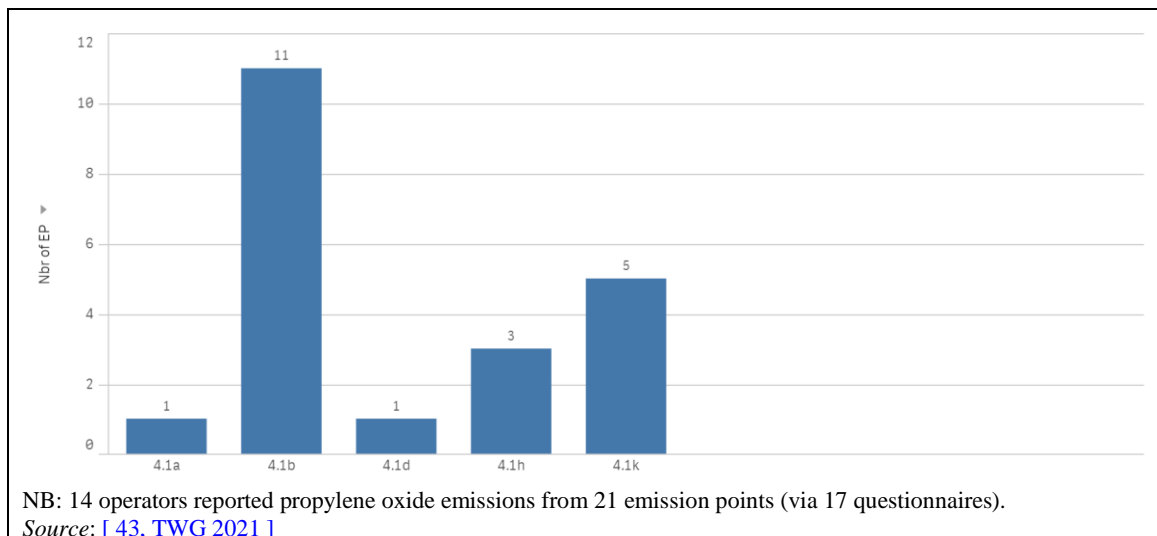
Percentile	Limit of quantification (µg/Nm <sup>3</sup> )	Limit of detection (µg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.00010	1.6 x 10 <sup>-5</sup>
50 <sup>th</sup>	0.00062	0.00056
80 <sup>th</sup>	0.0030	0.0054

NB: The numbers of instances reported for the limits of quantification and detection are 25 and 24, respectively.  
 Source: [43, TWG 2021]

### 2.3.2.12 Propylene oxide

#### 2.3.2.12.1 Sectors

Propylene oxide is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.51.



**Figure 2.51: Number of emission points for propylene oxide by IED category**

#### 2.3.2.12.2 Treated emissions

Propylene oxide is generally treated with at least one waste gas treatment technique. The typical emission levels of propylene oxide after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.52.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

- absorption;
- condensation;
- thermal or catalytic oxidation.

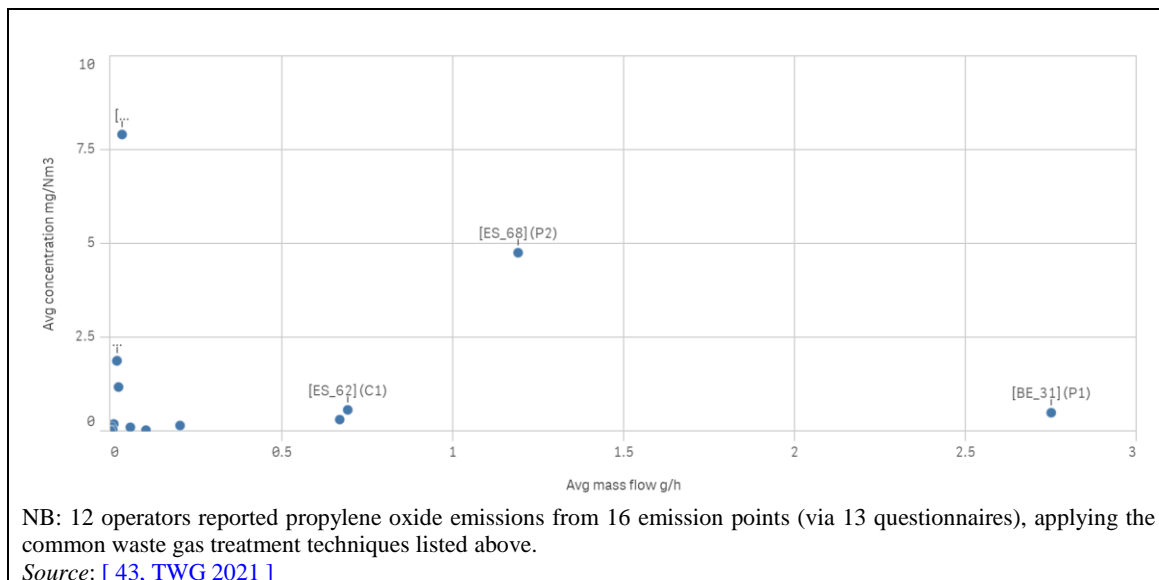


Figure 2.52: Propylene oxide emissions after waste gas treatment

2.3.2.12.3 Untreated emissions

All operators reported at least one waste gas treatment technique for their emissions of propylene oxide.

2.3.2.12.4 Monitoring

Periodic monitoring is more common than continuous monitoring: 43 instances of periodic monitoring and 5 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled propylene oxide emissions are shown in the bar chart of Figure 2.53.

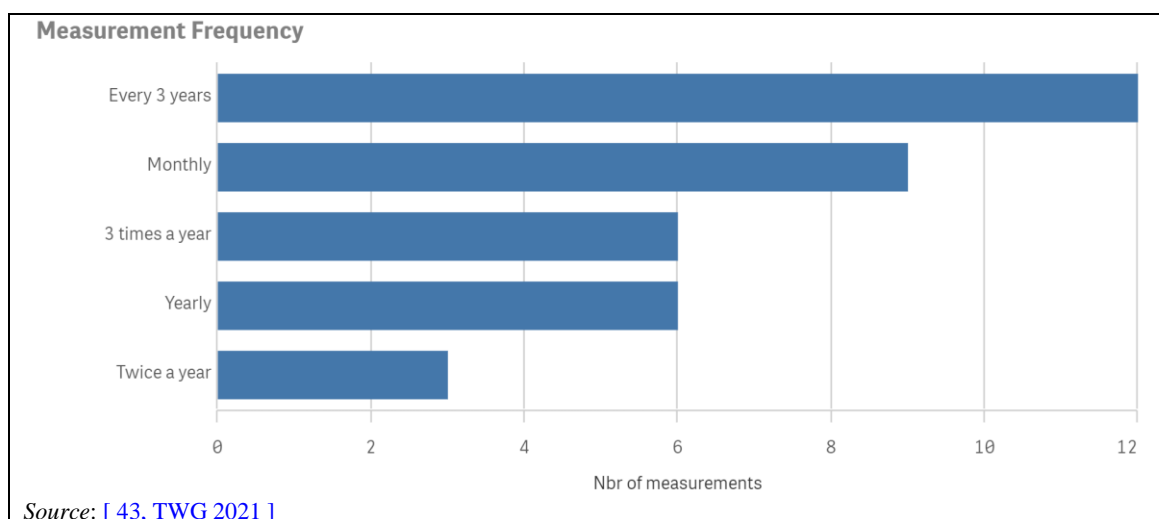


Figure 2.53: Reported measurement frequencies for periodic propylene oxide monitoring

Percentiles for reported limits of quantification and limits of detection for propylene oxide measurements are shown in Table 2.14.

**Table 2.14: Reported limits of quantification and detection for propylene oxide**

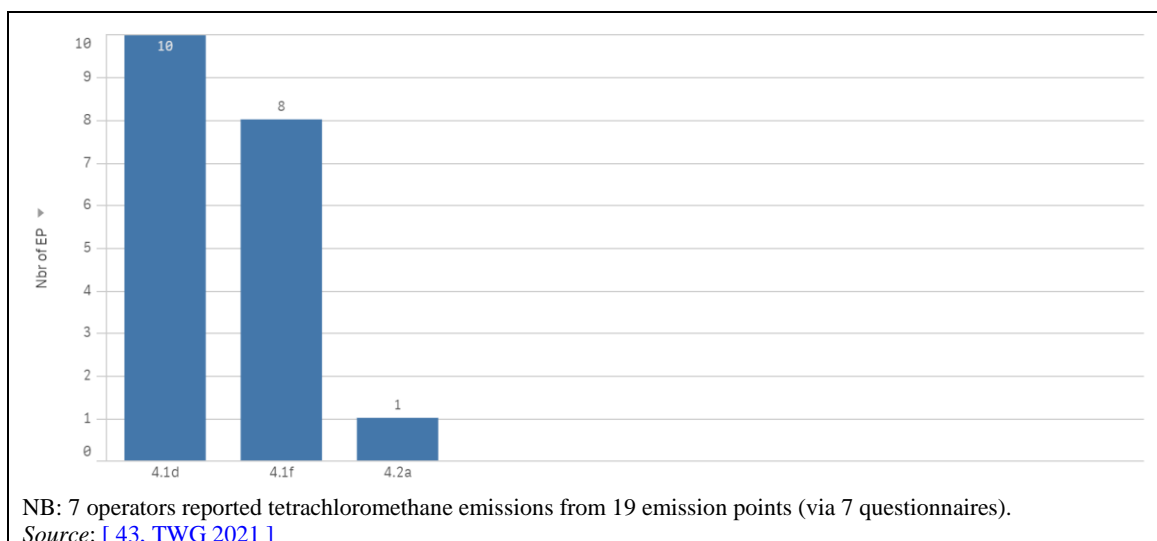
Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.07	0.06
50 <sup>th</sup>	0.40	0.06
80 <sup>th</sup>	0.50	0.20

NB: The numbers of instances reported for the limits of quantification and detection are 9 and 7, respectively.  
Source: [43, TWG 2021]

### 2.3.2.13 Tetrachloromethane

#### 2.3.2.13.1 Sectors

Tetrachloromethane is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.54.



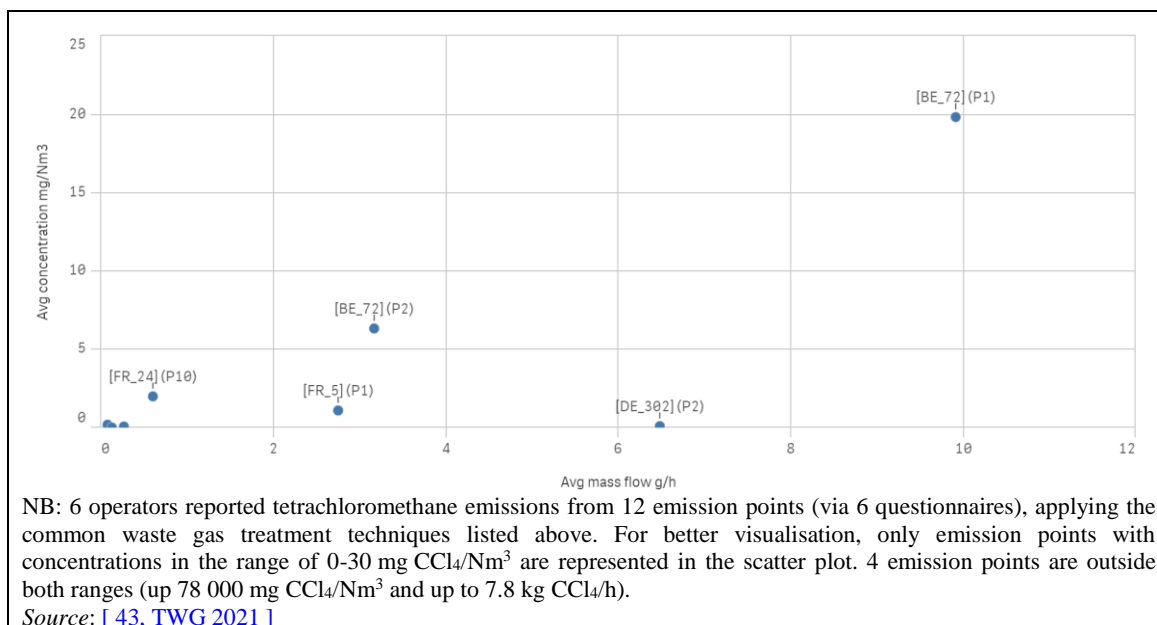
**Figure 2.54: Number of emission points for tetrachloromethane by IED category**

#### 2.3.2.13.2 Treated emissions

Tetrachloromethane is generally treated with at least one waste gas treatment technique. The typical emission levels of tetrachloromethane after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.55.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

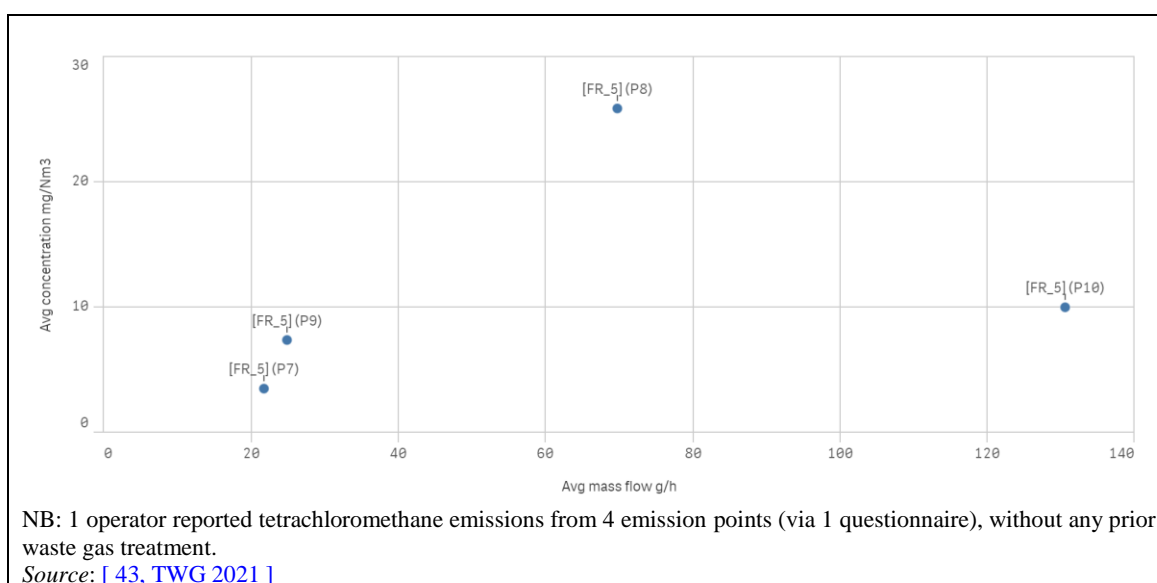
- adsorption;
- bioprocess;
- condensation;
- thermal or catalytic oxidation.



**Figure 2.55: Tetrachloromethane emissions after waste gas treatment**

### 2.3.2.13.3 Untreated emissions

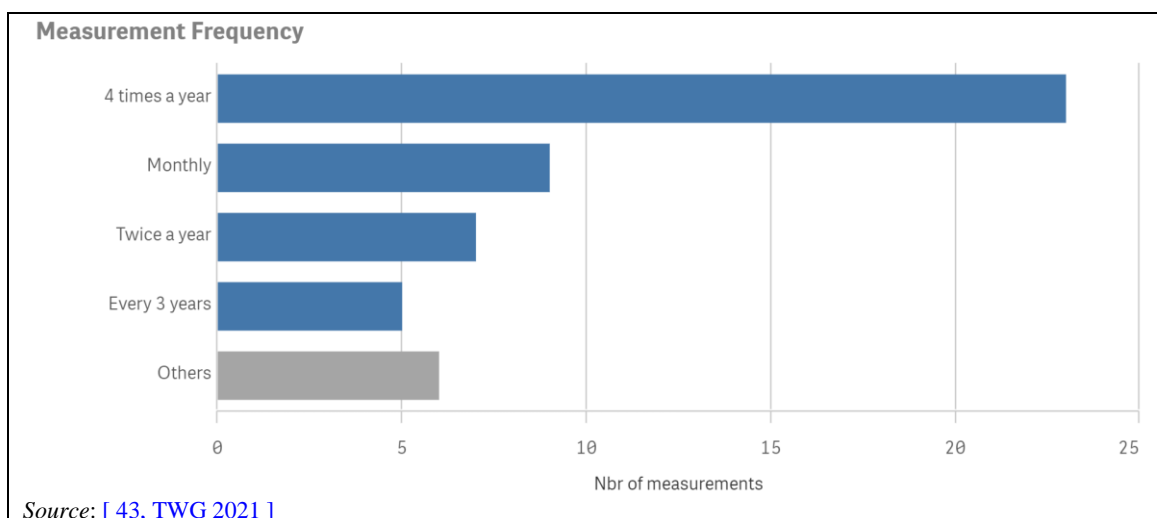
The typical emission levels of tetrachloromethane when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.56.



**Figure 2.56: Tetrachloromethane emission points with no waste gas treatment technique**

### 2.3.2.13.4 Monitoring

Only periodic monitoring was reported (52 instances). Typical frequencies for the monitoring of channelled tetrachloromethane emissions are shown in the bar chart of Figure 2.57.



**Figure 2.57: Reported measurement frequencies for periodic tetrachloromethane monitoring**

Percentiles for reported limits of quantification and limits of detection for tetrachloromethane measurements are shown in Table 2.15.

**Table 2.15: Reported limits of quantification and detection for tetrachloromethane**

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.10	0.01
50 <sup>th</sup>	5.0	0.22
80 <sup>th</sup>	100.0	0.22

NB: The numbers of instances reported for the limits of quantification and detection are 36 and 21, respectively.  
Source: [43, TWG 2021]

### 2.3.2.14 Toluene

#### 2.3.2.14.1 Sectors

Toluene is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.58.

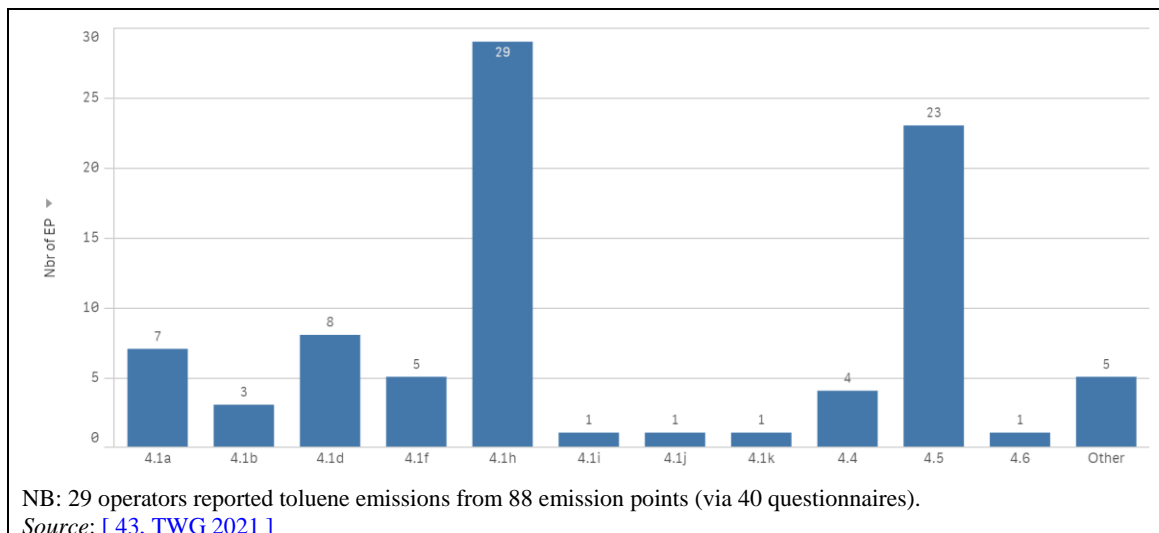


Figure 2.58: Number of emission points for toluene by IED category

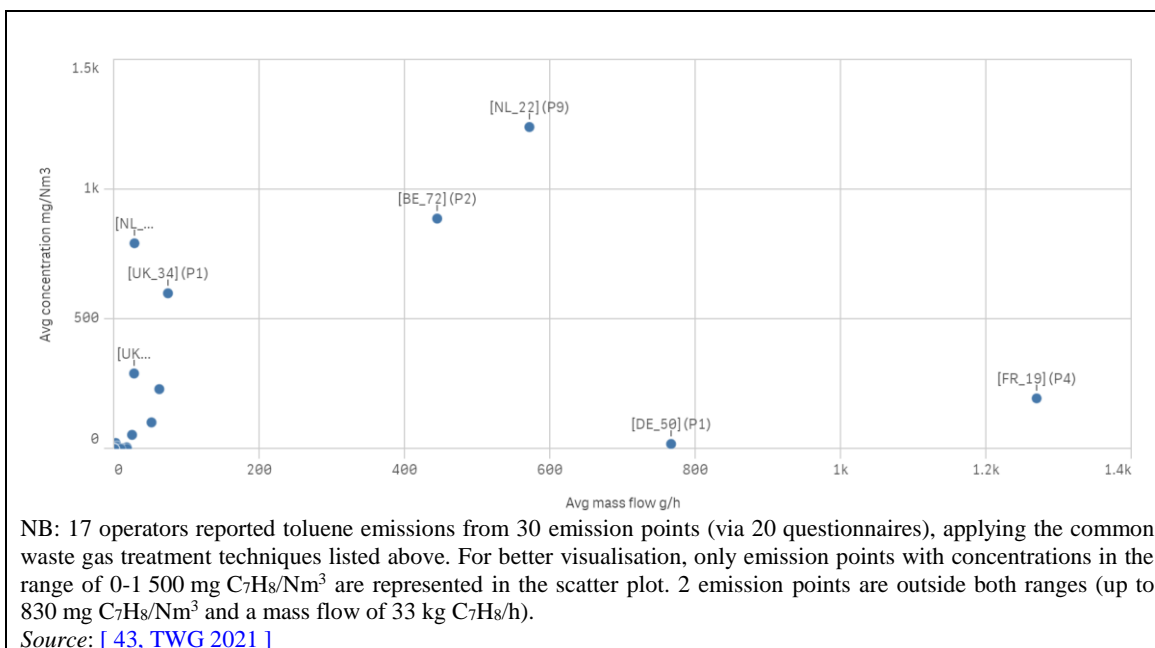
#### 2.3.2.14.2 Treated emissions

Toluene is generally treated with at least one waste gas treatment technique. The typical emission levels of toluene after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.59.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

- absorption;
- adsorption;
- condensation;
- thermal or catalytic oxidation.

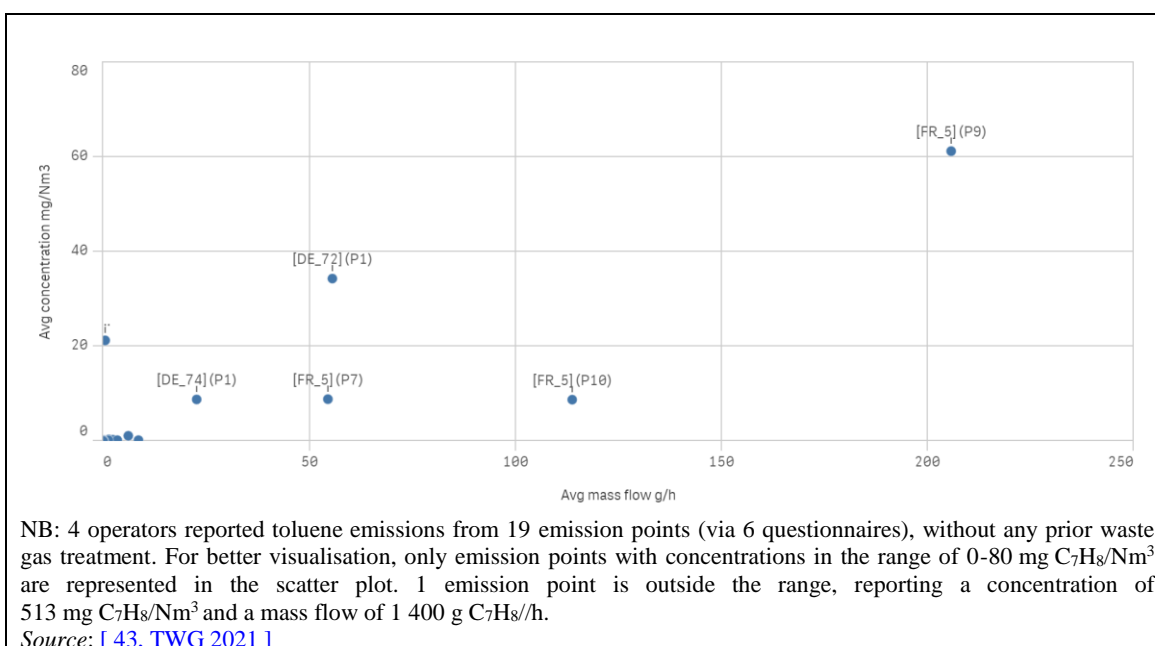




**Figure 2.59: Toluene emissions after waste gas treatment**

### 2.3.2.14.3 Untreated emissions

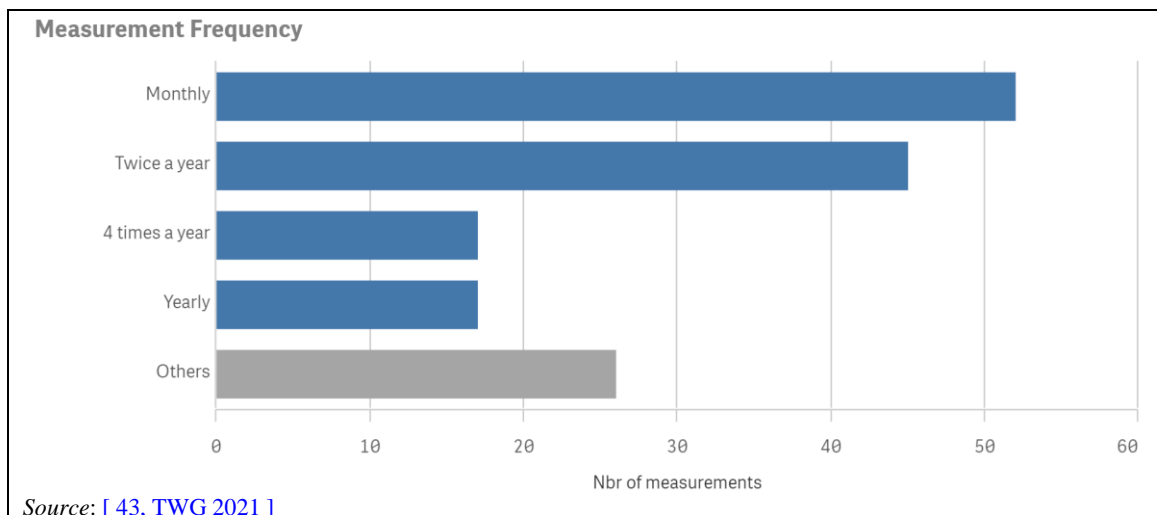
The typical emission levels of toluene when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.60.



**Figure 2.60: Toluene emission points with no waste gas treatment technique**

## 2.3.2.14.4 Monitoring

Periodic monitoring is more common than continuous monitoring: 176 instances of periodic monitoring and 3 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled toluene emissions are shown in the bar chart of Figure 2.61.



**Figure 2.61: Reported measurement frequencies for periodic toluene monitoring**

Percentiles for reported limits of quantification and limits of detection for toluene measurements are shown in Table 2.16.

**Table 2.16: Reported limits of quantification and detection for toluene**

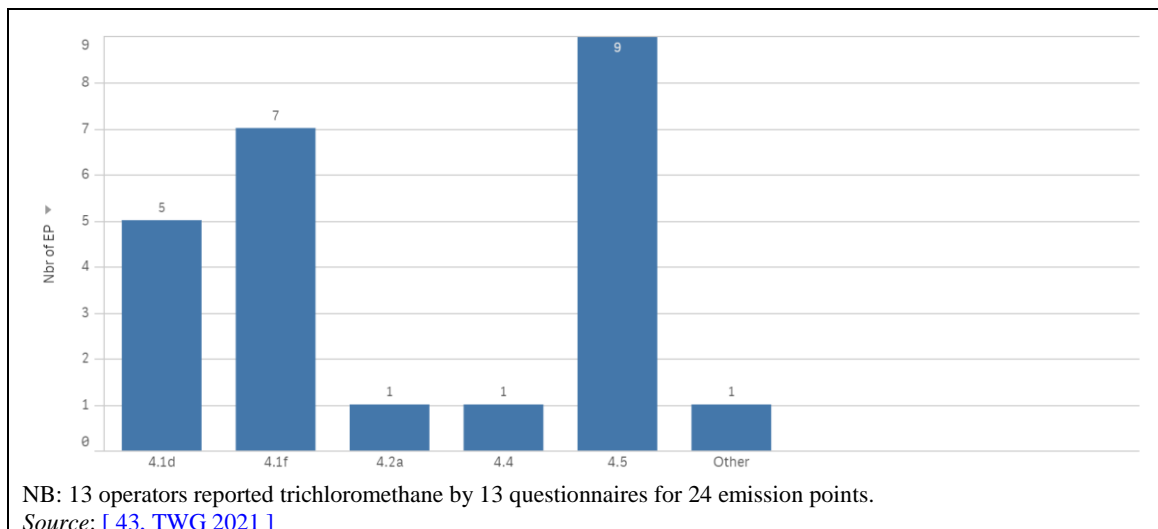
Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.05	0.05
50 <sup>th</sup>	0.13	0.20
80 <sup>th</sup>	0.50	0.43

NB: The numbers of instances reported for the limits of quantification and detection are 66 and 74, respectively.  
Source: [43, TWG 2021]

### 2.3.2.15 Trichloromethane

#### 2.3.2.15.1 Sectors

Trichloromethane is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.62.



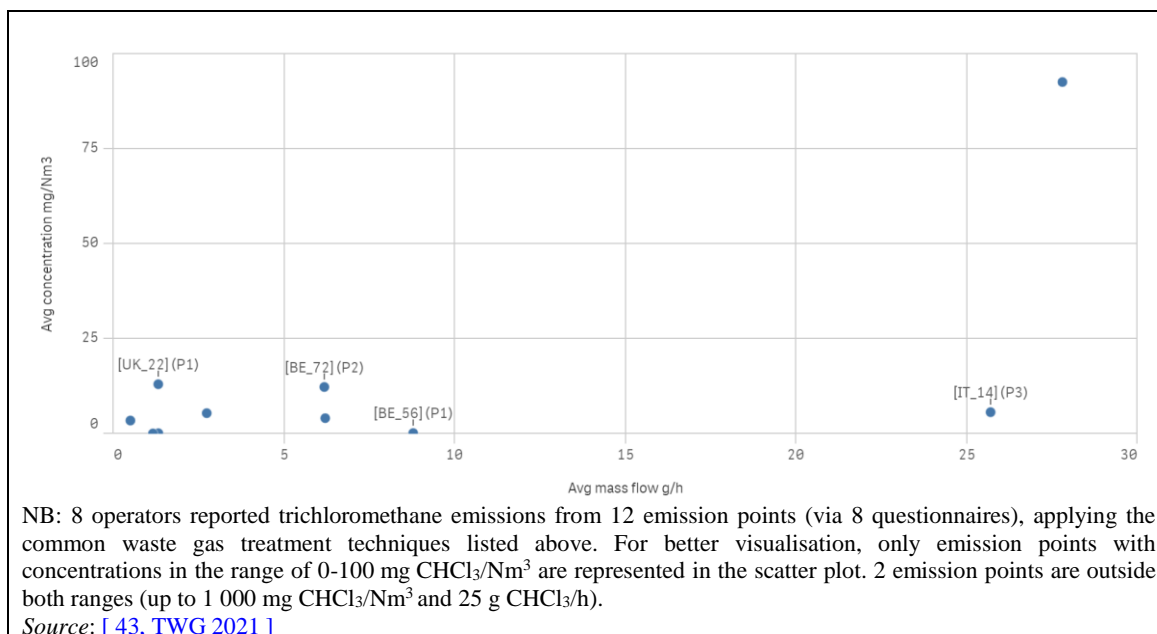
**Figure 2.62: Number of emission points for trichloromethane by IED category**

#### 2.3.2.15.2 Treated emissions

Trichloromethane is generally treated with at least one waste gas treatment technique. The typical emission levels of trichloromethane after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.63.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

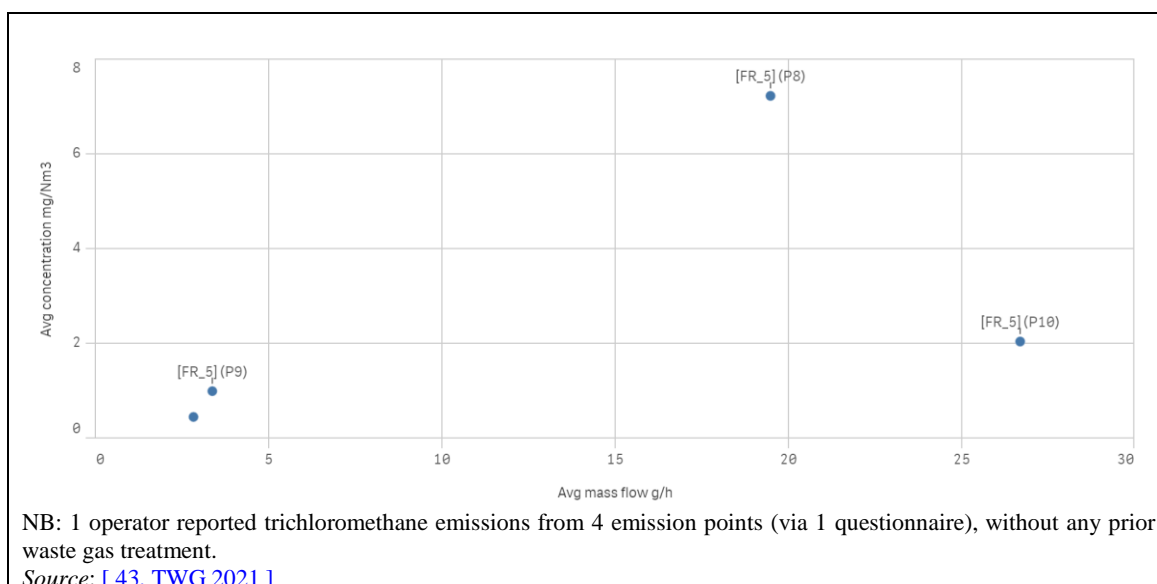
- absorption;
- adsorption;
- condensation;
- thermal or catalytic oxidation.



**Figure 2.63: Trichloromethane emissions after waste gas treatment**

### 2.3.2.15.3 Untreated emissions

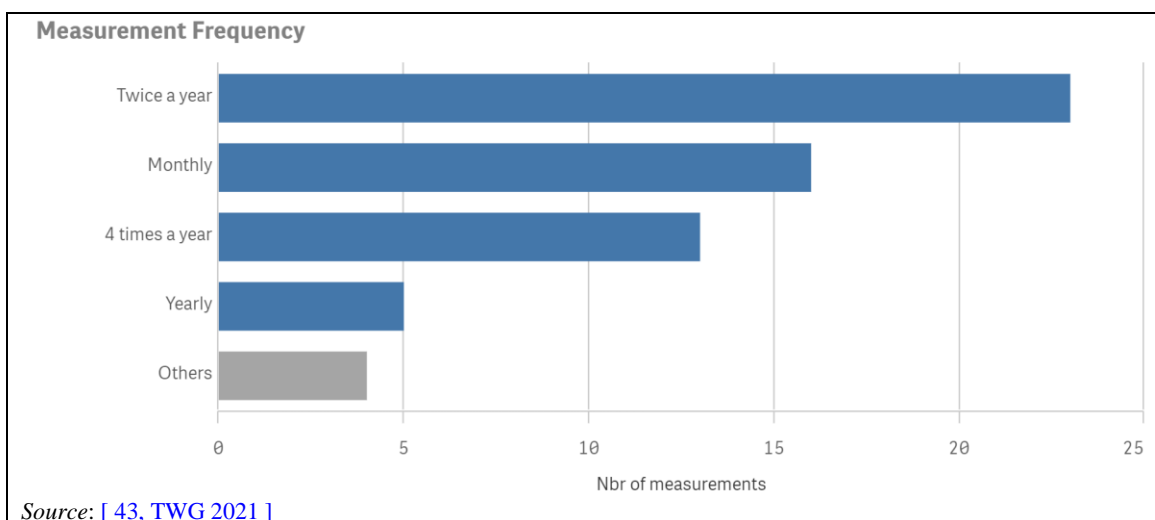
The typical emission levels of trichloromethane when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.64.



**Figure 2.64: Trichloromethane emission points with no waste gas treatment technique**

### 2.3.2.15.4 Monitoring

Only periodic monitoring was reported (63 instances). Typical frequencies for the monitoring of channelled trichloromethane emissions are shown in the bar chart of Figure 2.65.



**Figure 2.65: Reported measurement frequencies for periodic trichloromethane monitoring**

Percentiles for reported limits of quantification and limits of detection for trichloromethane measurements are shown in Table 2.17.

**Table 2.17: Reported limits of quantification and detection for trichloromethane**

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.1	0.13
50 <sup>th</sup>	1.0	0.13
80 <sup>th</sup>	5.0	0.3

NB: The numbers of instances reported for the limits of quantification and detection are 49 and 33, respectively.  
Source: [43, TWG 2021]

### 2.3.3 Dust (including PM<sub>10</sub>, and PM<sub>2.5</sub>) and particulate-bound metals

#### 2.3.3.1 Dust

##### 2.3.3.1.1 Sectors

Dust is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.66.

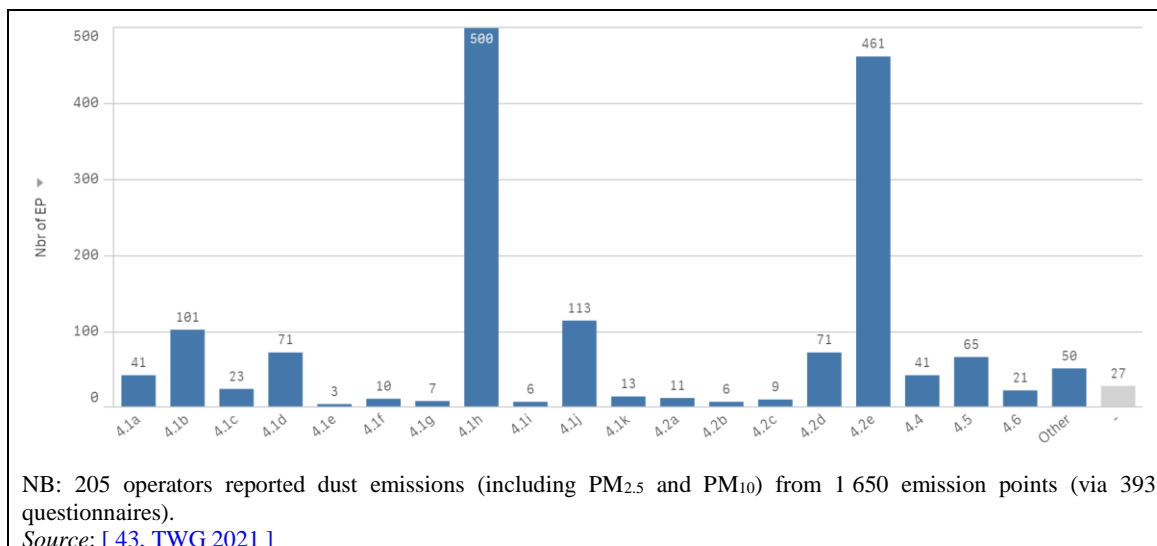


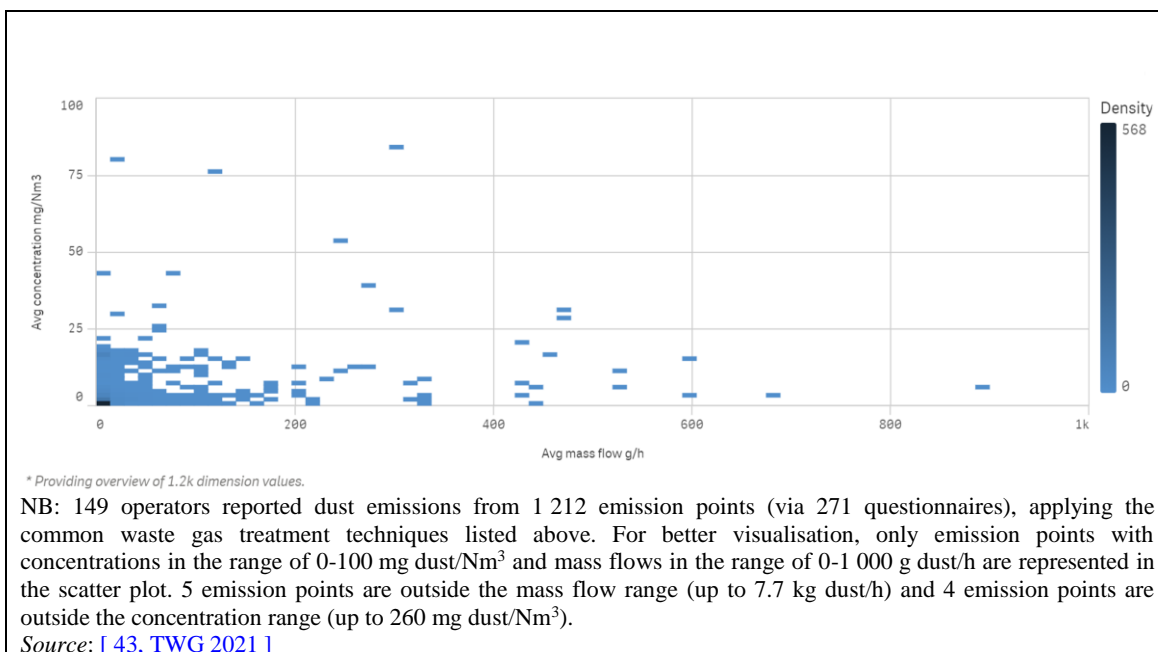
Figure 2.66: Number of emission points for dust by IED category

##### 2.3.3.1.2 Treated emissions

Dust is generally treated with at least one waste gas treatment technique. The typical emission levels of dust after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.67.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

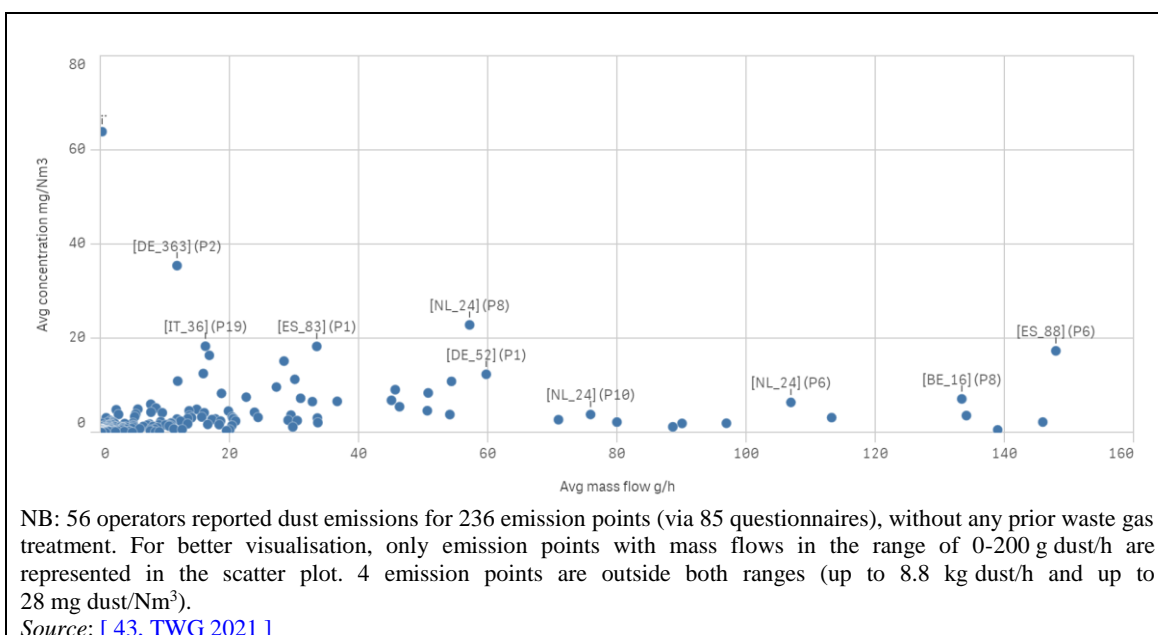
- absorption;
- gravitational separation;
- filtration (e.g. fabric filter, absolute filter);
- dust scrubbing;
- electrostatic precipitation.



**Figure 2.67: Dust emissions after waste gas treatment**

### 2.3.3.1.3 Untreated emissions

The typical emission levels of dust when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.68.



**Figure 2.68: Dust emission points with no waste gas treatment technique**

2.3.3.1.4 Monitoring

Periodic monitoring is more common than continuous monitoring: 3 241 instances of periodic monitoring and 59 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled dust emissions are shown in the bar chart of Figure 2.69.

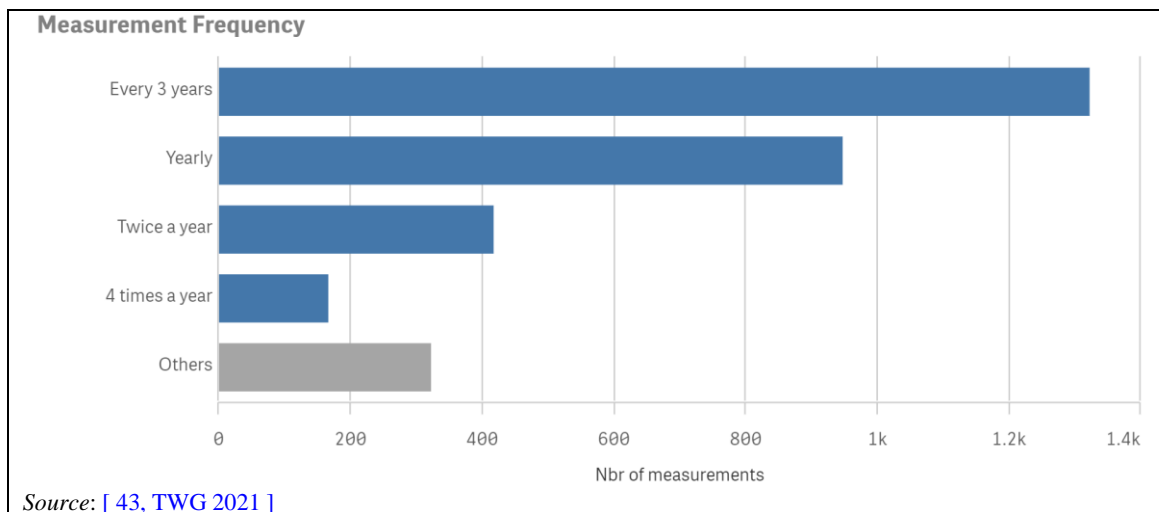


Figure 2.69: Reported measurement frequencies for periodic dust monitoring

Percentiles for reported limits of quantification and limits of detection for dust measurements are shown in Table 2.18.

Table 2.18: Reported limits of quantification and detection for dust

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.2	0.1
50 <sup>th</sup>	0.3	0.3
80 <sup>th</sup>	1.0	0.5

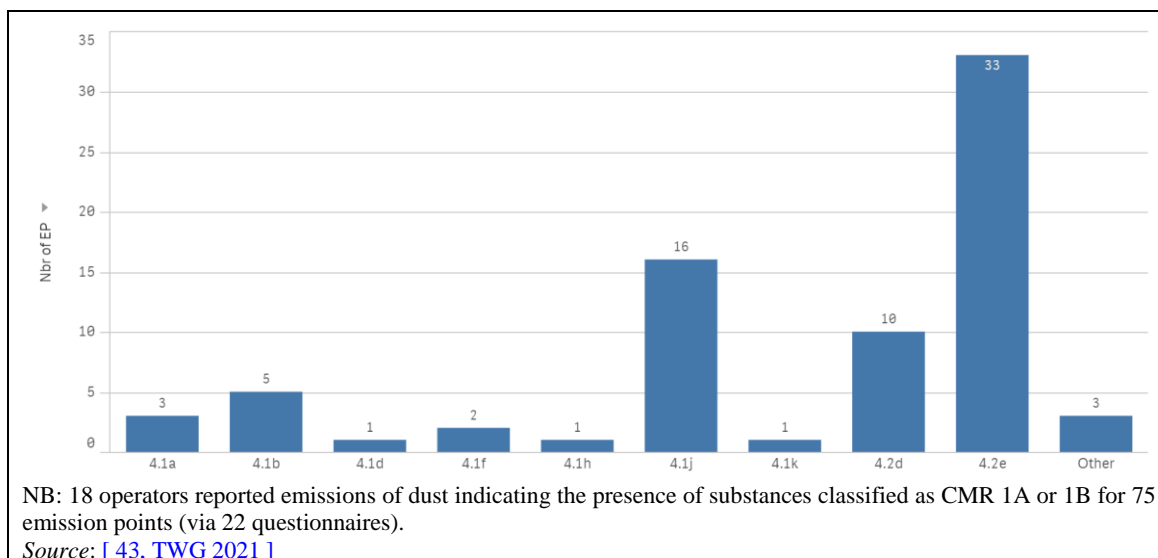
NB: The numbers of instances reported for the limits of quantification and detection are 1141 and 1239, respectively.  
 Source: [43, TWG 2021]



### 2.3.3.2 Dust containing substances classified as CMR 1A or 1B

#### 2.3.3.2.1 Sectors

Dust containing substances classified as CMR 1A or 1B is typically emitted by a few chemical sectors as shown in the bar chart of Figure 2.70.



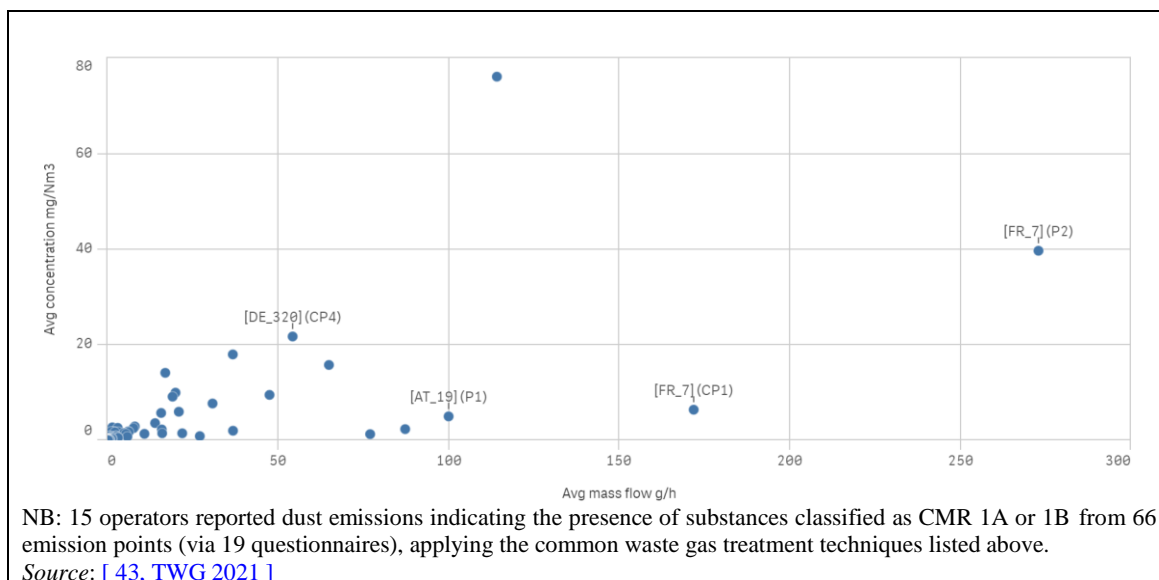
**Figure 2.70: Number of emission points for dust containing substances classified as CMR 1A or 1B by IED category**

#### 2.3.3.2.2 Emissions

Dust containing substances classified as CMR 1A or 1B is generally treated with at least one waste gas treatment technique. The typical emission levels of dust containing substances classified as CMR 1A or 1B after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.71.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

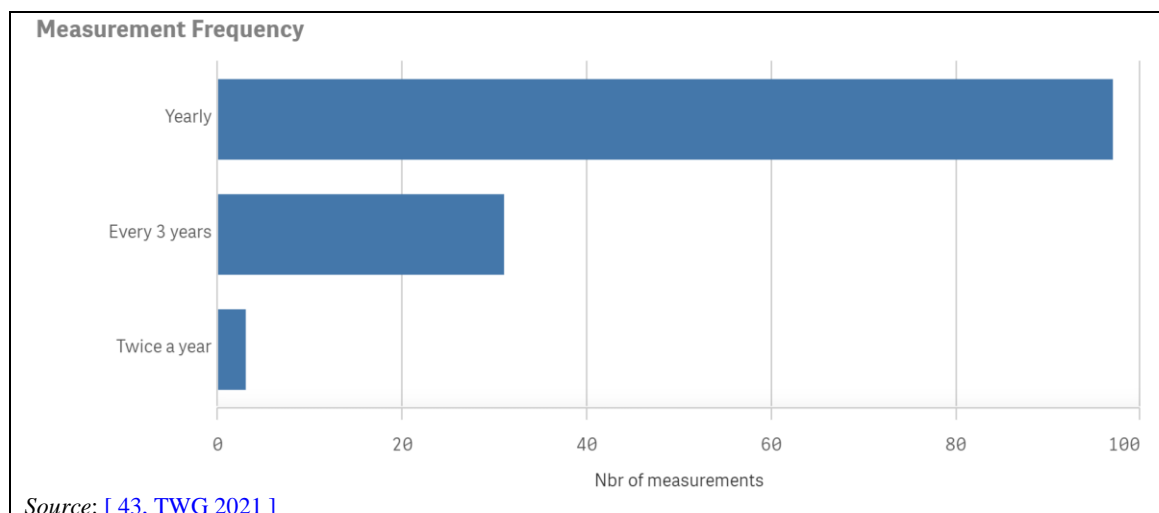
- absorption;
- gravitational separation;
- filtration (e.g. fabric filter, absolute filter);
- dust scrubbing.



**Figure 2.71: Emissions of dust containing substances classified as CMR 1A or 1B after waste gas treatment**

### 2.3.3.2.3 Monitoring

Periodic monitoring is more common than continuous monitoring: 176 instances of periodic monitoring and 3 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled dust emissions (containing substances classified as CMR 1A or 1B) are shown in the bar chart of Figure 2.72.



**Figure 2.72: Reported measurement frequencies for periodic monitoring of dust containing substances classified as CMR 1A or 1B**

Percentiles for reported limits of quantification and limits of detection for dust containing substances classified as CMR 1A or 1B are shown in Table 2.18.

**Table 2.19: Reported limits of quantification and detection for dust containing substances classified as CMR 1A or 1B**

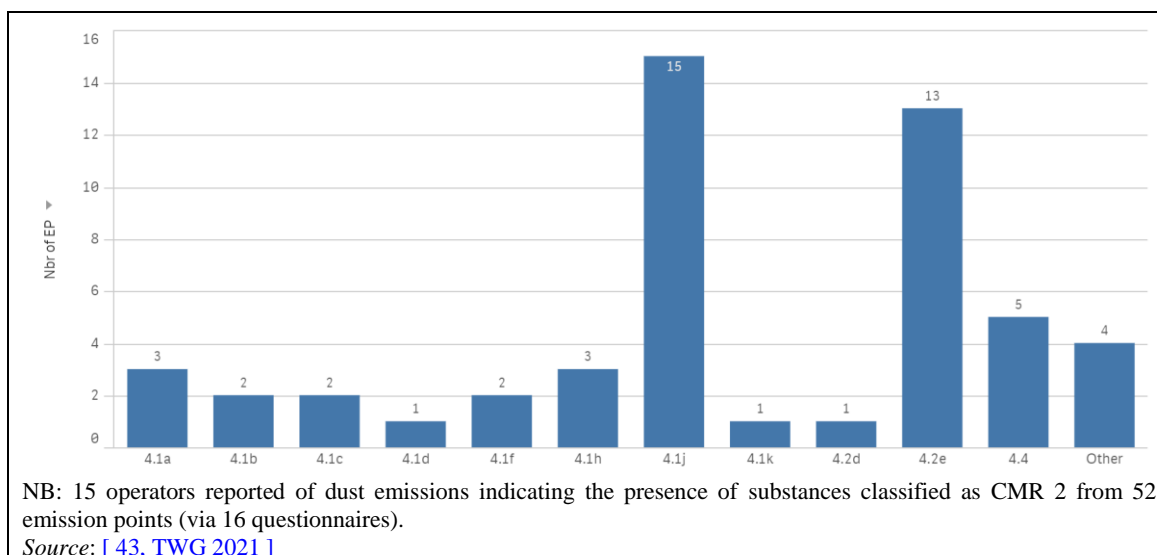
Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.30	0.28
50 <sup>th</sup>	0.30	0.30
80 <sup>th</sup>	0.30	0.30

NB: The numbers of instances reported for the limits of quantification and detection are 58 and 57, respectively.  
Source: [43, TWG 2021]

### 2.3.3.3 Dust containing substances classified as CMR 2

#### 2.3.3.3.1 Sectors

Dust containing substances classified as CMR 2 is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.73.



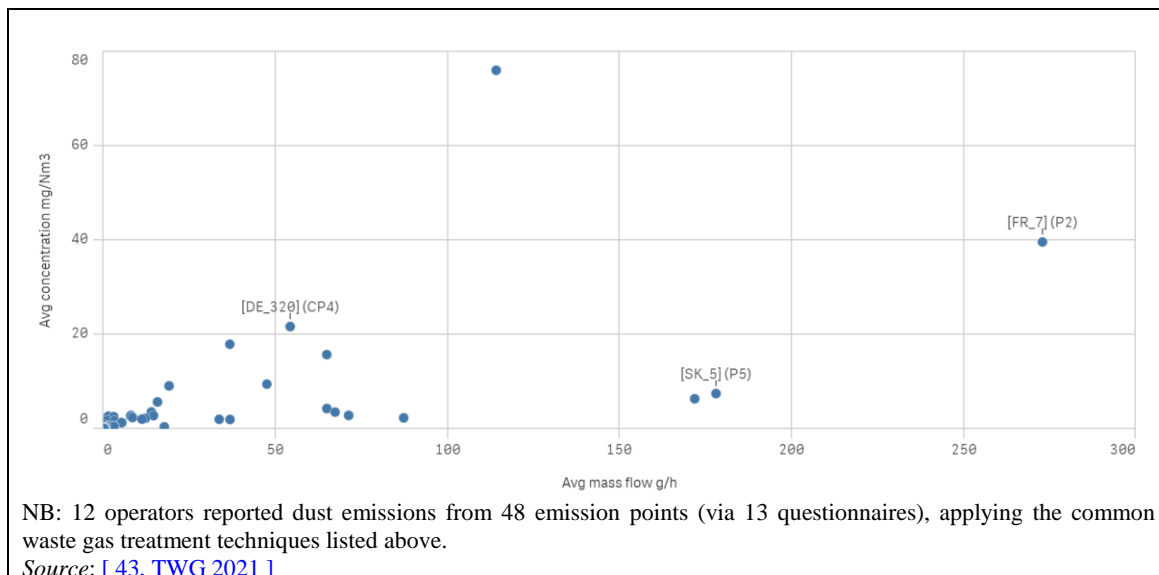
**Figure 2.73: Number of emission points for dust containing substances classified as CMR 2 by IED category**

#### 2.3.3.3.2 Emissions

Emissions of dust containing substances classified as CMR 2 are generally treated with at least one waste gas treatment technique. The typical emission levels of dust containing substances classified as CMR 2 after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.74.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

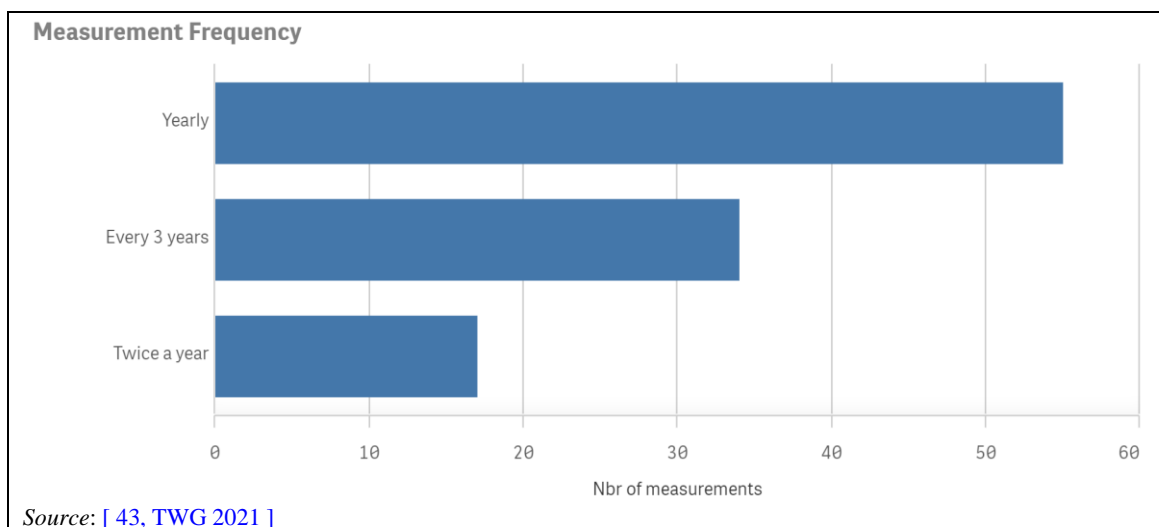
- absorption;
- gravitational separation;
- filtration (e.g. fabric filter, absolute filter);
- dust scrubbing.



**Figure 2.74: Emissions of dust containing substances classified as CMR 2 after waste gas treatment**

### 2.3.3.3.3 Monitoring

Periodic monitoring is more common than continuous monitoring: 114 instances of periodic monitoring and 3 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled dust emissions (containing substances classified as CMR 2) are shown in the bar chart of Figure 2.75.



**Figure 2.75: Reported measurement frequencies for periodic dust (containing substances classified as CMR 2) monitoring**

Percentiles for reported limits of quantification and limits of detection for dust (containing substances classified as CMR 2) measurements are shown in Table 2.18.

**Table 2.20: Reported limits of quantification and detection for dust containing substances classified as CMR 2**

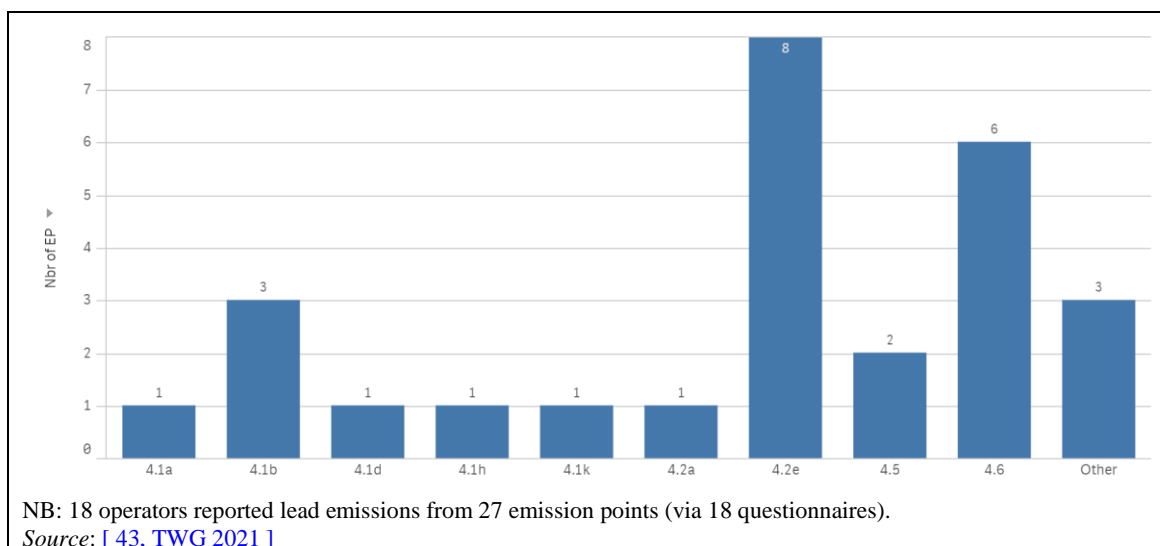
Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.20	0.20
50 <sup>th</sup>	0.30	0.30
80 <sup>th</sup>	0.31	0.30

NB: The numbers of instances reported for the limits of quantification and detection are 71 and 53, respectively.  
Source: [43, TWG 2021]

### 2.3.3.4 Lead and its compounds

#### 2.3.3.4.1 Sectors

Lead and its compounds are typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.76.



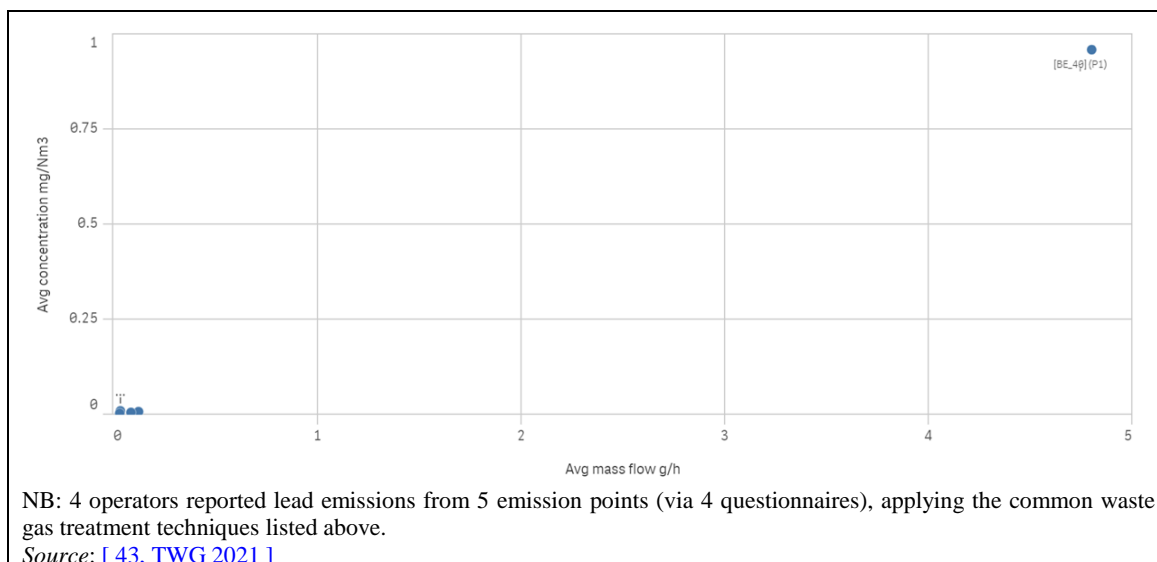
**Figure 2.76: Number of emission points for lead by IED category**

#### 2.3.3.4.2 Treated emissions

Emissions of lead and its compounds are generally treated with at least one waste gas treatment technique. The typical emission levels of lead after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.77.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

- filtration (e.g. fabric filter, absolute filter);
- dust scrubbing.

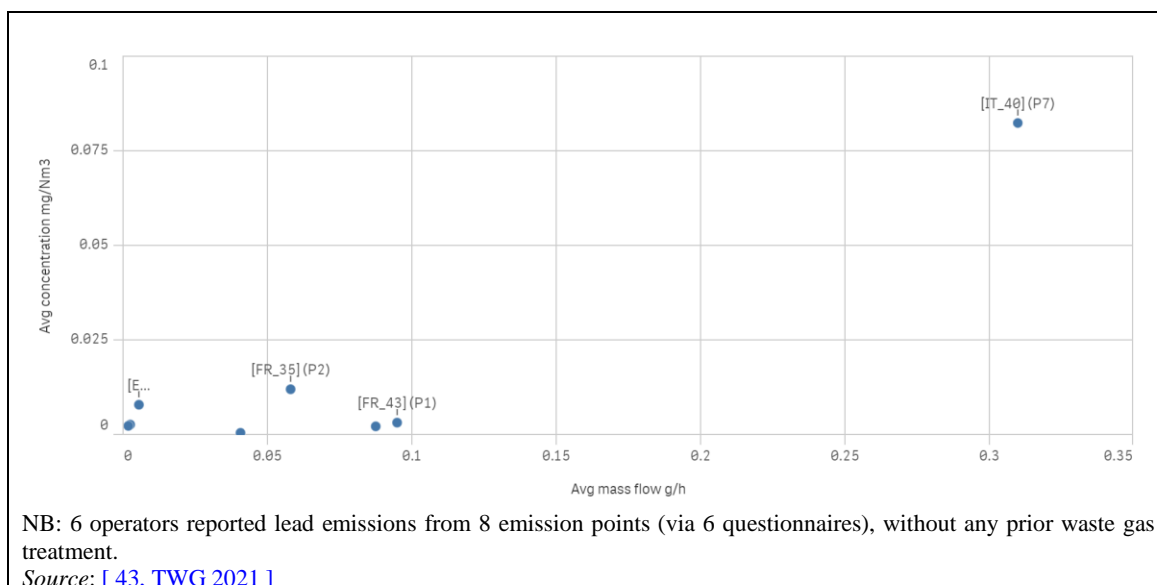


**Figure 2.77: Lead emissions after waste gas treatment**

A lead emission level lower than  $0.1 \text{ mg/Nm}^3$  is not achieved in the case of Plant BE\_40 which reported higher average lead emissions ( $1 \text{ mg/Nm}^3$ ) compared to the average concentrations reported by other installations (see Figure 2.77). The installation BE\_40 produces technical ZnO, starting from galvanic ashes, containing up to 2.5 % lead, applying dust scrubbing as a waste gas treatment with a reported abatement efficiency of 99.9 %.

### 2.3.3.4.3 Untreated emissions

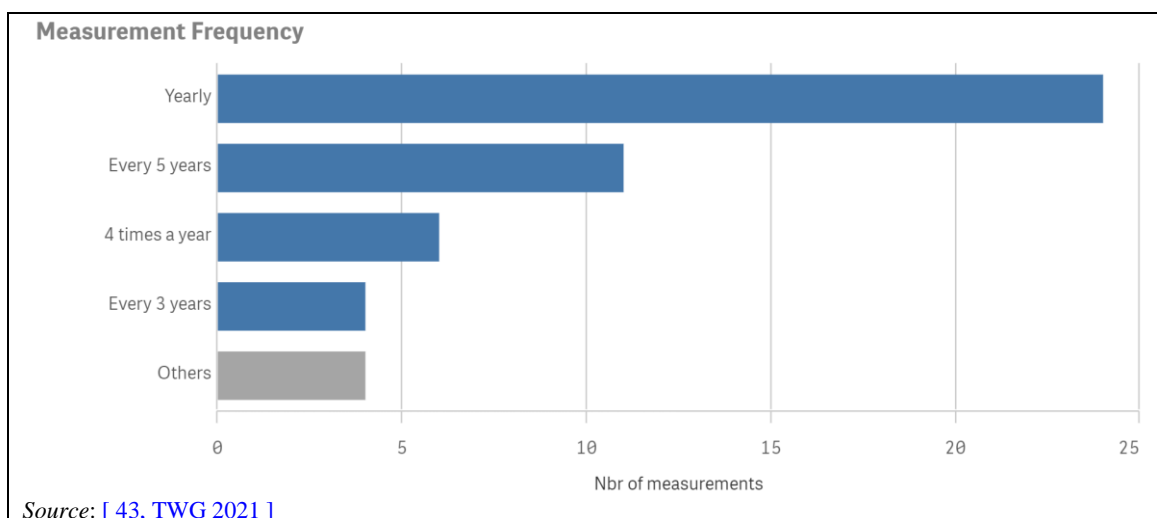
The typical emission levels of lead when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.78.



**Figure 2.78: Lead emission points with no waste gas treatment technique**

### 2.3.3.4.4 Monitoring

Only periodic monitoring was reported (56 instances). Typical frequencies for the monitoring of channelled lead emissions are shown in the bar chart of Figure 2.79.



**Figure 2.79: Reported measurement frequencies for periodic lead monitoring**

Percentiles for reported limits of quantification and limits of detection for lead measurements are shown in Table 2.21.

**Table 2.21: Reported limits of quantification and detection for lead and its compounds**

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.0001	0.00017
50 <sup>th</sup>	0.00024	0.0005
80 <sup>th</sup>	0.005	0.005

NB: The numbers of instances reported for the limits of quantification and detection are 9 and 8, respectively.  
Source: [43, TWG 2021]

### 2.3.3.5 Nickel and its compounds

#### 2.3.3.5.1 Sectors

Nickel and its compounds are typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.80.

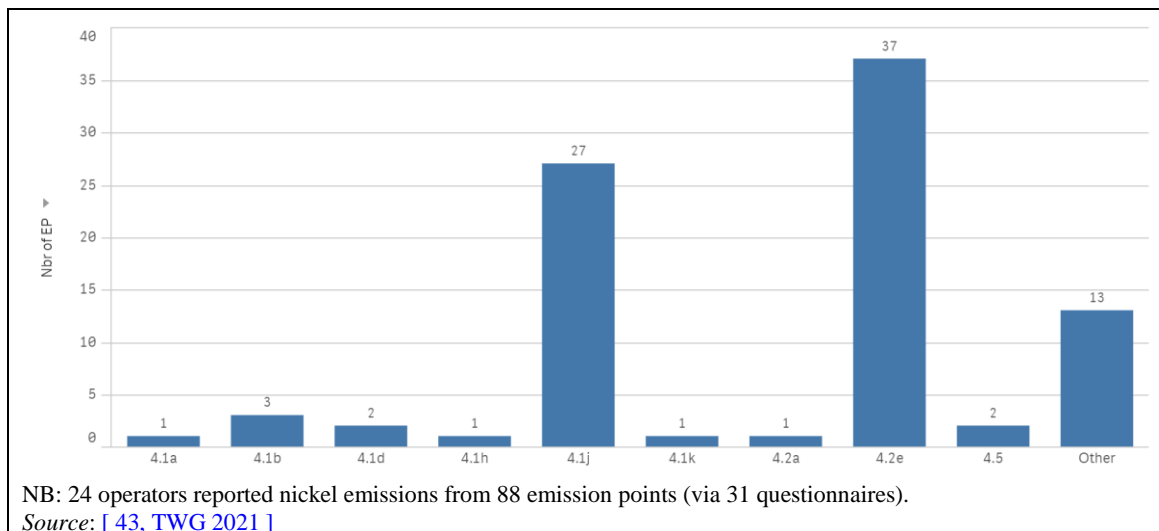


Figure 2.80: Number of emission points for nickel by IED category

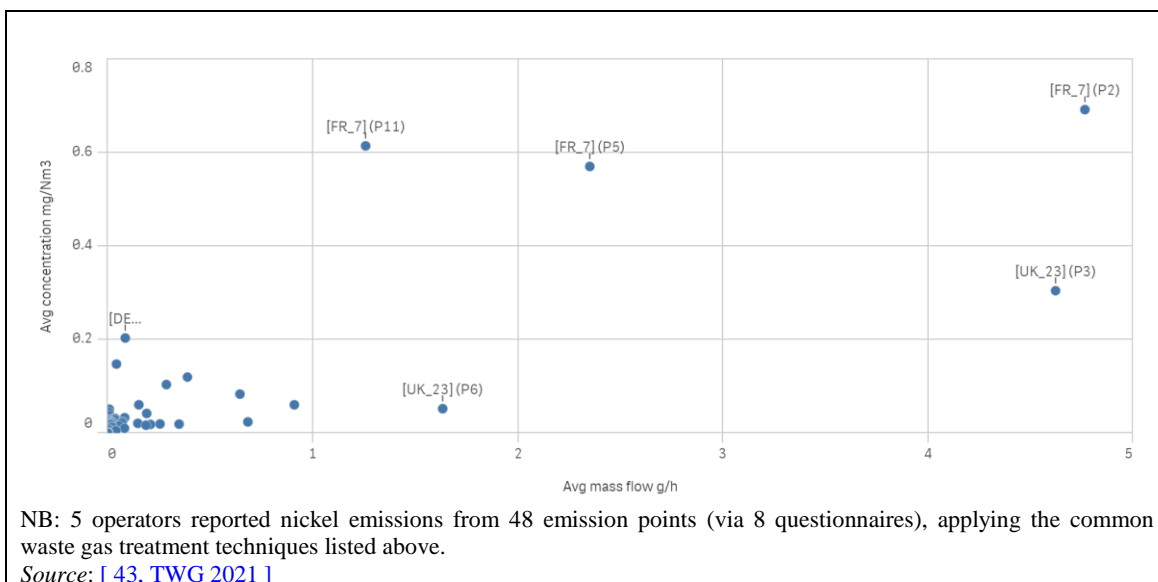
#### 2.3.3.5.2 Treated emissions

Emissions of nickel and its compounds are generally treated with at least one waste gas treatment technique. The typical emission levels of nickel after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.81.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

- absorption;
- gravitational separation;
- filtration (e.g. fabric filter, absolute filter);
- dust scrubbing.

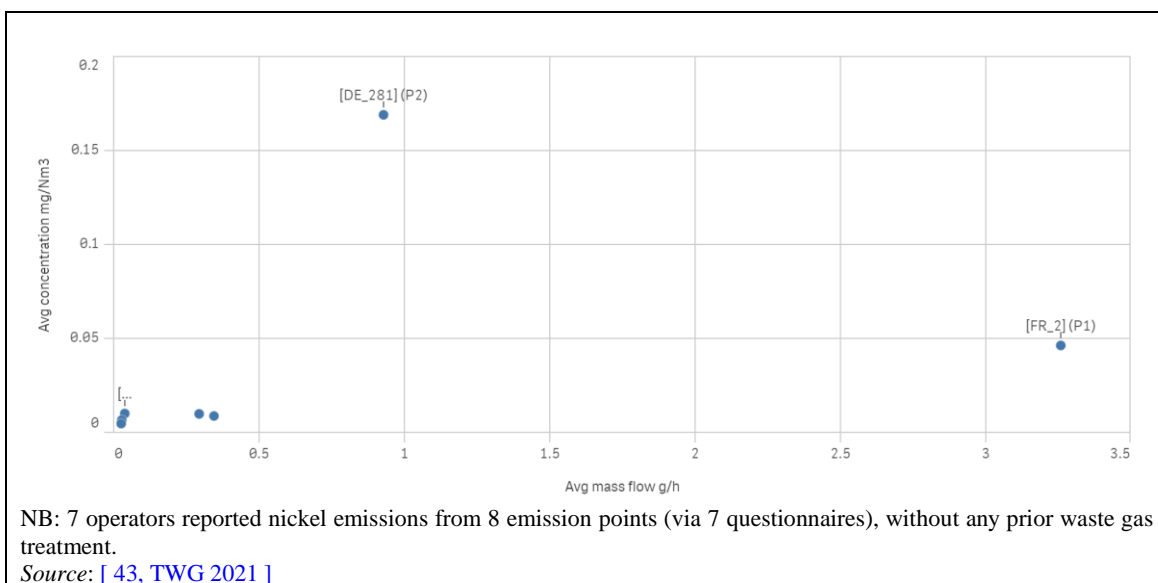




**Figure 2.81: Nickel emissions after waste gas treatment**

### 2.3.3.5.3 Untreated emissions

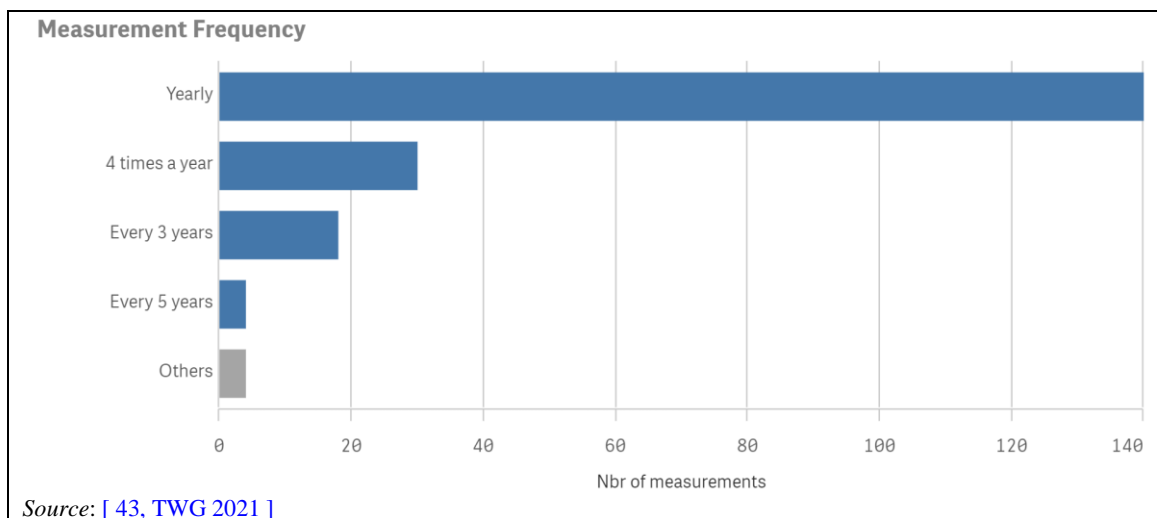
The typical emission levels of nickel when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.82.



**Figure 2.82: Nickel emission points with no waste gas treatment technique**

## 2.3.3.5.4 Monitoring

Only periodic monitoring was reported (202 instances). Typical frequencies for the monitoring of channelled nickel emissions are shown in the bar chart of Figure 2.83.



**Figure 2.83: Reported measurement frequencies for periodic nickel monitoring**

Percentiles for reported limits of quantification and limits of detection for nickel measurements are shown in Table 2.22.

**Table 2.22: Reported limits of quantification and detection for nickel and its compounds**

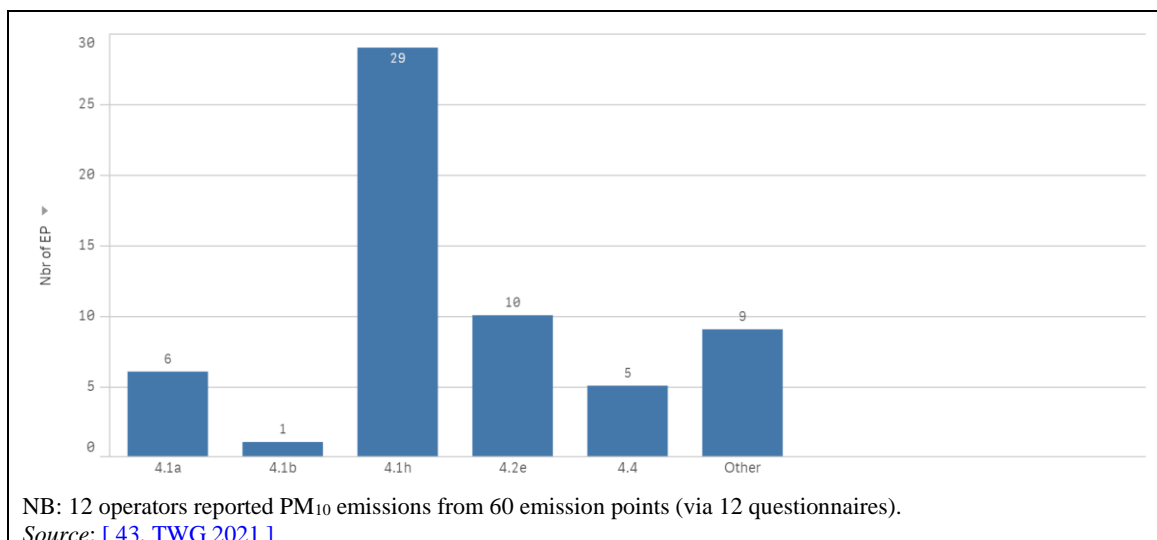
Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.003	0.001
50 <sup>th</sup>	0.005	0.05
80 <sup>th</sup>	0.005	0.05

NB: The numbers of instances reported for the limits of quantification and detection are 71 and 74, respectively.  
Source: [43, TWG 2021]

### 2.3.3.6 PM<sub>10</sub>

#### 2.3.3.6.1 Sectors

PM<sub>10</sub> is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.84.



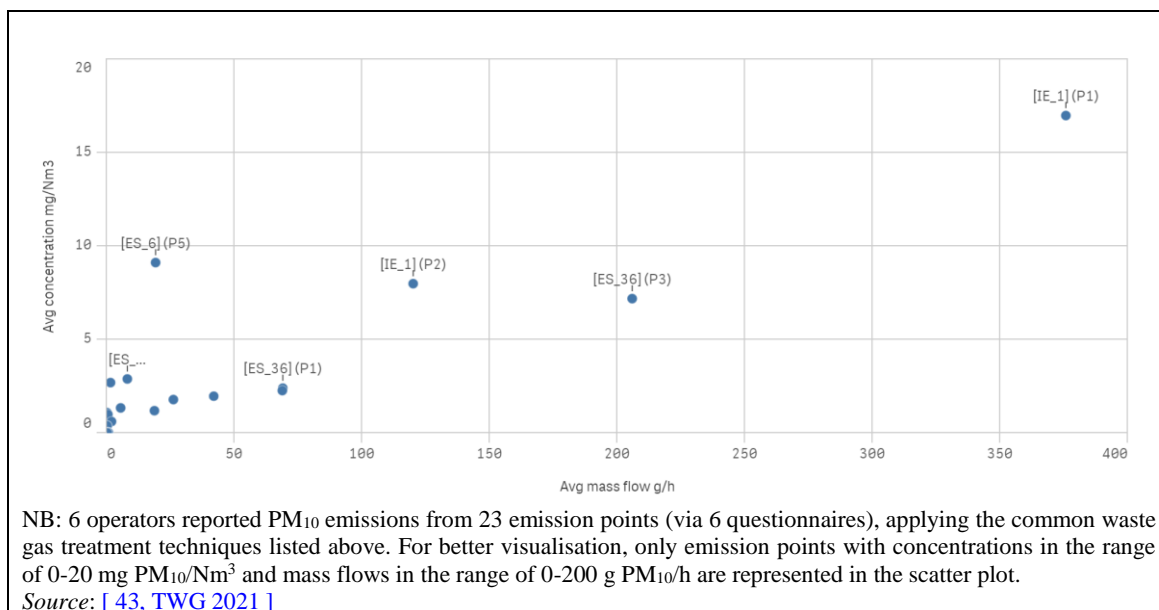
**Figure 2.84: Number of emission points for PM<sub>10</sub> by IED category**

#### 2.3.3.6.2 Treated emissions

Emissions of PM<sub>10</sub> may occur with at least one prior waste gas treatment technique applied. The typical emission levels of PM<sub>10</sub> after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.85.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

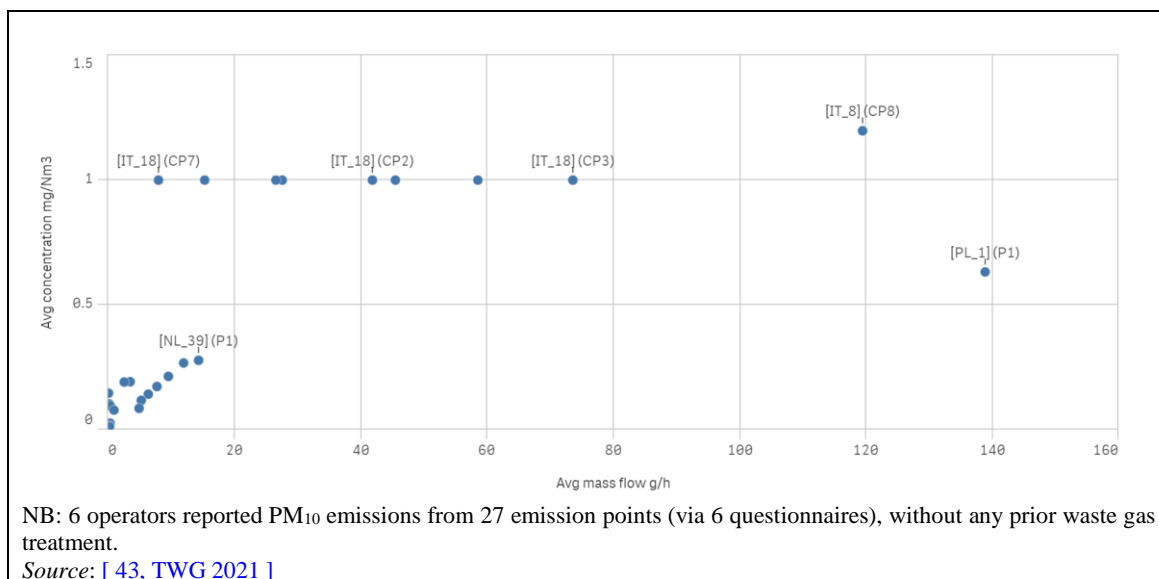
- filtration (e.g. fabric filter, absolute filter);
- dust scrubbing.



**Figure 2.85: PM<sub>10</sub> emissions after waste gas treatment**

### 2.3.3.6.3 Untreated emissions

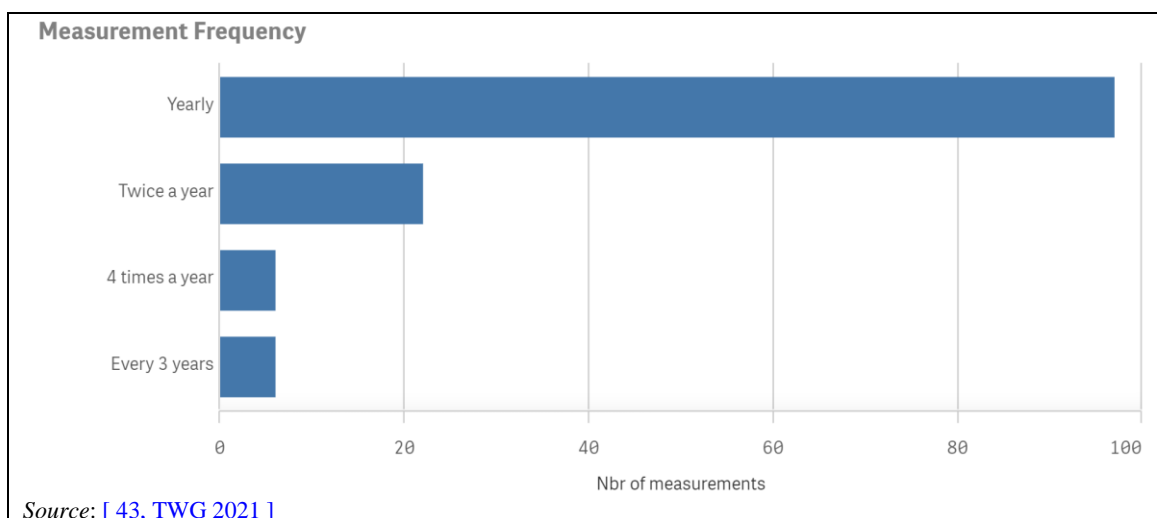
The typical emission levels of PM<sub>10</sub> when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.86.



**Figure 2.86: PM<sub>10</sub> emission points with no waste gas treatment technique**

### 2.3.3.6.4 Monitoring

Only periodic monitoring was reported (148 instances). Typical frequencies for the monitoring of channelled PM<sub>10</sub> emissions are shown in the bar chart of Figure 2.87.



**Figure 2.87: Reported measurement frequencies for periodic PM<sub>10</sub> monitoring**

Percentiles for reported limits of quantification and limits of detection for PM<sub>10</sub> measurements are shown in Table 2.23.

**Table 2.23: Reported limits of quantification and detection for PM<sub>10</sub>**

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.2	0.06
50 <sup>th</sup>	0.2	0.06
80 <sup>th</sup>	0.2	1.0

NB: The numbers of instances reported for the limits of quantification and detection are 78 and 106, respectively.  
Source: [43, TWG 2021]

2.3.3.7 PM<sub>2.5</sub>

2.3.3.7.1 Sectors

PM<sub>2.5</sub> is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.88.

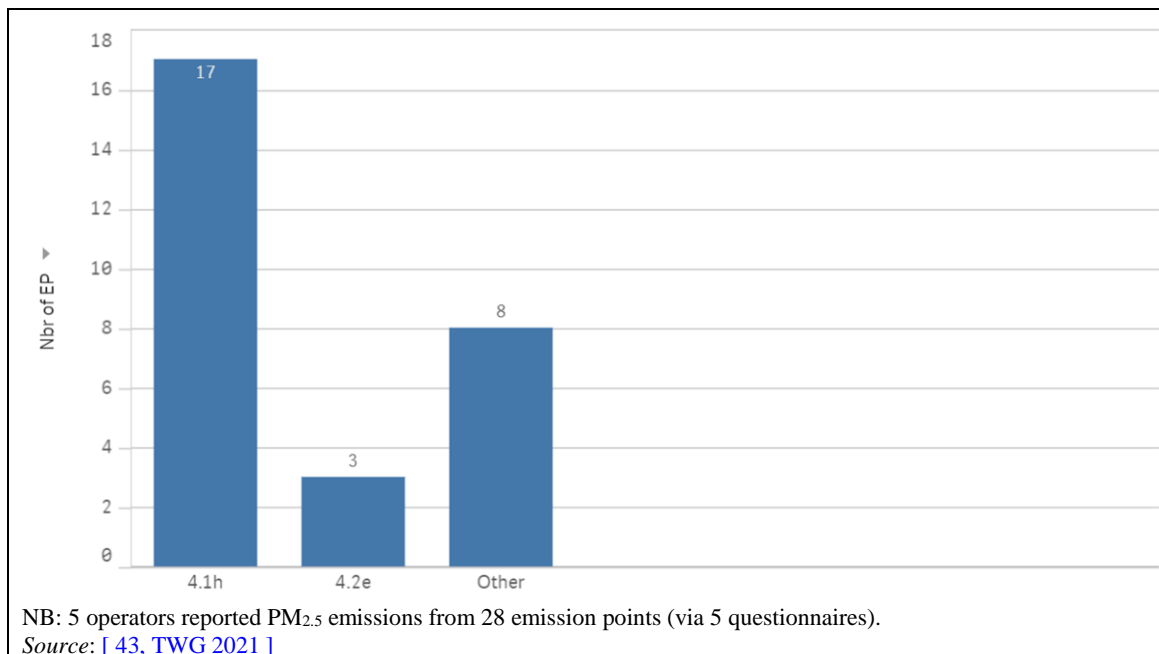
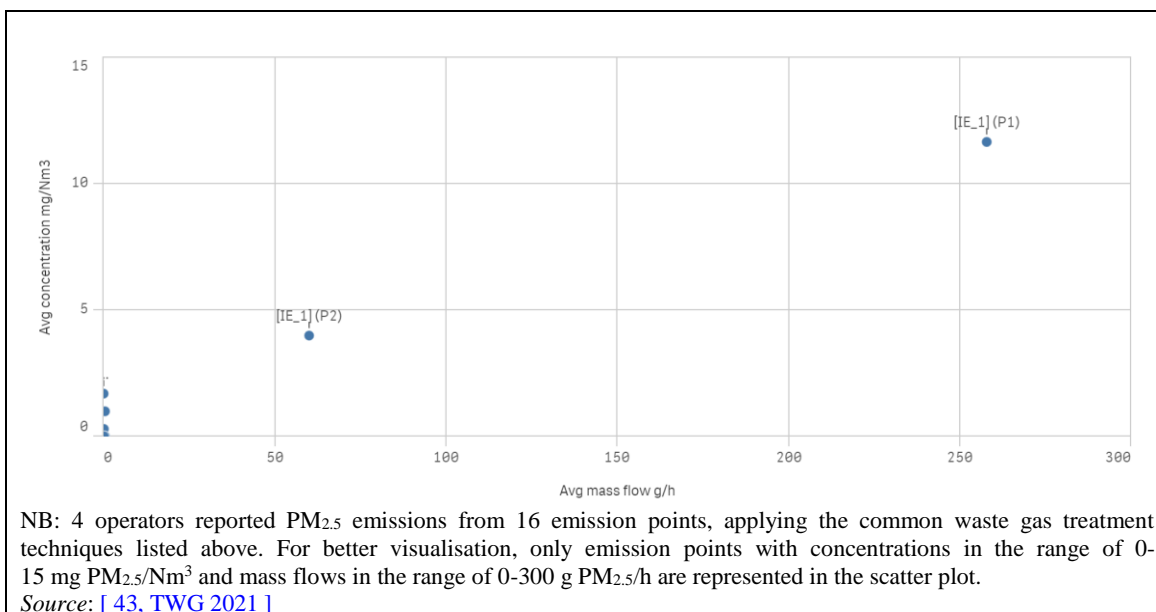


Figure 2.88: Number of emission points for PM<sub>2.5</sub> by IED category

2.3.3.7.2 Treated emissions

Emissions of PM<sub>2.5</sub> are generally treated with at least one waste gas treatment technique. The typical emission levels of PM<sub>2.5</sub> after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.89.

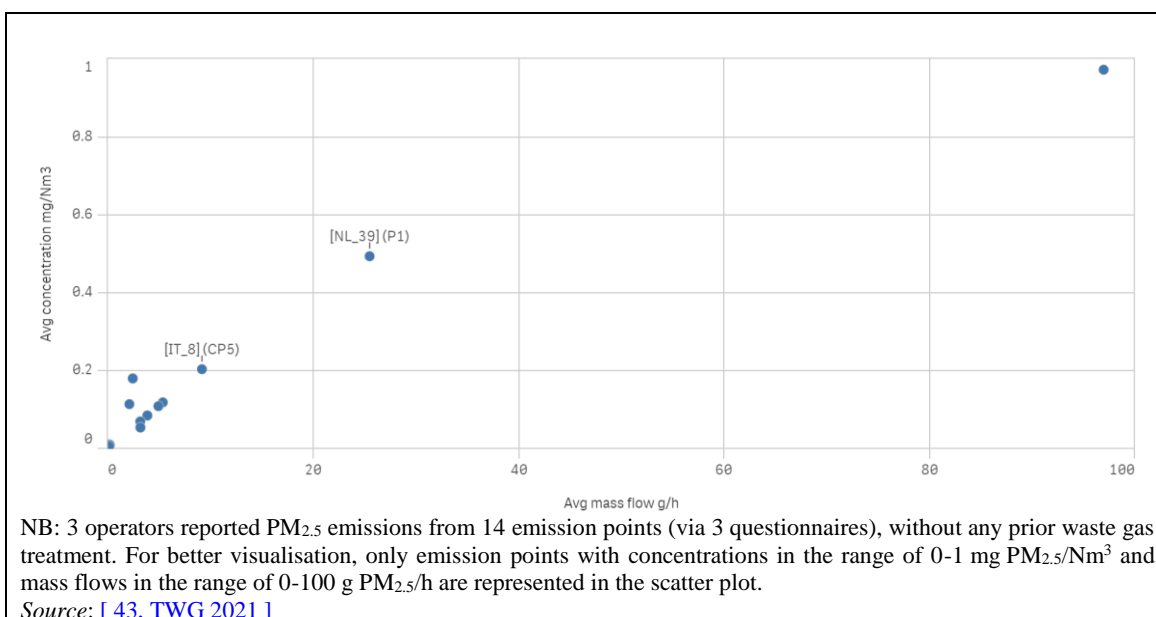
The technique most commonly applied in waste gas treatment systems of chemical plants is filtration (e.g. fabric filter, absolute filter).



**Figure 2.89: PM<sub>2.5</sub> emissions after waste gas treatment**

### 2.3.3.7.3 Untreated emissions

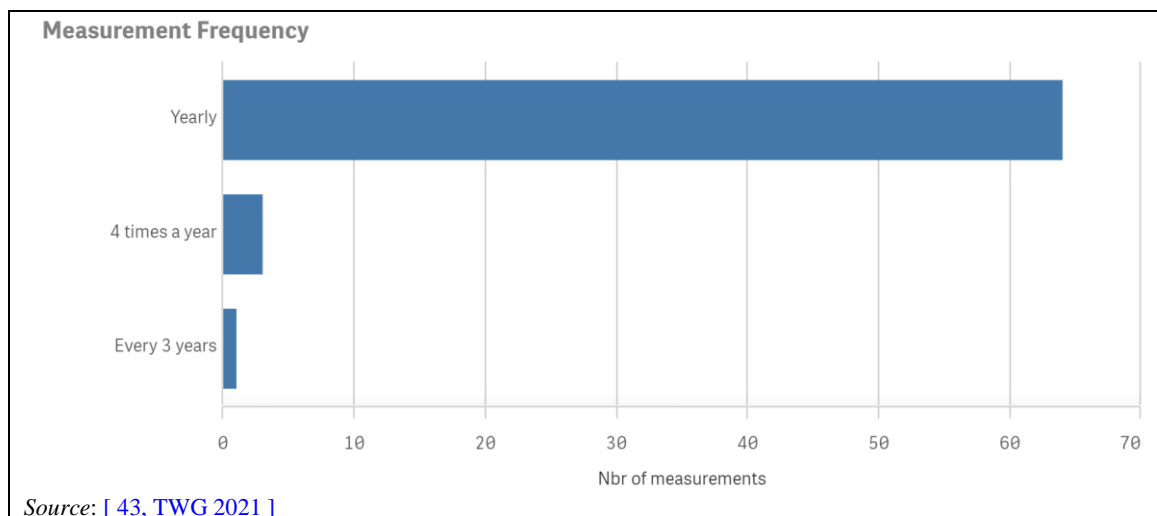
The typical emission levels of PM<sub>2.5</sub> when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.90.



**Figure 2.90: PM<sub>2.5</sub> emission points with no waste gas treatment technique**

## 2.3.3.7.4 Monitoring

Only periodic monitoring was reported (72 instances). Typical frequencies for the monitoring of channelled PM<sub>2.5</sub> emissions are shown in the bar chart of Figure 2.91.



**Figure 2.91: Reported measurement frequencies for periodic PM<sub>2.5</sub> monitoring**

Percentiles for reported limits of quantification and limits of detection for PM<sub>2.5</sub> measurements are shown in Table 2.24.

**Table 2.24: Reported limits of quantification and detection for PM<sub>2.5</sub>**

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.2	0.06
50 <sup>th</sup>	0.2	0.06
80 <sup>th</sup>	0.2	0.06

NB: The numbers of instances reported for the limits of quantification and detection are 66 and 67, respectively.  
Source: [43, TWG 2021]

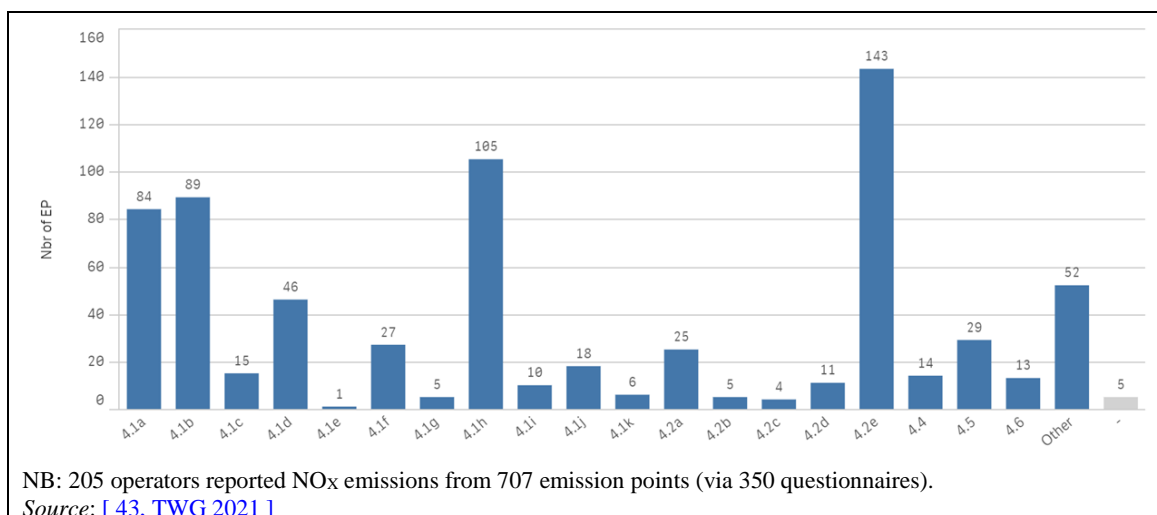


## 2.3.4 Inorganic substances

### 2.3.4.1 Nitrogen oxides

#### 2.3.4.1.1 Sectors

Nitrogen oxides are typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.92.

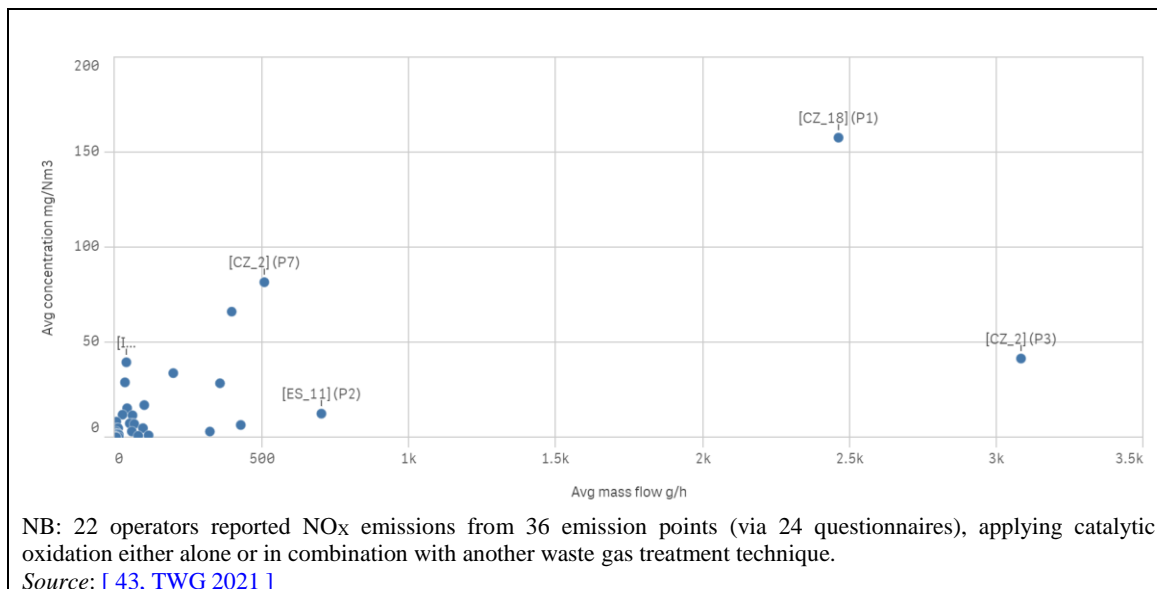


**Figure 2.92: Number of emission points for NO<sub>x</sub> by IED category**

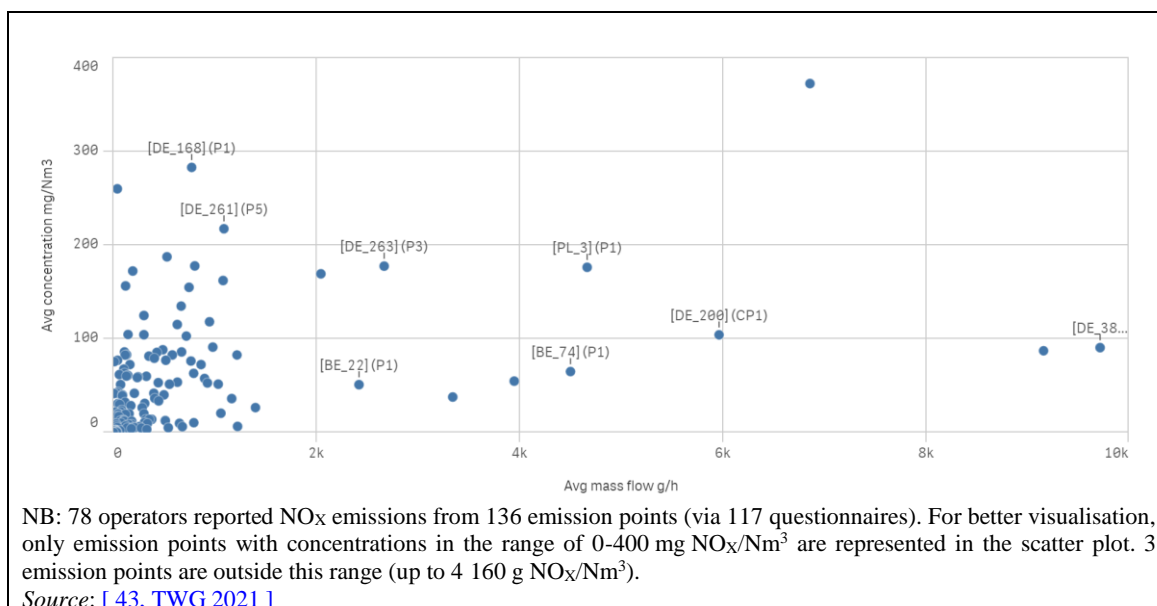
#### 2.3.4.1.2 Emissions

Emissions of nitrogen oxides may originate from different sources, e.g. from the use of catalytic or thermal oxidation of waste gases, or from chemical processes. Emissions of nitrogen oxides from process furnaces/heaters are described in Section 2.9.2.1.

The typical emission levels of nitrogen oxides from the use of thermal treatment are shown as concentration and mass flow in the scatter plots of Figure 2.93 and Figure 2.94.

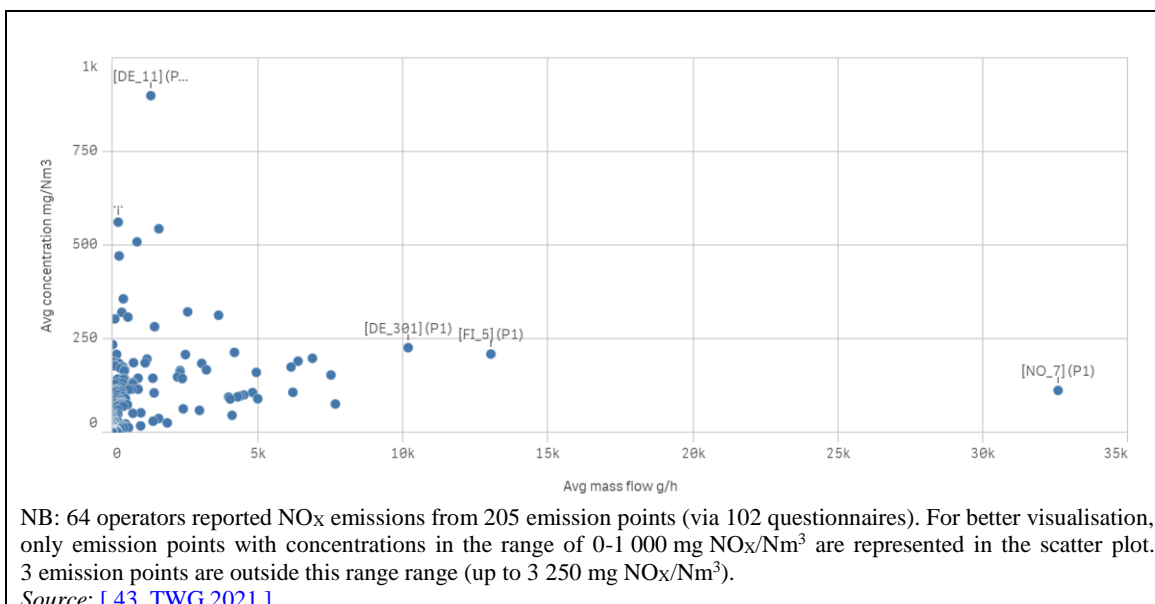


**Figure 2.93: NO<sub>x</sub> emissions from catalytic oxidation**



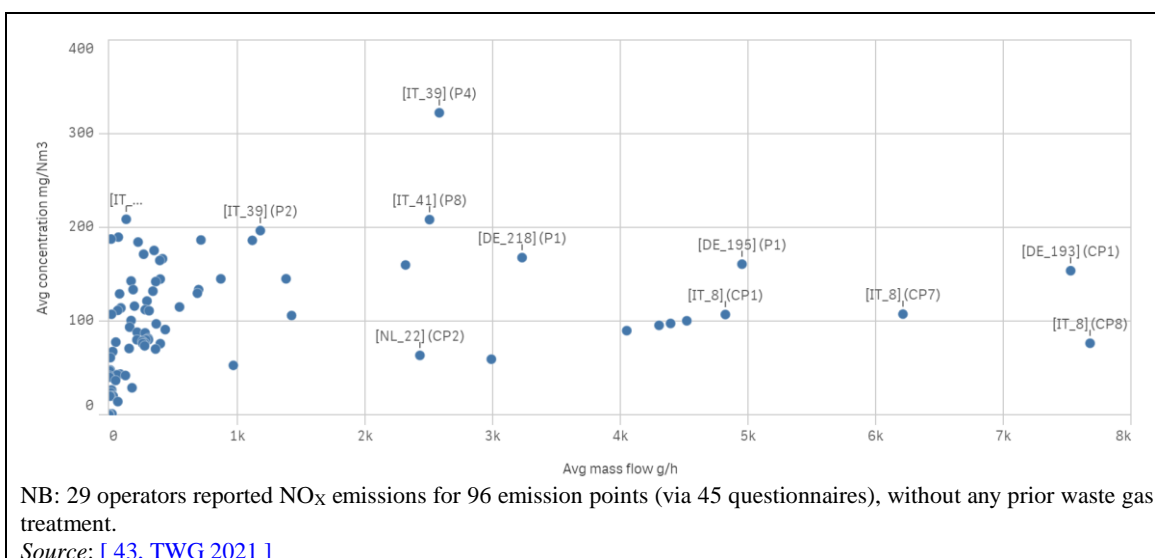
**Figure 2.94: NO<sub>x</sub> emissions from thermal oxidation**

In addition, emissions of nitrogen oxides may occur from chemical processes. The typical emission levels of nitrogen oxides in this case are shown as concentration and mass flow in the scatter plot of Figure 2.95.



**Figure 2.95: NO<sub>x</sub> emissions from chemical processes**

The typical emission levels of nitrogen oxide when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.96.

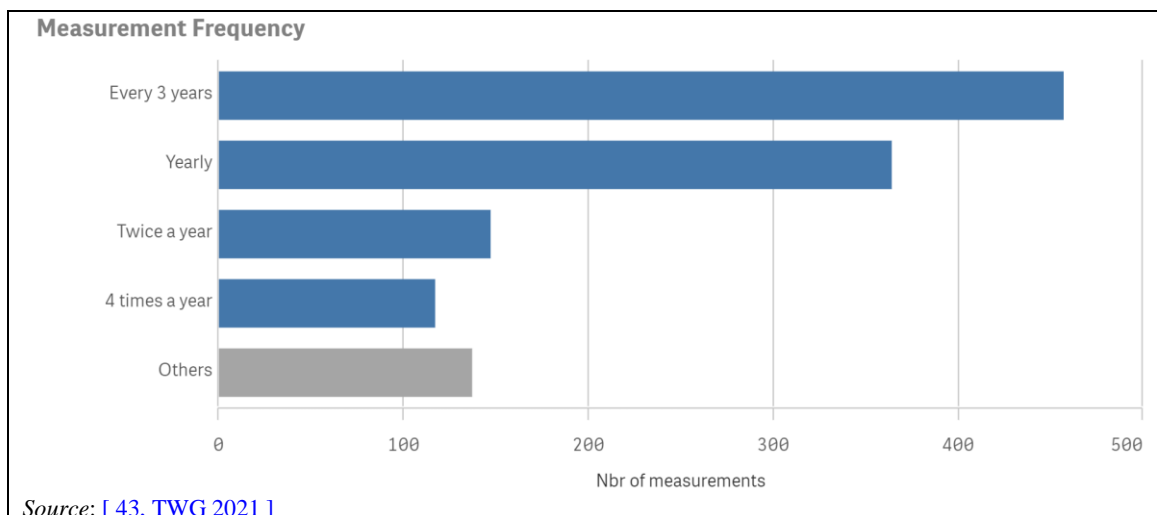


**Figure 2.96: NO<sub>x</sub> emission points from chemical processes with no waste gas treatment technique**

Higher levels of NO<sub>x</sub> emissions (e.g. up to 350 mg/Nm<sup>3</sup>) may occur if the process off-gas(es) contain(s) high levels of NO<sub>x</sub> precursors, like those originating from the process(es) of the integrated production of amino acids (e.g. methionine, such as in the case of Plant BE\_43) [57, BE 2021].

## 2.3.4.1.3 Monitoring

Periodic monitoring is more common than continuous monitoring: 1 330 instances of periodic monitoring and 216 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled nitrogen oxide emissions are shown in the bar chart of Figure 2.97. Measurement frequencies for periodic monitoring of nitrogen oxides from process furnaces/heaters are described in Section 2.9.2.2.



**Figure 2.97: Reported measurement frequencies for periodic NO<sub>x</sub> monitoring**

Percentiles for reported limits of quantification and limits of detection for nitrogen oxide measurements are shown in Table 2.25.

**Table 2.25: Reported limits of quantification and detection for NO<sub>x</sub>**

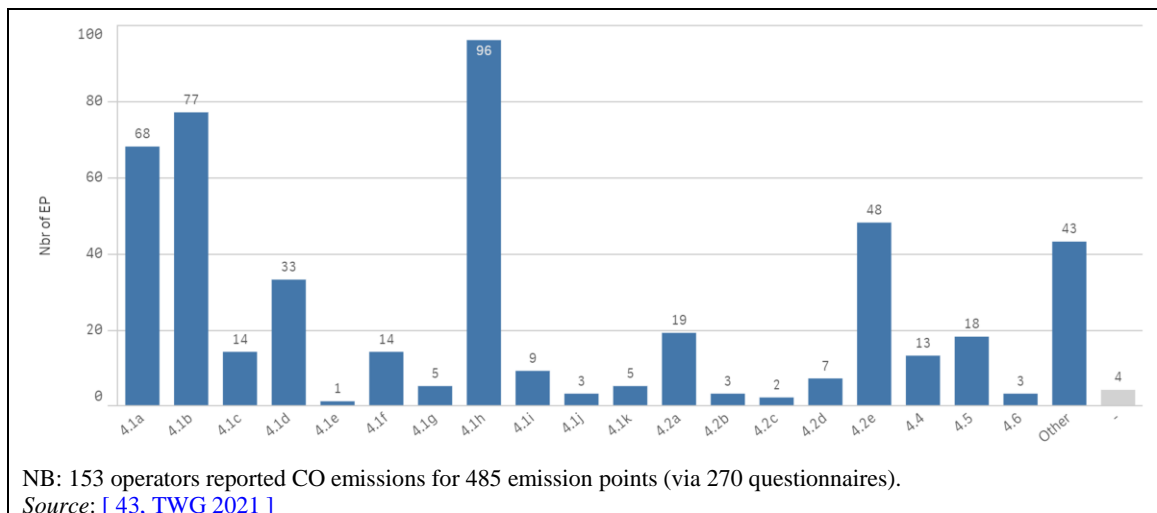
Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	1.0	0.65
50 <sup>th</sup>	4.5	2.0
80 <sup>th</sup>	7.0	5.0

NB: The numbers of instances reported for the limits of quantification and detection are 427 and 373, respectively.  
Source: [ 43, TWG 2021 ]

### 2.3.4.2 Carbon monoxide

#### 2.3.4.2.1 Sectors

Carbon monoxide is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.98.



**Figure 2.98: Number of emission points for carbon monoxide by IED category**

#### 2.3.4.2.2 Emissions

Emissions of carbon monoxide may originate from different sources from the use of catalytic or thermal oxidation of the waste gases. Emissions of carbon monoxide from process furnaces/heaters are described in Section 2.9.3.1.

For process furnaces/heaters, the typical emission levels of carbon monoxide are shown as concentration and mass flow in the scatter plot of Figure 2.202.

From the use of catalytic or thermal oxidation of the waste gases, the typical emission levels of carbon monoxide are shown as concentration and mass flow in the scatter plots of Figure 2.99 and Figure 2.100.

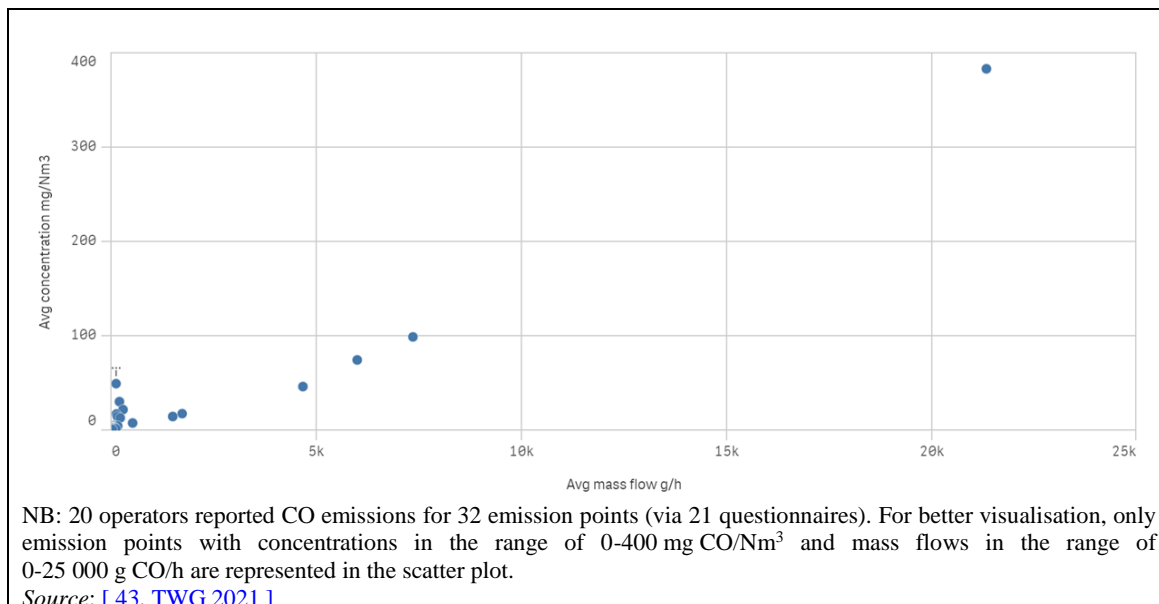


Figure 2.99: CO emissions from catalytic oxidation

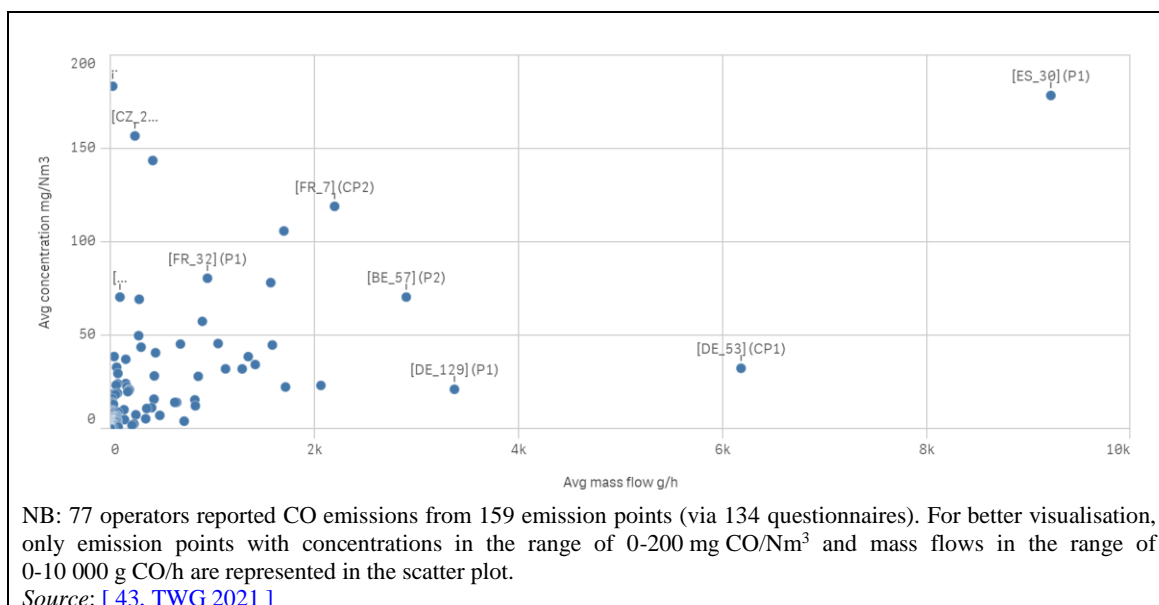


Figure 2.100: CO emissions from thermal oxidation

The typical emission levels of carbon monoxide when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.101.

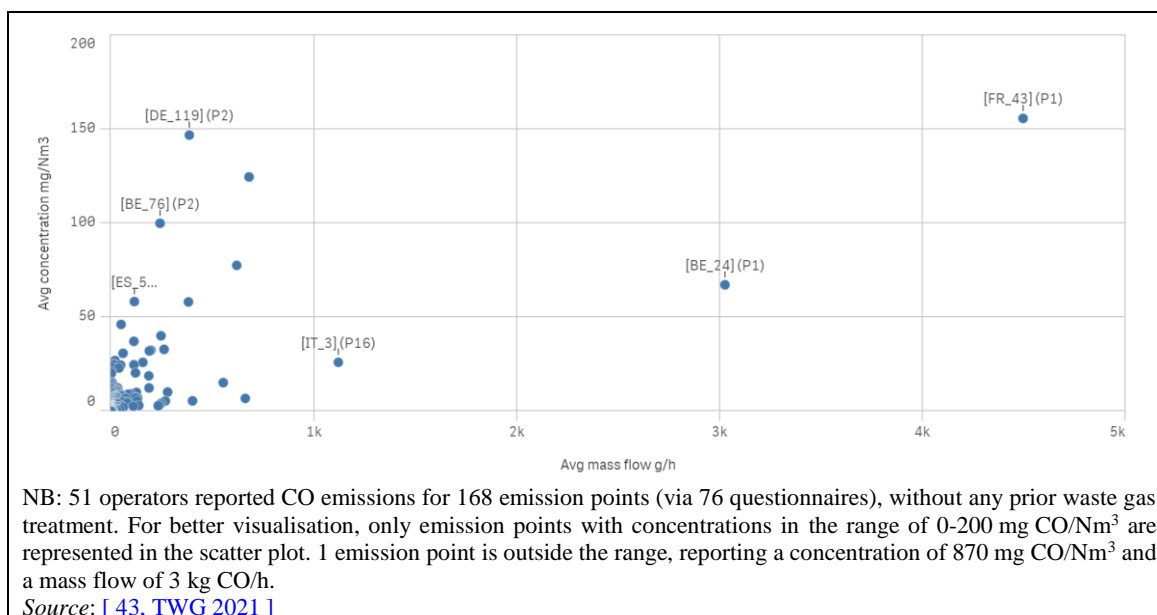


Figure 2.101: CO emission points with no waste gas treatment technique

### 2.3.4.2.3 Monitoring

Periodic monitoring is more common than continuous monitoring: 850 instances of periodic monitoring and 160 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled carbon monoxide emissions are shown in the bar chart of Figure 2.102. Measurement frequencies for periodic monitoring of carbon monoxide from process furnaces/heaters are described in Section 2.9.3.2.

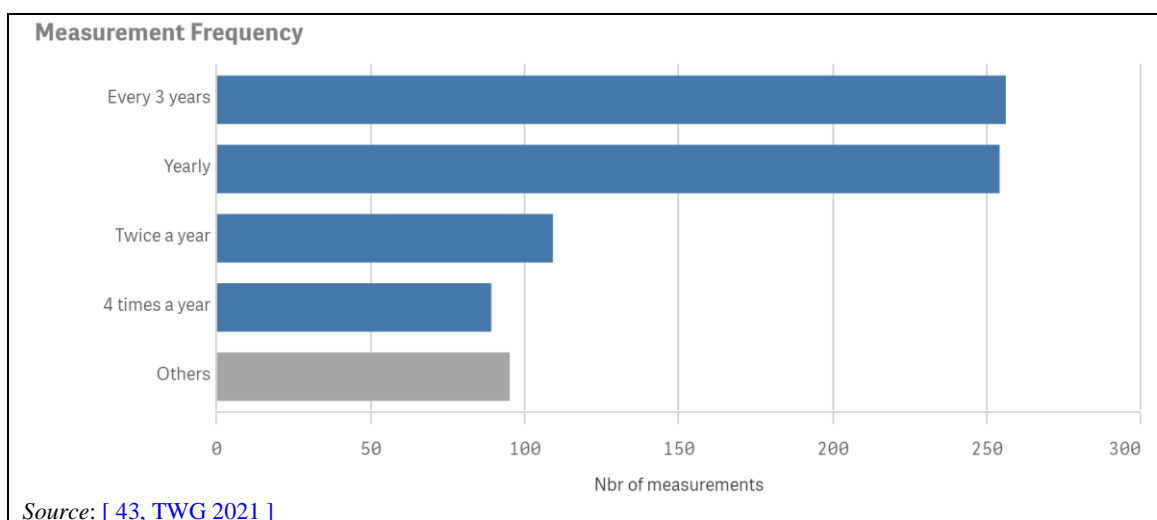


Figure 2.102: Reported measurement frequencies for periodic CO monitoring

Percentiles for reported limits of quantification and limits of detection for carbon monoxide measurements are shown in Table 2.26.

**Table 2.26: Reported limits of quantification and detection for CO**

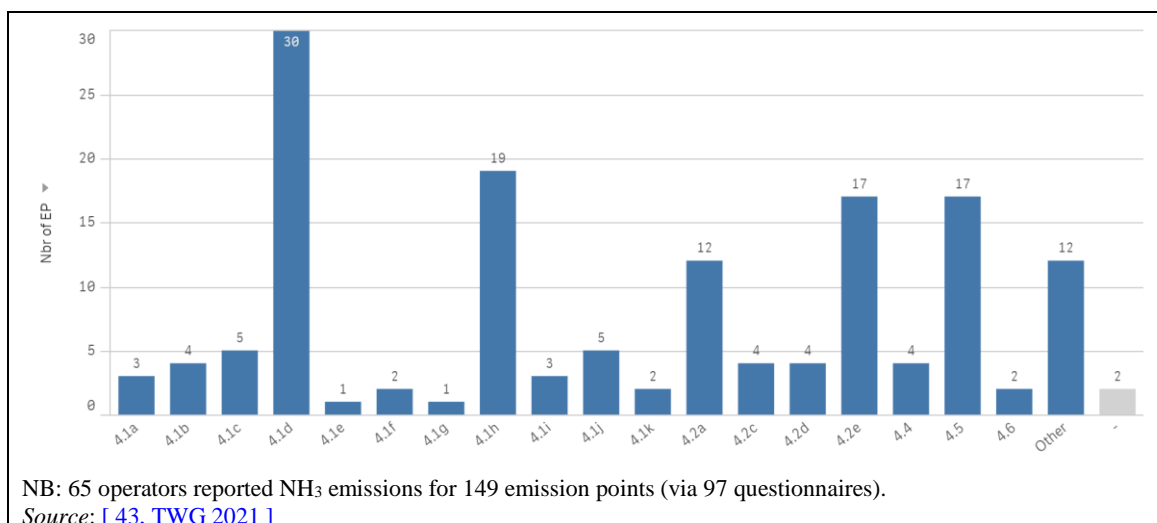
Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	1.0	0.4
50 <sup>th</sup>	3.2	1.3
80 <sup>th</sup>	6.3	2.5

NB: The numbers of instances reported for the limits of quantification and detection are 345 and 331, respectively.  
 Source: [43, TWG 2021]

### 2.3.4.3 Ammonia

#### 2.3.4.3.1 Sectors

Ammonia is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.103.



**Figure 2.103: Number of emission points for NH<sub>3</sub> by IED category**

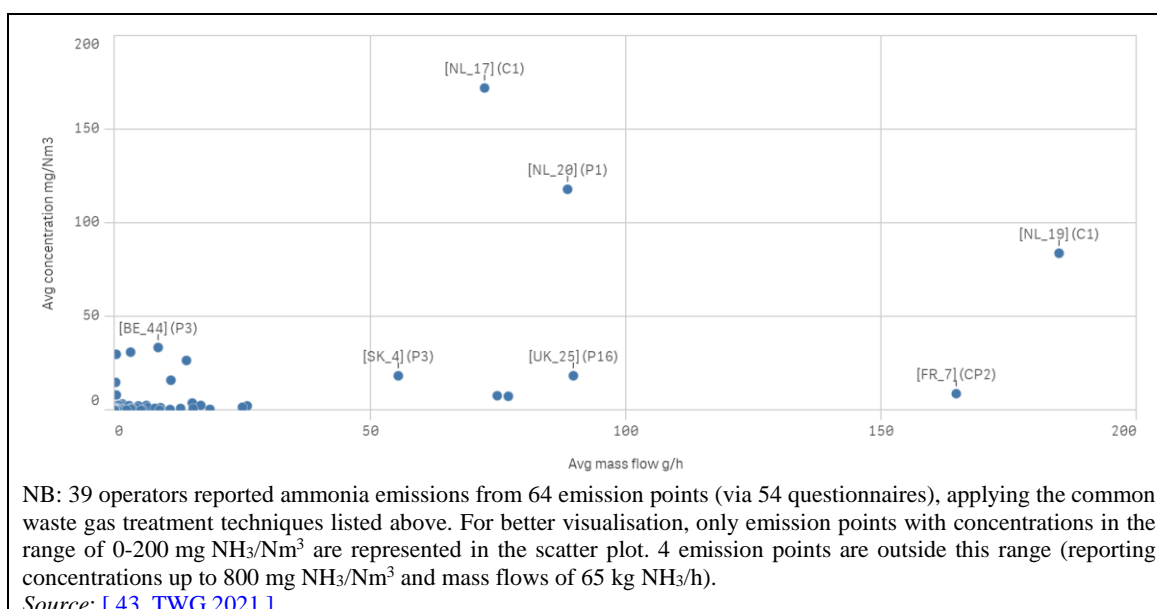
#### 2.3.4.3.2 Treated emissions

Emissions of ammonia are generally treated with at least one waste gas treatment technique. The typical emission levels of ammonia after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.104.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

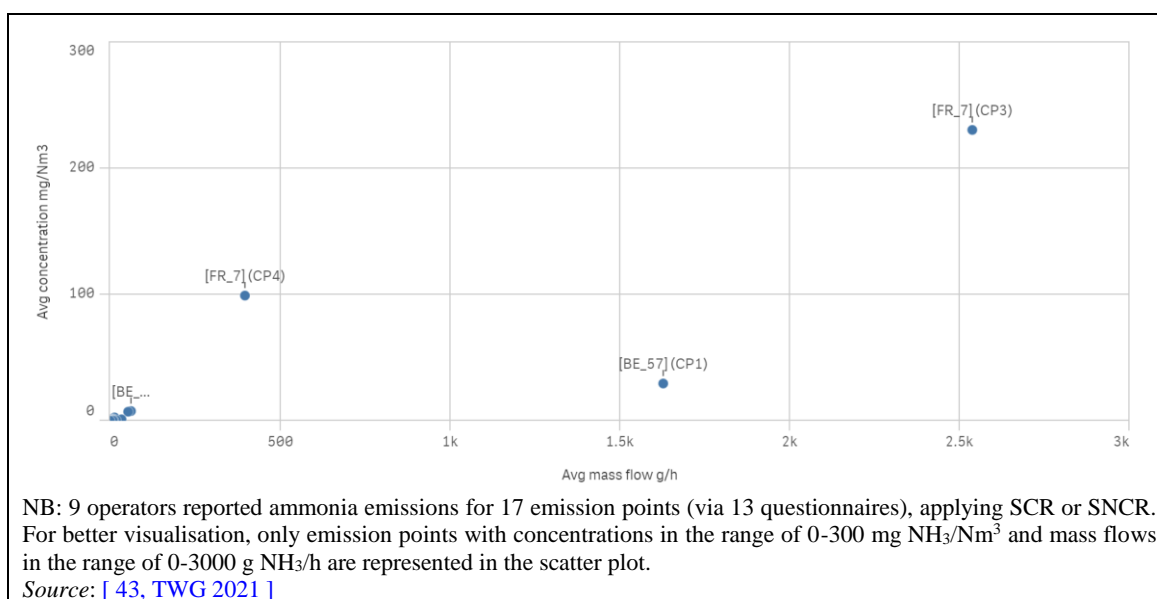
- absorption;
- adsorption;
- thermal oxidation.





**Figure 2.104: NH<sub>3</sub> emissions after waste gas treatment**

In addition, emissions of ammonia may occur when selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) are used for the abatement of NO<sub>x</sub> emissions to air. The typical emission levels of ammonia when using SCR or SNCR, are shown as concentration and mass flow in the scatter plot of Figure 2.105.



**Figure 2.105: NH<sub>3</sub> emissions for selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR)**

2.3.4.3.3 Untreated emissions

The typical emission levels of ammonia when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.106.

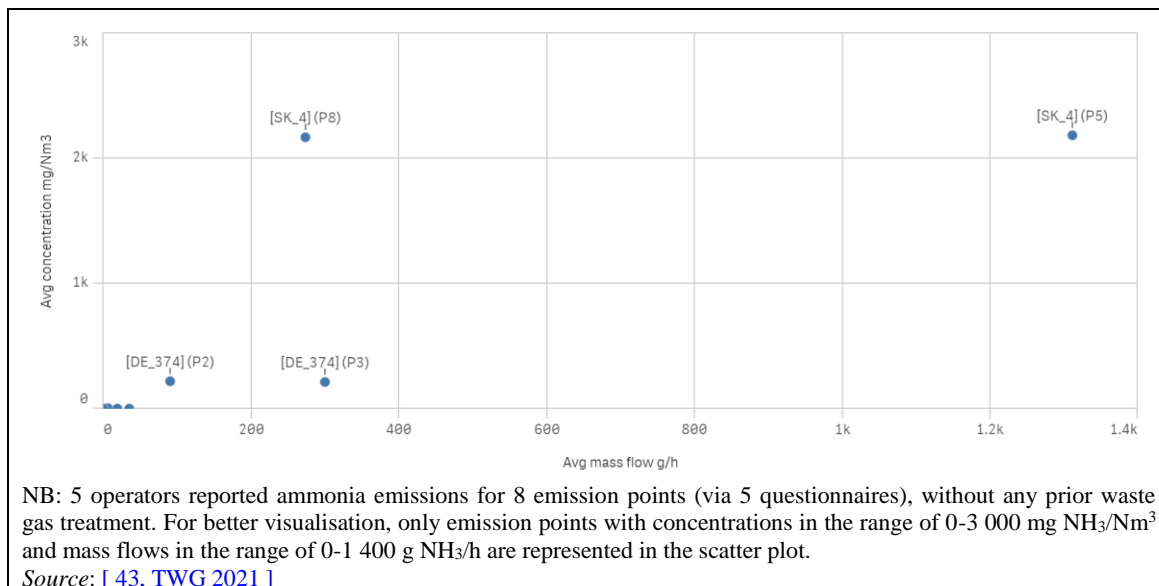


Figure 2.106: NH<sub>3</sub> emission points with no waste gas treatment technique

2.3.4.3.4 Monitoring

Periodic monitoring is more common than continuous monitoring: 265 instances of periodic monitoring and 29 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled ammonia emissions are shown in the bar chart of Figure 2.107.

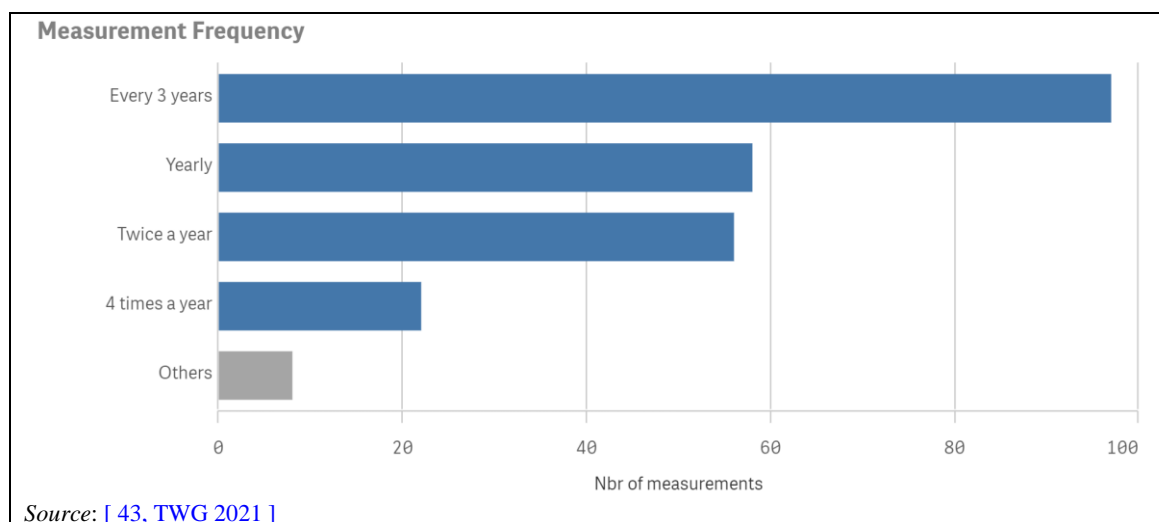


Figure 2.107: Reported measurement frequencies for periodic NH<sub>3</sub> monitoring

Percentiles for reported limits of quantification and limits of detection for ammonia measurements are shown in Table 2.27.

**Table 2.27: Reported limits of quantification and detection for NH<sub>3</sub>**

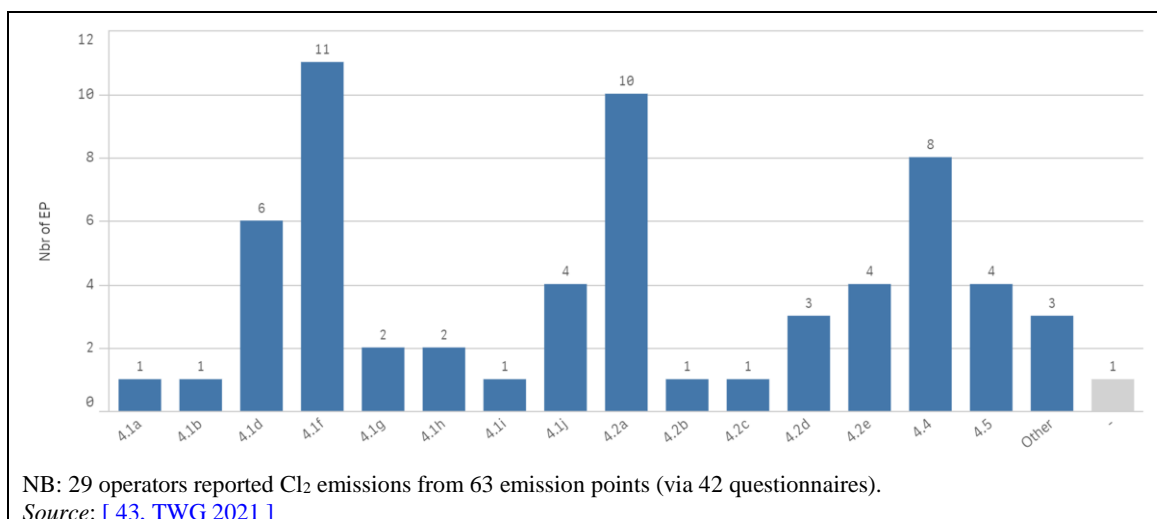
Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.05	0.05
50 <sup>th</sup>	0.40	0.25
80 <sup>th</sup>	1.08	0.40

NB: The numbers of instances reported for the limits of quantification and detection are 132 and 96, respectively.  
Source: [ 43, TWG 2021 ]

### 2.3.4.4 Elemental chlorine

#### 2.3.4.4.1 Sectors

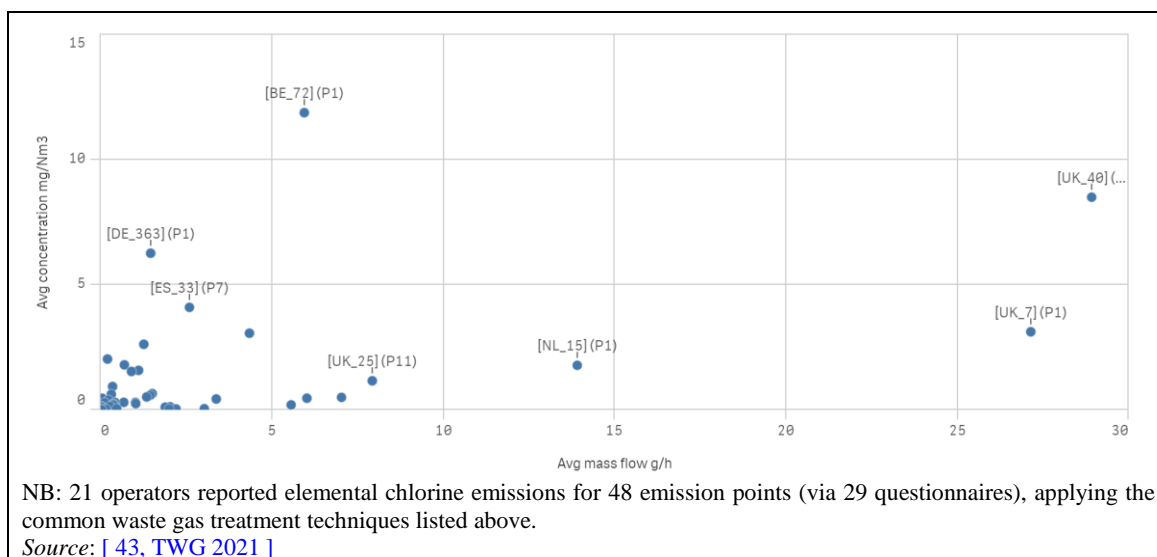
Elemental chlorine is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.108.



**Figure 2.108: Number of emission points for Cl<sub>2</sub> by IED category**

### 2.3.4.4.2 Treated missions

Emissions of elemental chlorine are generally treated with at least one waste gas treatment technique applied. The typical emission levels of elemental chlorine after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.109. The most commonly applied waste gas treatment technique is absorption. Thermal treatment is applied by two plants.



**Figure 2.109:Cl<sub>2</sub> emissions after waste gas treatment**

A Cl<sub>2</sub> emission level below 2 mg/Nm<sup>3</sup> was not achieved by the installation BE\_72 which reported higher average Cl<sub>2</sub> emissions due to the process used. To produce chlorinated toluenes, toluene and elemental chlorine are mixed and distilled afterwards. This results in high loads of chlorine in the waste gas stream even though a packed bed scrubber is applied for Cl<sub>2</sub> and HCl abatement with a very high removal efficiency, i.e. up to 99 % [ 57, BE 2021 ].

### 2.3.4.4.3 Untreated emissions

All operators reported at least one waste gas treatment technique for their emissions of elemental chlorine.

### 2.3.4.4.4 Monitoring

Periodic monitoring is more common than continuous monitoring: 108 instances of periodic monitoring and 24 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled elemental chlorine emissions are shown in the bar chart of Figure 2.110.

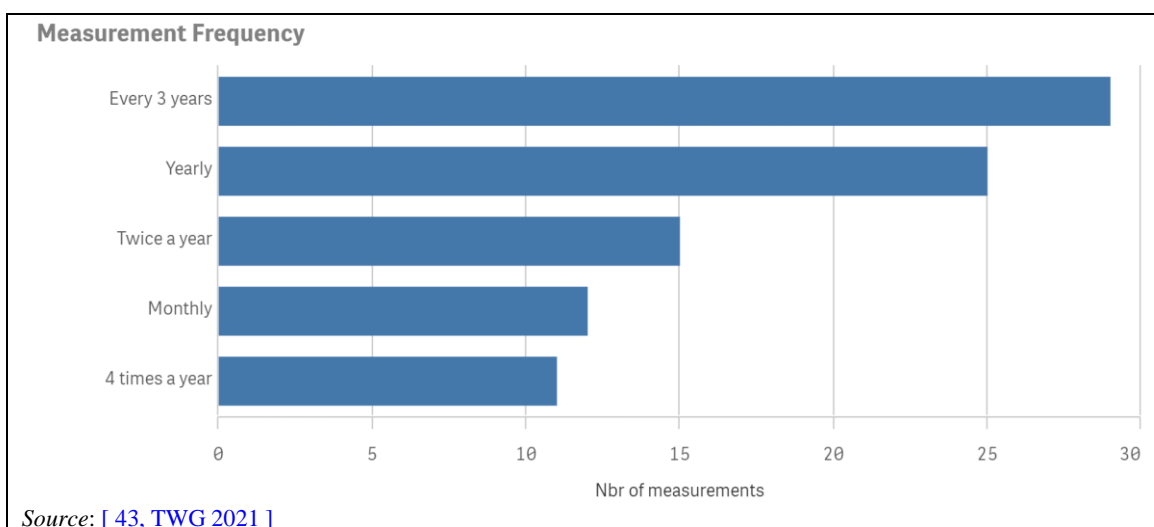


Figure 2.110: Reported measurement frequencies for periodic Cl<sub>2</sub> monitoring

Percentiles for reported limits of quantification and limits of detection for elemental chlorine measurements are shown in Table 2.28.

Table 2.28: Reported limits of quantification and detection for Cl<sub>2</sub>

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.13	0.02
50 <sup>th</sup>	0.25	0.16
80 <sup>th</sup>	0.50	0.25

NB: The numbers of instances reported for the limits of quantification and detection are 67 and 64, respectively.  
Source: [43, TWG 2021]

### 2.3.4.5 Gaseous chlorides

#### 2.3.4.5.1 Sectors

Gaseous chlorides, expressed as HCl, are typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.111.

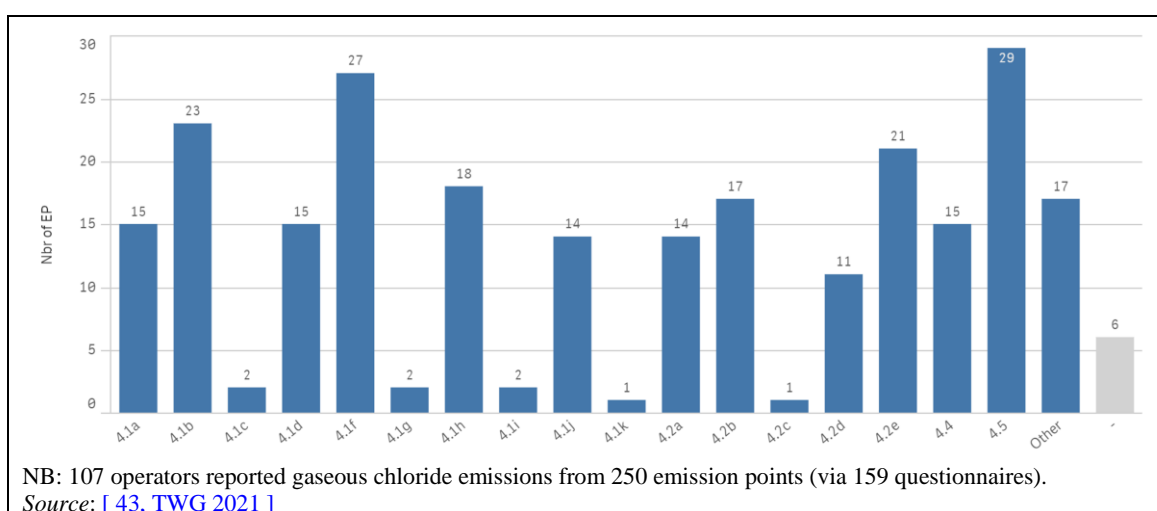


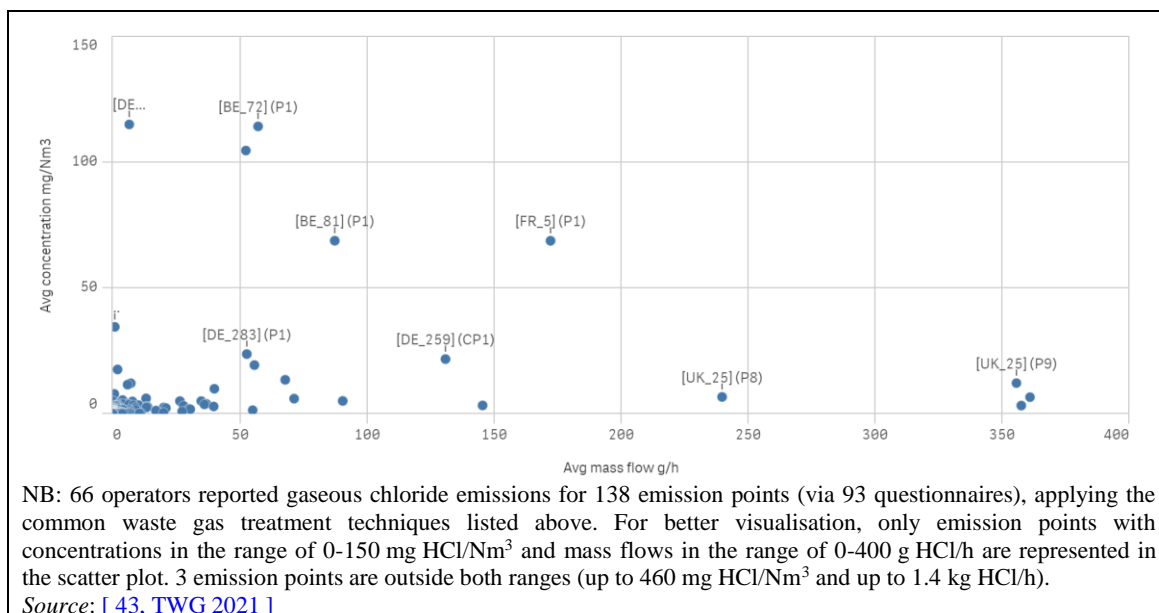
Figure 2.111: Number of emission points for HCl by IED category

## 2.3.4.5.2 Treated emissions

Emissions of gaseous chlorides are generally treated with at least one waste gas treatment technique. The typical emission levels of gaseous chloride after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.112.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

- absorption;
- adsorption.



**Figure 2.112: HCl emissions after waste gas treatment**

A HCl emission level below 10 mg/Nm<sup>3</sup> was not achieved by the installation BE\_72 which reported higher average HCl emissions due to the process used. To produce chlorinated toluenes, toluene and elemental chlorine are mixed and distilled afterwards. This results in high loads chlorine in the waste gas stream even though a packed bed scrubber is applied for Cl<sub>2</sub> and HCl abatement with a very high removal efficiency, i.e. up to 99 % [57, BE 2021].

### 2.3.4.5.3 Untreated emissions

The typical emission levels of gaseous chlorides when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.113.

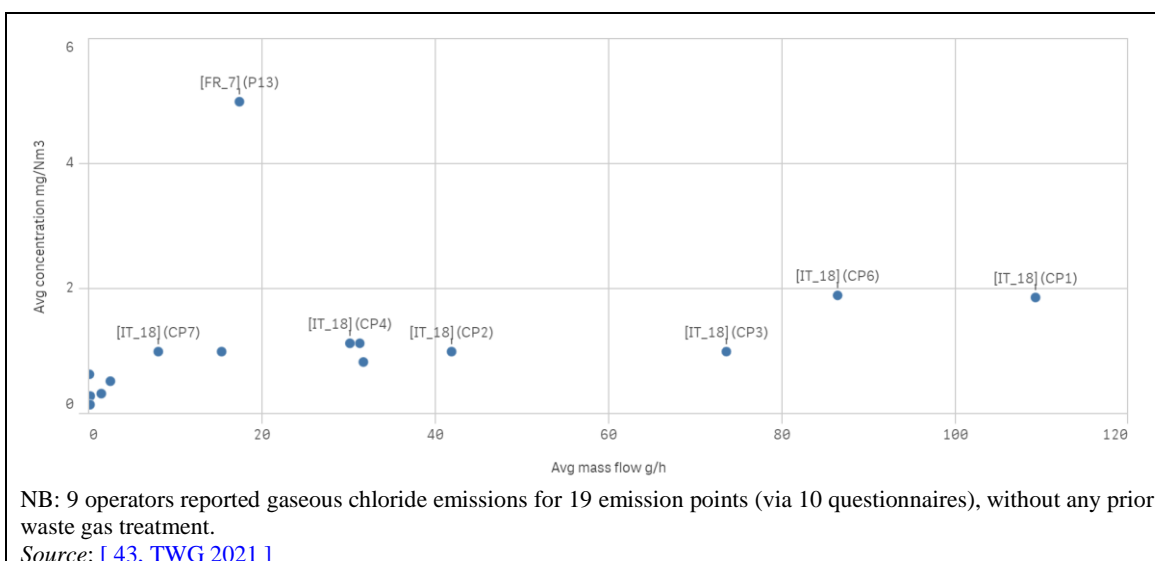


Figure 2.113:HCl emission points with no waste gas treatment technique

### 2.3.4.5.4 Monitoring

Periodic monitoring is more common than continuous monitoring: 484 instances of periodic monitoring and 36 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled gaseous chloride emissions are shown in the bar chart of Figure 2.114.

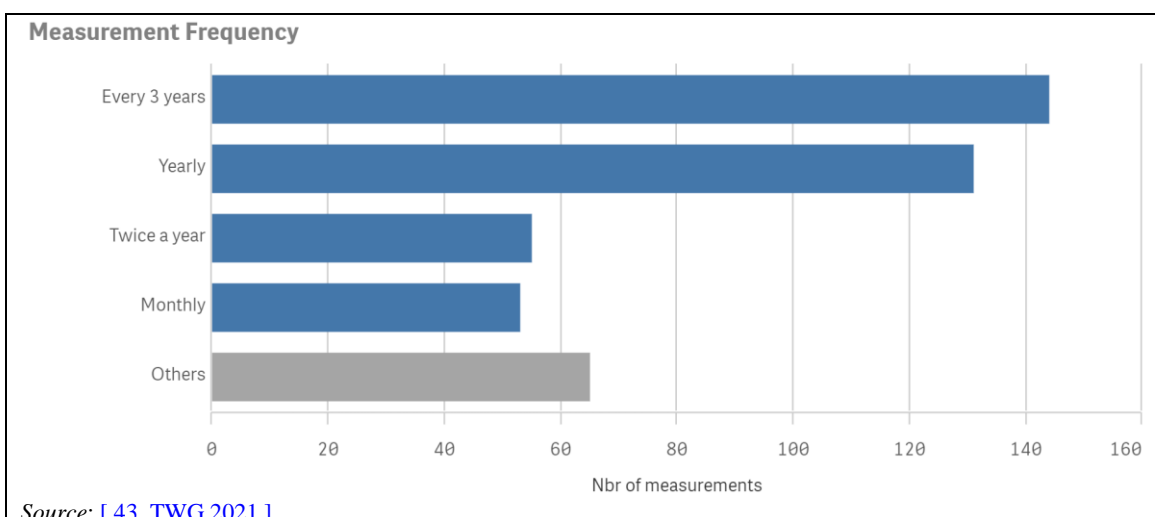


Figure 2.114:Reported measurement frequencies for periodic HCl monitoring

Percentiles for reported limits of quantification and limits of detection for gaseous chloride measurements are shown in Table 2.29.

**Table 2.29: Reported limits of quantification and detection for HCl**

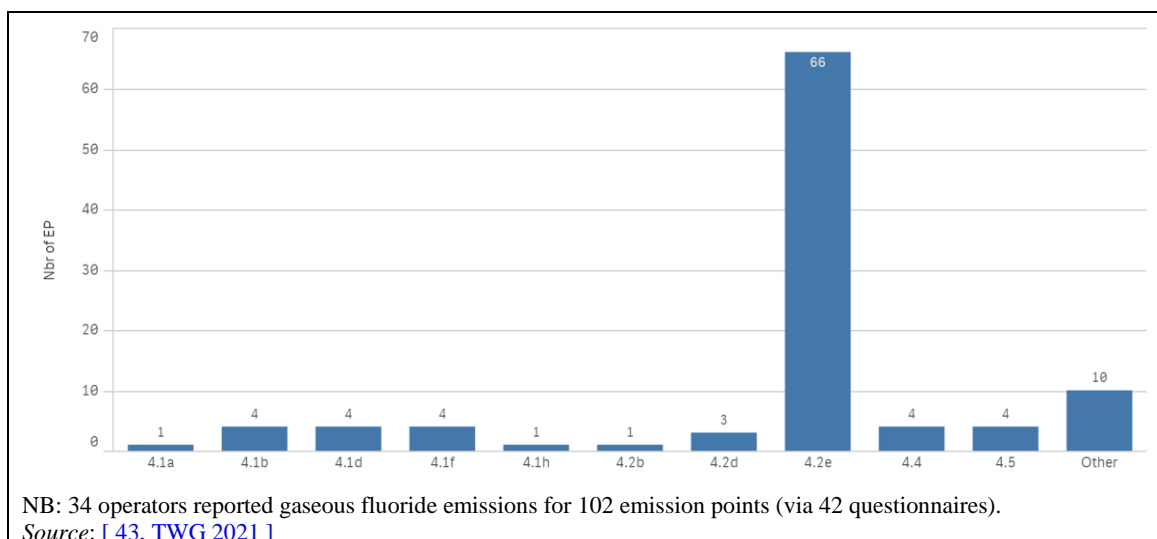
Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.13	0.03
50 <sup>th</sup>	0.5	0.2
80 <sup>th</sup>	1.0	1.0

NB: The numbers of instances reported for the limits of quantification and detection are 194 and 178, respectively.  
 Source: [43, TWG 2021]

### 2.3.4.6 Gaseous fluorides

#### 2.3.4.6.1 Sectors

Gaseous fluorides, expressed as HF, are typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.115.



**Figure 2.115: Number of emission points for HF by IED category**

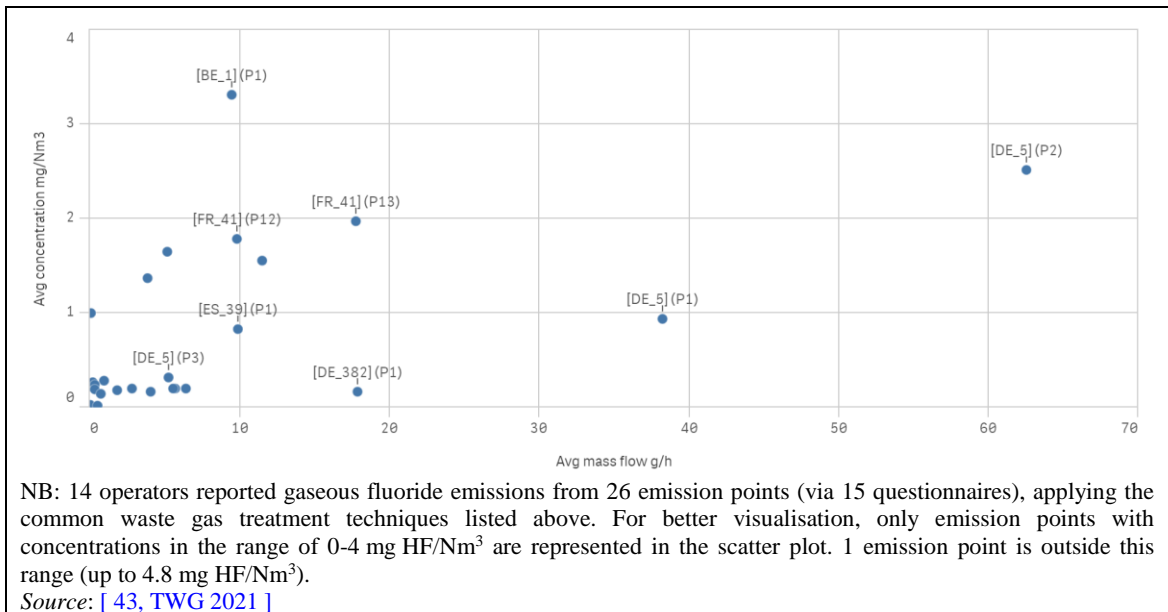
#### 2.3.4.6.2 Treated emissions

Emissions of gaseous fluorides are generally treated with at least one waste gas treatment technique. The typical emission levels of gaseous fluoride after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.116.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

- absorption;
- adsorption.

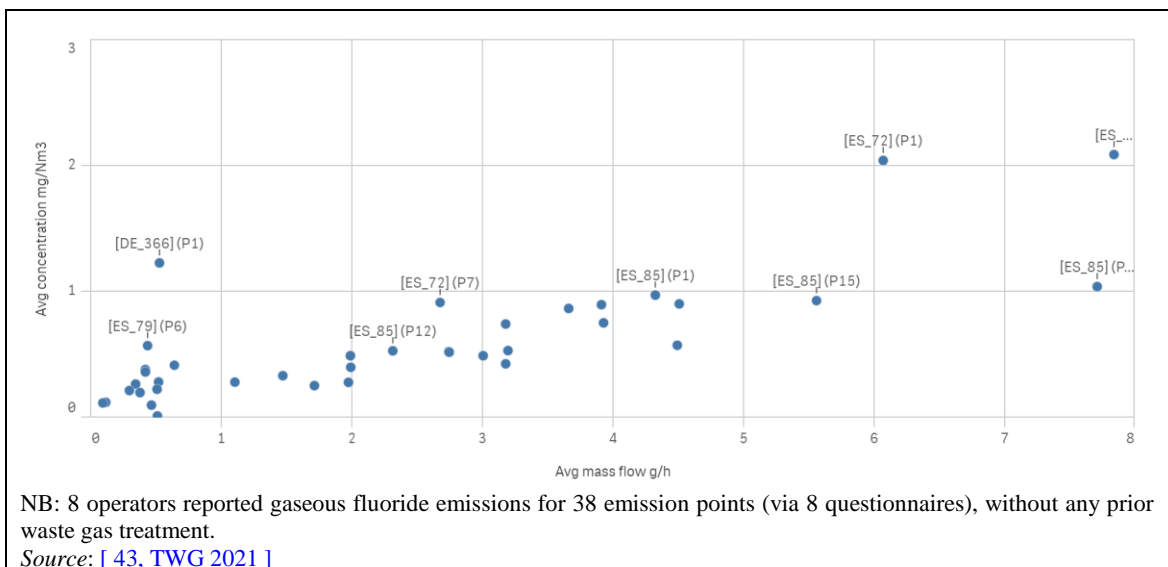




**Figure 2.116:HF emissions after waste gas treatment**

### 2.3.4.6.3 Untreated emissions

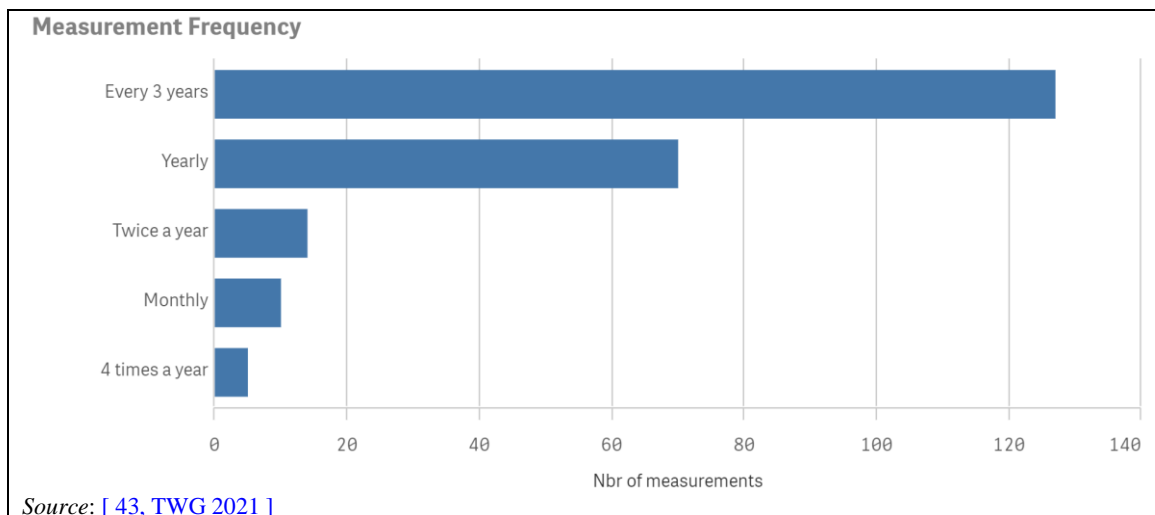
The typical emission levels of gaseous fluorides when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.117.



**Figure 2.117:HF emission points with no waste gas treatment technique**

## 2.3.4.6.4 Monitoring

Periodic monitoring is more common than continuous monitoring (238 instances of periodic monitoring and 4 of continuous monitoring were reported). Typical frequencies for the monitoring of channelled gaseous fluoride emissions are shown in the bar chart of Figure 2.118.



**Figure 2.118: Reported measurement frequencies for periodic HF monitoring**

Percentiles for reported limits of quantification and limits of detection for gaseous fluoride measurements are shown in Table 2.30.

**Table 2.30: Reported limits of quantification and detection for HF**

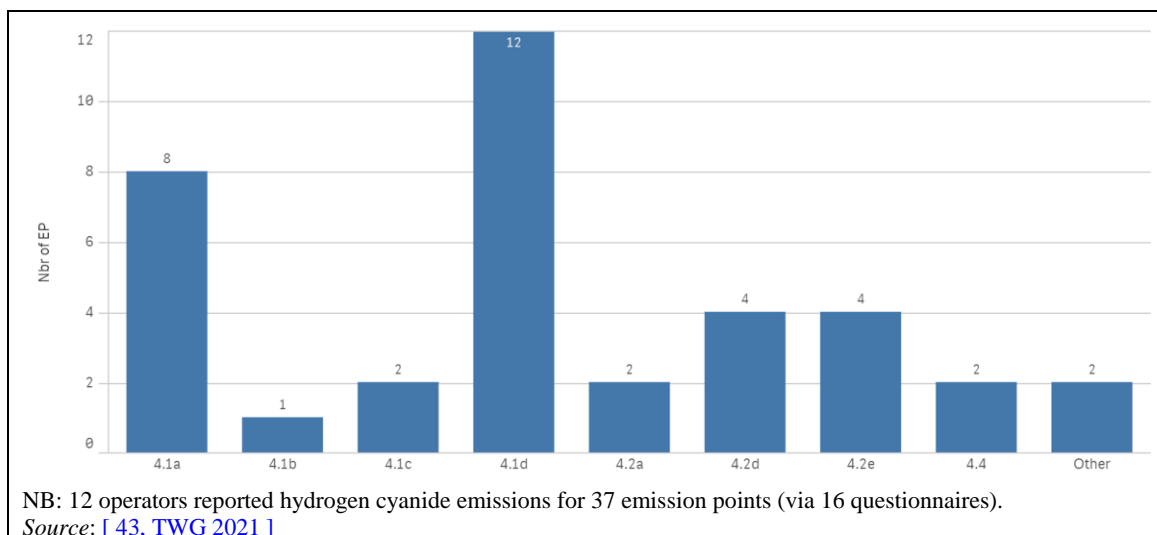
Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.14	0.01
50 <sup>th</sup>	0.2	0.06
80 <sup>th</sup>	1.0	0.14

NB: The numbers of instances reported for the limits of quantification and detection are 34 and 22, respectively.  
Source: [43, TWG 2021]

### 2.3.4.7 Hydrogen cyanide

#### 2.3.4.7.1 Sectors

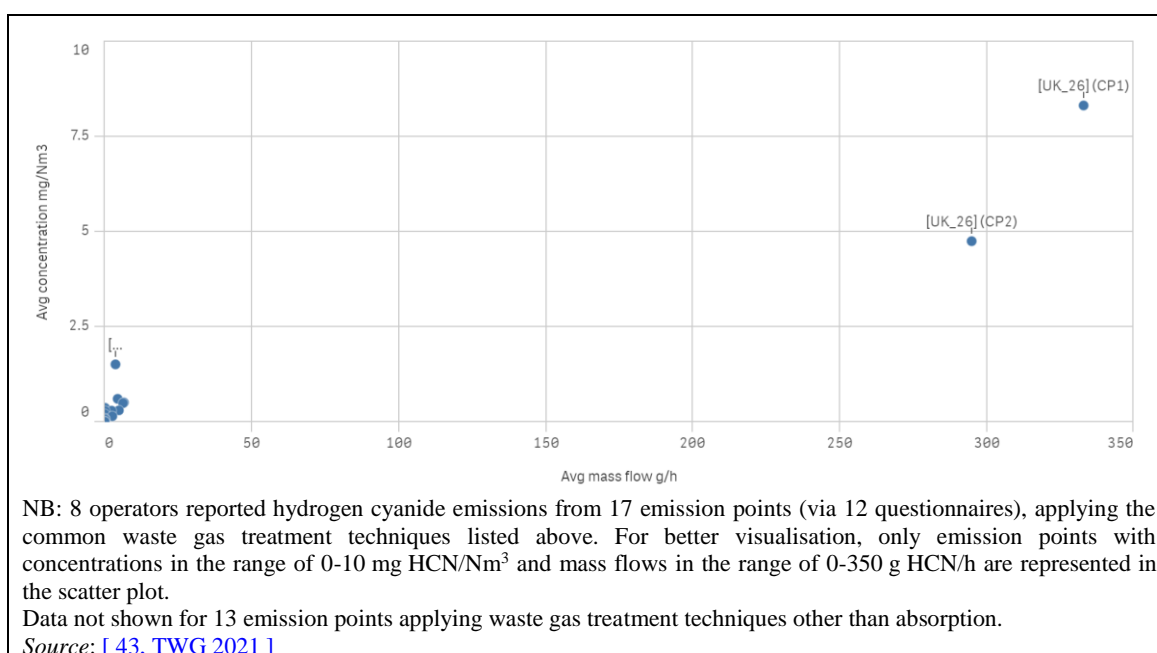
Hydrogen cyanide is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.119.



**Figure 2.119: Number of emission points for HCN by IED category**

#### 2.3.4.7.2 Treated emissions

Emissions of hydrogen cyanide are generally treated with at least one waste gas treatment technique. The typical emission levels of hydrogen cyanide after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.120. The most commonly applied waste gas treatment techniques are absorption, condensation and thermal treatment.



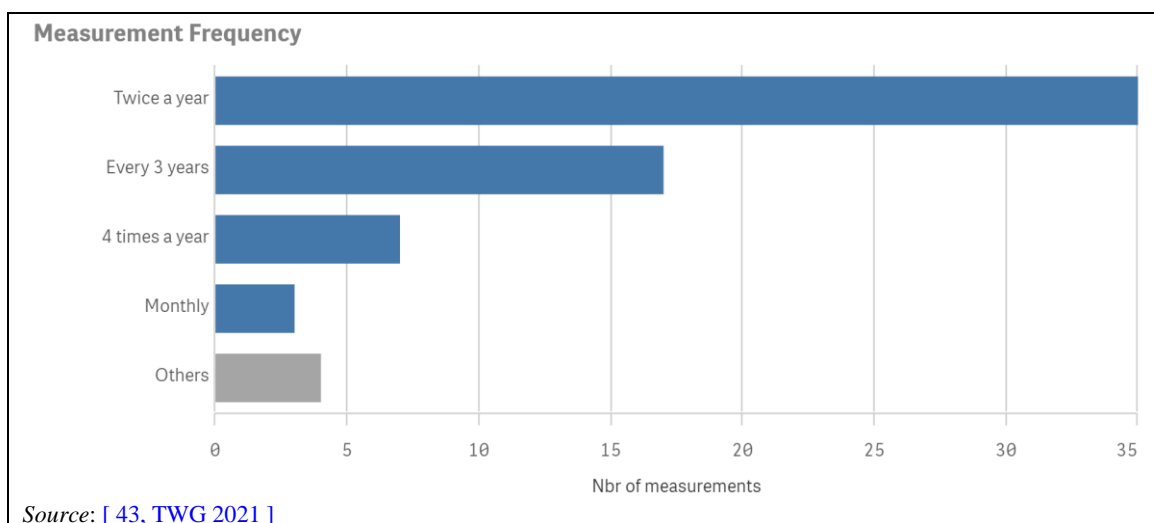
**Figure 2.120: HCN emissions after waste gas treatment**

### 2.3.4.7.3 Untreated emissions

All operators reported at least one waste gas treatment technique for their emissions of hydrogen cyanide.

### 2.3.4.7.4 Monitoring

Periodic monitoring is more common than continuous monitoring: 68 instances of periodic monitoring and 9 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled hydrogen cyanide emissions are shown in the bar chart of Figure 2.121.



**Figure 2.121: Reported measurement frequencies for periodic HCN monitoring**

Percentiles for reported limits of quantification and limits of detection for hydrogen cyanide measurements are shown in Table 2.31.

**Table 2.31: Reported limits of quantification and detection for HCN**

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.02	0.01
50 <sup>th</sup>	0.11	0.14
80 <sup>th</sup>	0.6	0.2

NB: The numbers of instances reported for the limits of quantification and detection are 19 and 6, respectively.  
Source: [43, TWG 2021]

### 2.3.4.8 Sulphur oxides

#### 2.3.4.8.1 Sectors

Sulphur oxides are typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.122.

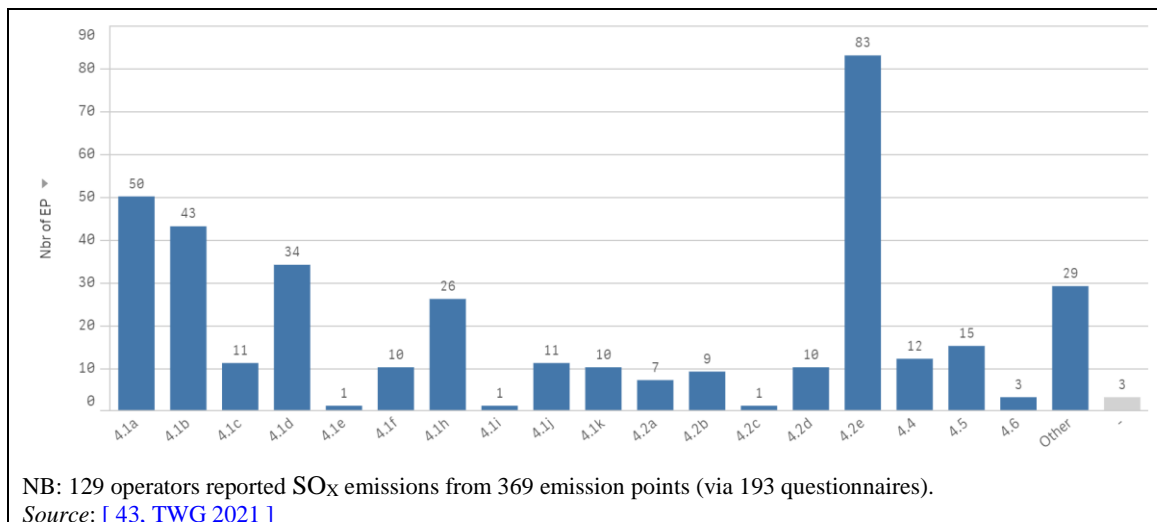


Figure 2.122: Number of emission points for SO<sub>x</sub> by IED category

#### 2.3.4.8.2 Treated emissions

Emissions of sulphur oxides are generally treated with at least one waste gas treatment technique. The typical emission levels of sulphur oxides after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.123.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

- absorption;
- adsorption.

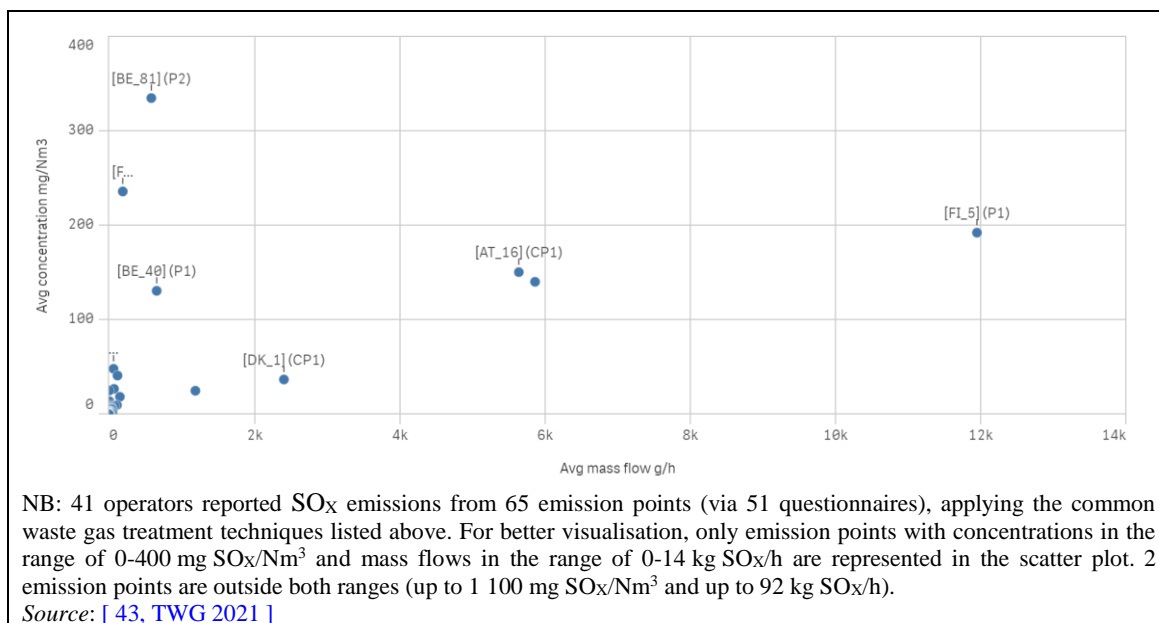


Figure 2.123:SO<sub>x</sub> emissions after waste gas treatment

2.3.4.8.3 Untreated emissions

The typical emission levels of sulphur oxides when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.124.

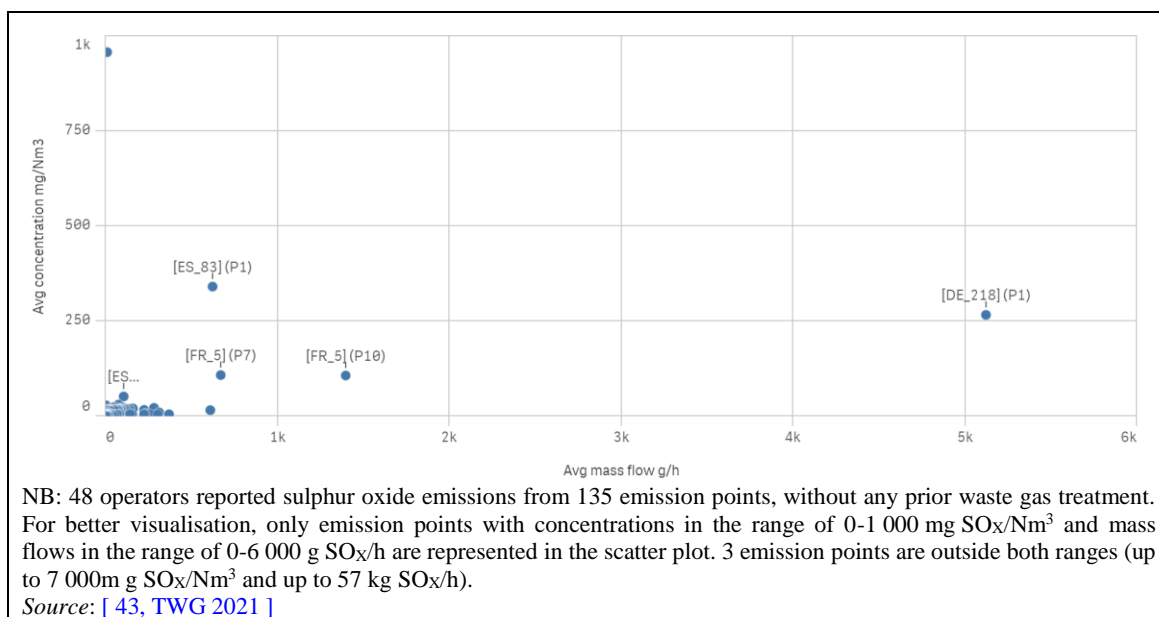
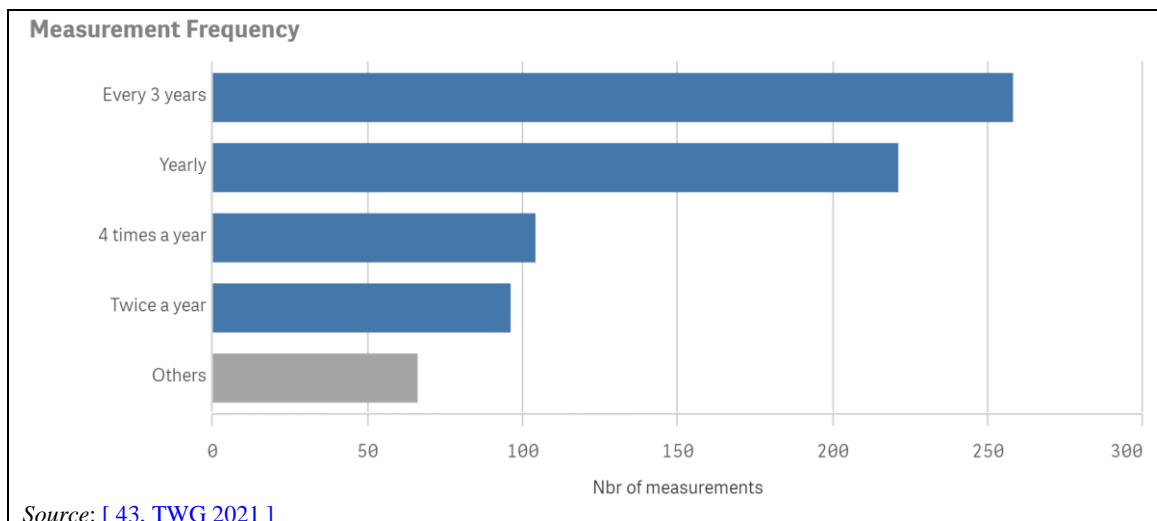


Figure 2.124:SO<sub>x</sub> emission points with no waste gas treatment technique

### 2.3.4.8.4 Monitoring

Periodic monitoring is more common than continuous monitoring: 795 instances of periodic monitoring and 60 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled sulphur oxide emissions are shown in the bar chart of Figure 2.125.



**Figure 2.125: Reported measurement frequencies for periodic SO<sub>x</sub> monitoring**

Percentiles for reported limits of quantification and limits of detection for sulphur oxide measurements are shown in Table 2.32.

**Table 2.32: Reported limits of quantification and detection for SO<sub>x</sub>**

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.1	0.03
50 <sup>th</sup>	1.0	1.5
80 <sup>th</sup>	11.0	14.0

NB: The numbers of instances reported for the limits of quantification and detection are 288 and 227, respectively.  
Source: [ 43, TWG 2021 ]

## 2.4 Diffuse VOC emissions

### 2.4.1 Fugitive VOC emissions

Substances/parameters reported as fugitive VOC emissions are shown in Table 2.33.

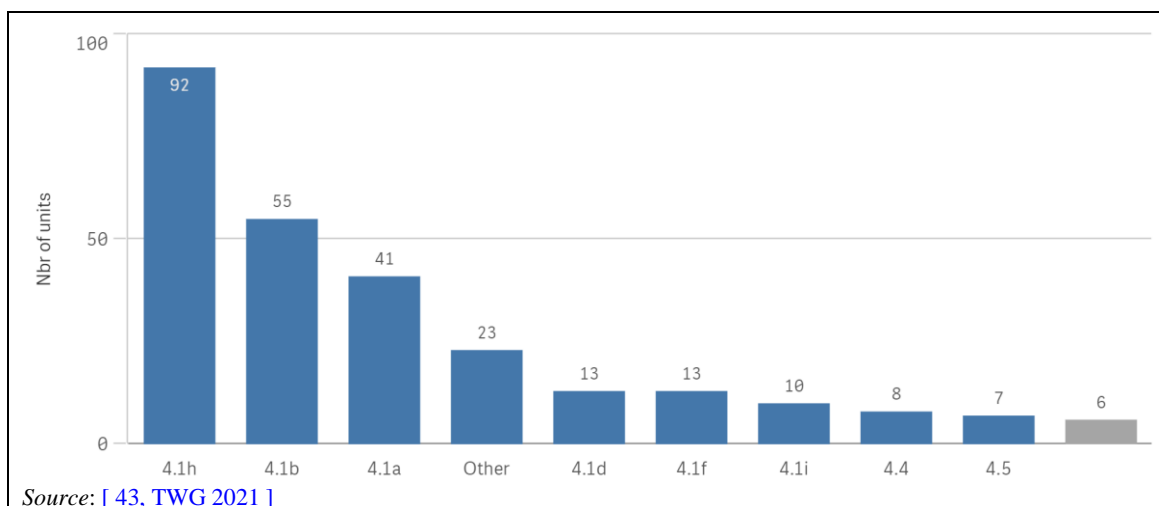
**Table 2.33: Substances/Parameters reported as fugitive VOC emissions**

Substance/Parameter	No of units
TVOC	270
TVOC containing substances classified as CMR 1A or 1B	104
TVOC containing substances classified as CMR 2	63
Benzene	35
1,3-Butadiene	30
Toluene	25
Vinyl chloride	22
Ethylene oxide	12
Others	35
<i>Source: [43, TWG 2021]</i>	

#### 2.4.1.1 Emissions

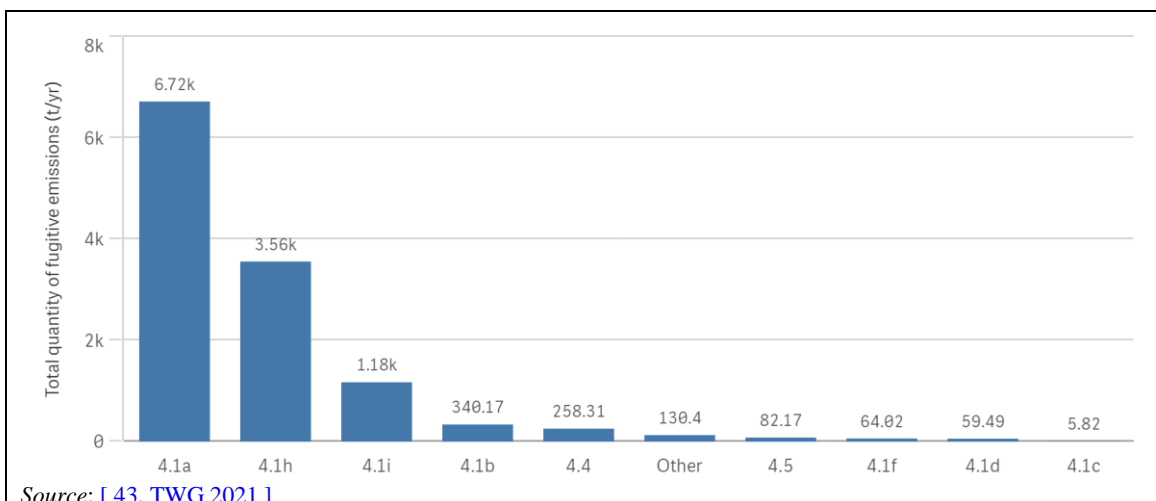
##### 2.4.1.1.1 TVOC

Figure 2.126 shows the number of units reporting fugitive TVOC emissions by IED chemical activity and Figure 2.127 shows the IED chemical activities that contribute to fugitive emissions of TVOC.



**Figure 2.126: Fugitive TVOC emissions reported by chemical activity**



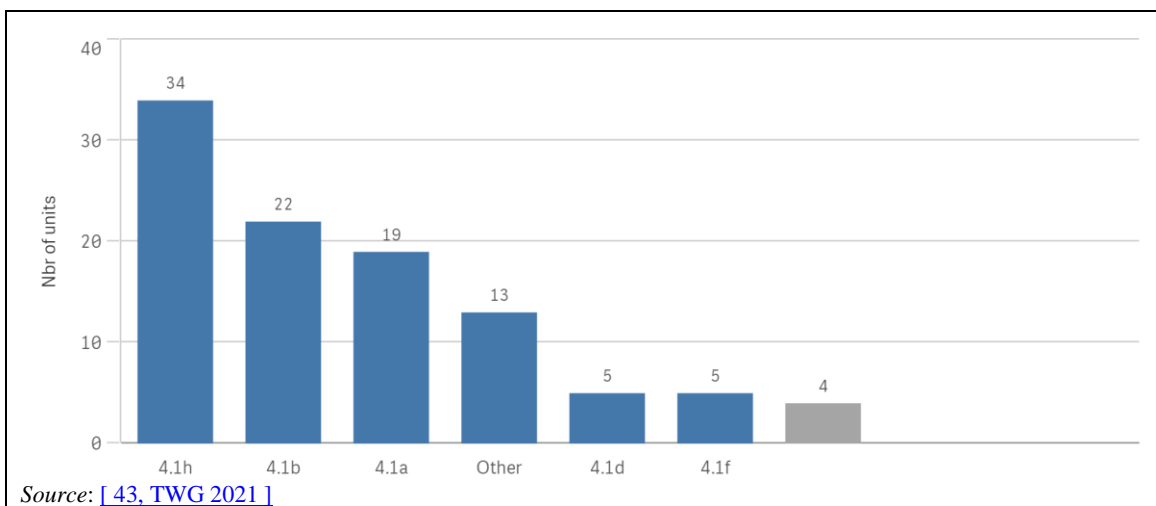


**Figure 2.127: Quantity of fugitive TVOC emissions reported by chemical activity**

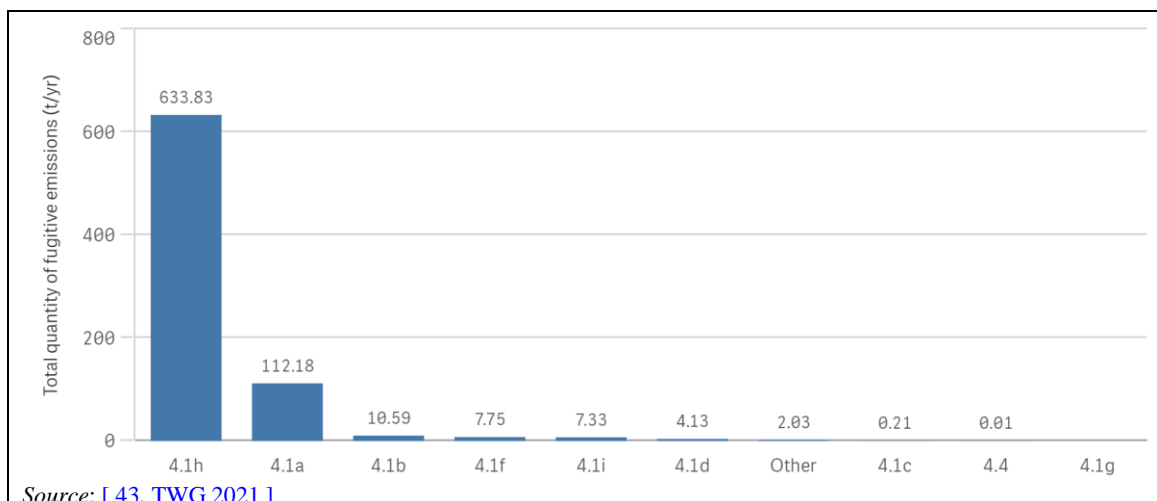
A wide range of quantities was reported from 70 g to 1 800 tonnes of TVOC per year. The total quantity of fugitive emissions of TVOC sums up to 12 400 tonnes per year.

#### 2.4.1.1.2 TVOC containing substances classified as CMR 1A or 1B

Figure 2.128 shows the number of units reporting fugitive emissions of TVOC containing substances classified as CMR 1A or 1B and Figure 2.129 shows the chemical activities contributing to fugitive emissions of TVOC containing substances classified as CMR 1A or 1B.



**Figure 2.128: Fugitive emissions of TVOC containing substances classified as CMR 1A or 1B reported by chemical activity**

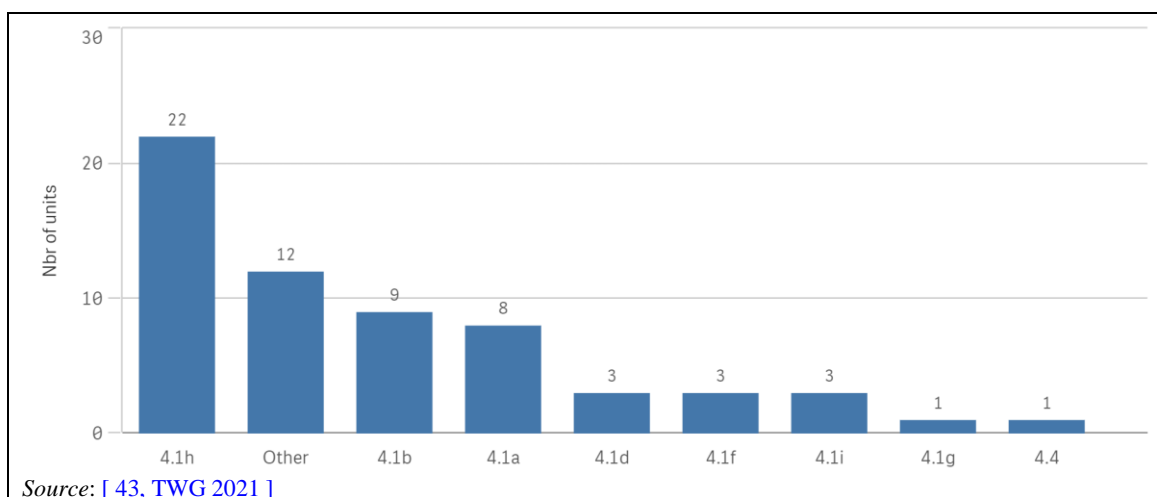


**Figure 2.129: Quantity of fugitive emissions of TVOC containing substances classified as CMR 1A or 1B reported by chemical activity**

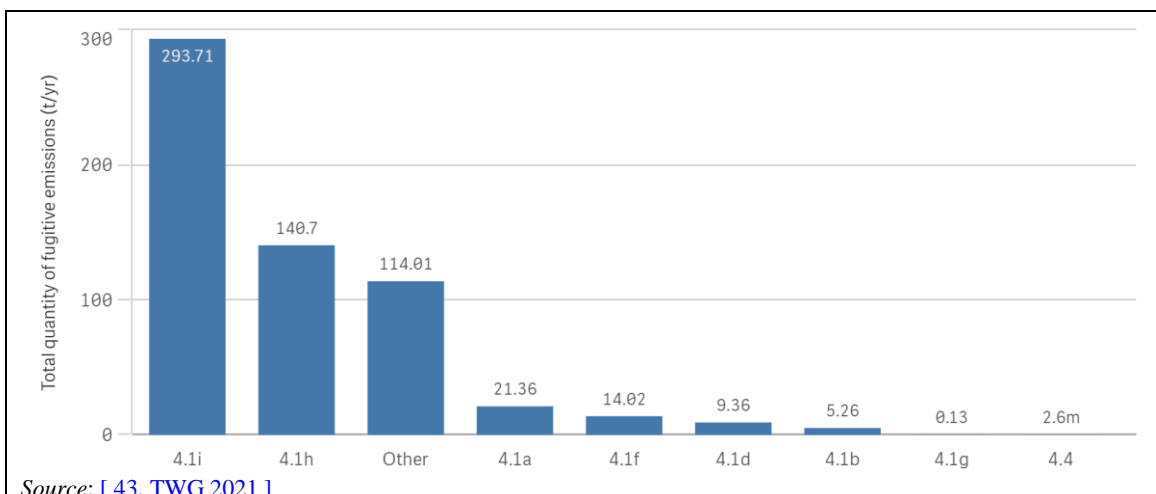
A wide range of quantities was reported from 70 g to 600 tonnes of TVOC containing substances classified as CMR 1A or 1B per year. The total quantity of fugitive emissions sums up to 778 tonnes per year of TVOC containing substances classified as CMR 1A or 1B.

#### 2.4.1.1.3 TVOC containing substances classified as CMR 2

Figure 2.130 shows the number of units reporting fugitive emissions of TVOC containing substances classified as CMR 2 and Figure 2.131 shows the chemical activities contributing to fugitive emissions of TVOC containing substances classified as CMR 2.



**Figure 2.130: Fugitive emissions of TVOC containing substances classified as CMR 2 reported by chemical activity**

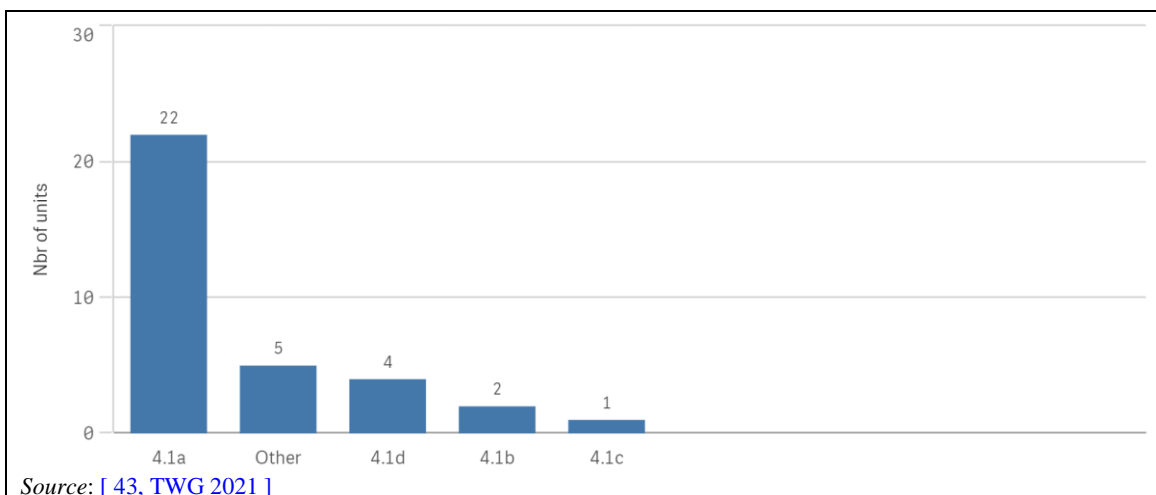


**Figure 2.131: Quantity of fugitive emissions of TVOC containing substances classified as CMR 2 reported by chemical activity**

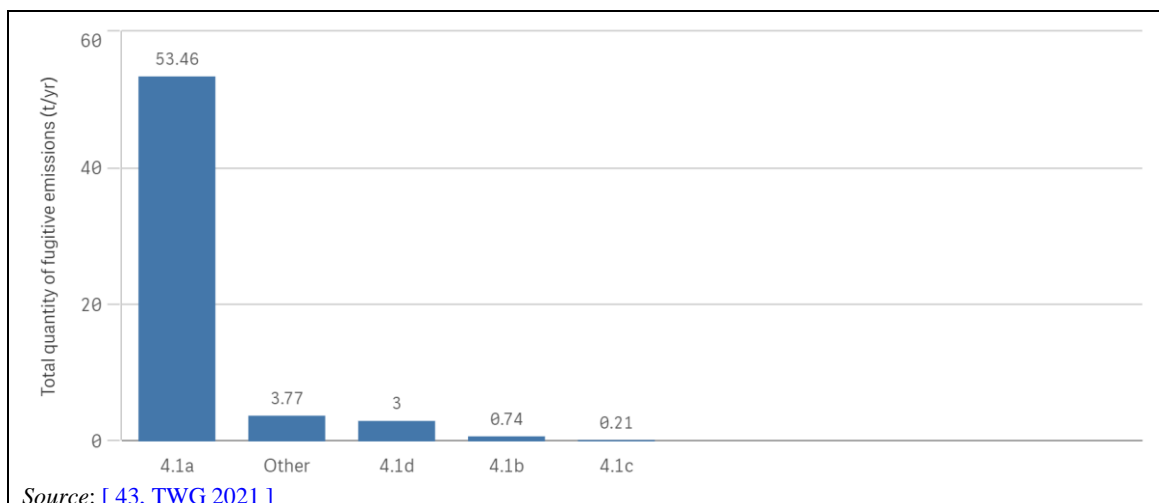
A wide range of quantities was reported from 1 kg to 294 tonnes of TVOC containing substances classified as CMR 2 per year. The total quantity of fugitive emissions sums up to 600 tonnes per year of TVOC containing substances classified as CMR 2.

#### 2.4.1.1.4 Benzene

Figure 2.132 shows the number of units reporting fugitive emissions of benzene and Figure 2.133 shows the chemical activities contributing to fugitive emissions of benzene.



**Figure 2.132: Fugitive benzene emissions reported by chemical activity**

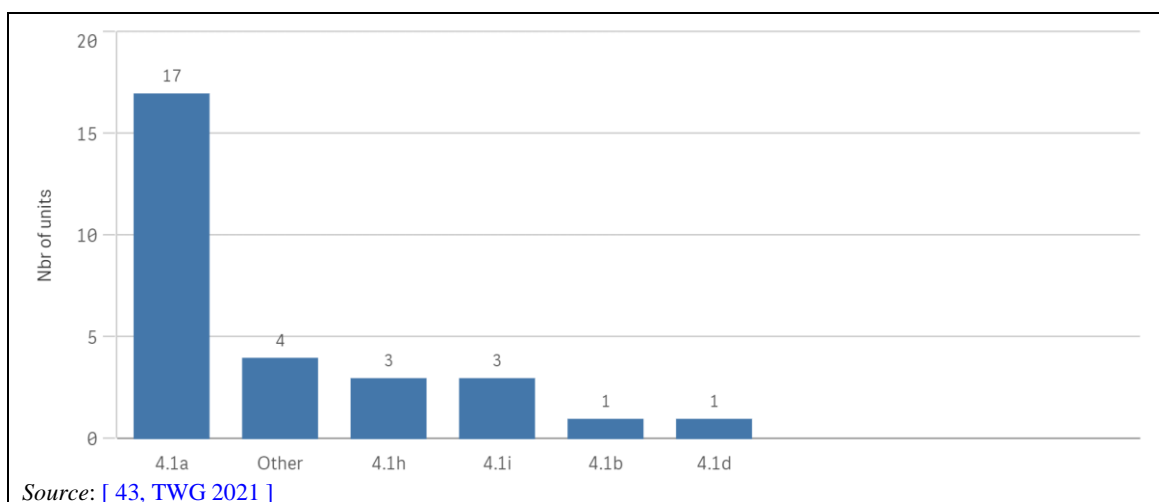


**Figure 2.133:Quantity of fugitive benzene emissions reported by chemical activity**

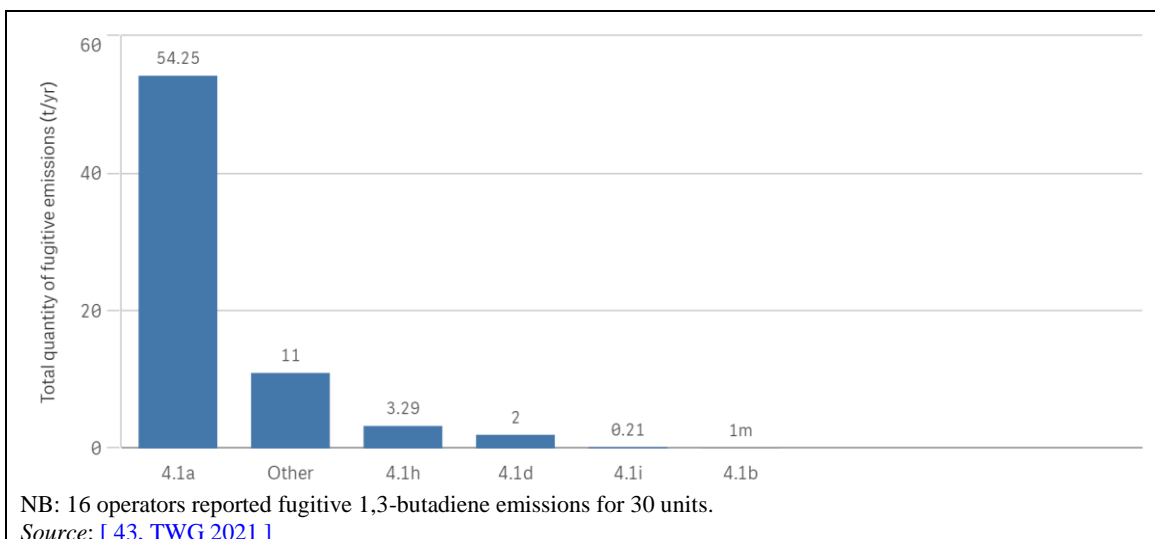
A wide range of quantities was reported from 36 kg to 22 tonnes of benzene per year. The total quantity of fugitive emissions of benzene sums up to 61 tonnes per year.

**2.4.1.1.5 1,3-Butadiene**

Figure 2.134 shows the number of units reporting fugitive emissions of 1,3-butadiene and Figure 2.135 shows the chemical activities contributing to fugitive emissions of 1,3-butadiene.



**Figure 2.134:Fugitive 1,3-butadiene emissions reported by chemical activity**

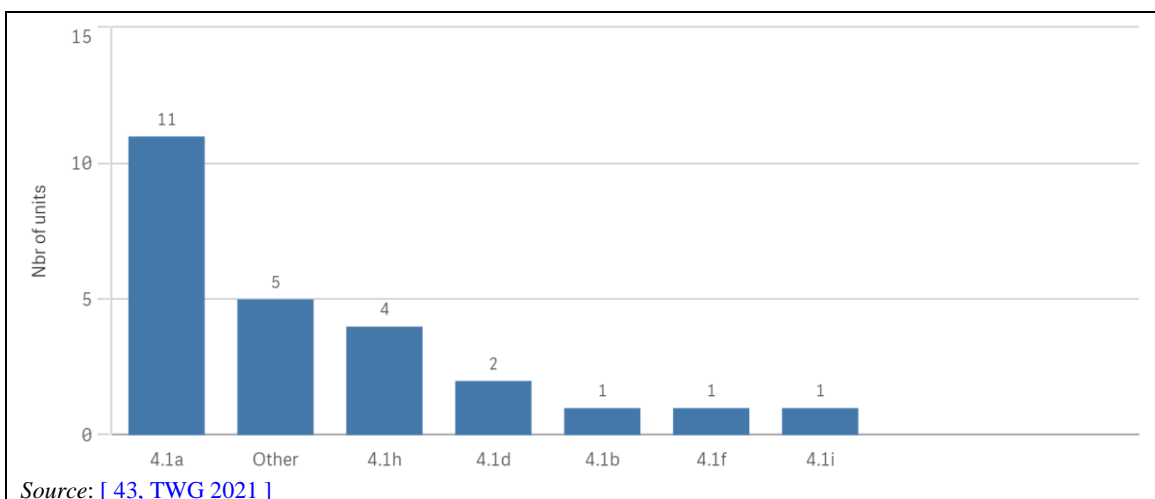


**Figure 2.135: Quantity of fugitive 1,3-butadiene emissions reported by chemical activity**

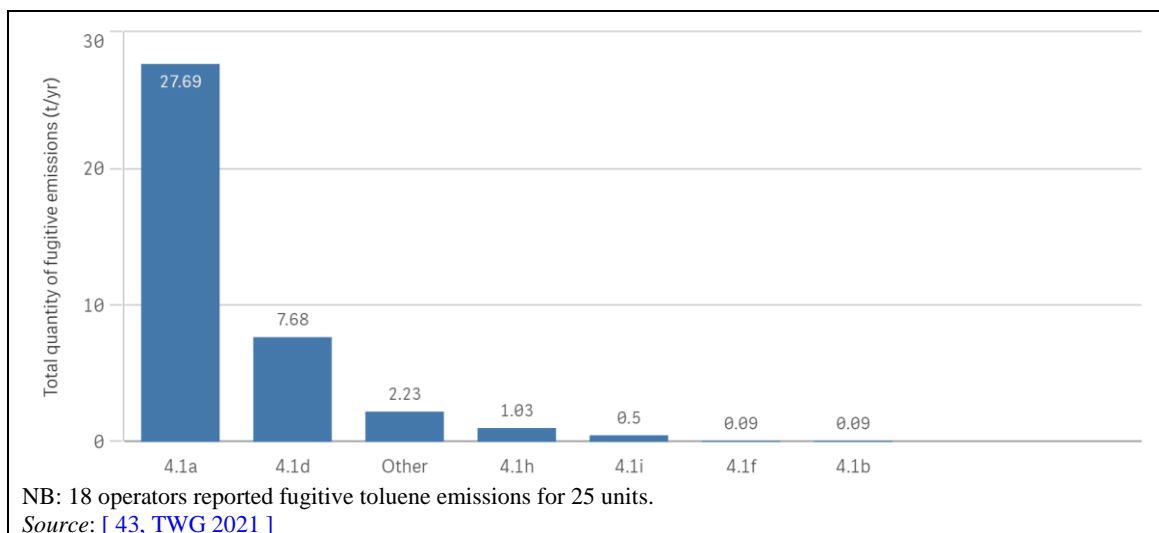
A wide range of quantities was reported from 10 kg to 17 tonnes of 1,3-butadiene per year. The total quantity of fugitive emissions of 1,3-butadiene sums up to 71 tonnes per year.

#### 2.4.1.1.6 Toluene

Figure 2.136 shows the number of units reporting fugitive emissions of toluene and Figure 2.137 shows the chemical activities contributing to fugitive emissions of toluene.



**Figure 2.136: Fugitive toluene emissions reported by chemical activity**

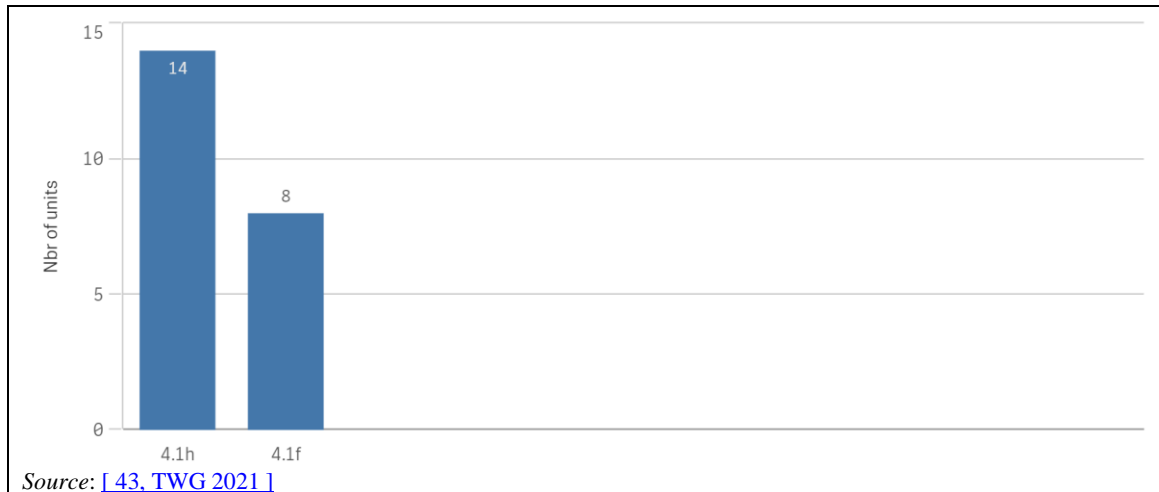


**Figure 2.137:Quantity of fugitive toluene emissions reported by chemical activity**

A wide range of quantities was reported from 20 kg to 22 tonnes of toluene per year. The total quantity of fugitive emissions of toluene sums up to 39 tonnes per year.

**2.4.1.1.7 Vinyl chloride**

Figure 2.138 shows the number of units reporting fugitive emissions of vinyl chloride and Figure 2.139 shows the chemical activities contributing to fugitive emissions of vinyl chloride.



**Figure 2.138:Fugitive vinyl chloride emissions reported by chemical activity**



**Figure 2.139:Quantity of fugitive vinyl chloride emissions reported by chemical activity**

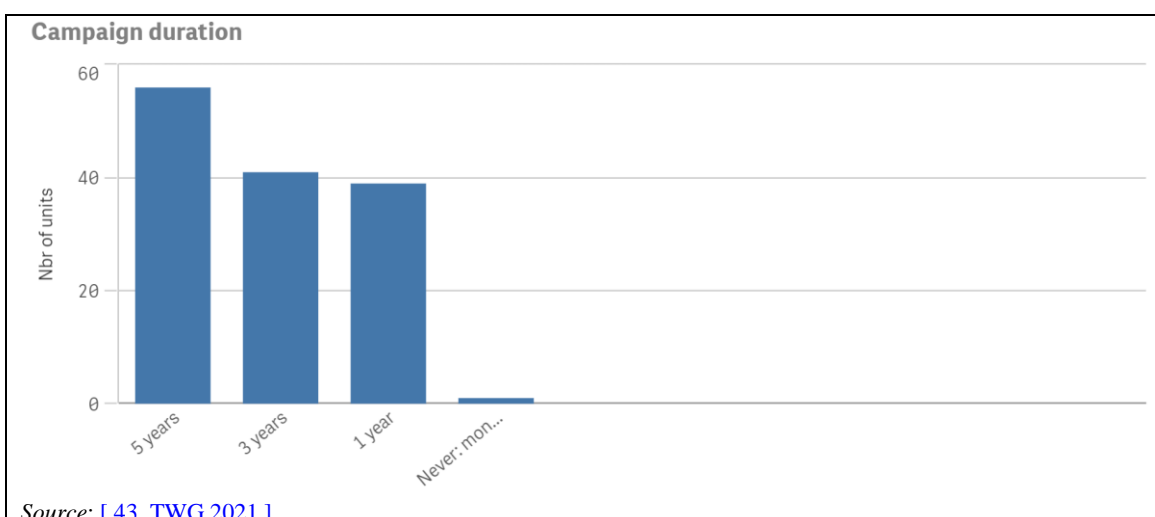
A wide range of quantities was reported from 30 kg to 3 tonnes of vinyl chloride per year. The total quantity of fugitive emissions of vinyl chloride sums up to 21 tonnes per year.

#### 2.4.1.1.8 Ethylene oxide

Information was provided by eight operators for 12 units of the chemical activity 4.1b. A wide range of quantities was reported from 500 g to 400 kg of ethylene oxide per year. The total quantity of fugitive emissions of ethylene oxide sums up to 0.5 tonnes per year.

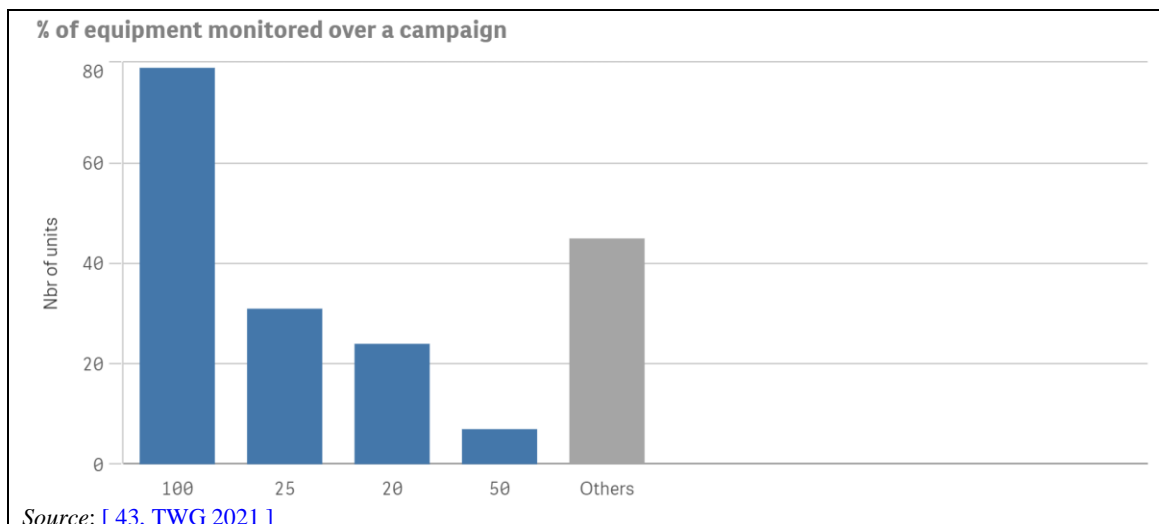
#### 2.4.1.2 Monitoring

Figure 2.140 shows the period of time for monitoring all equipment for fugitive VOC emissions. In most cases, the period of time over which 100 % of the equipment is monitored is 5 years (also including substances classified as CMR 1 or 2).



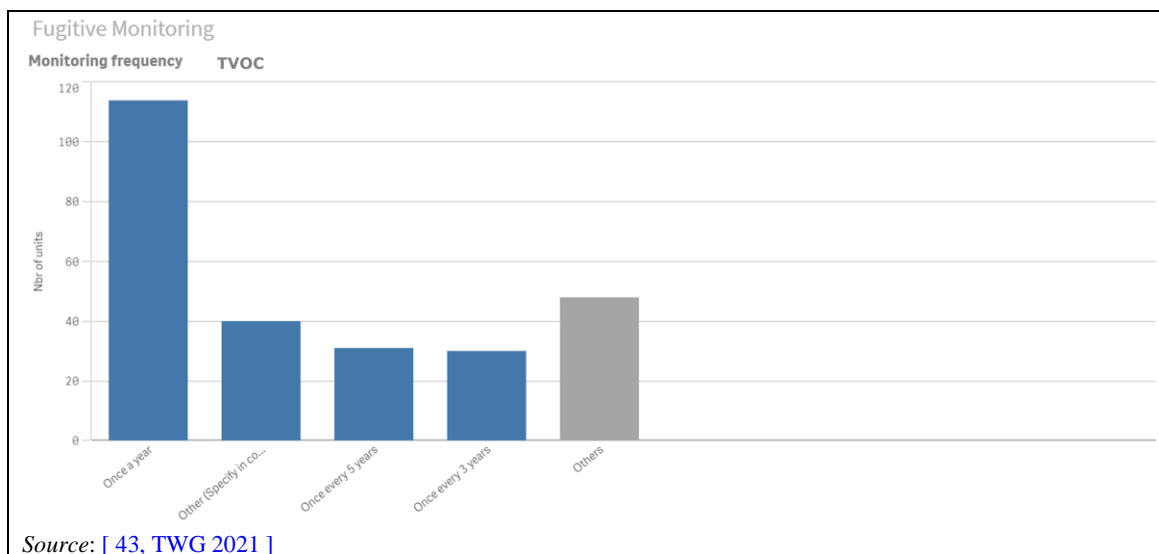
**Figure 2.140:Period of time to monitor all equipment for fugitive VOC emissions**

Figure 2.141 shows the percentage of equipment included in the monitoring of fugitive VOC emissions over a campaign.



**Figure 2.141: Percentage of equipment included in the monitoring of fugitive VOC emissions over a campaign**

Figure 2.142 shows the main monitoring frequency of equipment for fugitive VOC emissions. In most cases, 100 % of the equipment is monitored once a year.



**Figure 2.142: Monitoring frequency of fugitive VOC emissions from equipment**

Sometimes monitoring is carried out before and after a turnaround of the plant (49 units) and then, in most cases, all equipment is included in the monitoring (27 units).



Two monitoring standards are generally reported:

- Emission factors (99 units);
- EN 15446, also referred to as ‘sniffing’ (52 units).

Figure 2.143 shows the main techniques to monitor fugitive VOC emissions. In most cases, OGI camera is used as a complementary technique to sniffing. The monitoring is typically performed by accredited laboratories (104 units).

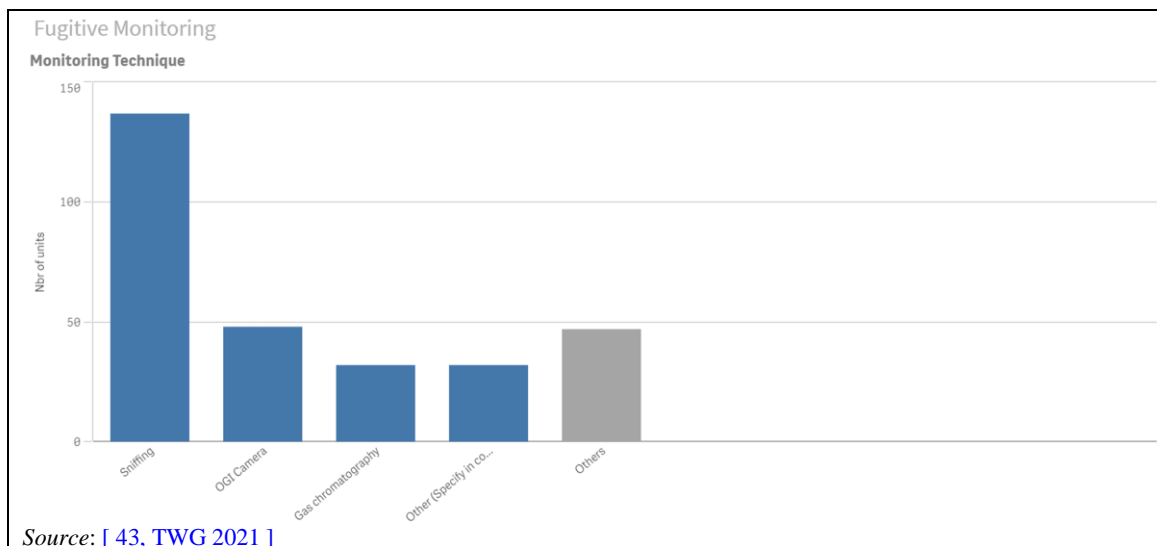


Figure 2.143: Techniques to monitor fugitive emissions

## 2.4.2 Non-fugitive VOC emissions

Substances/Parameters reported as non-fugitive VOC emissions are shown in Table 2.34.

Table 2.34: Substances/Parameters reported as non-fugitive VOC emissions

Substance/Parameter	No of units
TVOC	146
TVOC containing substances classified as CMR 1A or 1B	31
TVOC containing substances classified as CMR 2	21
Benzene (C <sub>6</sub> H <sub>6</sub> )	13
Toluene	12
Vinyl chloride	12
Others	29

Source: [43, TWG 2021]

2.4.2.1 Emissions

2.4.2.1.1 TVOC

Figure 2.144 shows the number of units reporting non-fugitive TVOC emissions and Figure 2.145 shows the chemical activities that most contribute to non-fugitive emissions of TVOC.

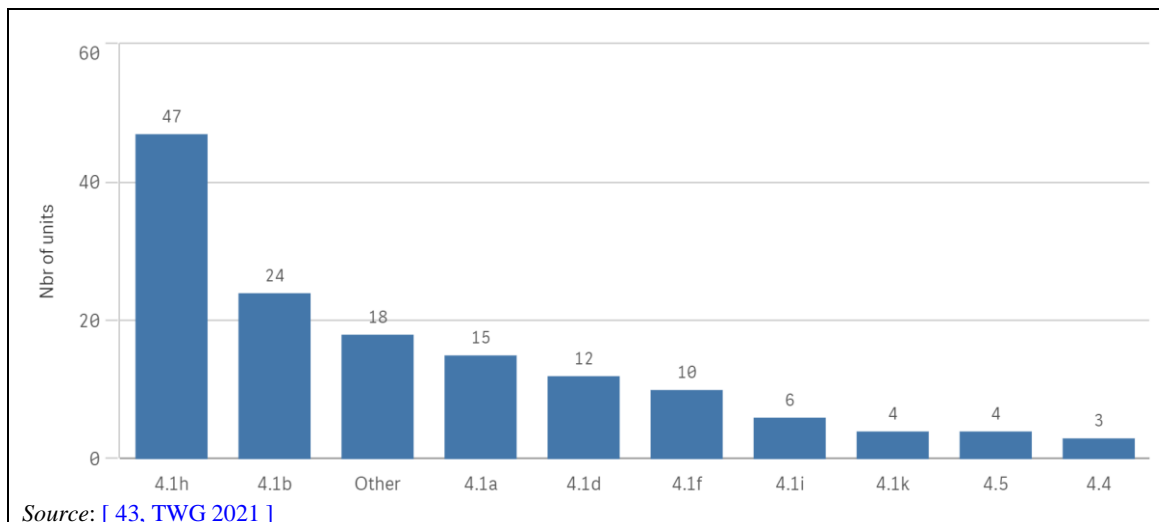


Figure 2.144: Non-fugitive TVOC emissions reported by chemical activity

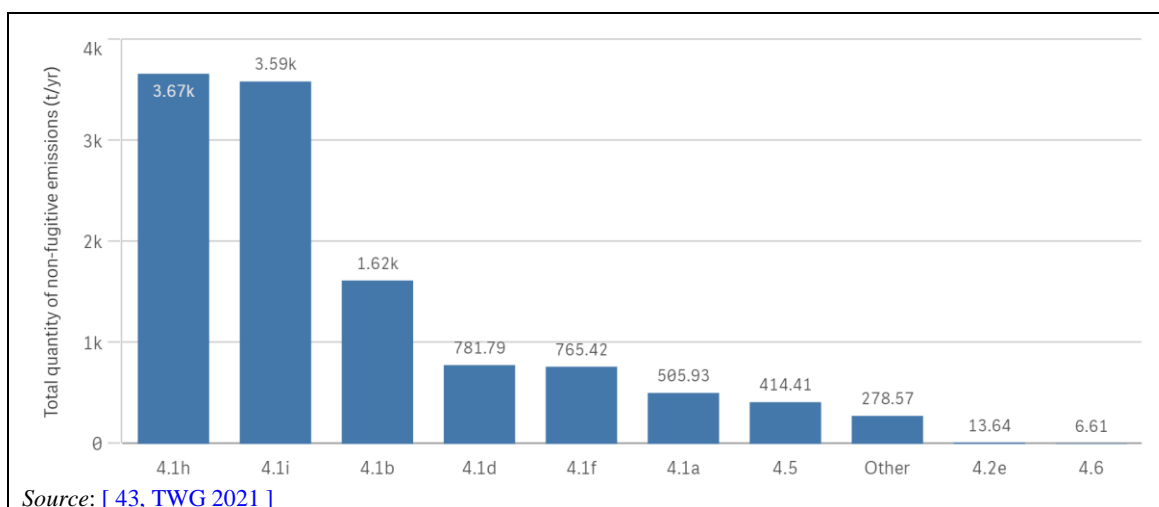
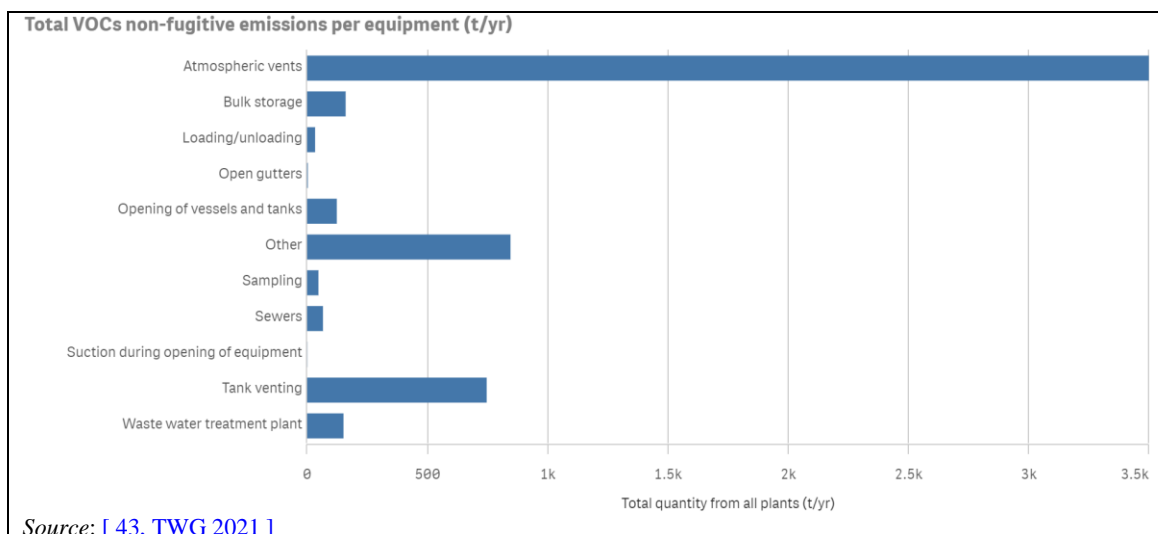


Figure 2.145: Quantity of non-fugitive TVOC emissions reported by chemical activity

A wide range of quantities was reported by 146 units in a range from less than 1 kg to 1 685 tonnes of TVOC per year. The total quantity of non-fugitive emissions of TVOC sums up to 11 645 tonnes per year.

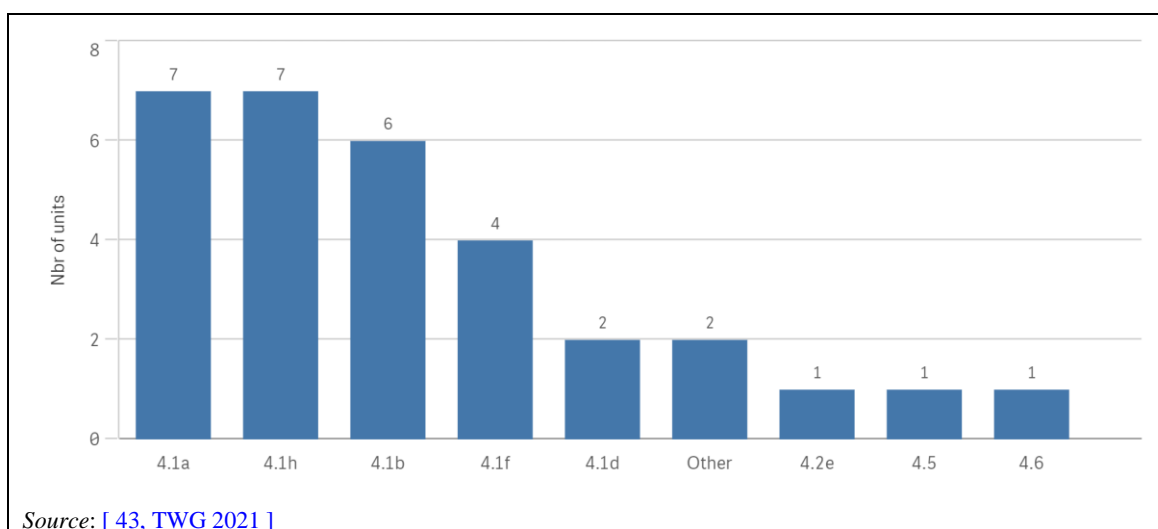
Figure 2.146 shows the total quantity of non-fugitive VOC emissions per type of relevant source.



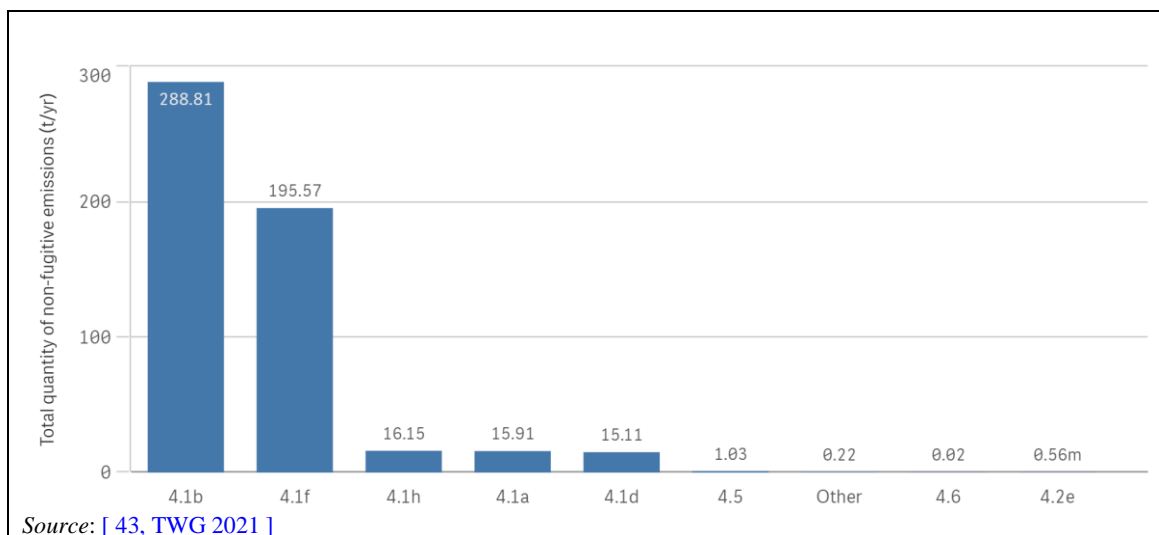
**Figure 2.146: Total quantity of non-fugitive VOC emissions per type of relevant source**

#### 2.4.2.1.2 TVOC containing substances classified as CMR 1A or 1B

Figure 2.147 shows the number of units reporting non-fugitive emissions of TVOC containing substances classified as CMR 1A or 1B and Figure 2.148 shows the IED chemical activities that most contribute to non-fugitive emissions of TVOC containing substances classified as CMR 1A or 1B.



**Figure 2.147: Non-fugitive emissions of TVOC containing substances classified as CMR 1A or 1B reported by chemical activity**

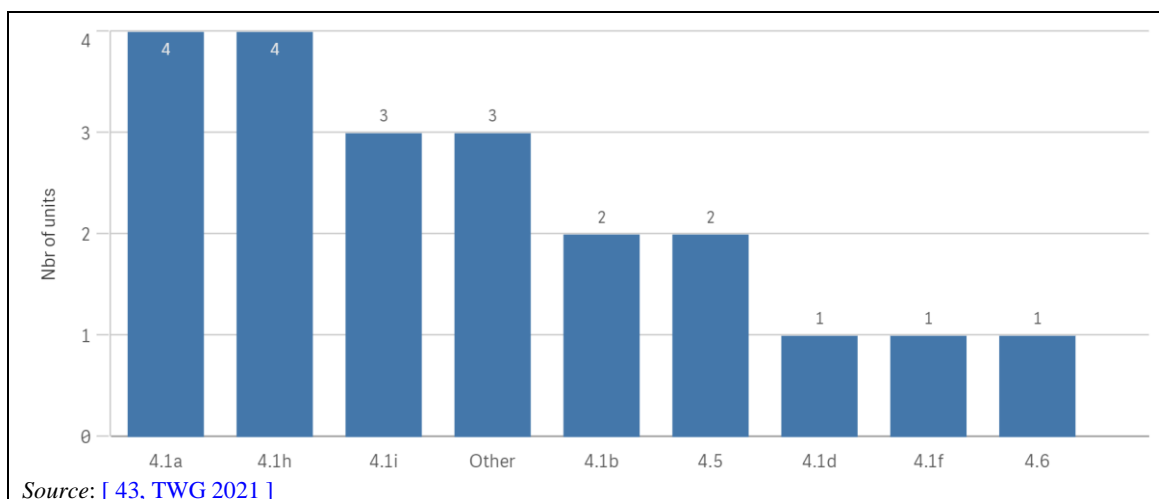


**Figure 2.148:Quantity of non-fugitive emissions of TVOC containing substances classified as CMR 1A or 1B reported by chemical activity**

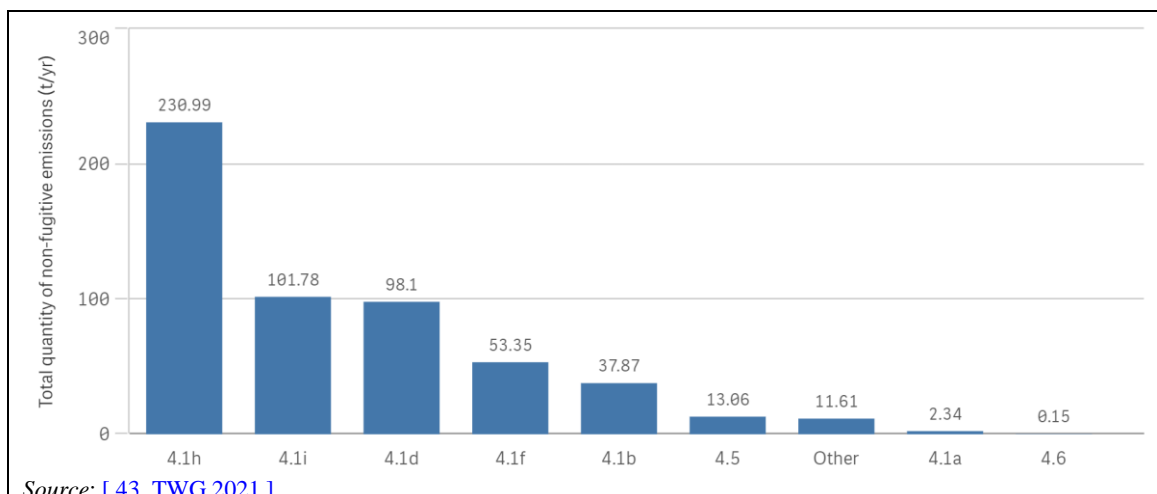
A wide range of quantities was reported by 23 units in a range from 560 g to 283 tonnes of TVOC containing substances classified as CMR 1A or 1B per year. The total quantity of non-fugitive emissions of TVOC containing substances classified as CMR 1A or 1B sums up to 533 tonnes per year.

### 2.4.2.1.3 TVOC containing substances classified as CMR 2

Figure 2.149 shows the number of units reporting non-fugitive TVOC containing substances classified as CMR 2 emissions and Figure 2.150 shows the IED chemical activities that most contribute to non-fugitive emissions of TVOC containing substances classified as CMR 2.



**Figure 2.149:Non-fugitive emissions of TVOC containing substances classified as CMR 2 reported by chemical activity**

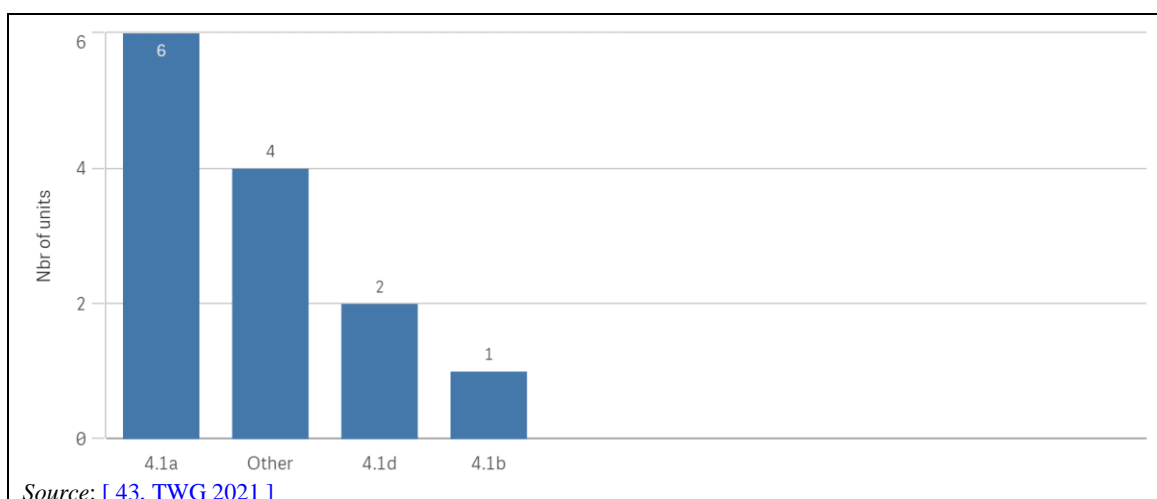


**Figure 2.150: Quantity of non-fugitive emissions of TVOC containing substances classified as CMR 2 reported by chemical activity**

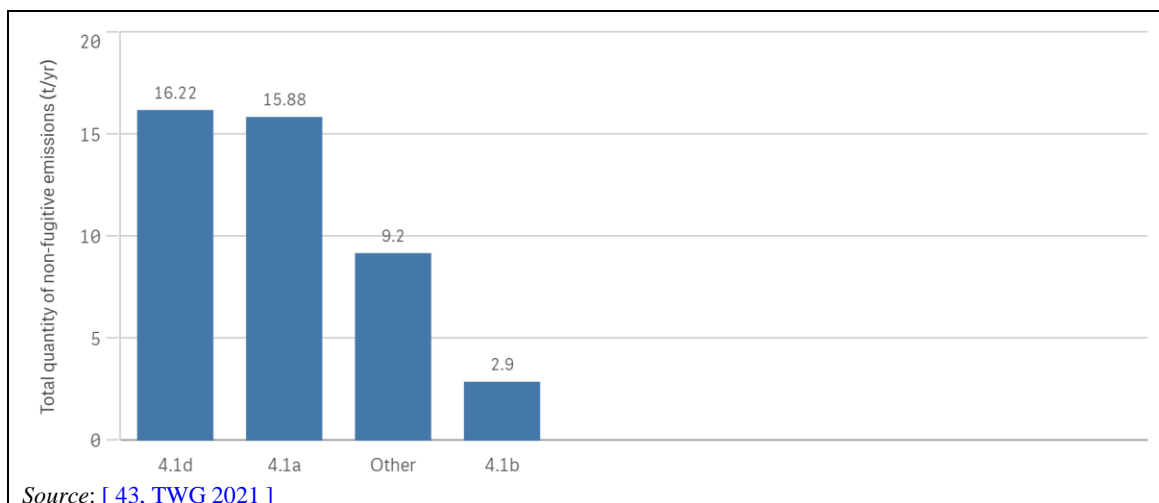
A wide range of quantities was reported by 21 units in a range from 7 kg to 242 tonnes of TVOC containing substances classified as CMR 2 per year. The total quantity of non-fugitive emissions of TVOC containing substances classified as CMR 2 sums up to 549 tonnes per year.

#### 2.4.2.1.4 Benzene

Figure 2.151 shows the number of units reporting non-fugitive benzene emissions and Figure 2.152 shows the chemical activities that most contribute to non-fugitive benzene emissions.



**Figure 2.151: Non-fugitive benzene emissions reported by chemical activity**

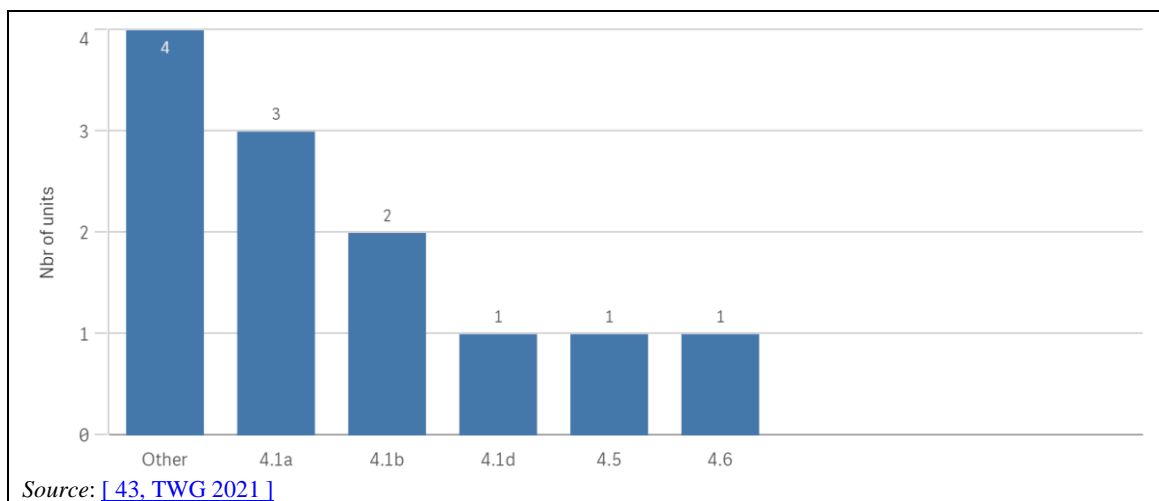


**Figure 2.152:Quantity of non-fugitive benzene emissions reported by chemical activity**

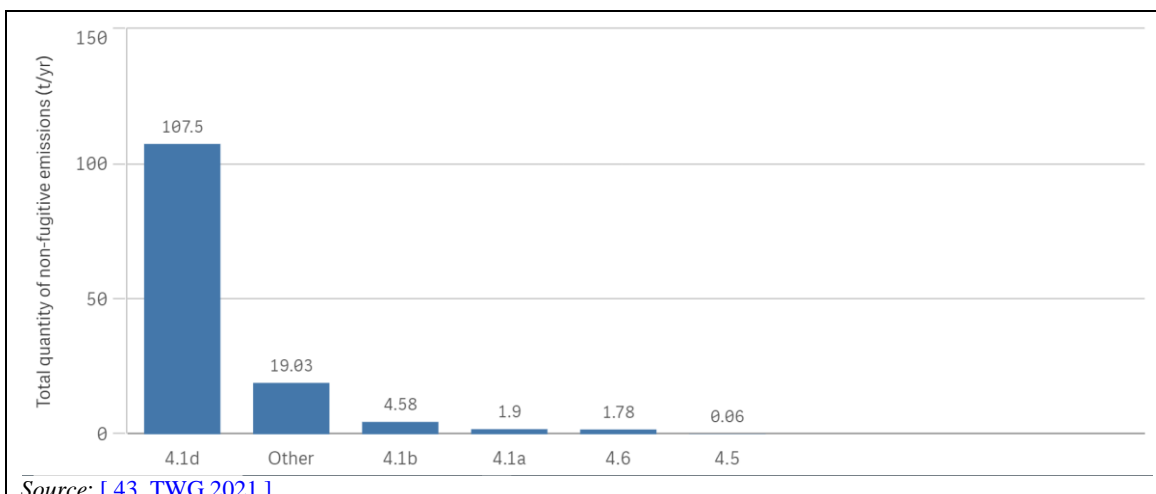
A wide range of quantities was reported by 11 units in a range from 50 kg to 19 tonnes of benzene per year. The total quantity of non-fugitive emissions of benzene sums up to 44 tonnes per year.

#### 2.4.2.1.5 Toluene

Figure 2.153 shows the number of units reporting non-fugitive toluene emissions and Figure 2.154 shows the chemical activities contributing to non-fugitive emissions of toluene.



**Figure 2.153:Non-fugitive toluene emissions reported by chemical activity**

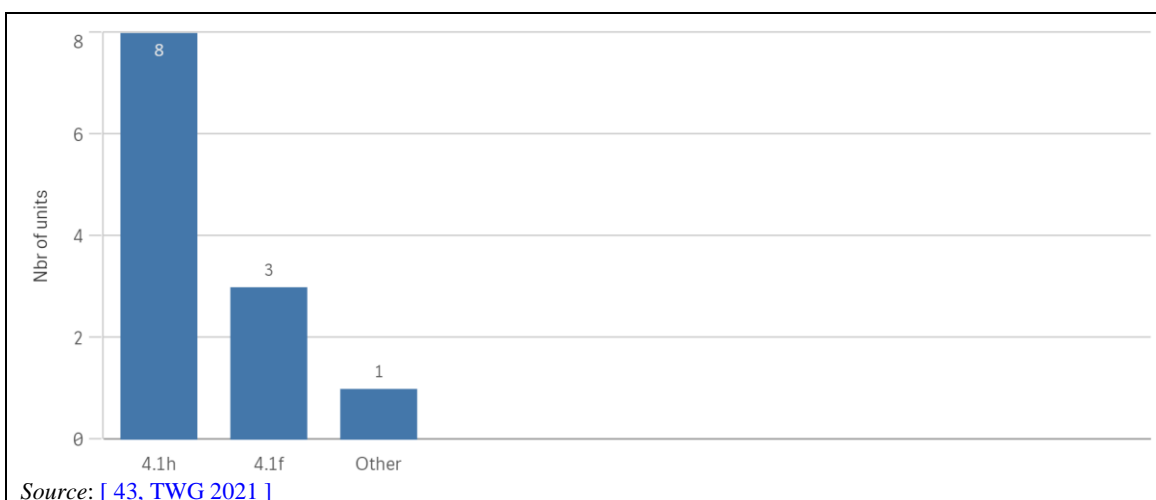


**Figure 2.154: Quantity of non-fugitive toluene emissions reported by chemical activity**

A wide range of quantities was reported by 13 units in a range from 60 kg to 108 tonnes of toluene per year. The total quantity of non-fugitive emissions of toluene sums up to 135 tonnes per year.

#### 2.4.2.1.6 Vinyl chloride

Figure 2.155 shows the number of units reporting non-fugitive vinyl chloride emissions and Figure 2.156 shows the chemical activities contributing to non-fugitive emissions of vinyl chloride.



**Figure 2.155: Non-fugitive vinyl chloride emissions reported by chemical activity**

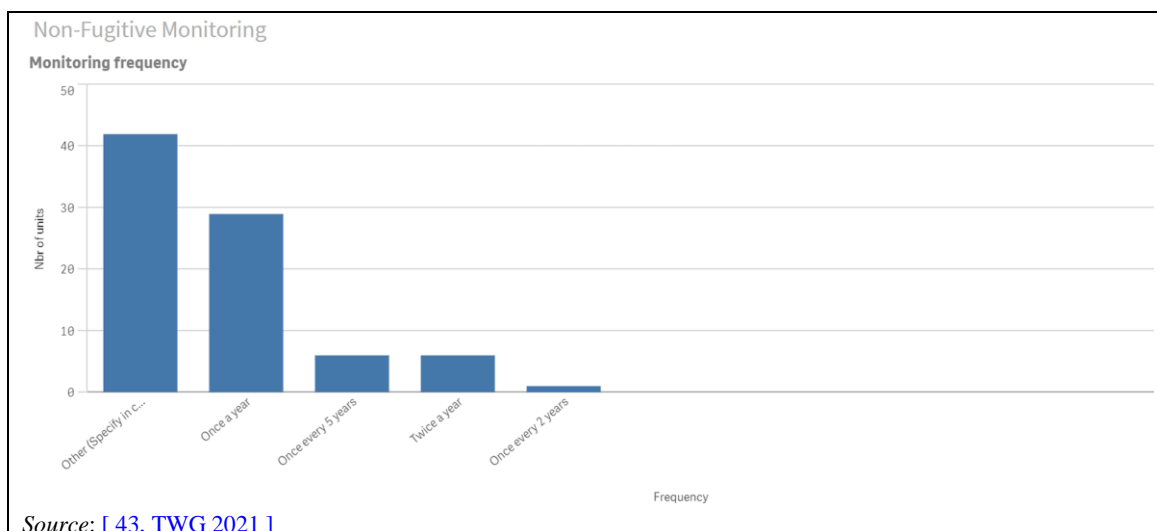


**Figure 2.156: Quantity of non-fugitive vinyl chloride emissions reported by chemical activity**

A wide range of quantities was reported by 12 units in a range from 15 kg to 80 tonnes of vinyl chloride per year. The total quantity of non-fugitive emissions of vinyl chloride sums up to 96 tonnes per year.

### 2.4.2.2 Monitoring

Figure 2.157 shows the monitoring frequency for non-fugitive VOC emissions. In most cases, monitoring is carried out between once every 4 months (in particular for tanks) and every 2 years.



**Figure 2.157: Monitoring frequency for non-fugitive VOC emissions**

The following sources, i.e. types of equipment, are included in the monitoring (number of reporting units included in brackets):

- atmospheric vents (32);
- bulk storage (6);
- loading/unloading operations (15);
- open gutters (2);
- opening of vessel and tanks (11);



- sampling systems (8);
- sewers (2);
- suction during opening of equipment (2);
- tank venting (42);
- waste water treatment plants (16);
- others (16).

Figure 2.158 shows the monitoring methods for non-fugitive VOC emissions. In most cases, calculation methods are applied.

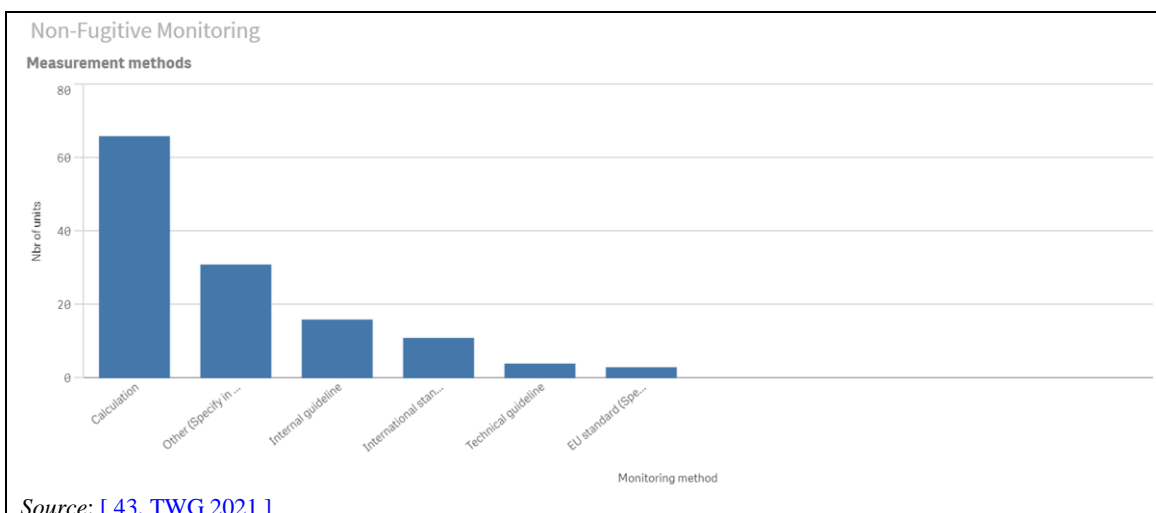


Figure 2.158: Monitoring methods for non-fugitive VOC emissions

### 2.4.3 Solvent management plan

Figure 2.159 shows diffuse emissions to air from the use of solvents or the reuse of recovered solvents.

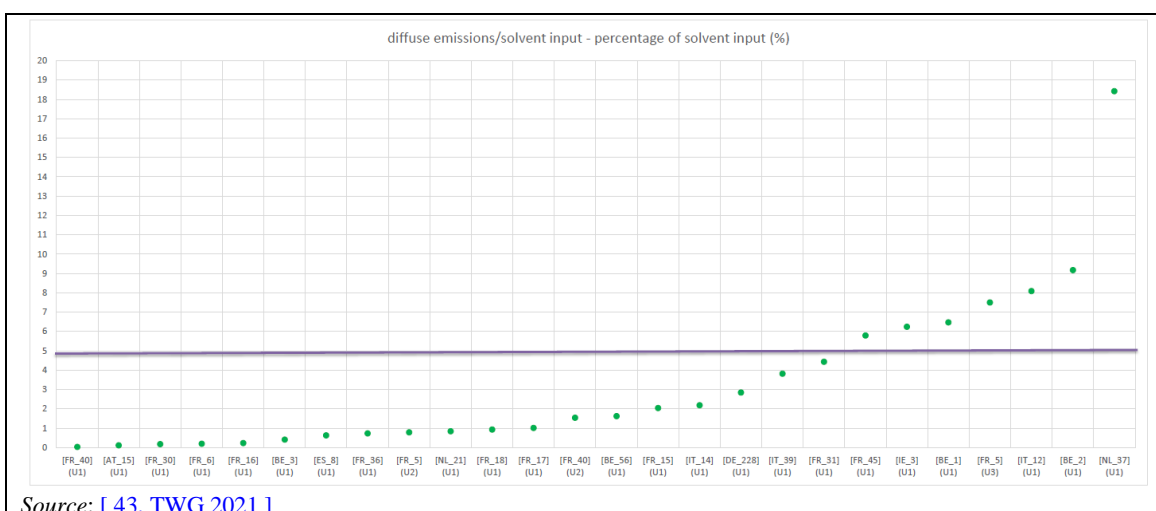
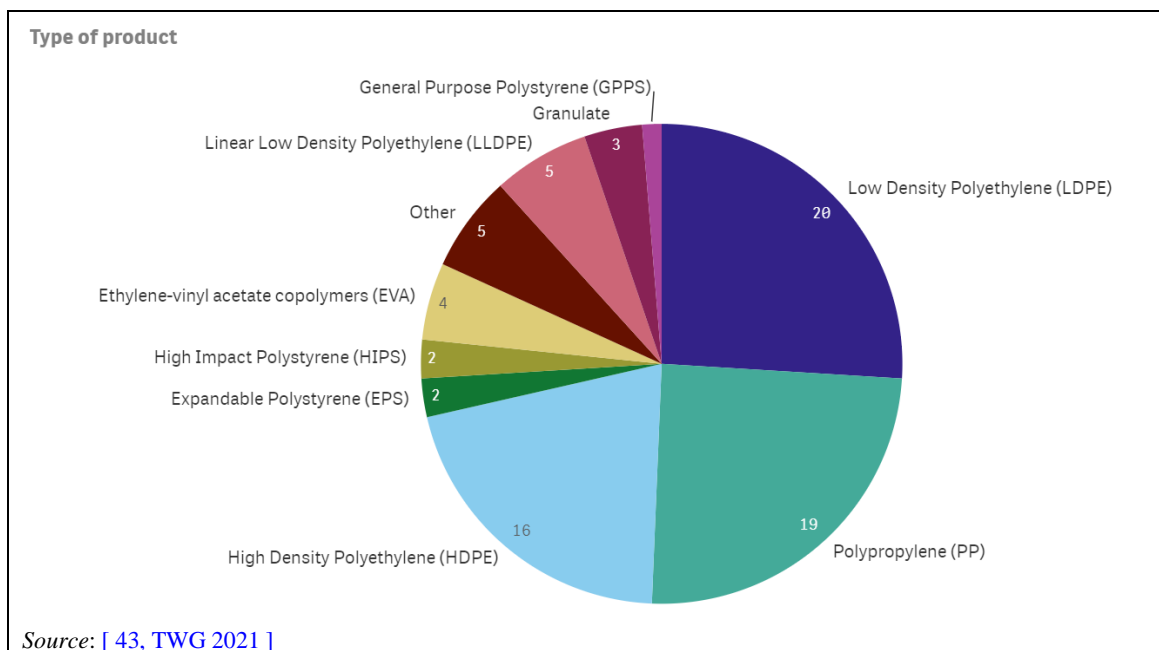


Figure 2.159: Diffuse emissions to air from the use of solvents or the reuse of recovered solvents

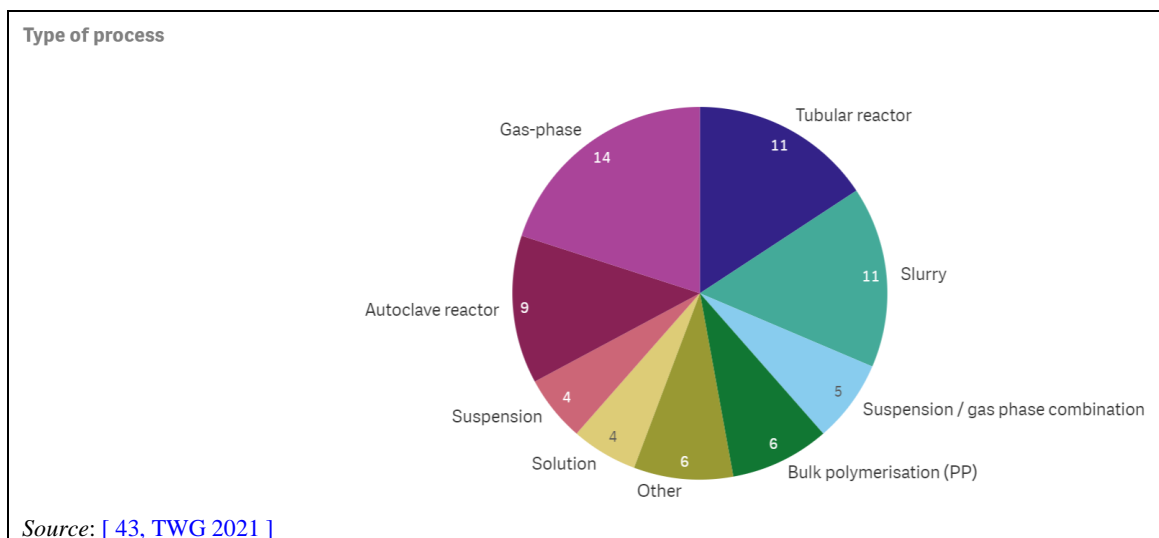
## 2.5 Production of polyolefins

### 2.5.1 Overview

Information on polyolefins was provided by 21 operators via 41 questionnaires representing 258 emission points and 63 units. Seven operators indicated using an external treatment for their waste gases. Figure 2.160 and Figure 2.161 show the types of products and the types of processes reported in the data collection.



**Figure 2.160:**Types of polyolefin products



**Figure 2.161:**Types of production processes for polyolefins

### 2.5.2 Treated channelled emissions

TVOC is generally treated with at least one waste gas treatment technique. The typical emission levels of TVOC after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.162.

The techniques most commonly applied for the removal of VOCs, alone or in combination, in waste gas treatment systems of chemical plants are the following:

- absorption;
- adsorption;
- thermal or catalytic oxidation.

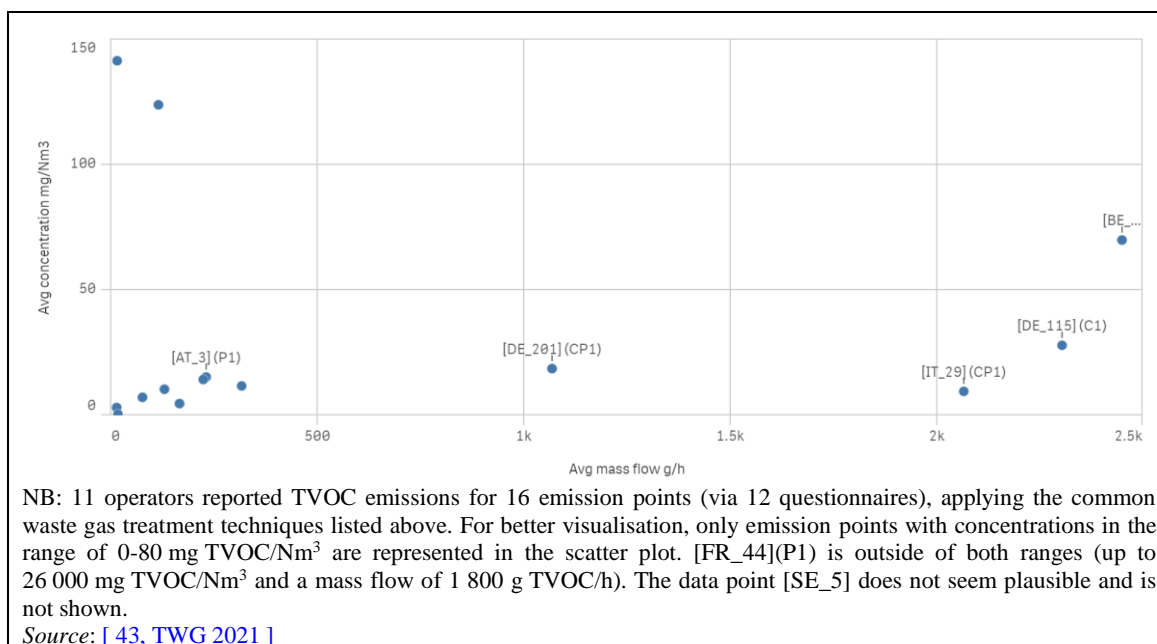


Figure 2.162: TVOC emissions after waste gas treatment

### 2.5.3 Untreated channelled emissions

The typical emission levels of TVOC when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.163.

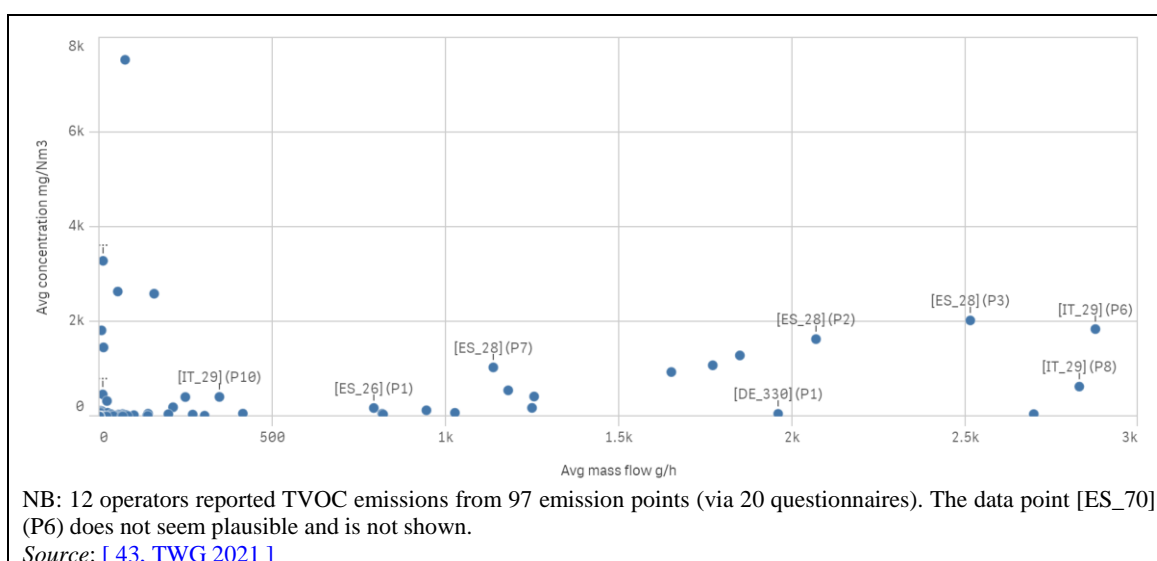
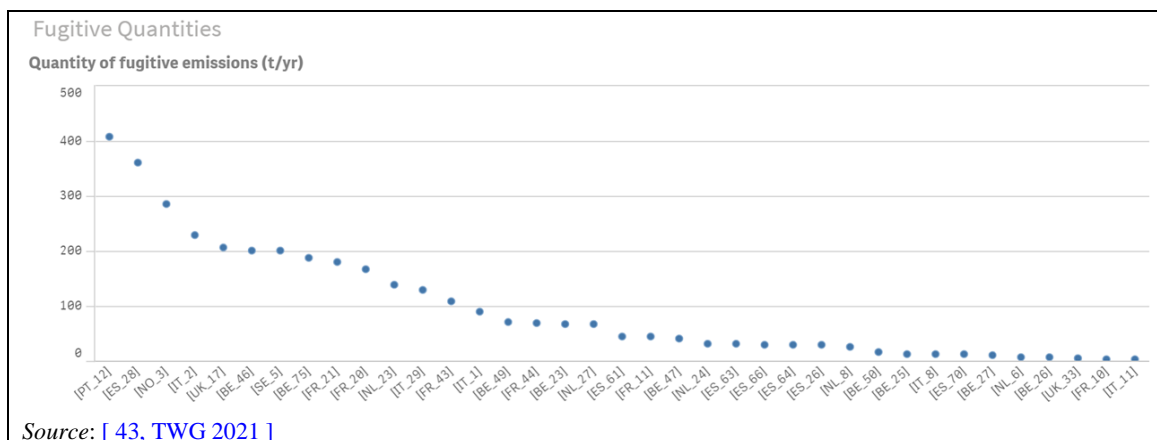


Figure 2.163: TVOC emission points with no waste gas treatment

## 2.5.4 Fugitive emissions

Fugitive TVOC emissions are shown in Figure 2.164.

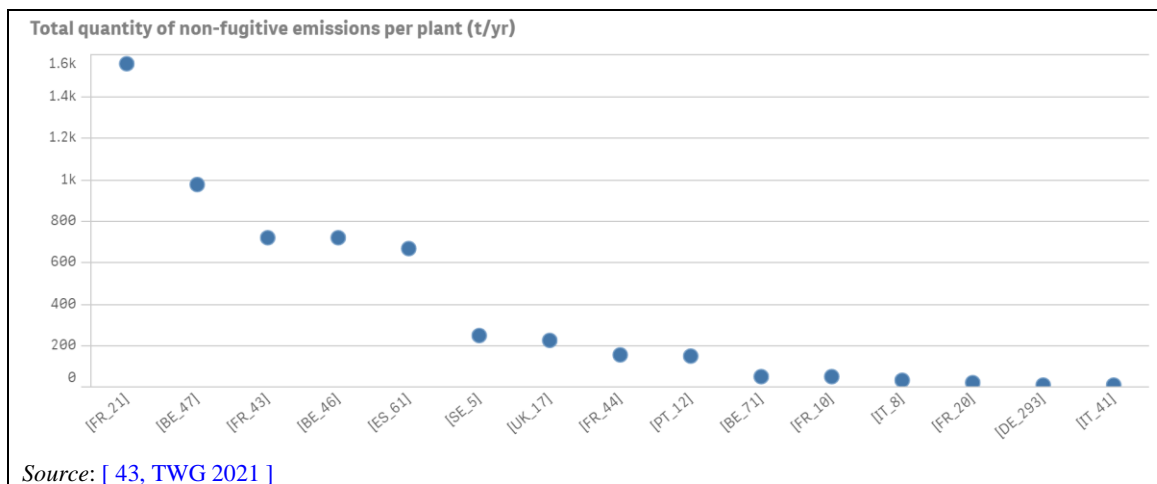


**Figure 2.164:Fugitive TVOC emissions**

A wide range of quantities of fugitive emissions was reported by 37 units in a range from 310 kg to 404 tonnes of TVOC per year. The total quantity of non-fugitive emissions of TVOC sums up to 3 476 tonnes per year.

## 2.5.5 Non-fugitive emissions

Seven questionnaires reported non-fugitive TVOC emissions. Non-fugitive emissions are shown in Figure 2.165.

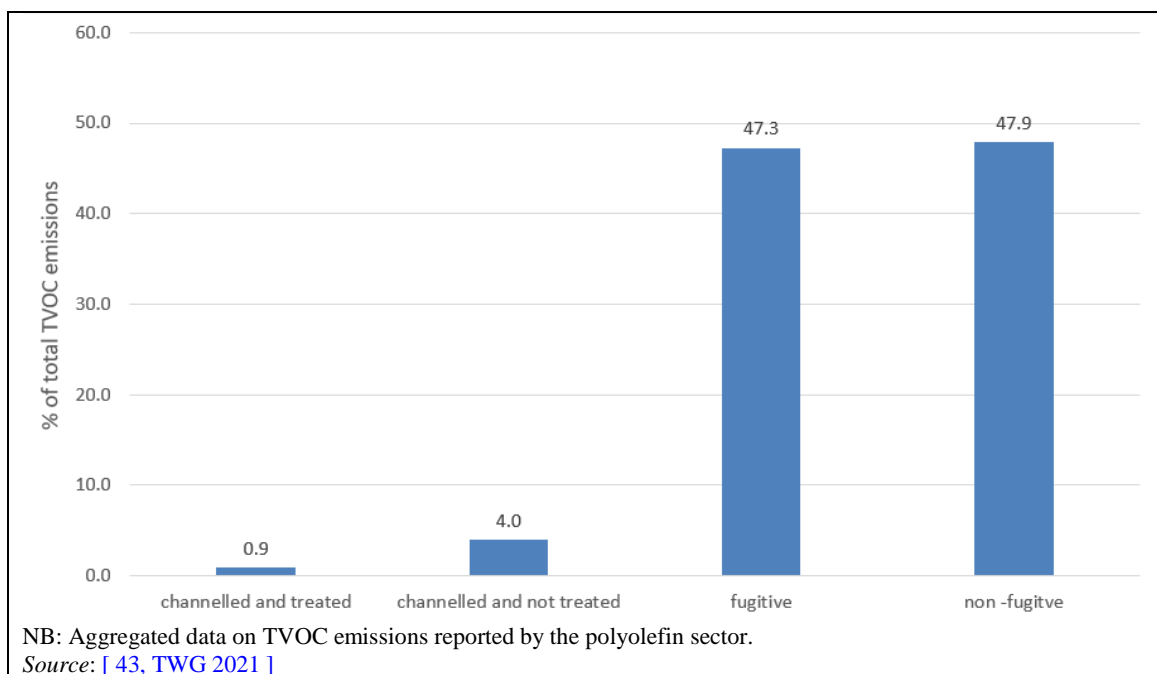


**Figure 2.165:Non-fugitive TVOC emissions**

A wide range of quantities of non-fugitive emissions was reported by 15 units in a range from less than 300 kg to 1 685 tonnes of TVOC per year. The total quantity of non-fugitive emissions of TVOC sums up to 11 644 tonnes per year.

## 2.5.6 Total TVOC emissions

TVOC emissions reported for the polyolefins sector, aggregated by the type of emission source, are shown as percentages in Figure 2.166. Data reported for fugitive and non-fugitive emissions provided in tonnes per year were converted into grams per hour.



**Figure 2.166: Total TVOC emissions**

## 2.5.7 Specific loads

Information on specific loads was provided by 12 operators via 34 questionnaires (see Section 2.5.1). Specific loads are considered confidential business information. Data are only shown if the number of companies that reported information is greater than five.

Figure 2.167, Figure 2.168, Figure 2.169 and Figure 2,170 show specific loads for common types of polyolefins, showing the upper and lower ends of the BAT-AEL range from Table 4.8.

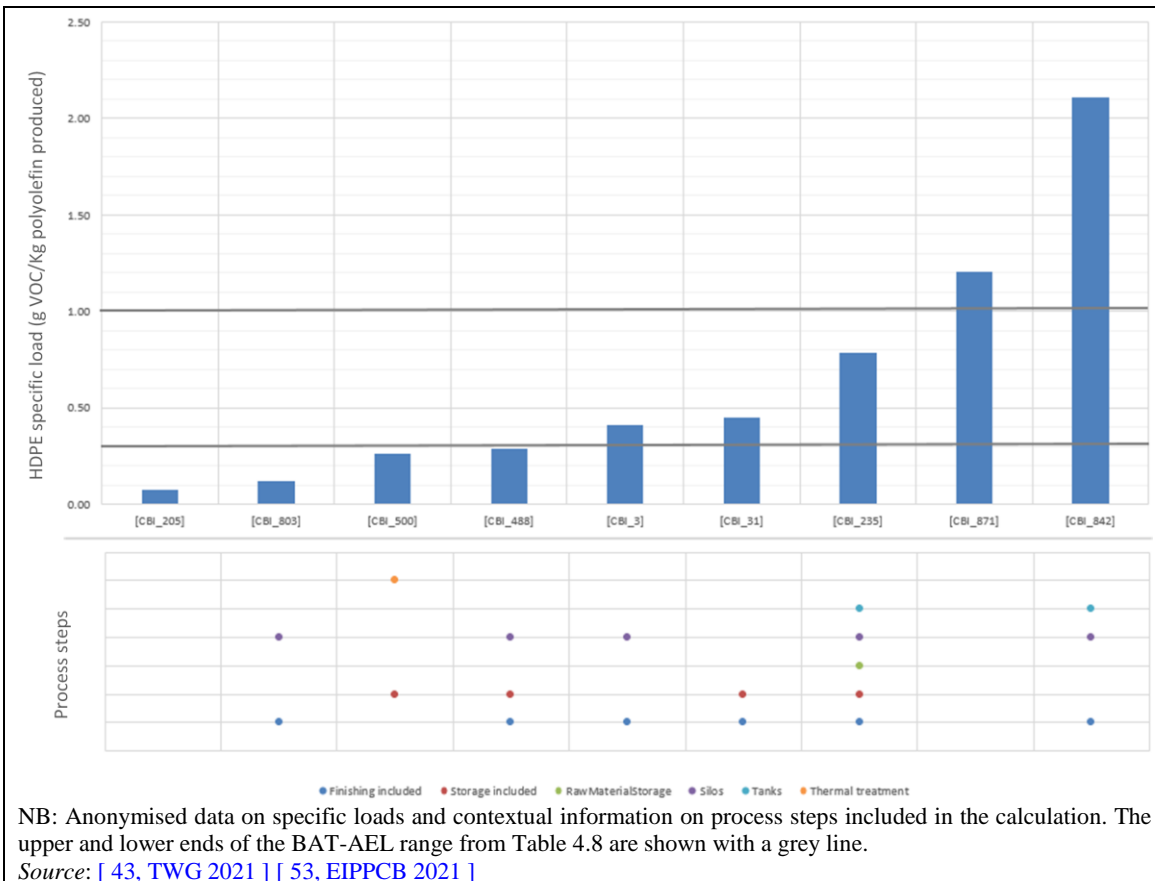


Figure 2.167: Specific loads of HDPE

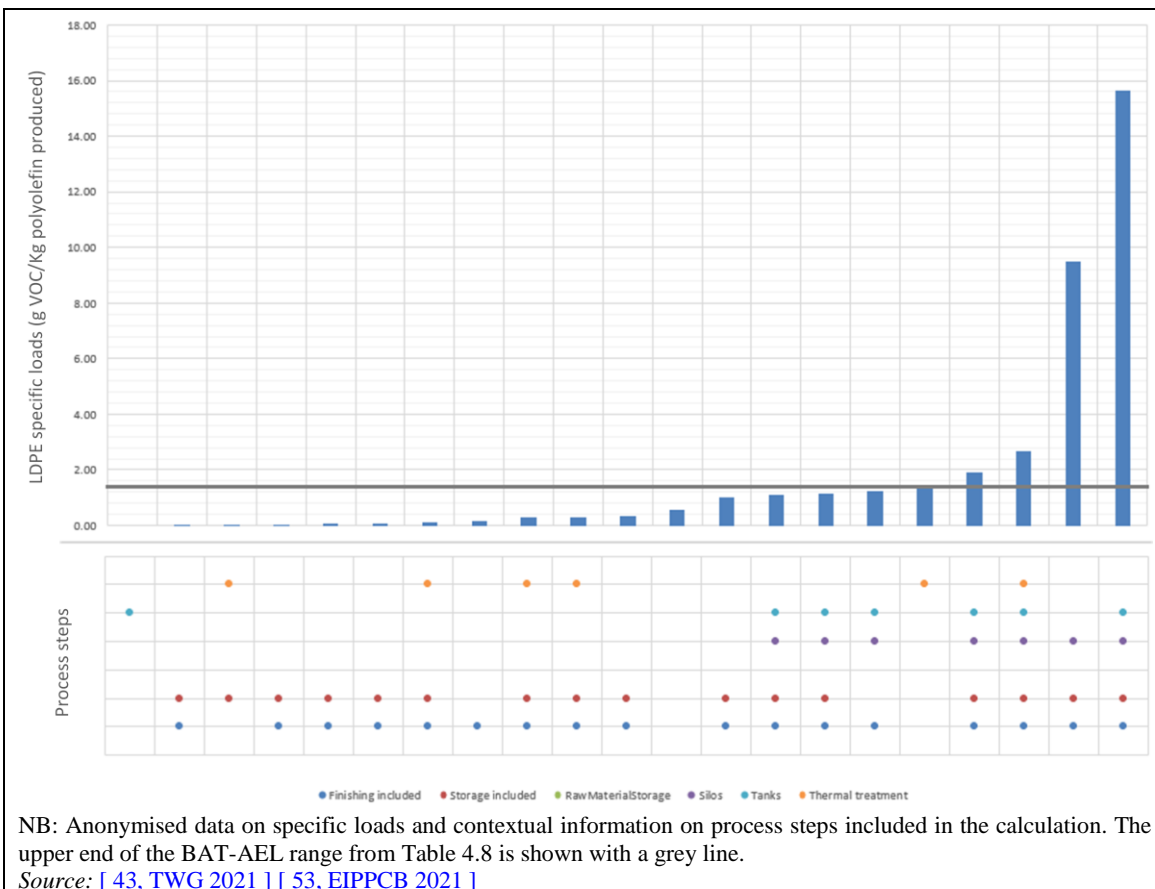


Figure 2.168: Specific loads of LDPE

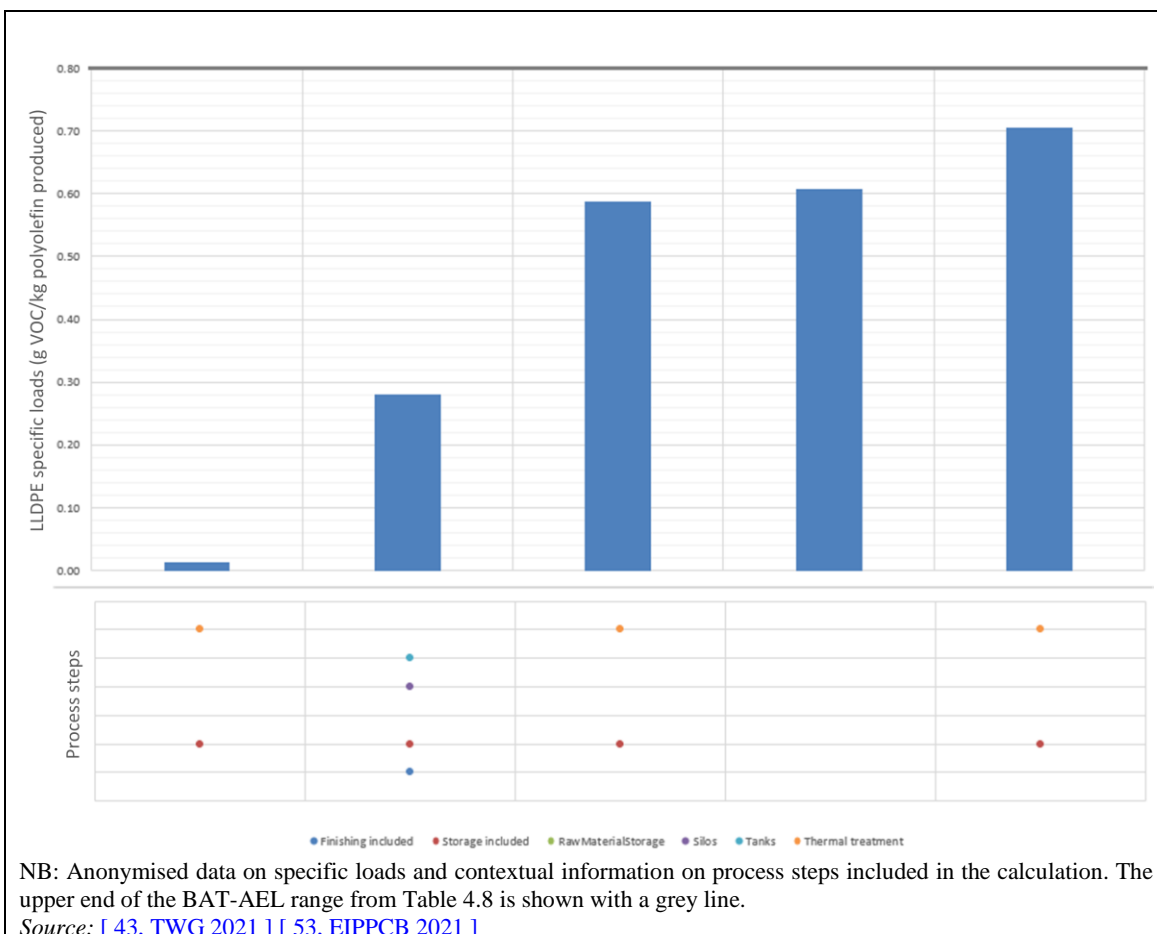


Figure 2.169: Specific loads of LLDPE

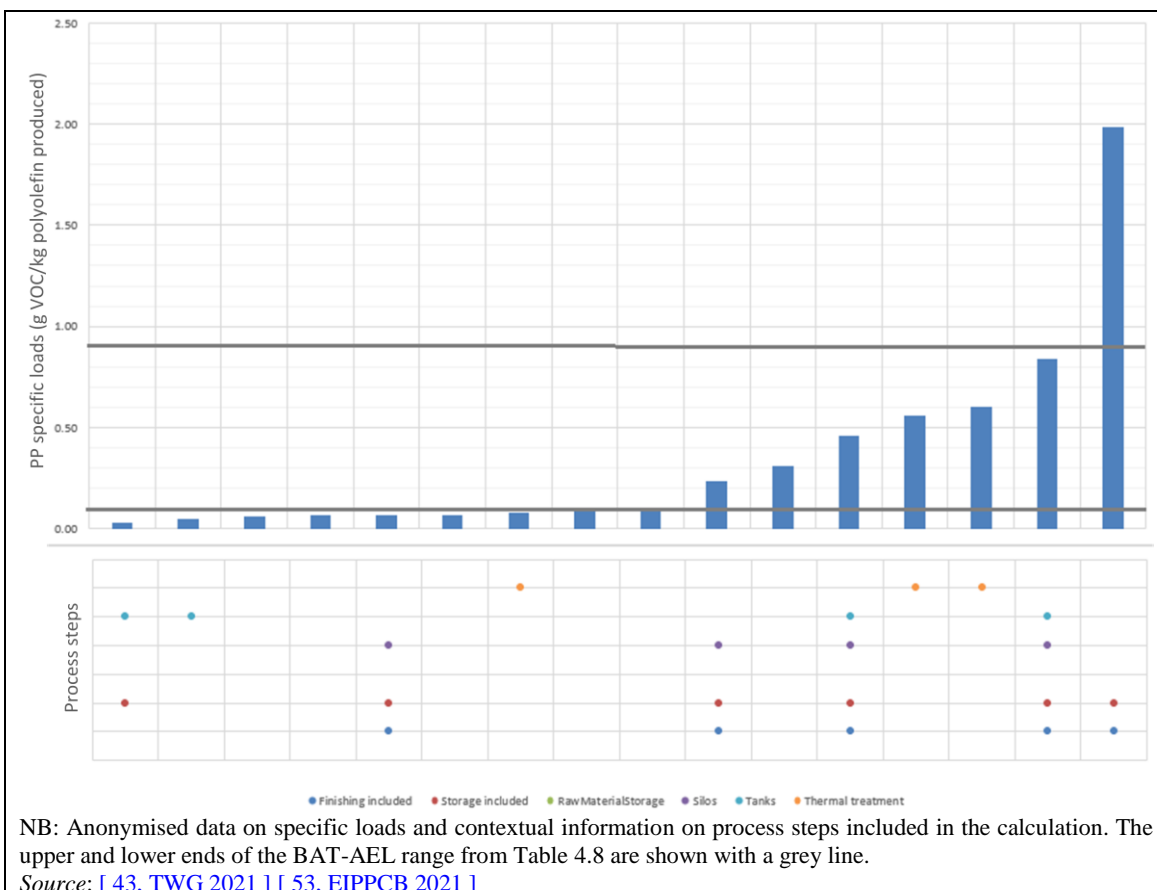


Figure 2.170: Specific loads of PP

### 2.5.8 Monomer concentration in the product after treatment

Five operators provided information on the monomer concentration in the product after final treatment via 33 questionnaires. Monomer concentrations in the product after treatment are considered confidential business information. Data are only shown if the number of companies that reported data is greater than five.

Table 2.35 shows monomer concentrations after treatment (see Section 3.5.1.3).

**Table 2.35: Monomer concentrations after treatment for types of polyolefins (g VOCs/kg of product)**

No of companies	No of emission points / units	Type	Min.	Average	Max.
5	33	All	0.025	1.1	4.4
4	18	LDPE	Data not shown		
1	3	HDPE			
1	4	PP			
<i>Source: [ 43, TWG 2021 ]</i>					



## 2.6 Production of polyvinyl chloride (PVC)

### 2.6.1 Overview

Information on the production of PVC was provided by 21 operators via 26 questionnaires representing 100 emission points and 25 units. Five operators indicated using an external treatment for their waste gases.

Figure 2.171 shows the types of PVC reported in the data collection.

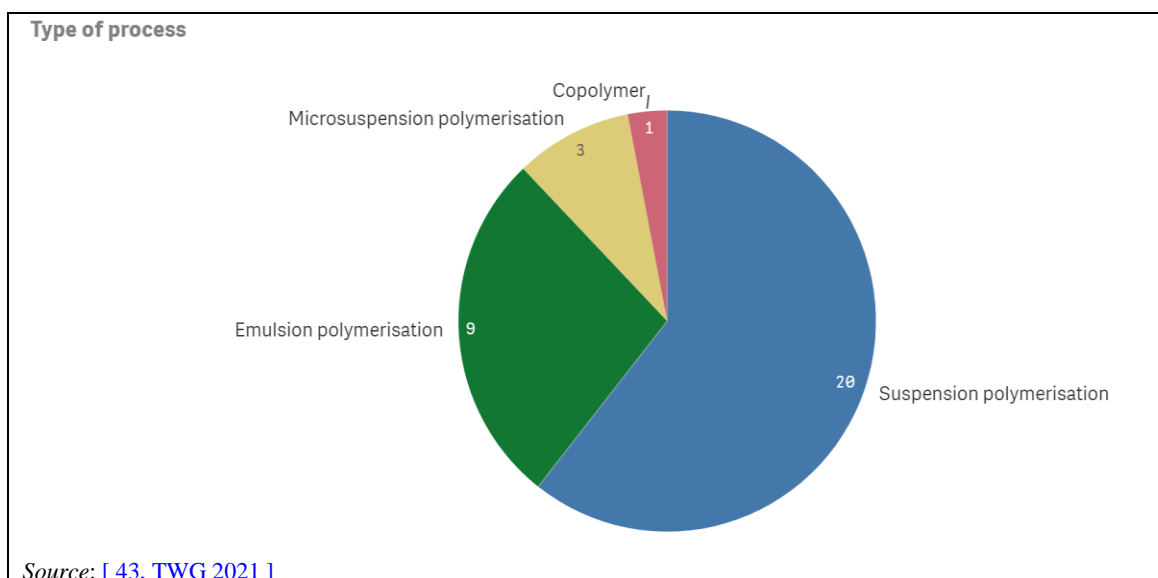


Figure 2.171: Types of PVC

### 2.6.2 Treated channelled emissions

VCM is generally treated with at least one waste gas treatment technique. The typical emission levels of VCM after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.172.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

- absorption;
- adsorption;
- condensation.

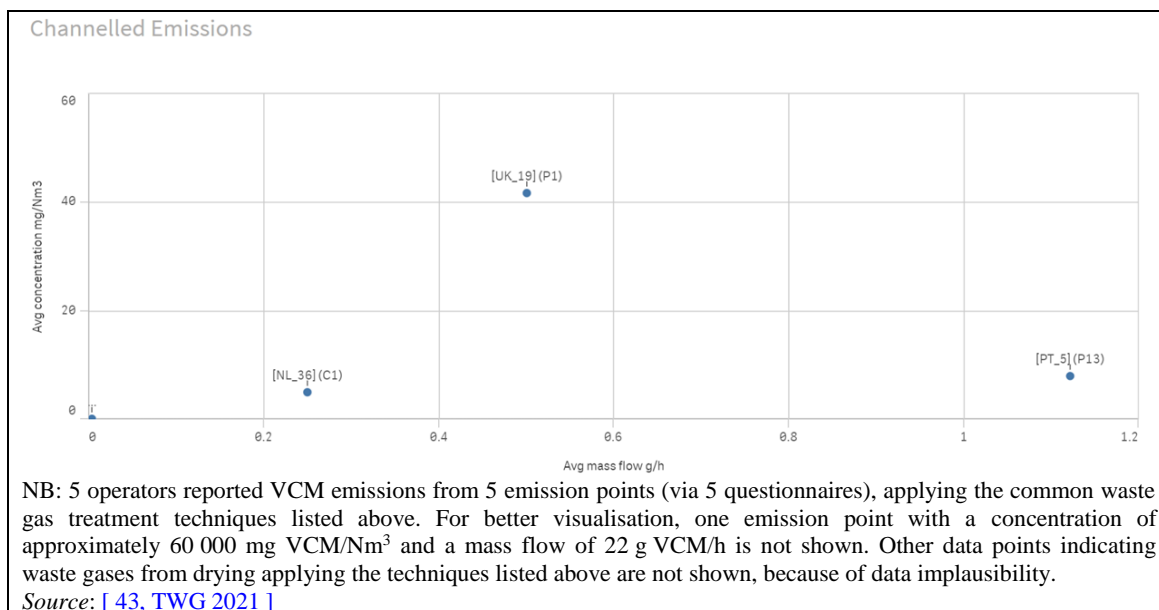


Figure 2.172:VCM emissions after waste gas treatment

The total quantity of treated VCM emissions sums up to 24 g VCM/h (see Figure 2.172).

### 2.6.3 Untreated channelled emissions

The typical emission levels of VCM when no waste gas treatment for the removal of VCM is applied are shown as concentration and mass flow in the scatter plot of Figure 2.173.

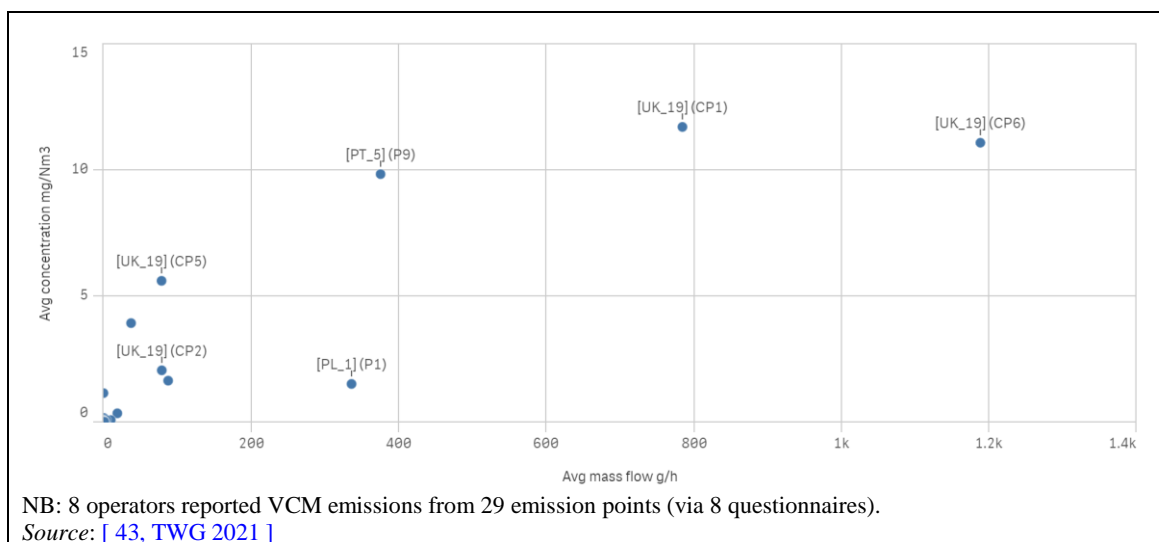
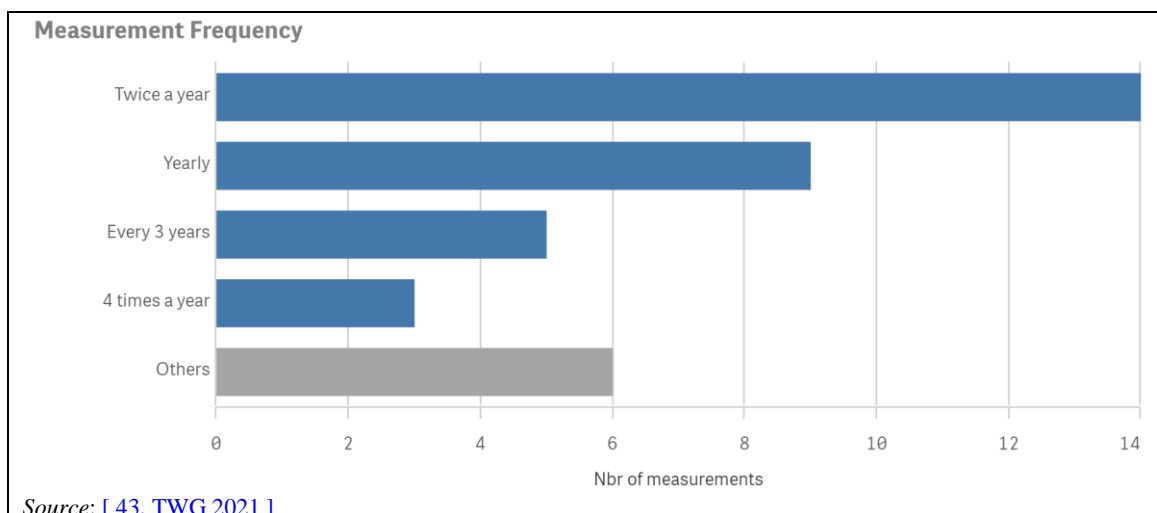


Figure 2.173:VCM emission points with no waste gas treatment technique

The total quantity of VCM emissions not treated sum up to 7.5 kg VCM/h (see Figure 2.173).

## 2.6.4 Monitoring

Periodic monitoring and continuous monitoring are both commonly used: 42 instances of periodic monitoring and 27 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled VCM emissions are shown in the bar chart of Figure 2.174.



**Figure 2.174: Reported measurement frequencies for periodic VCM monitoring**

Percentiles for reported limits of quantification and limits of detection for VCM measurements are shown in Table 2.36.

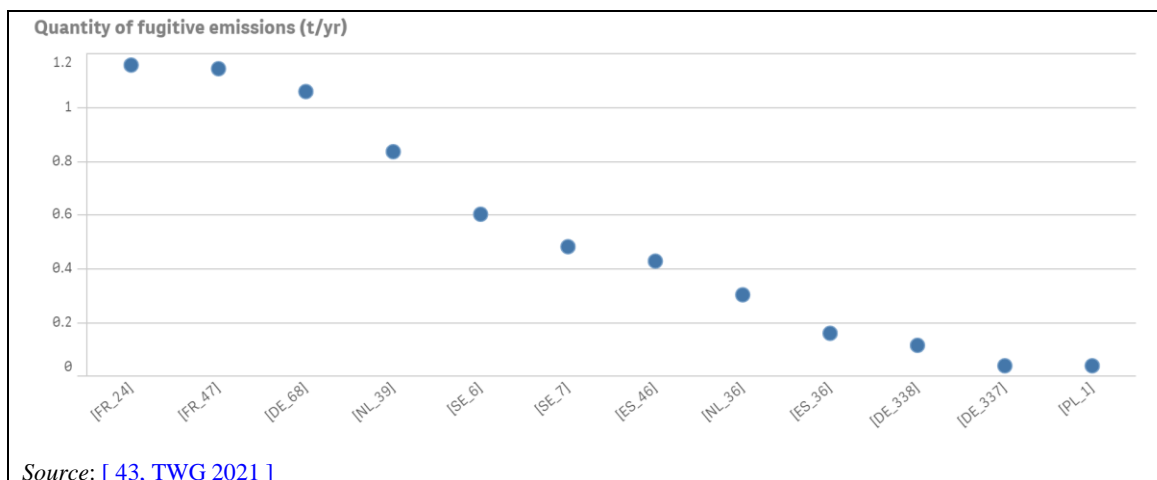
**Table 2.36: Reported limits of quantification and detection for VCM**

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.04	0.03
50 <sup>th</sup>	0.06	0.06
80 <sup>th</sup>	0.07	0.10

NB: The numbers of instances reported for the limits of quantification and detection are 22 and 18, respectively.  
Source: [ 43, TWG 2021 ]

## 2.6.5 Fugitive emissions

Figure 2.175 shows fugitive emissions of vinyl chloride.

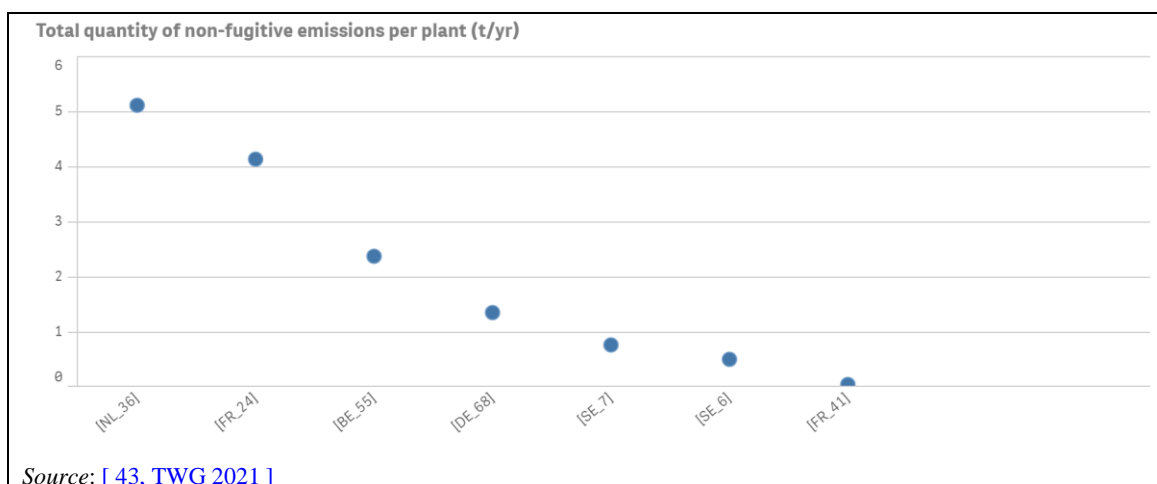


**Figure 2.175:Fugitive vinyl chloride emissions**

A wide range of quantities of fugitive VCM emissions was reported by 12 units in a range from 30 kg VCM to 1.2 tonnes VCM tonnes per year (see Figure 2.175). The total quantity of fugitive VCM emissions sums up to 6.3 tonnes VCM per year.

## 2.6.6 Non-fugitive emissions

Non-fugitive vinyl chloride emissions are shown in Figure 2.176.

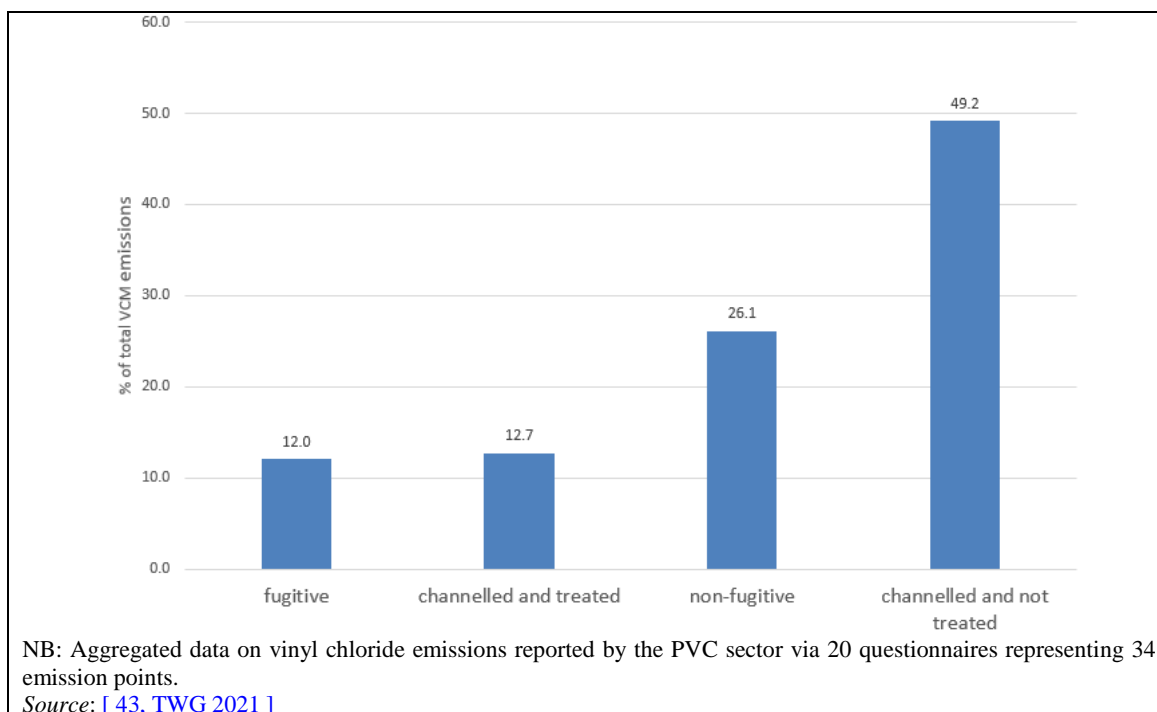


**Figure 2.176:Non-fugitive vinyl chloride emissions**

A wide range of quantities of non-fugitive VCM emissions was reported by six units in a range from 460 kg VCM to 4.1 tonnes VCM tonnes per year. The total quantity of non-fugitive VCM emissions sums up to 6.3 tonnes VCM per year (see Figure 2.176).

## 2.6.7 Total vinyl chloride emissions

Vinyl chloride emissions reported for the PVC sector, aggregated by the type of emission source, are shown as percentages in Figure 2.177. Data reported for fugitive and non-fugitive emissions provided in tonnes per year were converted into grams per hour.



**Figure 2.177: Total vinyl chloride emissions**

Channelled and non-treated emissions in Figure 2.177 are mostly emissions from PVC driers. Stripping or other techniques to reduce channelled emissions from PVC production are described in Section 3.

## 2.6.8 Specific loads

Information on specific loads was provided by 21 operators via 26 questionnaires. Specific loads are considered confidential business information. Data are only shown if the number of companies that reported information is greater than five.

Figure 2.178 and Figure 2.179 show specific loads for common types of PVC, indicating the upper and lower ends of the BAT-AEL range from Table 4.8.

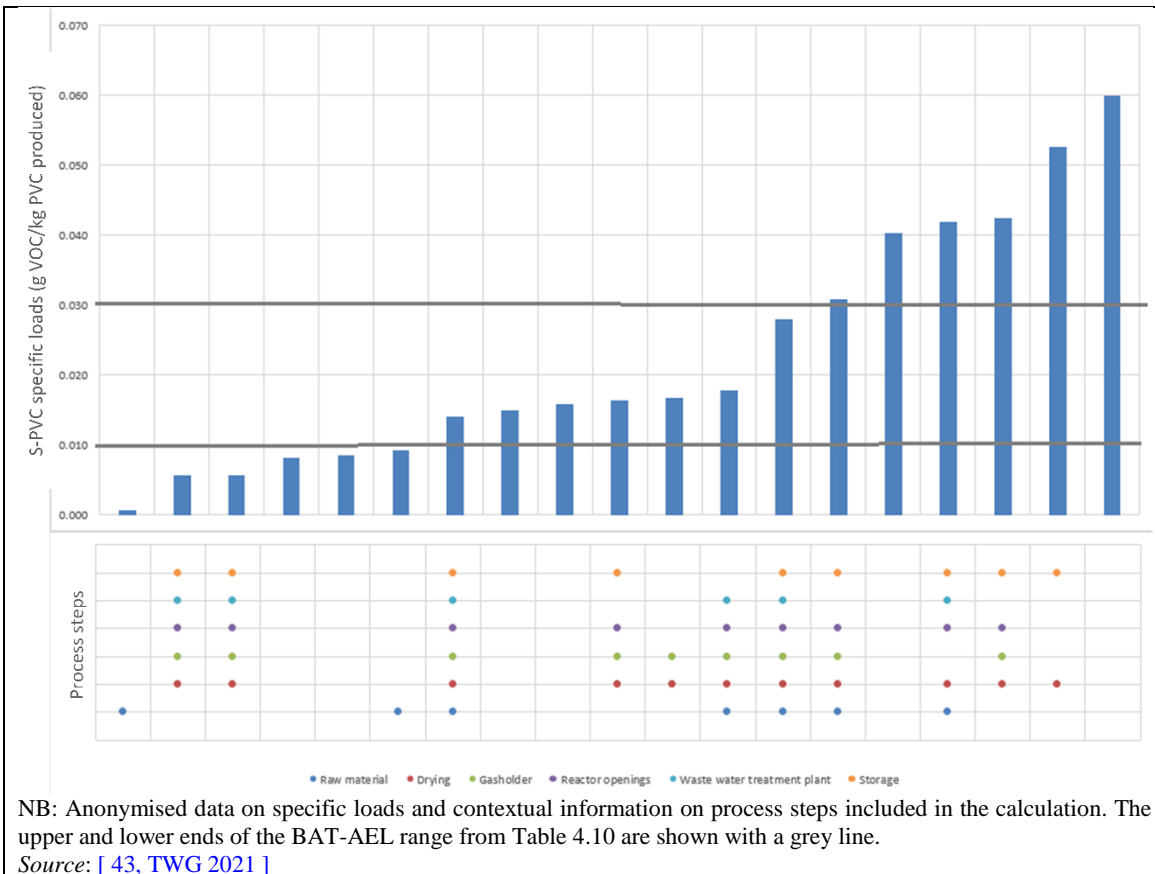


Figure 2.178: Specific loads S-PVC

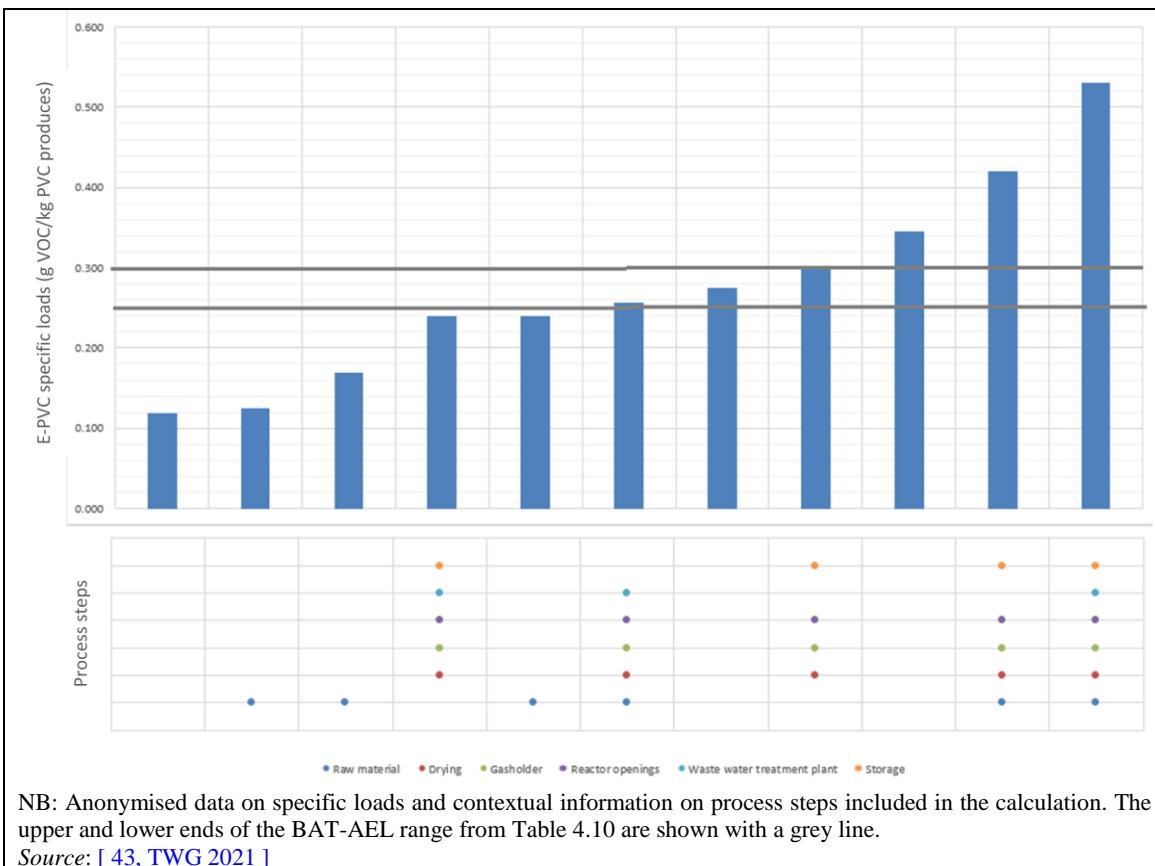
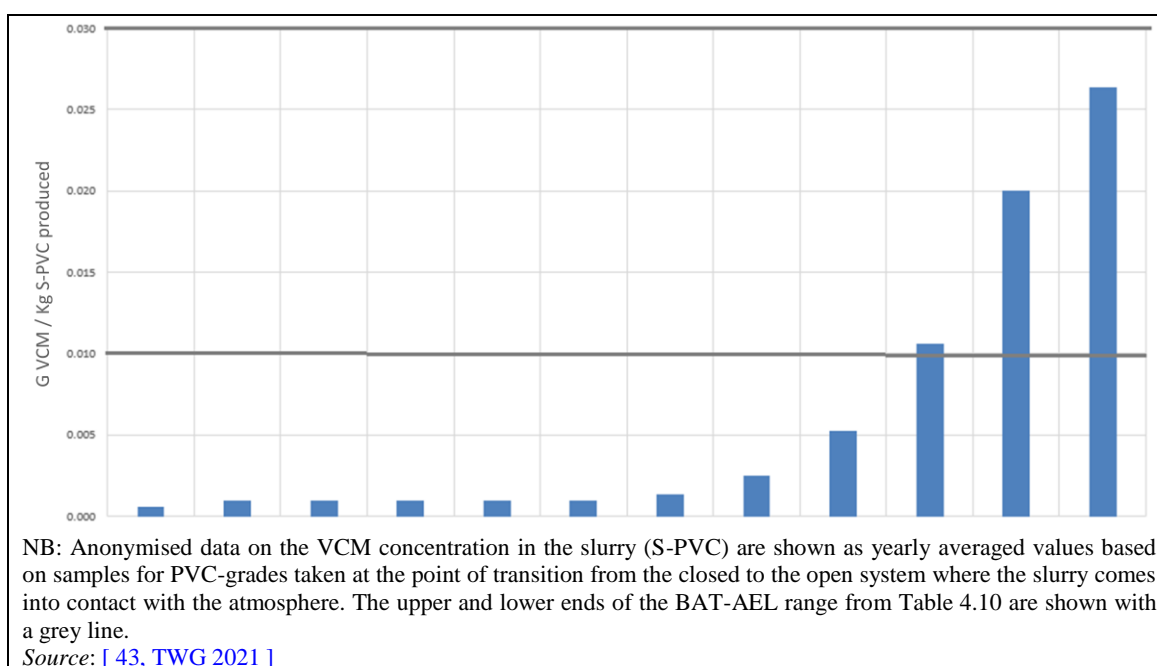


Figure 2.179: Specific loads for E-PVC

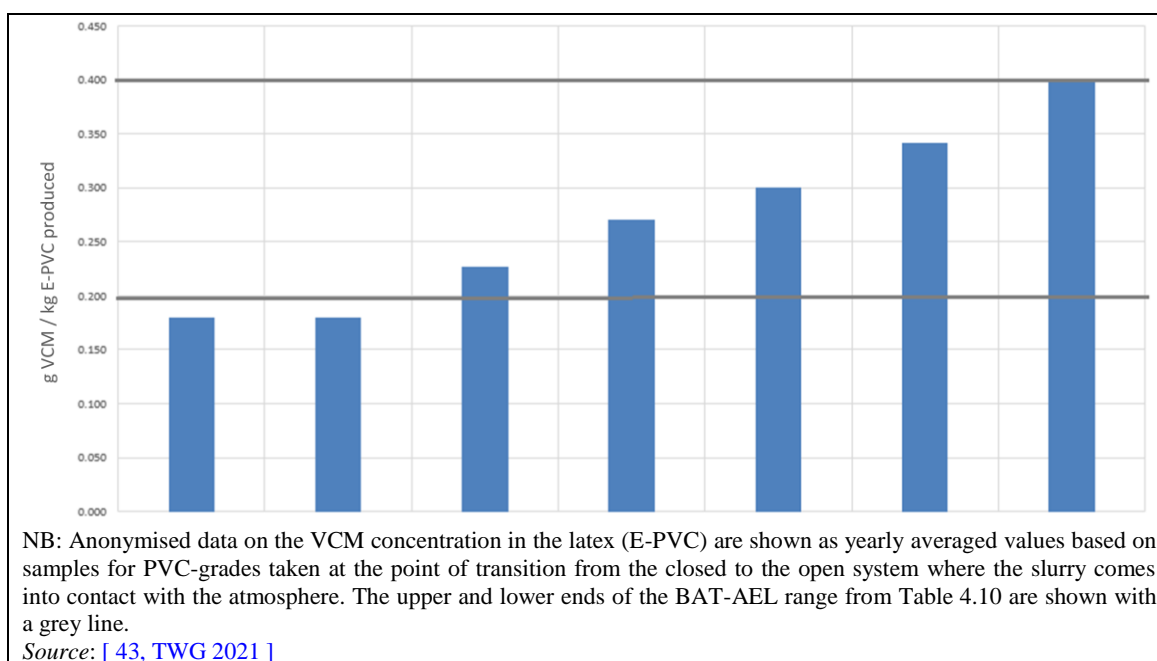
### 2.6.9 Monomer concentrations in the product after treatment

Monomer concentrations in the product after treatment are considered confidential business information. Data are only shown if the number of companies that reported data is greater than five.

Figure 2.180 and Figure 2.181 below show monomer concentrations in the product after treatment (see Section 3.5.2.1), indicating the upper and lower ends of the BAT-AEL range from Table 4.10.



**Figure 2.180: VCM content in the slurry (S-PVC) after treatment**



**Figure 2.181: VCM content in the latex (E-PVC)**

## 2.7 Production of synthetic rubbers

### 2.7.1 Overview

Information on the production of synthetic rubbers was provided by 10 operators via 11 questionnaires representing 36 emission points and 13 units. Two operators reported using an external treatment for their waste gases.

Figure 2.182 shows the types of synthetic rubbers reported in the data collection.

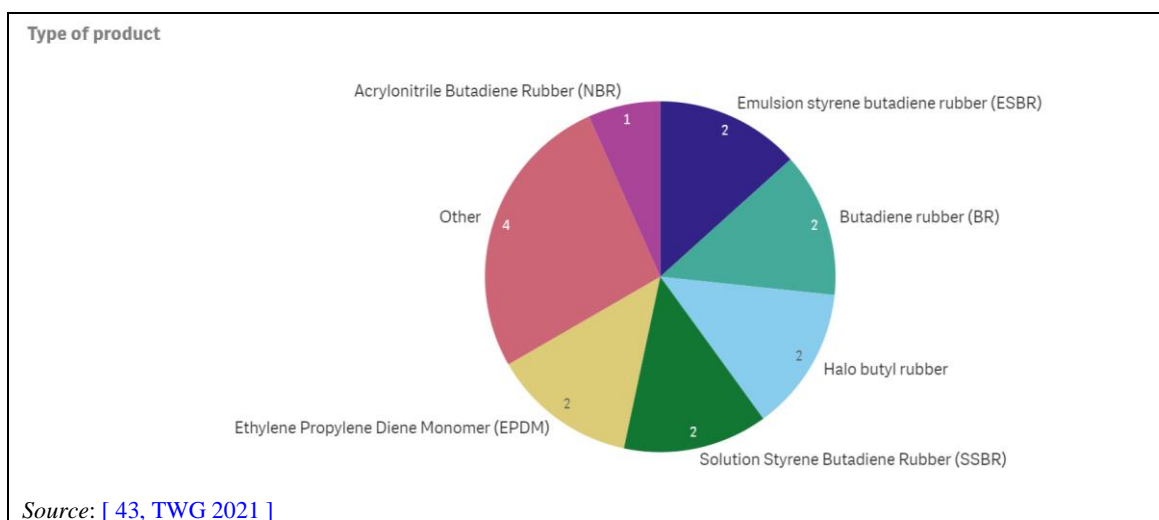


Figure 2.182: Types of synthetic rubbers

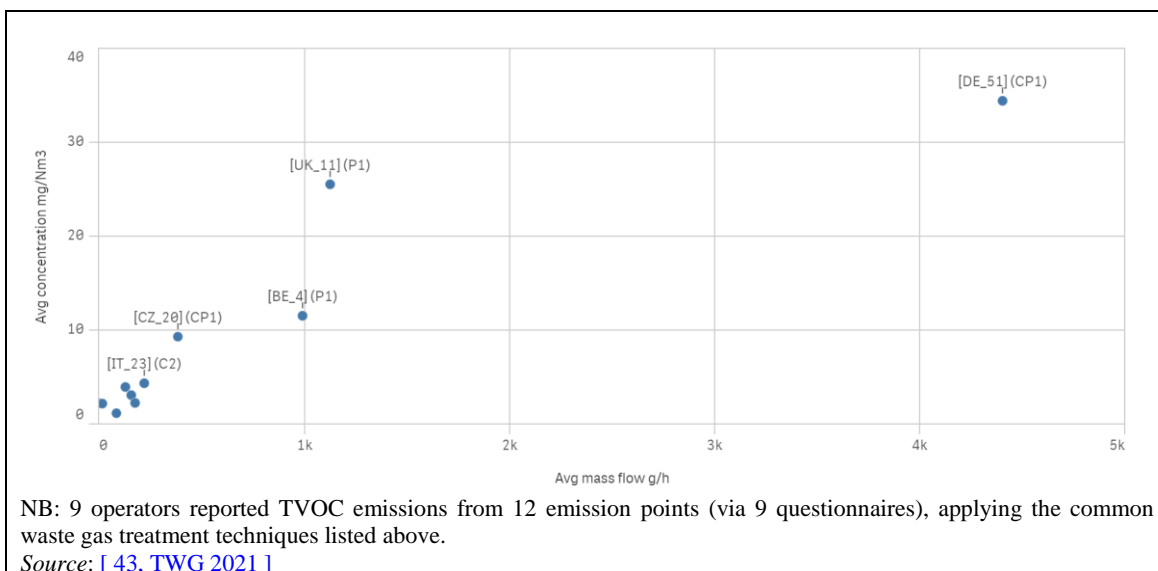
### 2.7.2 Treated channelled emissions

TVOC and 1,3-butadiene are generally treated with at least one waste gas treatment technique. The typical emission levels of TVOC and 1,3-butadiene after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.183 and Figure 2.184.

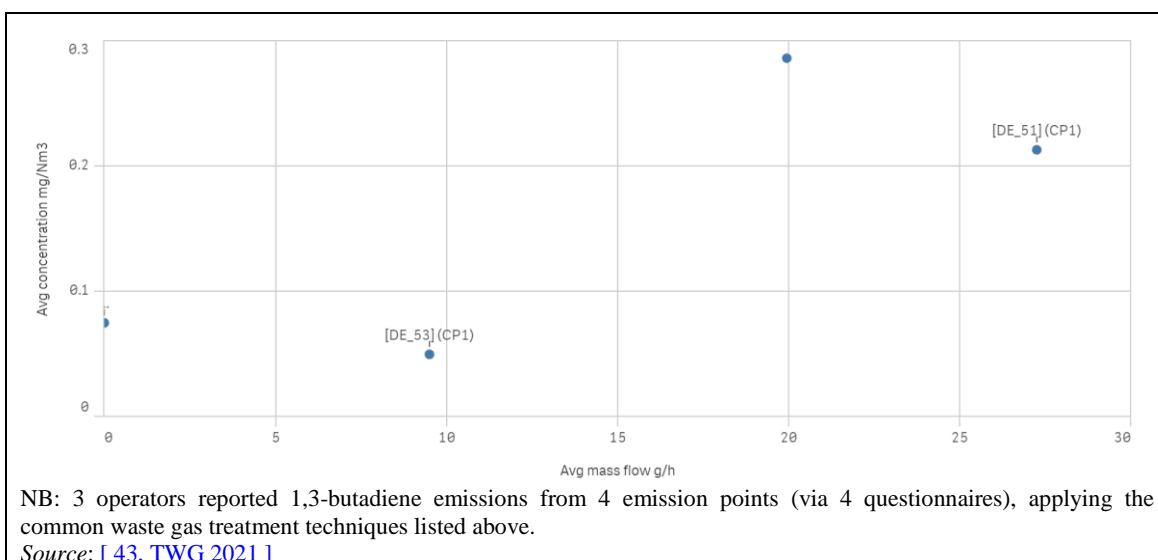
The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants for the production of synthetic rubbers are the following:

- adsorption;
- bioprocess;
- thermal oxidation.





**Figure 2.183:TVOC emissions after waste gas treatment**



**Figure 2.184:1,3-Butadiene emissions after waste gas treatment**

### 2.7.3 Untreated channelled emissions

The typical emission levels of TVOC when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.185. No data for 1,3-butadiene were reported in the data collection.

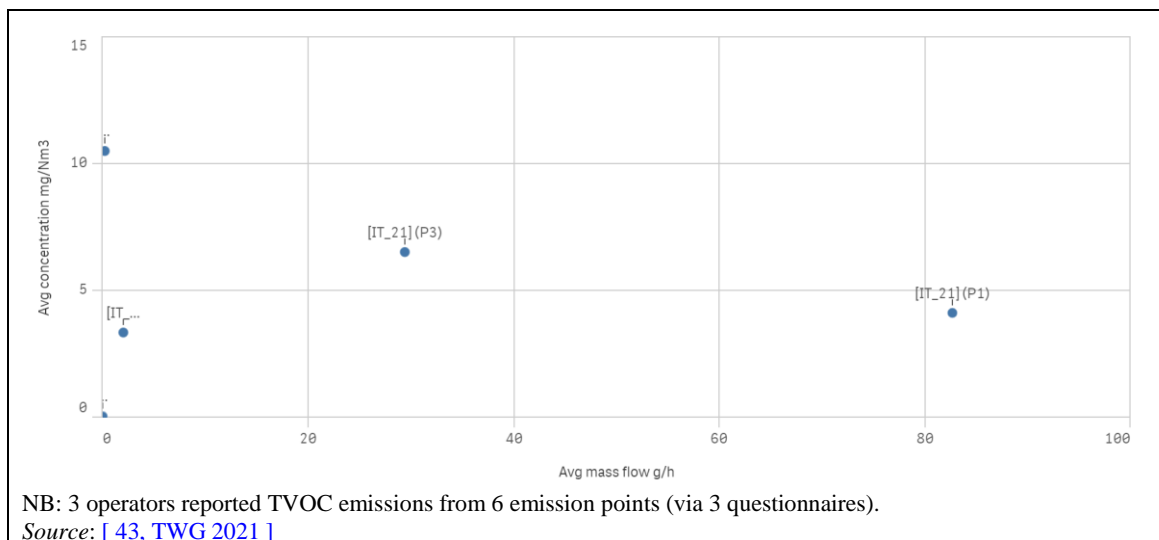


Figure 2.185:TVOC emission points with no waste gas treatment technique

No data were reported for emission levels of 1,3-butadiene when no waste gas treatment is applied.

### 2.7.4 Monitoring

The typical frequency for the monitoring of channelled TVOC emissions and 1,3-butadiene is once a year. Only periodic monitoring was reported (9 instances).

### 2.7.5 Fugitive emissions

Figure 2.186 shows reported data for fugitive TVOC emissions.

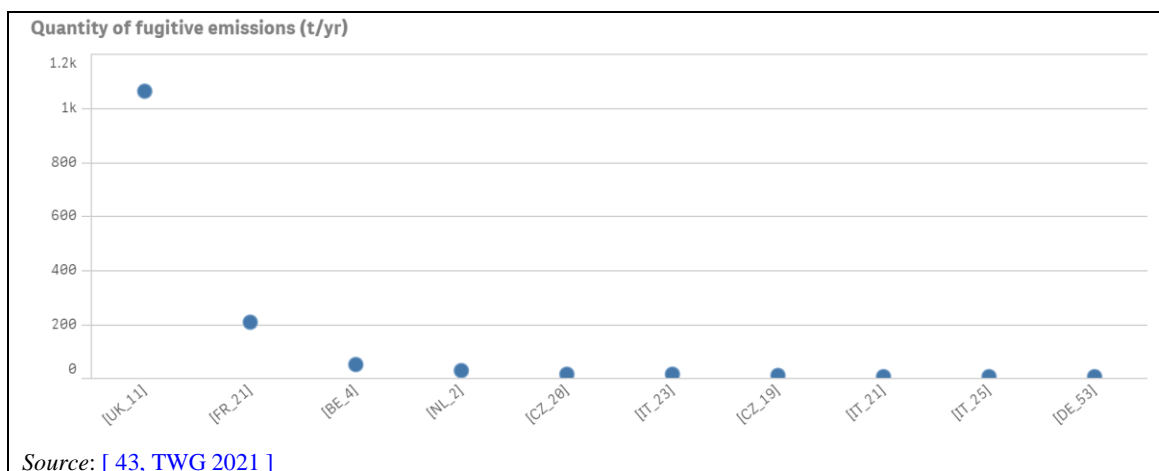
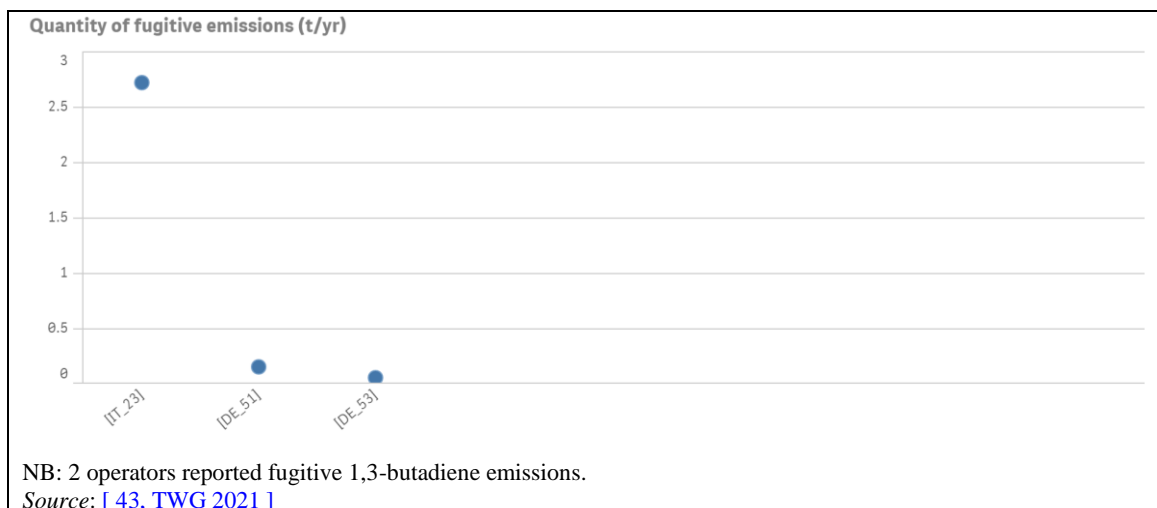


Figure 2.186:Fugitive TVOC emissions

A wide range of quantities of fugitive VOC emissions was reported as TVOC by 11 units in a range from 500 kg to 1 060 tonnes TVOC per year. The total quantity of fugitive TVOC emissions sums up to 1 360 tonnes per year.

Figure 2.187 shows reported data for fugitive 1,3-butadiene emissions.

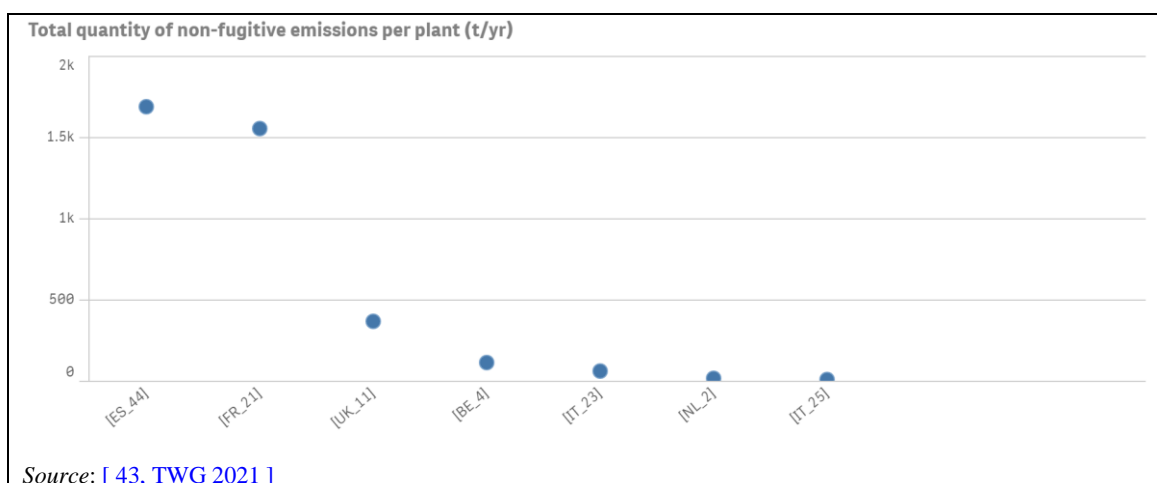


**Figure 2.187:Fugitive 1,3-butadiene emissions**

The total quantity of 1,3-butadiene fugitive emissions sum up to 2.9 tonnes/year.

## 2.7.6 Non-fugitive emissions

Figure 2.188 shows reported data for the non-fugitive TVOC emissions.



**Figure 2.188:Non-fugitive TVOC emissions**

A wide range of quantities of non-fugitive VOC emissions was reported as TVOC by 7 units in a range from 7 tonnes to 1 685 tonnes TVOC per year. The total quantity of non-fugitive TVOC emissions sums up to 3 770 tonnes per year.

No information was provided on non-fugitive 1,3-butadiene emissions.

### 2.7.7 Total TVOC emissions

TVOC emissions reported for the synthetic rubber sector, aggregated by the type of emission source, are shown as percentages in Figure 2.189. Data reported for fugitive and non-fugitive emissions provided in tonnes per year were converted into grams per hour.

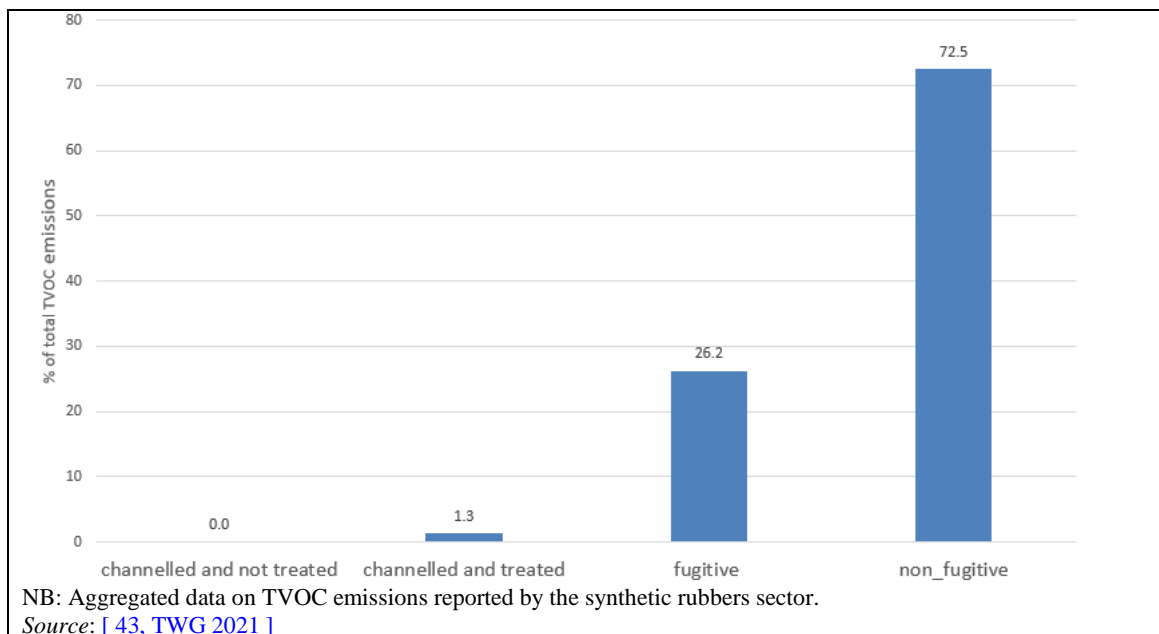


Figure 2.189: Total TVOC emissions

### 2.7.8 Specific loads

Information on specific loads was provided by six operators via eight questionnaires. Specific loads are considered confidential business information. Data are only shown if the number of companies that reported information is greater than five.

Figure 2.190 shows specific loads for common types of solution-polymerised rubbers (see Section 2.7.1).

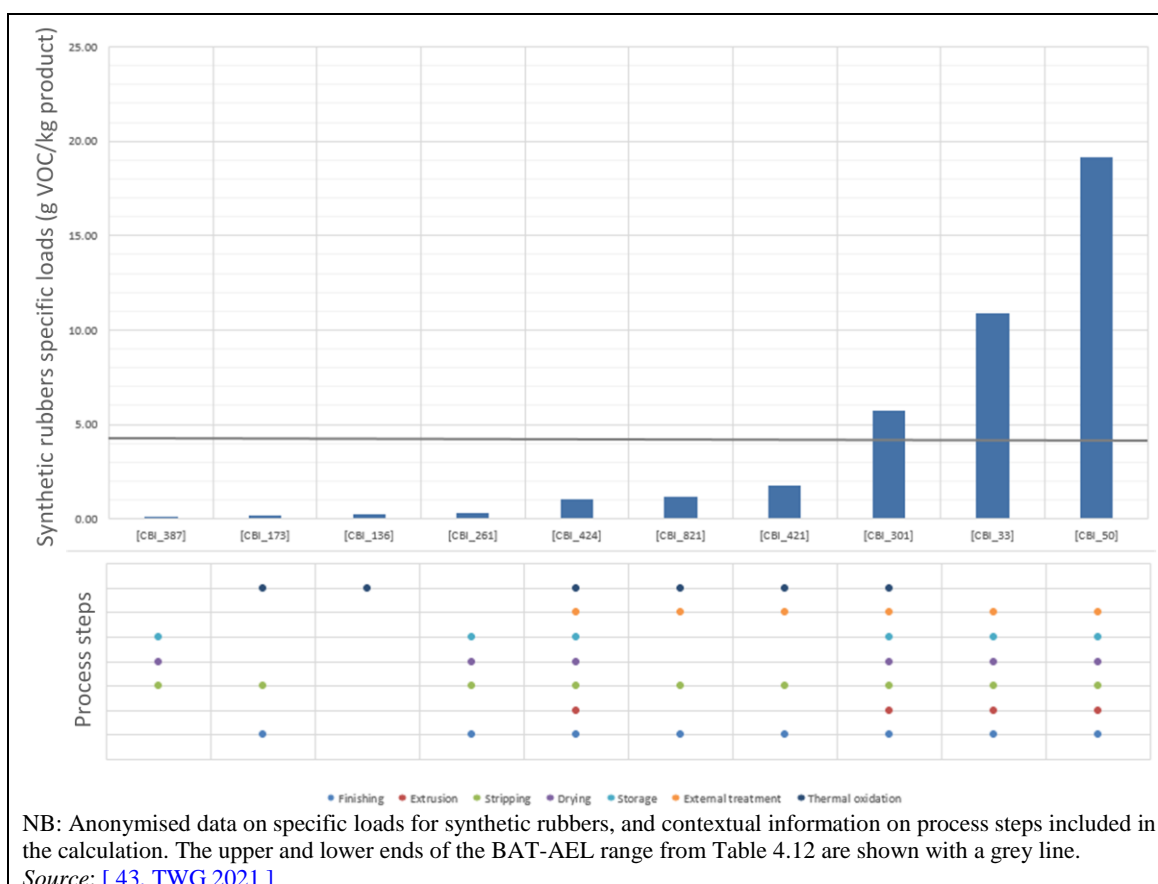


Figure 2.190: Specific loads for synthetic rubbers

### 2.7.9 Monomer concentrations in the product after treatment

Monomer concentrations in the product after treatment are considered confidential business information. Data are not shown as the number of companies that reported information is less than five.

## 2.8 Production of viscose using carbon disulphide (CS<sub>2</sub>)

### 2.8.1 Overview

Information on the production of viscose using carbon disulphide was provided by nine operators through nine questionnaires representing 12 emission points. Quantities of fugitive and non-fugitive emissions were not reported.

Table 2.37 shows the types of products reported in the data collection.

**Table 2.37: Types of viscose**

Product	Plant
Cellophane	UK_12
Filament fibre	CZ_6, DE_376, DE_377
Food casings	BE_73, DE_378, DE_383, FI_4, FR_48, FR_49
Sponge cloth	DE_378
Staple fibre	AT_8, DE_341
<i>Source: [43, TWG 2021]</i>	

### 2.8.2 Channelled emissions of carbon disulphide (CS<sub>2</sub>) to air

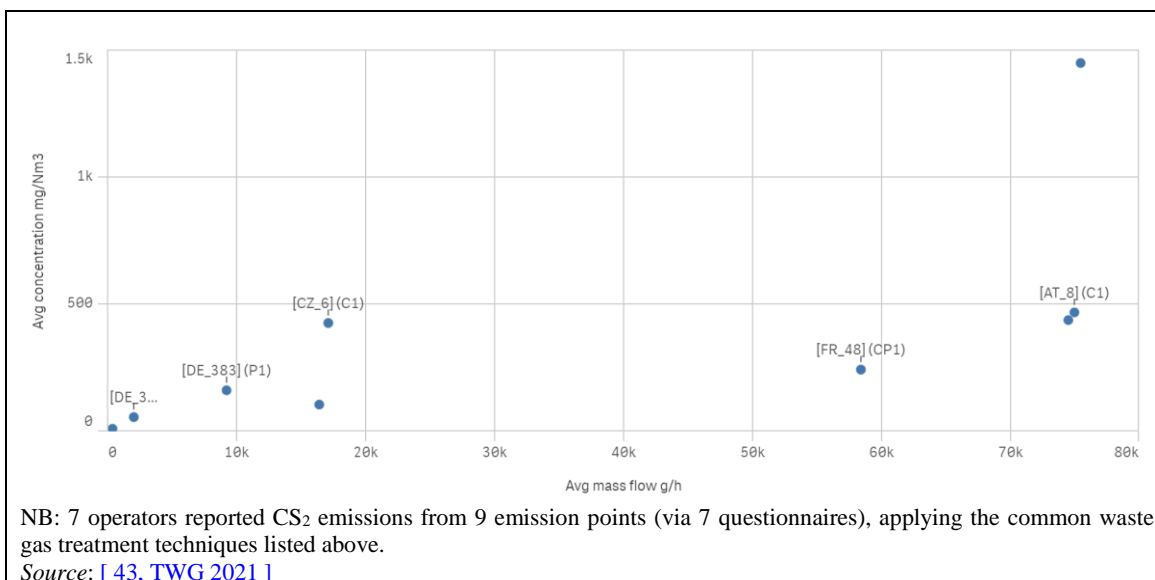
CS<sub>2</sub> is typically emitted from the production of viscose and it was reported by nine operators for 23 emission points in the data collection.

#### 2.8.2.1 Treated emissions

CS<sub>2</sub> is generally treated with at least one waste gas treatment technique. The typical emission levels of CS<sub>2</sub> after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.191.

The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

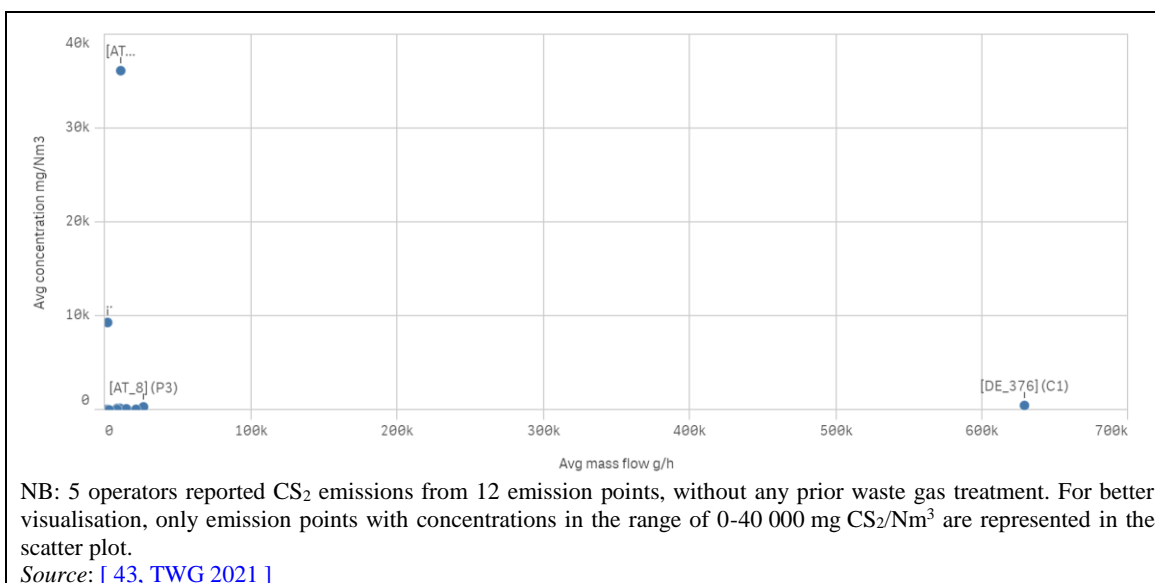
- absorption;
- adsorption;
- bioprocess;
- condensation;
- thermal or catalytic oxidation.



**Figure 2.191:CS<sub>2</sub> emissions after waste gas treatment**

### 2.8.2.2 Untreated emissions

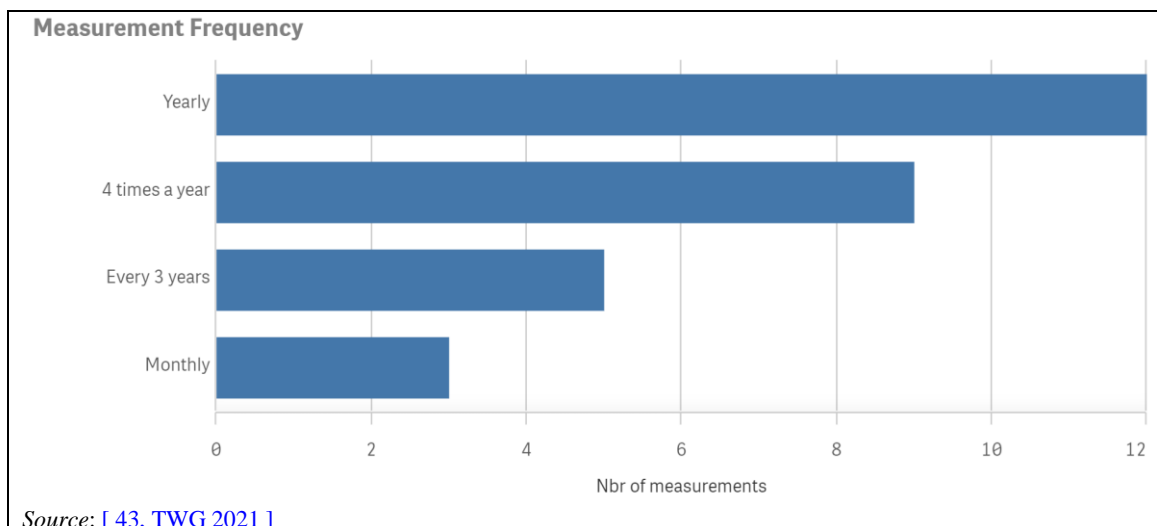
The typical emission levels of CS<sub>2</sub> when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.192.



**Figure 2.192:CS<sub>2</sub> emission points with no waste gas treatment technique**

### 2.8.2.3 Monitoring

Periodic monitoring and continuous monitoring are both commonly used: 33 instances of periodic monitoring and 32 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled CS<sub>2</sub> emissions are shown in the bar chart of Figure 2.193.



**Figure 2.193: Reported measurement frequencies for periodic CS<sub>2</sub> monitoring**

Percentiles for reported limits of quantification and limits of detection for CS<sub>2</sub> measurements are shown in Table 2.38.

**Table 2.38: Reported limits of quantification and detection for CS<sub>2</sub>**

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	18.0	0.1
50 <sup>th</sup>	63.0	0.2
80 <sup>th</sup>	172.0	7.0

NB: The numbers of instances reported for the limits of quantification and detection are 21 and 14, respectively.  
Source: [43, TWG 2021]

## 2.8.3 Channelled emissions of hydrogen sulphide (H<sub>2</sub>S) to air

H<sub>2</sub>S is typically emitted from the production of viscose and it was reported by eight operators representing 19 emission points in the data collection.

### 2.8.3.1 Treated emissions

H<sub>2</sub>S is generally treated with at least one waste gas treatment technique. The typical emission levels of H<sub>2</sub>S after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.194.



The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

- absorption;
- adsorption;
- bioprocess;
- thermal or catalytic oxidation.

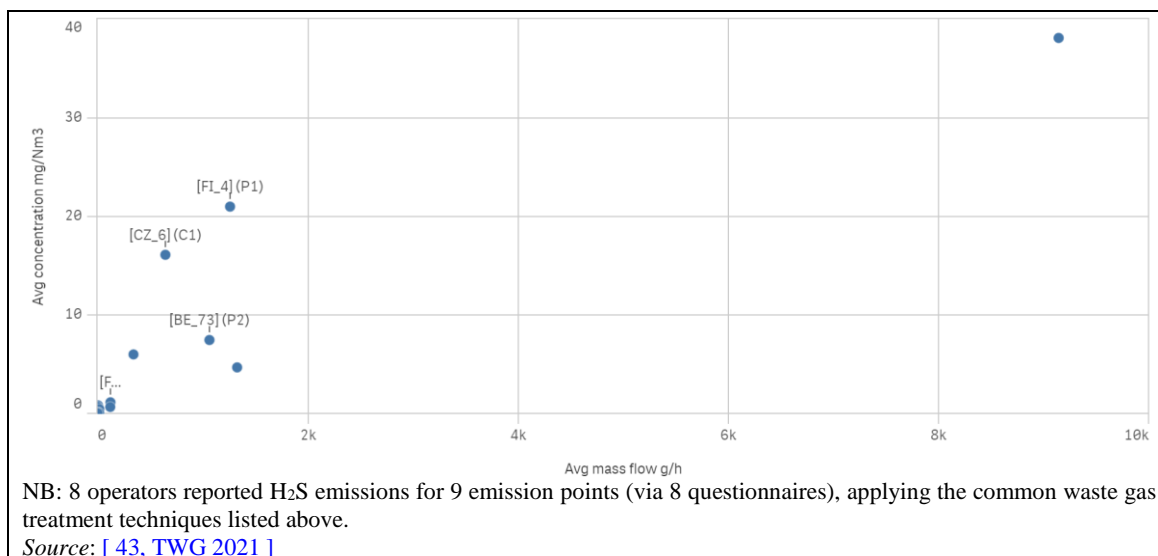


Figure 2.194:H<sub>2</sub>S emissions after waste gas treatment

### 2.8.3.2 Untreated emissions

The typical emission levels of H<sub>2</sub>S when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.195.

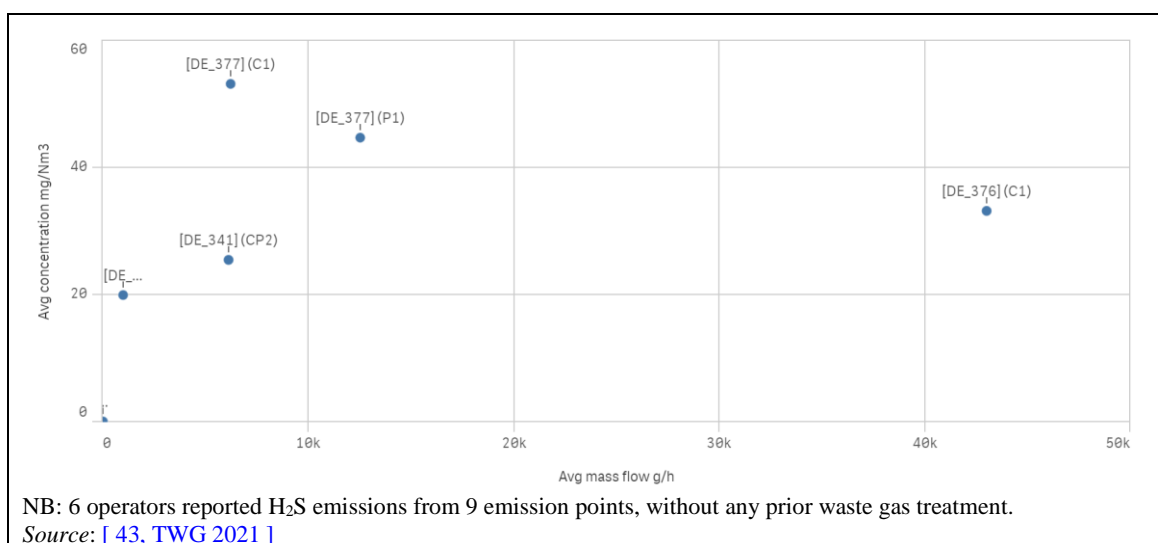


Figure 2.195:H<sub>2</sub>S emission points with no waste gas treatment technique

### 2.8.3.3 Monitoring

Periodic monitoring and continuous monitoring are both commonly used: 15 instances of periodic monitoring and 20 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled H<sub>2</sub>S emissions are shown in the bar chart of Figure 2.196.

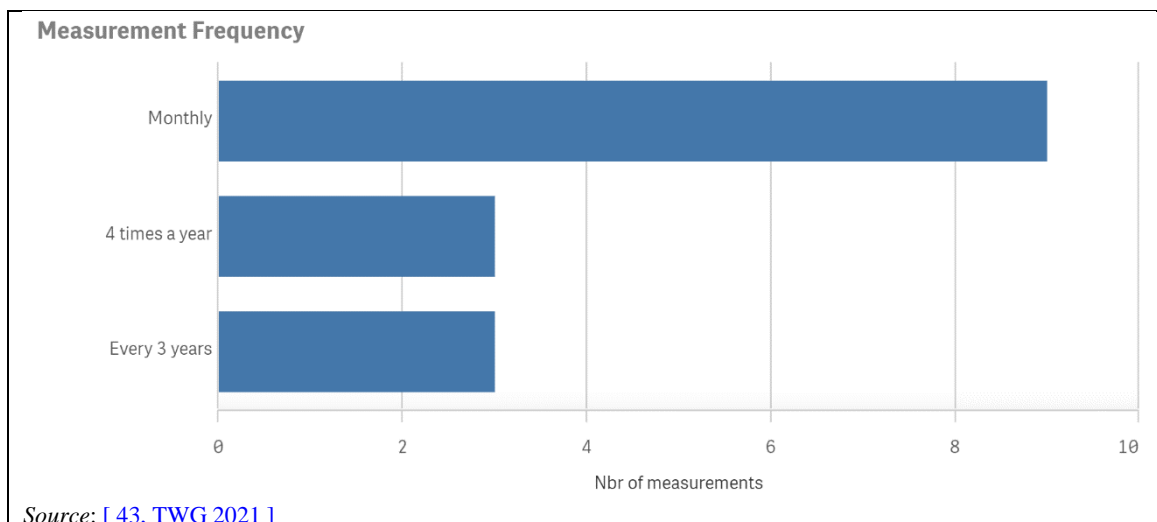


Figure 2.196: Reported measurement frequencies for periodic H<sub>2</sub>S monitoring

Percentiles for reported limits of quantification and limits of detection for H<sub>2</sub>S measurements are shown in Table 2.39.

Table 2.39: Reported limits of quantification and detection for H<sub>2</sub>S

Percentile	Limit of quantification (mg/Nm <sup>3</sup> )	Limit of detection (mg/Nm <sup>3</sup> )
20 <sup>th</sup>	0.19	0.1
50 <sup>th</sup>	5.22	1.5
80 <sup>th</sup>	162	1.8

NB: The numbers of instances reported for the limits of quantification and detection are 13 and 23, respectively.  
Source: [43, TWG 2021]

### 2.8.4 Specific loads of carbon disulphide (CS<sub>2</sub>) to air

Information on specific loads of CS<sub>2</sub> was provided by six operators via six questionnaires. The range of specific loads is between 8 kg and 250 kg CS<sub>2</sub> per tonne of product. Specific loads are considered confidential business information. Data on types of products are not shown as the number of companies is less than five.

### 2.8.5 Specific loads of hydrogen sulphide (H<sub>2</sub>S) to air

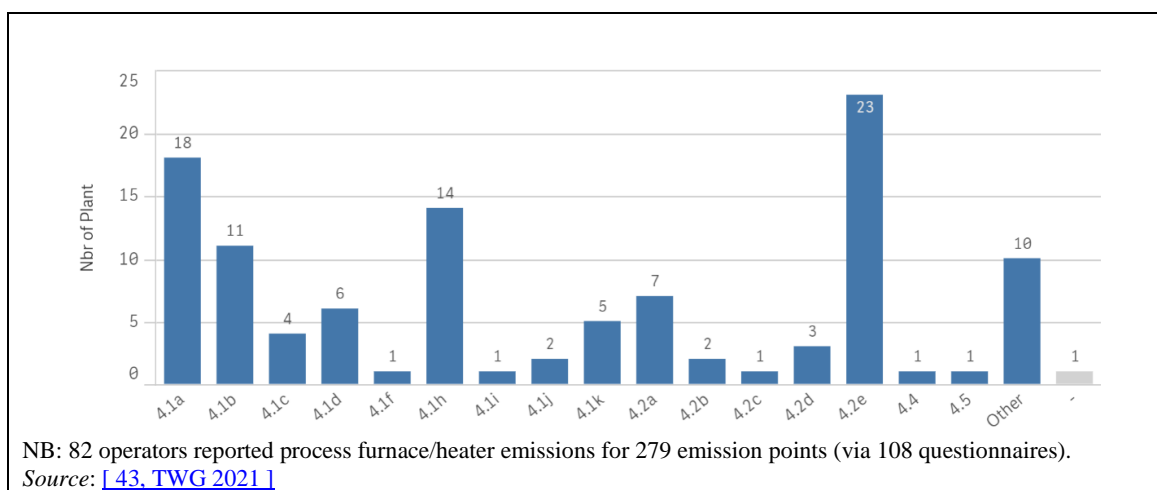
Information on specific loads of H<sub>2</sub>S was provided by five operators via five questionnaires. The range of specific loads is between 0.1 kg and 23 kg H<sub>2</sub>S per tonne of product. Specific loads are considered confidential business information. Data on types of products are not shown as the number of companies is less than five.

## 2.9 Process furnaces/heaters

### 2.9.1 Overview

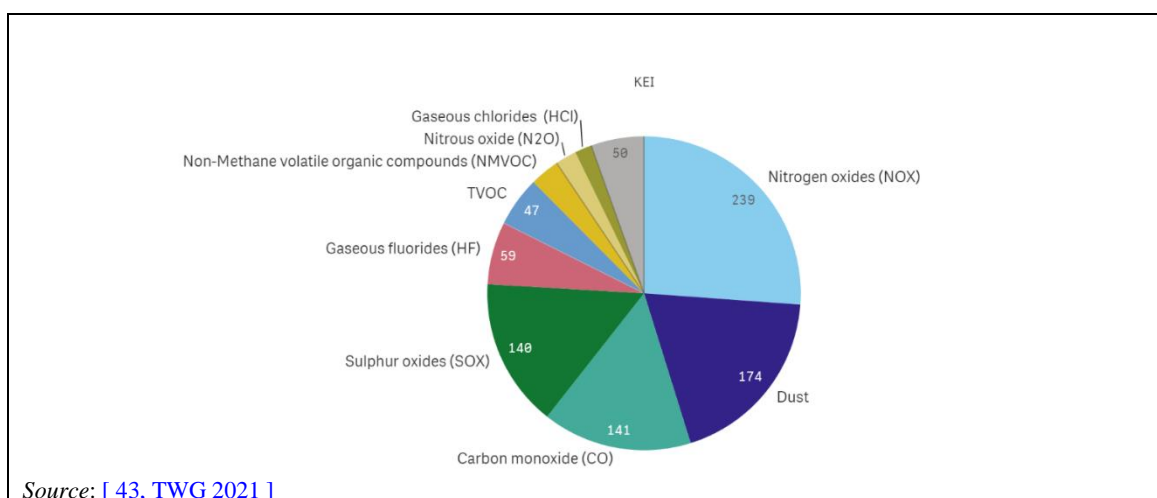
Information on process furnaces/heaters was provided by 82 operators via 108 questionnaires representing 279 emission points.

Figure 2.197 shows the use of process furnaces/heaters across the chemical industry.



**Figure 2.197: Process furnace/heater emissions reported by main IED activity**

Figure 2.198 shows the main substances/parameters emitted by process furnaces/heaters.



**Figure 2.198: Main substances/parameters emitted by process furnaces/heaters**

Table 2.40 shows thermal input of individual process furnaces/heaters reported by emission point in the data collection.

**Table 2.40: Thermal input per emission point (MW)**

Thermal input (MW)	No of emission points
< 1	67
1-10	132
10-50	34
> 50	5
<i>Source: [43, TWG 2021]</i>	

In most cases, natural gas is used as the fuel. Sometimes, process gases such as hydrogen are used as fuel in addition to natural gas.

Seven companies reported via seven questionnaires the use of oxy-fuel burners for the combustion process, mainly for chemical processes regarding IED activity 4.2e. In that case, the fuel is used for direct heating or as dual-use fuel (used as raw material and for combustion) and the maximum process temperatures may exceed 1 200 °C.

According to the data collection, there are plants with process furnaces/heaters using indirect heating that do not seem to be permitted with a reference oxygen level. Table 2.41 summarises relevant data collected on the reference oxygen level.

**Table 2.41: Reference oxygen level reported by process furnaces/heaters**

Main chemical activity	No. of EPs (total)*	No. of EPs reporting a reference oxygen level as permitted	Range of permitted reference oxygen level	Range/level of measured oxygen level	Type of fuel (No. of EPs)*
4.1 (a)	15	12	3 %	2.5-16	Other (16), multi-fuel (1)
4.1 (b)	2	1	3 %	8	Other (2)
4.1 (c)	3	1	3 %	No data	Natural gas (3)
4.1 (d)	6	5	3 %	3.2-4.6	Natural gas (1), Other (5)
4.1 (f)	2	2	3 %	6.0-11.5	Natural gas
4.1 (h)	8	4	3 %	4.5-16.5	Natural gas (6)
4.1 (i)	1	No data	No data	No data	Natural gas
4.2 (c)	1	1	3 %	8	Natural gas
4.2 (d)	2	No data	No data	8	Natural gas, Other
4.2 (e)	45	13	15.0-20.2 %	14.8-20.7	Natural gas

\* Differences might occur between 'No. of EPs (total)' reporting NO<sub>x</sub> emission data and 'No. of EPs' reporting the type of fuel used, according to the information provided within the questionnaires.

As indicated in Table 2.41, process furnaces/heaters are used for a wide range of chemical activities. Moreover, evidence from the data collected shows that the related characteristics and operating conditions vary significantly, as briefly summarised below:

- operating temperature: within a range from less than 180 °C to more than 1 350 °C;
- operating times: in a range from less than 500 h/year to 8 760 h/year;
- fuels: natural gas is typically used as fuel (70 EPs), followed by other fuels.

For the main chemical activity 4.2e in particular, the data collection shows measured oxygen content levels close to 21 % and process temperatures typically higher than 1 000 °C.

For the other main chemical activities, the measured oxygen content is in the range 2.5 % to 16.5 %.

## 2.9.2 Nitrogen oxides

### 2.9.2.1 Emissions

For process furnaces/heaters, the typical emission levels of nitrogen oxide are shown as concentration and mass flow in the scatter plot of Figure 2.199. The data collected includes different type of fuels used such as natural gas, oil, multi-fuel and others.

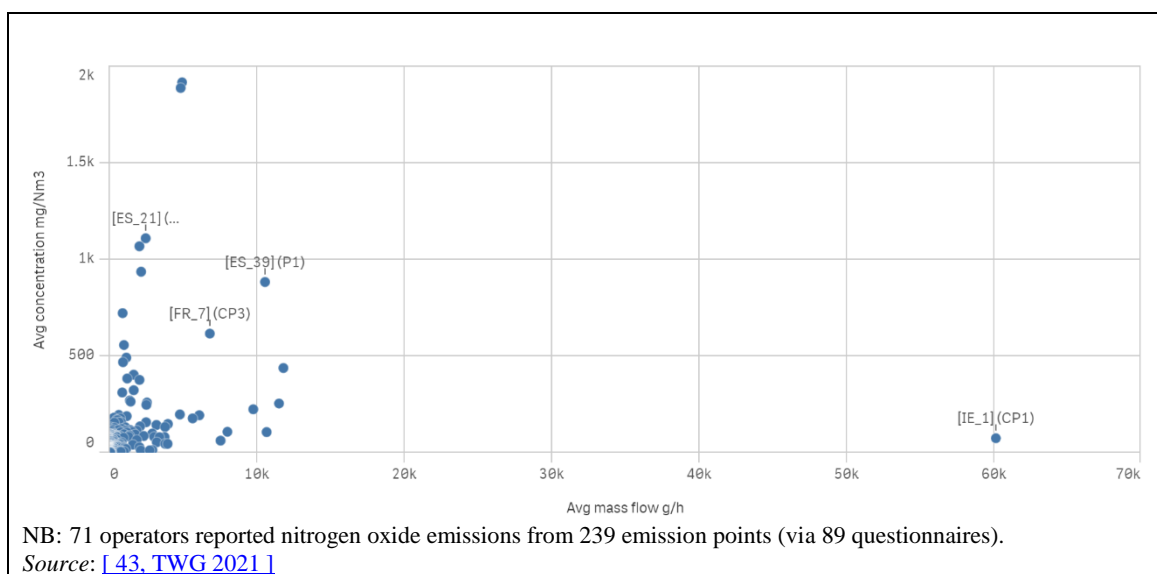
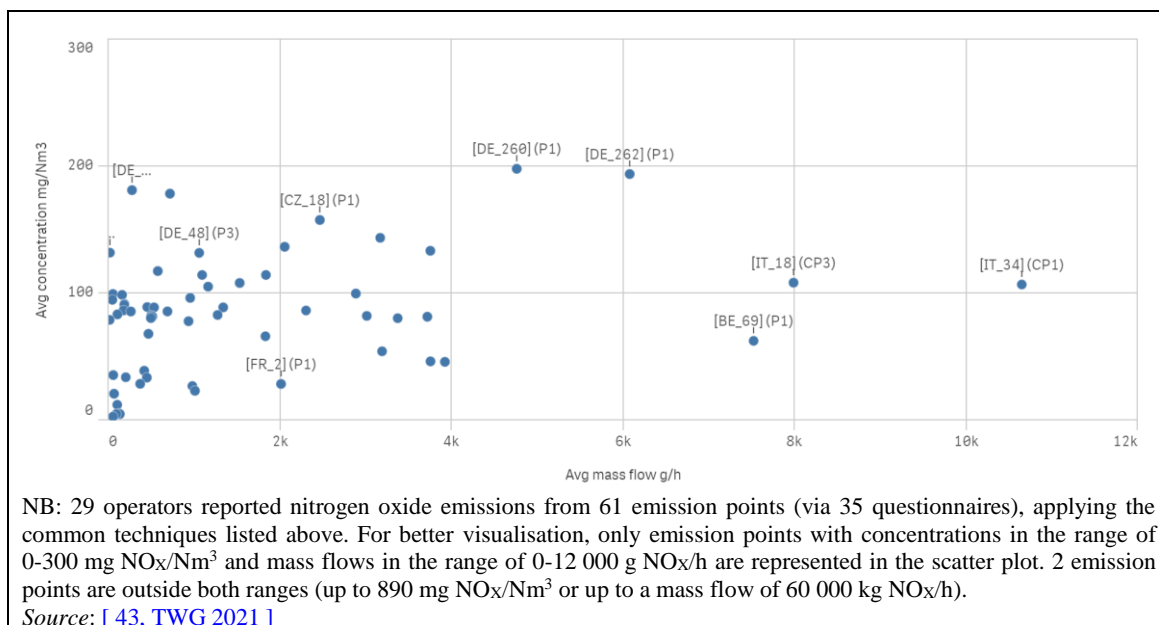


Figure 2.199: NO<sub>x</sub> emissions from process furnaces/heaters

The techniques most commonly applied, alone or in combination, in order to reduce nitrogen oxide emissions from process furnaces/heaters are the following:

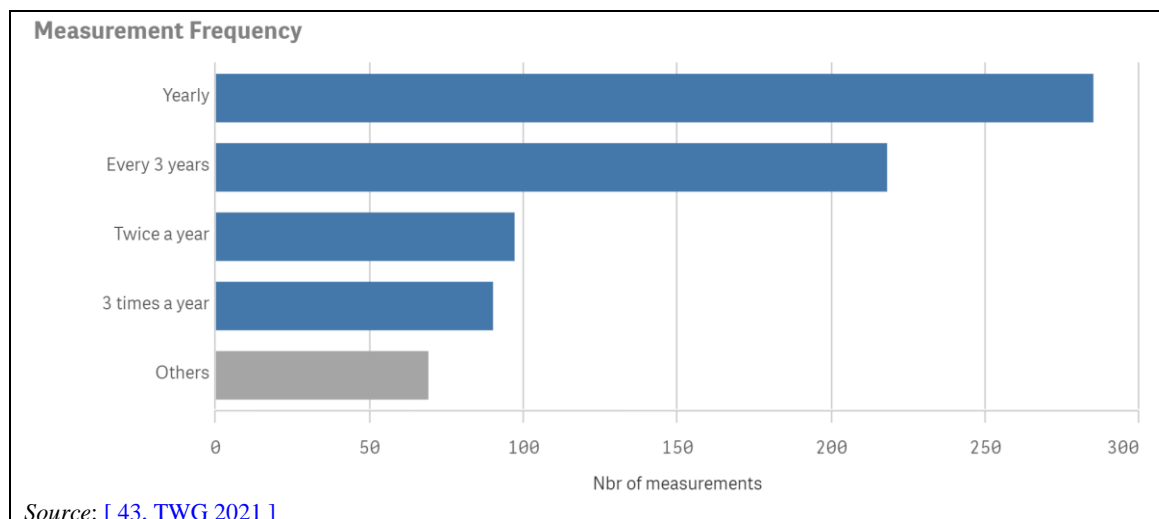
- optimised combustion;
- choice of fuel;
- low-NO<sub>x</sub> burners;
- reduction (SCR or SNCR).



**Figure 2.200: NO<sub>x</sub> emissions from process furnaces/heaters applying common techniques for NO<sub>x</sub> reduction**

### 2.9.2.2 Monitoring

Periodic monitoring is more common than continuous monitoring: 530 instances of periodic monitoring and 55 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled nitrogen oxide emissions are shown in the bar chart of Figure 2.201.

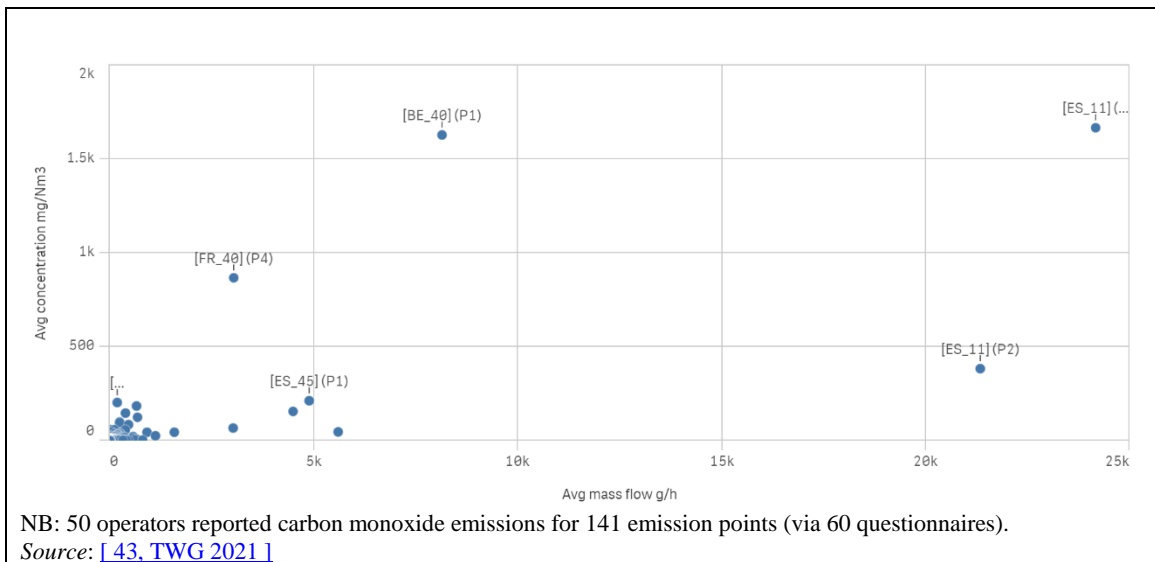


**Figure 2.201: Reported measurement frequencies for periodic monitoring of NO<sub>x</sub> from process furnaces/heaters**

## 2.9.3 Carbon monoxide

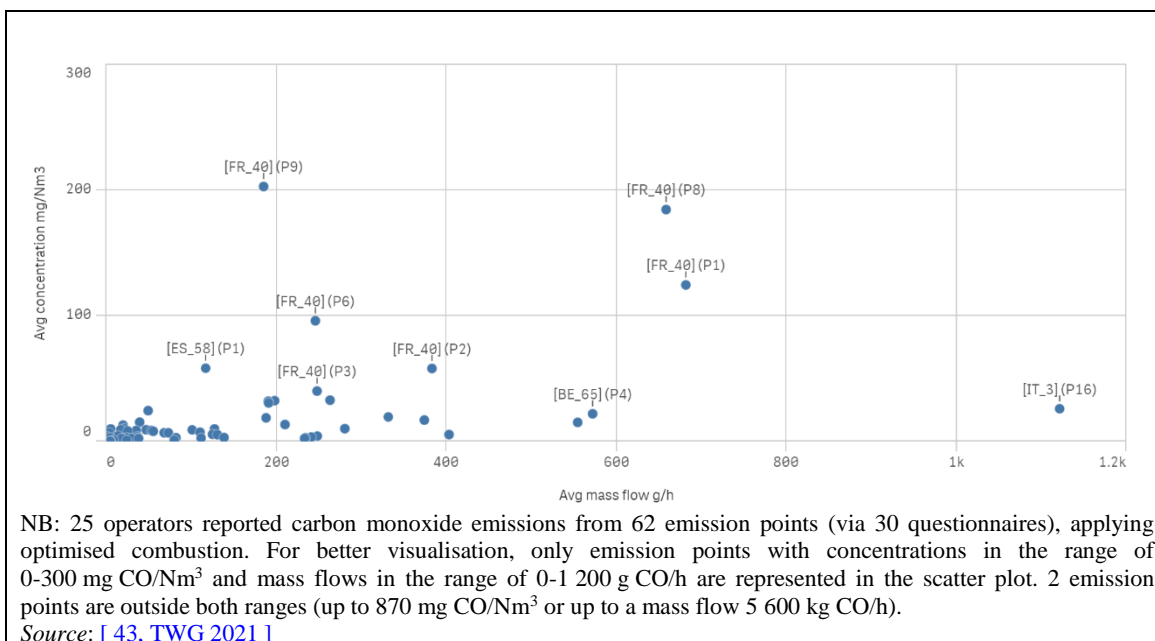
### 2.9.3.1 Emissions

For process furnaces/heaters, the typical emission levels of carbon monoxide are shown as concentration and mass flow in the scatter plot of Figure 2.202.



**Figure 2.202:CO emissions from process furnaces/heaters**

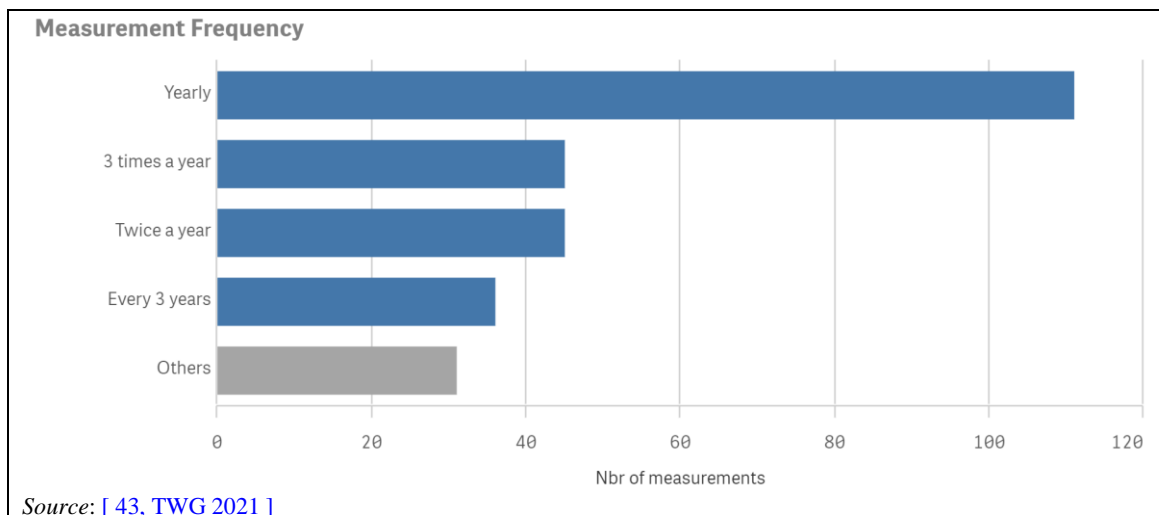
The technique most commonly applied in order to reduce carbon monoxide emissions from process furnaces/heaters is optimised combustion.



**Figure 2.203:CO emissions from process furnaces/heaters applying optimised combustion**

### 2.9.3.2 Monitoring

Periodic monitoring is more common than continuous monitoring: 286 instances of periodic monitoring and 44 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled carbon monoxide emissions are shown in the bar chart of Figure 2.204.



**Figure 2.204: Reported measurement frequencies for periodic monitoring of CO from process furnaces/heaters**



### 3 TECHNIQUES TO CONSIDER IN THE DETERMINATION OF BAT

This chapter describes techniques (or combinations thereof), and associated monitoring, considered to have the potential for achieving a high level of environmental protection in the activities within the scope of this document. The techniques described will include both the technology used and the way in which the installations are designed, built, maintained, operated and decommissioned.

The main focus of this chapter is on general techniques for environmental management, for the recovery of materials and energy, for the end-of-pipe treatment of waste gases as well as to reduce diffuse emissions. Other issues that are covered include techniques to reduce emissions from the production of specific polymers and from the use of process furnaces/heaters.

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 3.1 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 chapter does not necessarily provide an exhaustive list of techniques that could be applied in the sector. Other techniques may exist, or may be developed, which could be considered in the determination of BAT for an individual installation.

**Table 3.1: Information for each technique**

<b>Headings within the sections</b>
Description
Technical description
Achieved environmental benefits
Environmental performance and operational data
Cross-media effects
Technical considerations relevant to applicability
Economics
Driving force for implementation
Example plants
Reference literature

## 3.1 Management techniques

### 3.1.1 Environmental management system

#### Description

A formal system to demonstrate compliance with environmental objectives.

#### Technical description

The 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 3.1).



Figure 3.1: 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 [ 22, CEN 2015 ]. 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 [ 24, EU 2009 ]. 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;
- iii. development of an environmental policy that includes the continuous improvement of the environmental performance of the installation;
- iv. establishing objectives and performance indicators in relation to significant environmental aspects, including safeguarding compliance with applicable legal requirements;
- 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;
- 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;
- 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;

- 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;
- xx. following and taking into account the development of cleaner techniques.

Specifically for chemical plants, the following features can also be incorporated in the EMS:

- xxi. an inventory of channelled and diffuse emissions to air (see Section 3.1.2);
- xxii. an OTNOC management plan for emissions to air;
- xxiii. an integrated waste gas management and treatment strategy for channelled emissions to air;
- xxiv. a management system to prevent and reduce diffuse VOC emissions to air (see Section 3.4.1);
- xxv. a chemicals management system that includes an inventory of the hazardous substances and substances of very high concern used in the process(es); the potential for substitution of the substances that are listed in this inventory, focusing on those substances other than raw materials, is analysed periodically (e.g. annually) in order to identify possible new available and safer alternatives, with no or lower environmental impacts.

### **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**

No information provided.

### **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.

### **Driving force 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.

#### Reference literature

[ 22, CEN 2015 ], [ 24, EU 2009 ], [ 13, COM 2016 ].

### 3.1.2 Inventory of channelled and diffuse emissions to air

#### Description

An inventory provides a comprehensive compilation of information about channelled and diffuse emissions to air from the chemical installation.

#### Technical description

The inventory of channelled and diffuse emissions can contain the following features:

- i. Information, as comprehensive as is reasonably possible, about the chemical production process(es), including:
  - a. chemical reaction equations, also showing side products;
  - b. simplified process flow sheets that show the origin of the emissions.
- ii. Information, as comprehensive as is reasonably possible, about channelled emissions to air, such as:
  - a. emission point(s);
  - b. average values and variability of flow and temperature;
  - c. average concentration and load values of relevant pollutants/parameters and their variability (e.g. TVOC, CO, NO<sub>x</sub>, SO<sub>x</sub>, Cl<sub>2</sub>, HCl);
  - d. presence of other substances that may affect the waste gas treatment system(s) or plant safety (e.g. oxygen, nitrogen, water vapour, dust);
  - e. techniques used to prevent and/or reduce channelled emissions;
  - f. flammability, lower and higher explosive limits, reactivity;
  - g. monitoring methods;
  - h. presence of substances classified as CMR 1A or 1B, or CMR 2; the presence of such substances may for example be assessed according to the criteria of Regulation (EC) 1272/2008 on classification, labelling and packaging (CLP).
- iii. Information, as comprehensive as is reasonably possible, about diffuse emissions to air, such as:
  - a. identification of the emission source(s);
  - b. characteristics of each emission source (e.g. fugitive or non-fugitive; static or moving; accessibility of the emission source; included in an LDAR programme or not);
  - c. the characteristics of the gas or liquid in contact with the emission source(s), including:
    - 1) physical state;
    - 2) vapour pressure of the substance(s) in the liquid, pressure of the gas;
    - 3) temperature;
    - 4) composition (by weight for liquids or by volume for gases);

- 5) hazardous properties of the substance(s), or mixtures, including substances or mixtures classified as CMR 1A or 1B, or CMR 2;
- d. techniques used to prevent and/or reduce diffuse emissions to air;
- e. monitoring.

The inventory is updated when substantial changes of the plant are carried out, e.g. addition, replacement or dismantling of equipment.

### **Achieved environmental benefits**

The inventory of channelled and diffuse emissions to air facilitates the reduction of emissions to air.

### **Environmental performance and operational data**

Some Member States have adopted criteria in their regional or general binding rules to determine which sources in contact with VOCs are to be considered a relevant source of diffuse emissions [ 1, BE FR SE UK 2019 ]. In those countries, relevant sources of fugitive VOC emissions are determined according to the following criteria:

- in Belgium: sources connected to pipes whose diameter is greater than 12.7 mm (0.5 inch) and in contact with streams containing more than 10 vol-% (for gases) or 20 wt-% (for liquids) organic compounds with a vapour pressure greater than 0.3 kPa at 20 °C;
- in Italy: sources connected to pipes whose diameter is greater than 25.4 mm (1 inch);
- in France (Provence-Alpes-Côte-d'Azur region): sources connected to pipes whose diameter is greater than 12.7 mm (0.5 inch) and in contact with streams containing organic compounds with a vapour pressure greater than 0.3 kPa at 20 °C or having corresponding volatility under special conditions of use.

### **Cross-media effects**

None reported.

### **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 inventory will generally be related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have.

The inventory of diffuse emissions to air is particularly relevant for activities using large amounts of organic substances or mixtures (e.g. production of pharmaceuticals, production of large volumes of organic chemicals or of polymers).

Equipment operated under subatmospheric pressure may be excluded from the inventory.

### **Economics**

No information provided.

### **Driving force for implementation**

- Improved plant management.
- Environmental legislation.

### **Example plants**

No information provided.

### **Reference literature**

[ 1, BE FR SE UK 2019 ], [ 13, COM 2016 ].

## 3.2 General techniques

### 3.2.1 Waste gas management and treatment strategy

The integrated waste gas management and treatment strategy is based on the inventory of channelled and diffuse emissions to air (see Section 3.1.2), giving priority to process integrated-techniques over waste gas treatment techniques. It also takes into account factors such as greenhouse gas emissions and the consumption or reuse of energy, water and materials associated with the use of different techniques.

Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#) and the LVOC BREF [\[ 12, COM 2017 \]](#).

### 3.2.2 Waste gas collection and channelling

#### Description

Waste gases are collected and channelled for subsequent treatment.

#### Technical description

Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#) and the LVOC BREF [\[ 12, COM 2017 \]](#).

#### Achieved environmental benefits

- Possible material or energy recovery.
- Reduction of emissions to air.

#### Environmental performance and operational data

Accurate information on the effectiveness of this technique is difficult to obtain because it depends on site-specific factors such as the layout of the plant or the diffuse nature of the sources of these emissions. The level of reduction achieved depends on the subsequent treatment.

#### Cross-media effects

Energy is consumed to collect waste gases (e.g. to operate fans).

#### Technical considerations relevant to applicability

The applicability may be restricted by concerns on operability (access to equipment) and/or safety (avoiding concentrations close to the lower explosive limit).

#### Economics

The costs are site-specific. Costs will be lower for new plants. Economic benefits could result from material or energy recovery.

#### Driving force for implementation

- Environmental legislation.
- Economic benefits due to material or energy recovery.

#### Example plants

Waste gas collection and channelling is used throughout the whole chemical sector.

#### Reference literature

[\[ 13, COM 2016 \]](#), [\[ 12, COM 2017 \]](#).

## 3.3 Channelled emissions to air

### 3.3.1 Monitoring

#### 3.3.1.1 Monitoring of key process parameters of waste gas streams

##### Description

Key process parameters of waste gas streams being sent to pretreatment and/or final treatment are monitored.

##### Technical description

The proper functioning of waste gas treatment systems can be ensured by monitoring operational parameters, e.g. temperature of the combustion chamber (in the case of thermal oxidation), pressure difference (in the case of fabric filters), cooling temperature (in the case of condensers), TVOC (in the case of adsorption units) and pH, redox, reagent flow and/or fresh water (in the case of scrubbers).

Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#), the LVOC BREF [\[ 12, COM 2017 \]](#) and the ROM [\[ 16, COM 2018 \]](#).

##### Achieved environmental benefits

Monitoring as such has no direct environmental benefit. It is, however, the prerequisite for corrective action.

##### Environmental performance and operational data

The flow and the temperature of waste gases that are sent to pretreatment and final treatment are usually measured continuously.

##### Cross-media effects

Some equipment, ancillary materials and energy are required for the monitoring.

##### Technical considerations relevant to applicability

Generally, there are no technical restrictions to the applicability of this technique.

##### Economics

The costs are site-specific. They depend on the parameters that are monitored, the number of monitoring points and the monitoring frequencies.

##### Driving force for implementation

- Environmental legislation.
- Improved process control.

##### Example plants

The technique is used throughout the whole chemical sector.

##### Reference literature

[\[ 13, COM 2016 \]](#), [\[ 12, COM 2017 \]](#), [\[ 16, COM 2018 \]](#).

#### 3.3.1.2 Monitoring of emissions to air

##### Description

Channelled emissions to air of relevant substances/parameters are monitored using periodic or continuous measurement methods that are based on EN standards.

##### Technical description



The type of monitoring that is used (e.g. continuous or periodic measurements; the frequency of periodic measurements) depends on a number of factors, e.g. the nature of the pollutant, the environmental significance of the emission, or the variability of the emission. In some EU Member States, a threshold approach is followed based on the mass emission rate, with continuous monitoring required above the mass emissions threshold or reducing monitoring frequencies for periodic measurements below a certain mass emissions threshold.

For some substances/parameters, EN standards are not available. In this case, ISO, national or other international standards are used. For example, for organic substances (e.g. benzene) the monitoring is often carried out using the technical specification CEN/TS 13649:2014.

In a number of EU Member States, the measurements are carried out at the highest expected emission state under normal operating conditions.

Further information is provided in the ROM [\[ 16, COM 2018 \]](#).

#### **Achieved environmental benefits**

Monitoring as such has no direct environmental benefit. It is, however, the prerequisite for corrective action.

#### **Environmental performance and operational data**

Information on monitoring was collected through the plant-specific questionnaires and is summarised in Chapter 2 in the sections on contextual information.

#### **Cross-media effects**

Some equipment, ancillary materials and energy are required for the monitoring.

#### **Technical considerations relevant to applicability**

Generally, there are no technical restrictions to the applicability of this technique.

#### **Economics**

The costs are site-specific. They depend on the parameters that are monitored, the number of emission points and the monitoring frequencies. Information on costs can be found in the ROM [\[ 16, COM 2018 \]](#).

#### **Driving force for implementation**

Environmental legislation.

#### **Example plants**

The technique is used throughout the whole chemical sector.

#### **Reference literature**

[\[ 16, COM 2018 \]](#), [\[ 43, TWG 2021 \]](#).

### **3.3.2 Techniques to reduce channelled emissions to air**

#### **3.3.2.1 Absorption**

##### **Description**

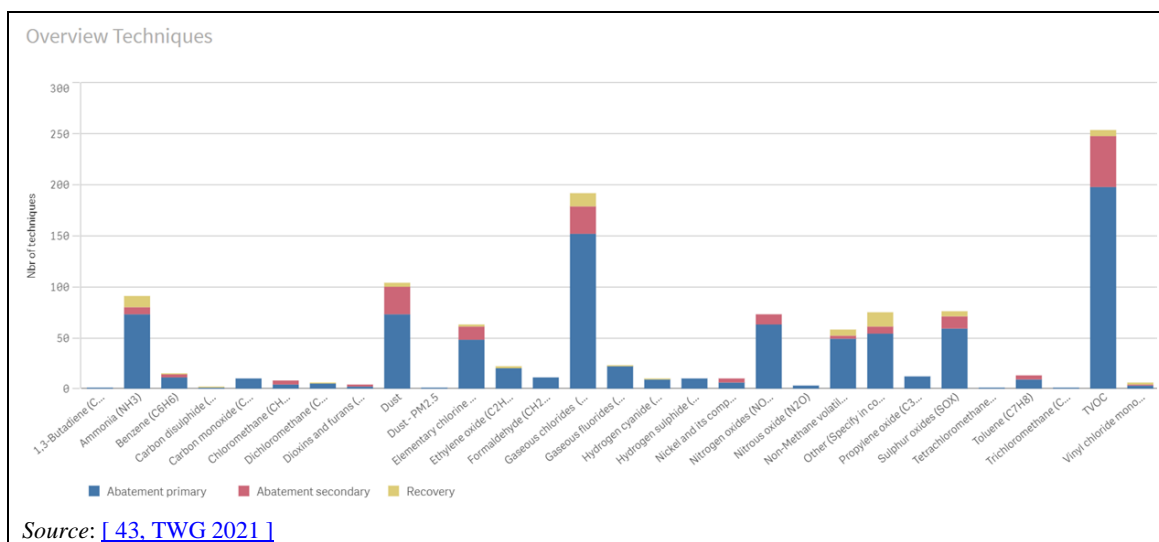
The removal of gaseous or particulate pollutants from a process off-gas or waste gas stream via mass transfer to a suitable liquid, often water or an aqueous solution. It may involve a chemical reaction (e.g. in an acid or alkaline scrubber). In some cases, the compounds may be recovered from the liquid.

##### **Technical description**

Wet scrubbers are typically used to remove water-soluble organic and inorganic compounds as well as dust. Alkaline scrubbers are typically used to remove acid gases, such as hydrogen

chloride, hydrogen fluoride and hydrogen sulphide, while acid scrubbers are typically used to remove ammonia.

Absorption is mostly used as an abatement technique, although it is sometimes also used to recover gaseous organic (e.g. benzene, vinyl chloride monomer) or inorganic compounds (e.g. ammonia, gaseous chlorides) as well as dust (see Figure 3.2). In most cases, packed-bed scrubbers and spray towers are used.



Source: [43, TWG 2021]

Figure 3.2: Use of absorption for abatement or recovery

Further information is provided in the CWW BREF [13, COM 2016] and the LVOC BREF [12, COM 2017].

**Achieved environmental benefits**

- Reduced pollutant load sent to final waste gas treatment.
- Reduced emissions to air.
- Possible material recovery.

**Environmental performance and operational data**

Absorption is used alone or in combination with other waste gas treatment techniques. Reported waste gas flows for absorption are shown in Table 3.2.

Table 3.2: Reported waste gas flows for absorption

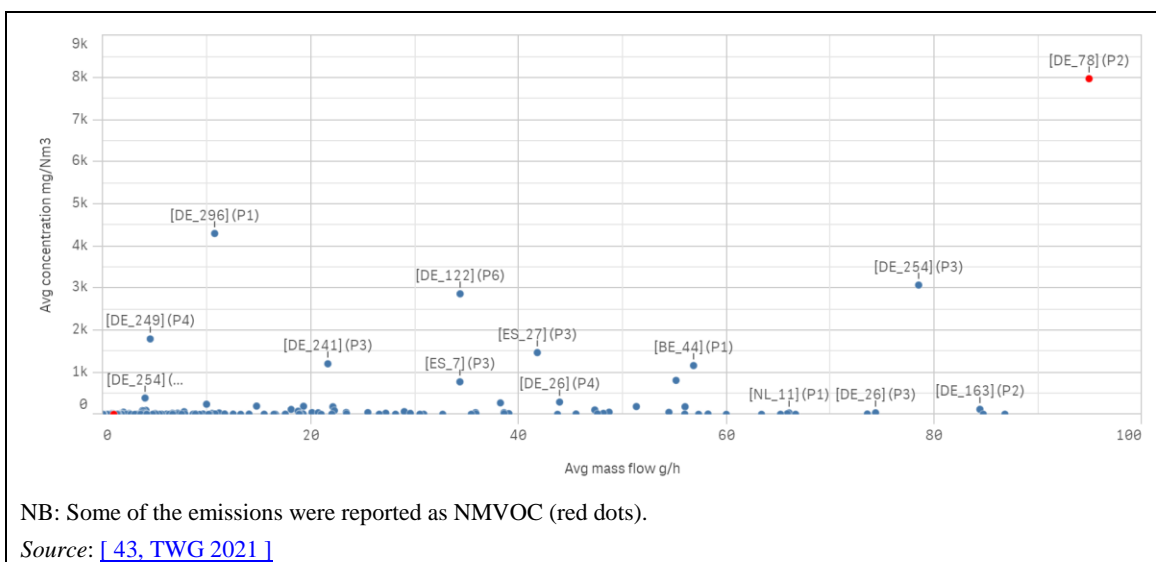
Type	Waste gas flows (Nm <sup>3</sup> /h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	1	30	2 000	30 000	360 000	793

Source: [43, TWG 2021]

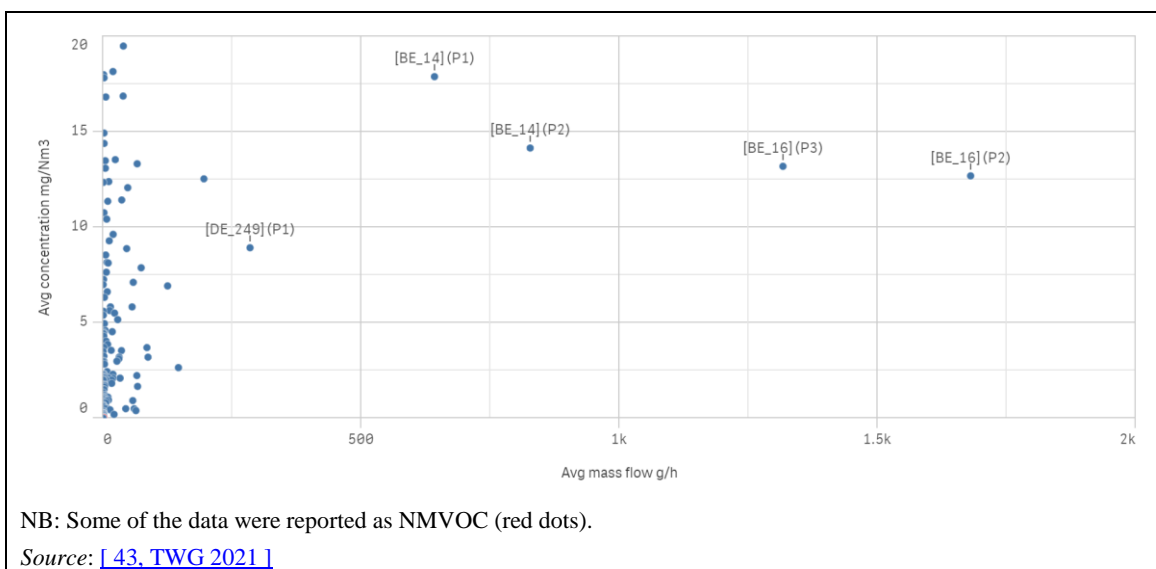
### Organic compounds

In the case of organic compounds, absorption may be combined with a pretreatment by condensation and a post-treatment by thermal oxidation. Removal efficiencies for organic compounds typically range from 80 % to more than 99 % [43, TWG 2021].

Figure 3.3 and Figure 3.4 show TVOC concentration versus mass flow when absorption is used as the final waste gas treatment technique and thermal oxidation is not used. Figure 3.3 shows data from emission points with a mass flow of less than 100 g/h and Figure 3.4 shows data from emission points with a concentration of less than 20 mg/Nm<sup>3</sup>.



**Figure 3.3:** TVOC concentration versus mass flow, for mass flows < 100 g/h when absorption is used as the final waste gas treatment

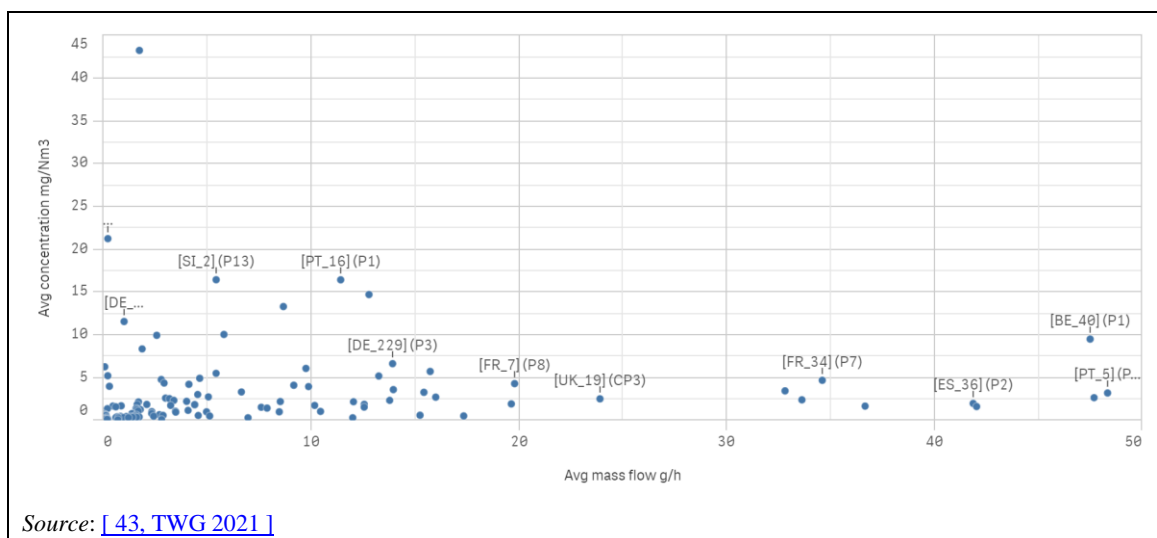


**Figure 3.4:** TVOC concentration versus mass flow, for concentrations < 20 mg/Nm<sup>3</sup> when absorption is used as the final waste gas treatment

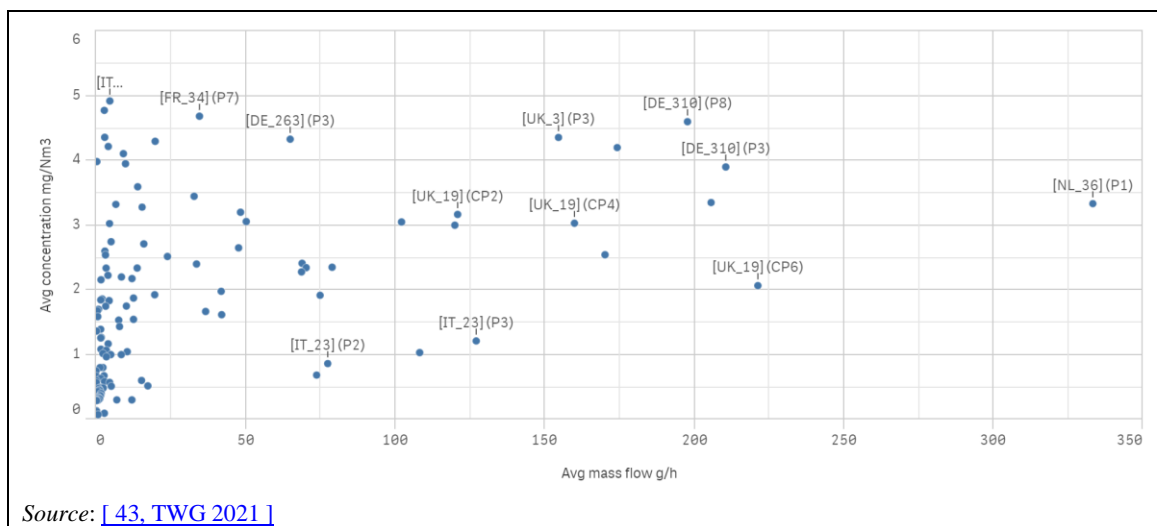
*Dust*

In the case of dust, absorption (also referred to as dust scrubbing) may be combined with a post-treatment by filtration (i.e. absolute filters or fabric filters) or electrostatic precipitation. Removal efficiencies for dust typically range from 90 % to more than 99 % [43, EIPPCB 2019].

Figure 3.5 and Figure 3.6 show dust concentration versus mass flow when absorption is used as the final waste gas treatment technique. Figure 3.5 shows data from emission points with a mass flow of less than 50 g/h and Figure 3.6 shows data from emission points with a concentration of less than 5 mg/Nm<sup>3</sup>.



**Figure 3.5:** Dust concentration versus mass flow, for mass flows < 50 g/h when absorption is used as the final waste gas treatment

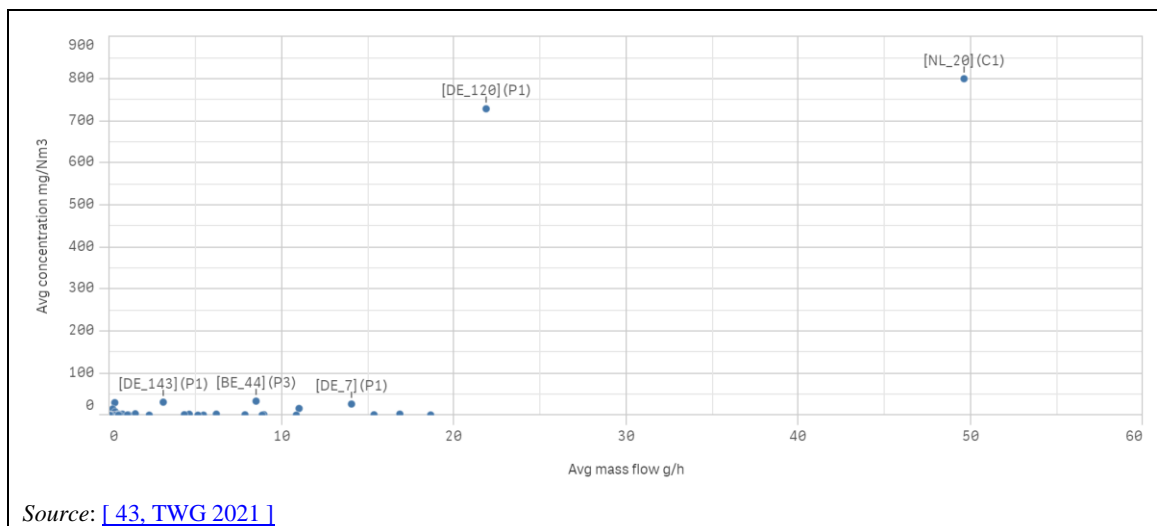


**Figure 3.6:** Dust concentration versus mass flow, for concentrations < 5 mg/Nm<sup>3</sup> when absorption is used as the final waste gas treatment

### Ammonia

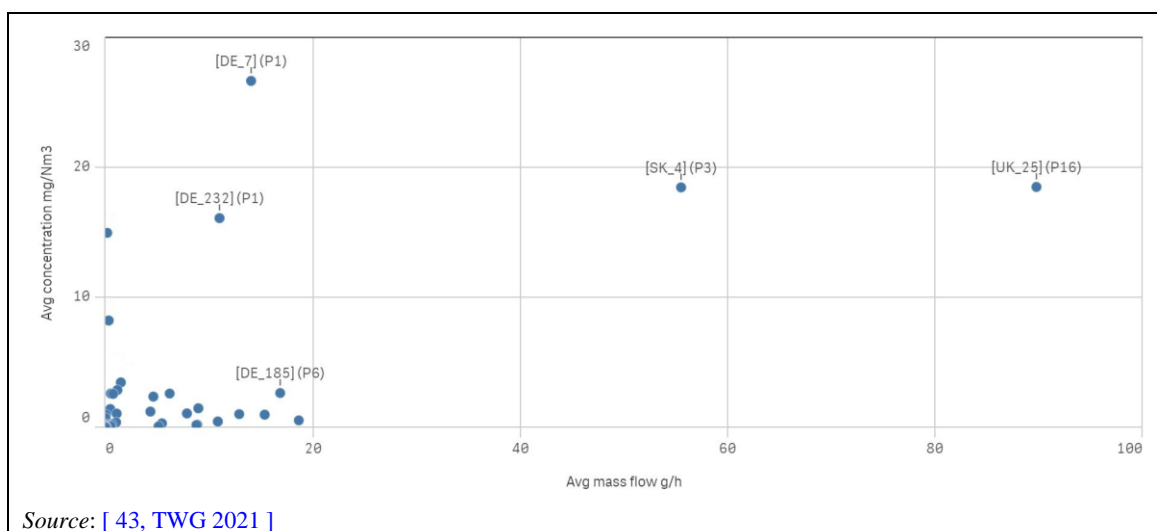
Absorption is often reported as the main technique to remove ammonia. Removal efficiencies for ammonia typically range from 95 % to more than 99 % [43, TWG 2021].

Figure 3.7 and Figure 3.8 show ammonia concentration versus mass flow when absorption is used as the final waste gas treatment technique and reduction is not used. Figure 3.7 shows data from emission points with a mass flow of less than 50 g/h and Figure 3.8 shows data from emission points with a concentration of less than 10 mg/Nm<sup>3</sup>.



Source: [43, TWG 2021]

**Figure 3.7:** Ammonia concentration versus mass flow, for mass flows < 50 g/h when absorption is used as the final waste gas treatment



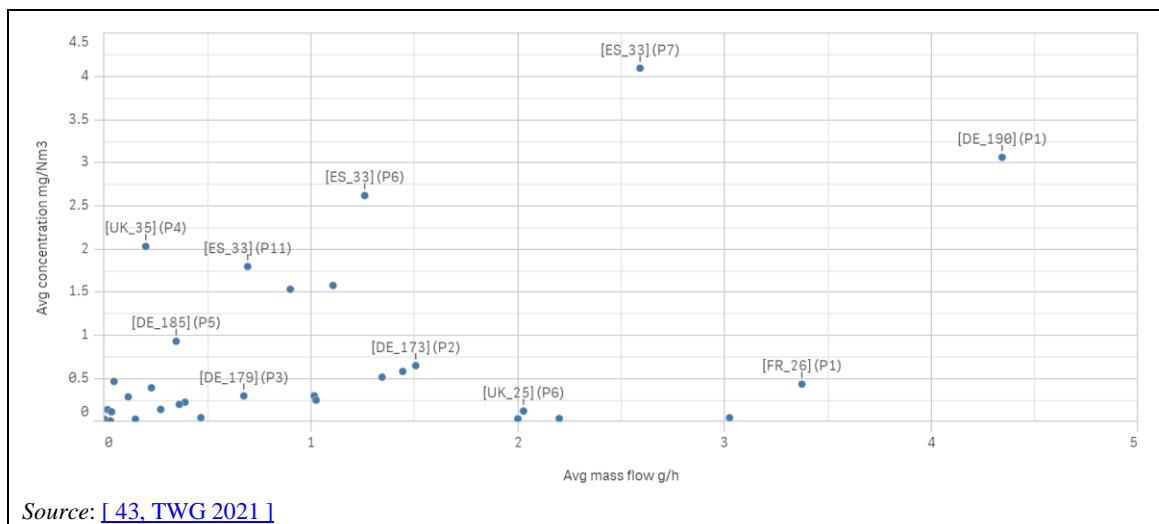
Source: [43, TWG 2021]

**Figure 3.8:** Ammonia concentration versus mass flow, for concentrations < 30 mg/Nm<sup>3</sup> when absorption is used as the final waste gas treatment

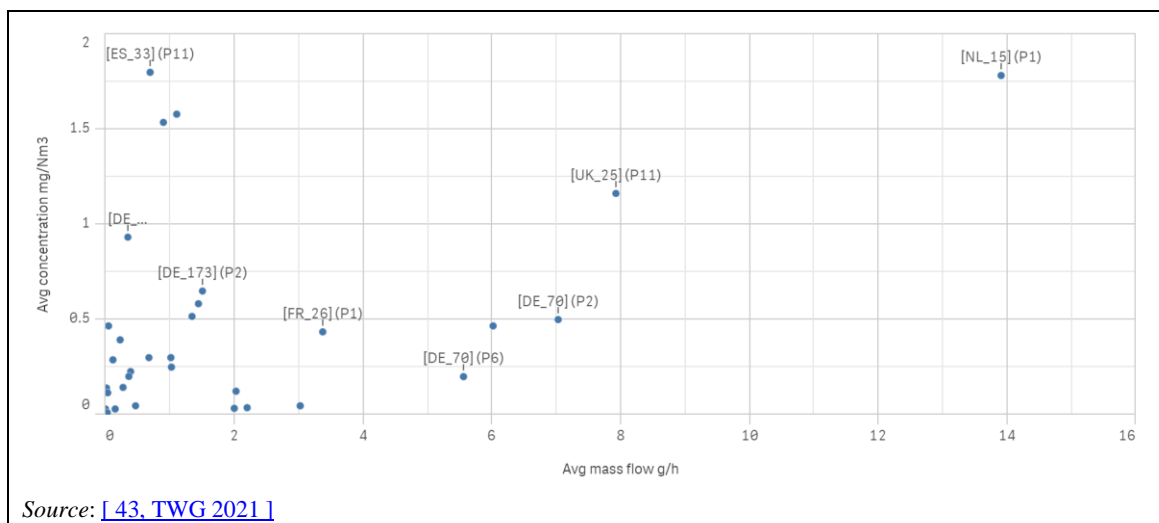
*Elemental chlorine*

Absorption is often reported as the main technique to remove elemental chlorine. Removal efficiencies for elemental chlorine typically range from 95 % to more than 99 % [43, TWG 2021].

Figure 3.9 and Figure 3.10 show elemental chlorine concentration versus mass flow when absorption is used as the final waste gas treatment technique. Figure 3.9 shows data from emission points with a mass flow of less than 5 g/h and Figure 3.10 shows data from emission points with a concentration of less than 2 mg/Nm<sup>3</sup>.



**Figure 3.9: Elemental chlorine concentration versus mass flow, for mass flows < 5 g/h when absorption is used as the final waste gas treatment**

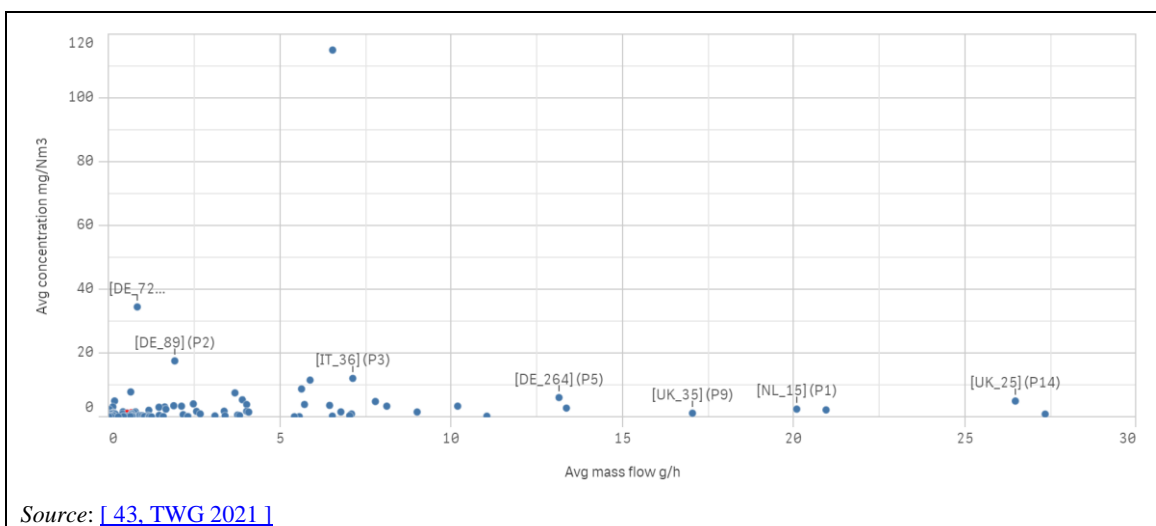


**Figure 3.10: Elemental chlorine concentration versus mass flow, for concentrations < 2 mg/Nm<sup>3</sup> when absorption is used as the final waste gas treatment**

*Gaseous chlorides*

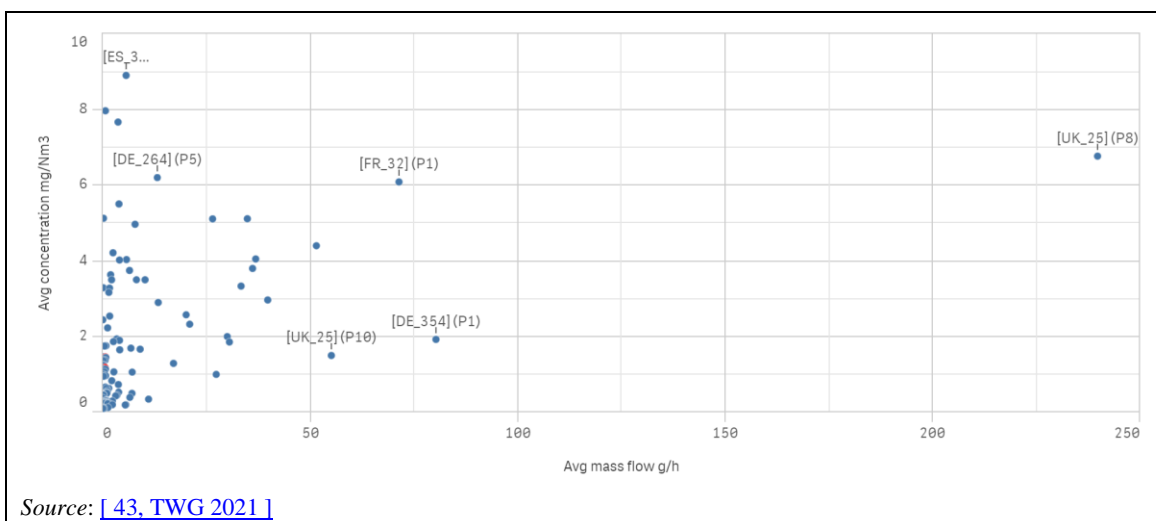
Absorption is often reported as the main technique to remove gaseous chlorides. Removal efficiencies for gaseous chlorides typically range from 80 % to more than 99 % [43, TWG 2021].

Figure 3.11 and Figure 3.12 show gaseous chloride concentration versus mass flow when absorption is used as the final waste gas treatment technique. Figure 3.11 shows data from emission points with a mass flow of less than 30 g/h and Figure 3.12 shows data from emission points with a concentration of less than 10 mg/Nm<sup>3</sup>.



Source: [43, TWG 2021]

**Figure 3.11: Gaseous chloride concentration versus mass flow, for mass flows < 30 g/h when absorption is used as the final waste gas treatment**



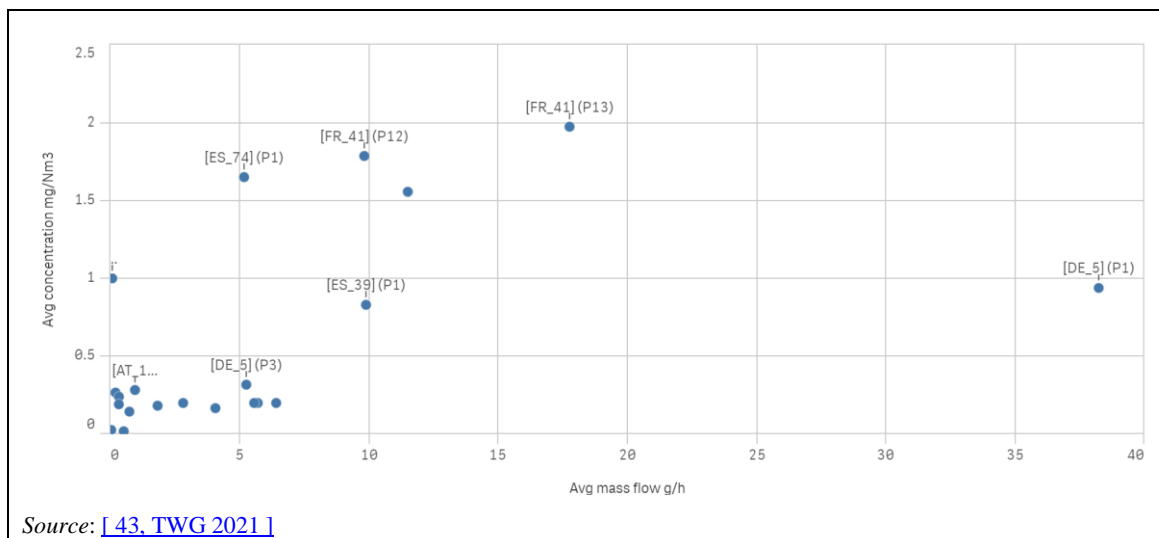
Source: [43, TWG 2021]

**Figure 3.12: Gaseous chloride concentration versus mass flow, for concentrations < 10 mg/Nm<sup>3</sup> when absorption is used as the final waste gas treatment**

*Gaseous fluorides*

Absorption is often reported as the main technique to remove gaseous fluorides. Removal efficiencies for gaseous fluorides are typically above 99 % [43, TWG 2021].

Figure 3.13 shows gaseous fluoride concentration versus mass flow when absorption is used as the final waste gas treatment technique. Only data from emission points with a concentration of less than 1 mg/Nm<sup>3</sup> are shown.

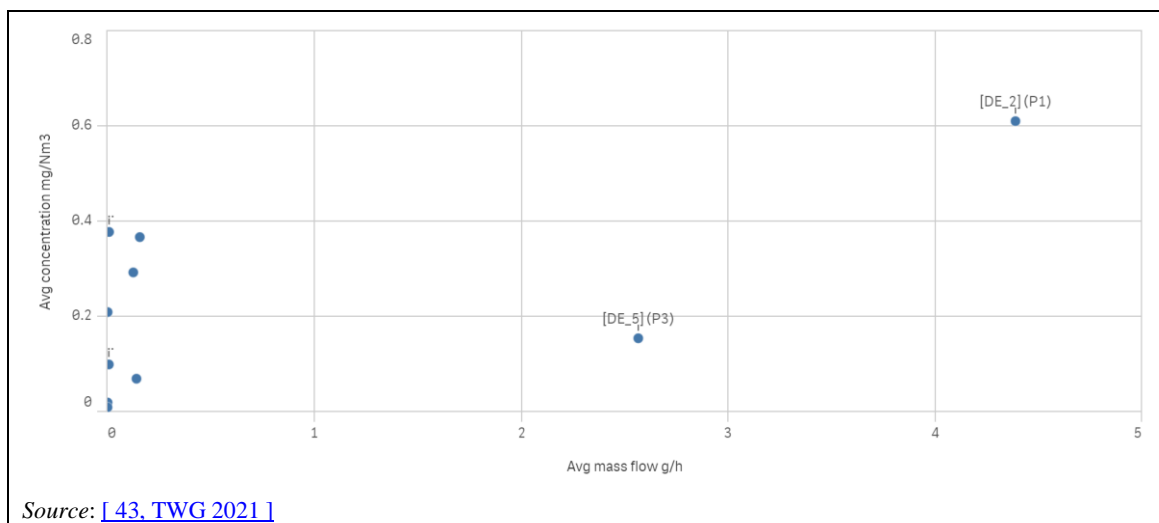


**Figure 3.13: Gaseous fluoride concentration versus mass flow, for concentrations < 2 mg/Nm<sup>3</sup> when absorption is used as the final waste gas treatment**

*Hydrogen cyanide*

Absorption is often reported as the main technique to remove hydrogen cyanide. Removal efficiencies for hydrogen cyanide typically range from 90 % to more than 95 % [43, TWG 2021].

Figure 3.14 shows hydrogen cyanide concentration versus mass flow when absorption is used as the final waste gas treatment technique. Only data from emission points with a concentration of less than 1 mg/Nm<sup>3</sup> are shown.



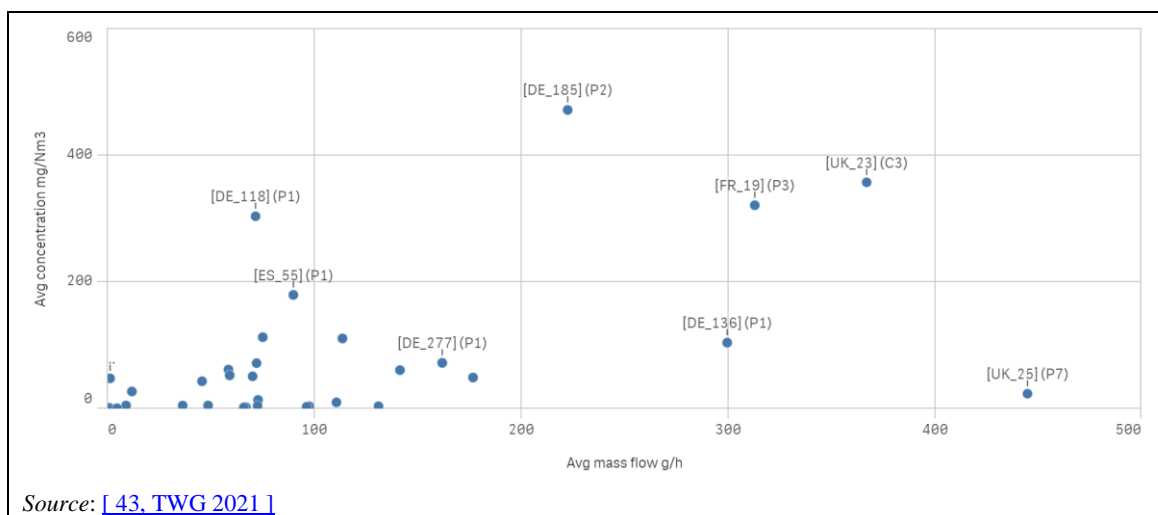
**Figure 3.14: Hydrogen cyanide concentration versus mass flow, for concentrations < 1 mg/Nm<sup>3</sup> when absorption is used as the final waste gas treatment**



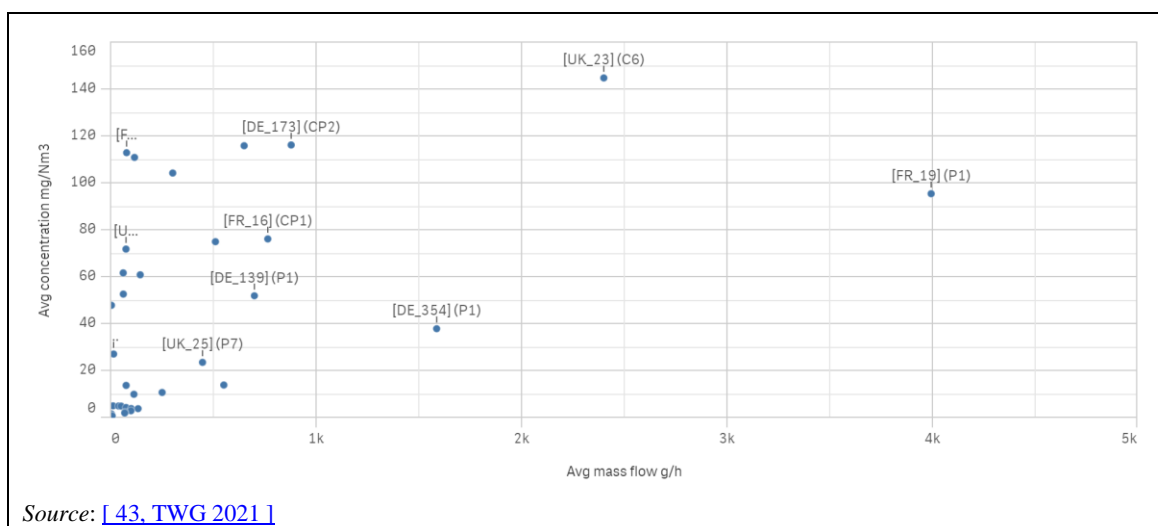
### Nitrogen oxides

Absorption is often reported as the main technique to remove nitrogen oxides. Removal efficiencies for nitrogen oxides typically range from 80 % to more than 99 % [43, TWG 2021].

Figure 3.15 and Figure 3.16 show nitrogen oxides concentration versus mass flow when absorption is used as the final waste gas treatment technique and thermal oxidation is not used. Figure 3.15 shows data from emission points with a mass flow of less than 500 g/h and Figure 3.16 shows data from emission points with a concentration of less than 150 mg/Nm<sup>3</sup>.



**Figure 3.15: Nitrogen oxides concentration versus mass flow, for mass flows < 500 g/h when absorption is used as the final waste gas treatment**

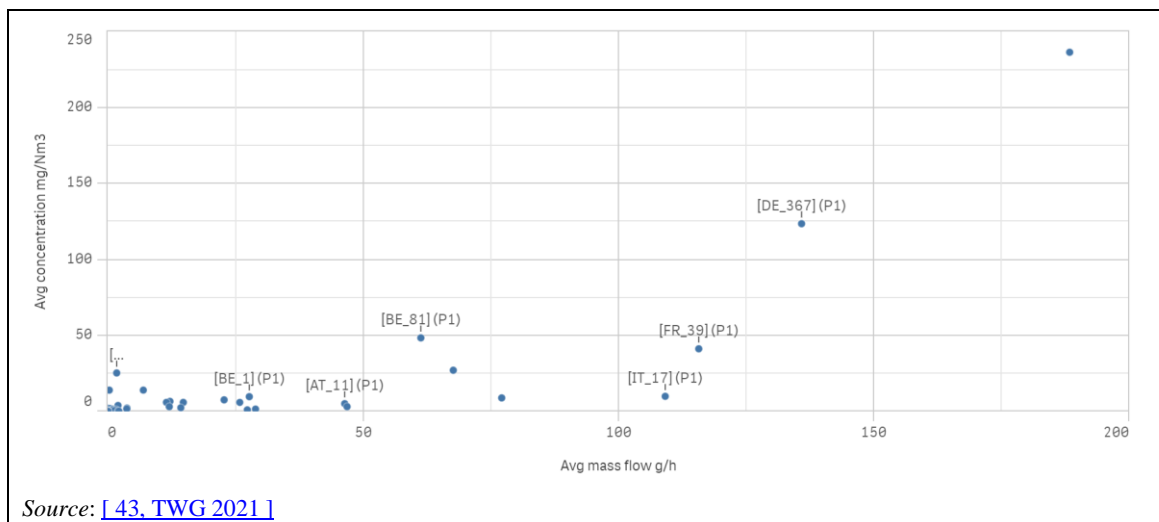


**Figure 3.16: Nitrogen oxides concentration versus mass flow, for concentrations < 150 mg/Nm<sup>3</sup> when absorption is used as the final waste gas treatment**

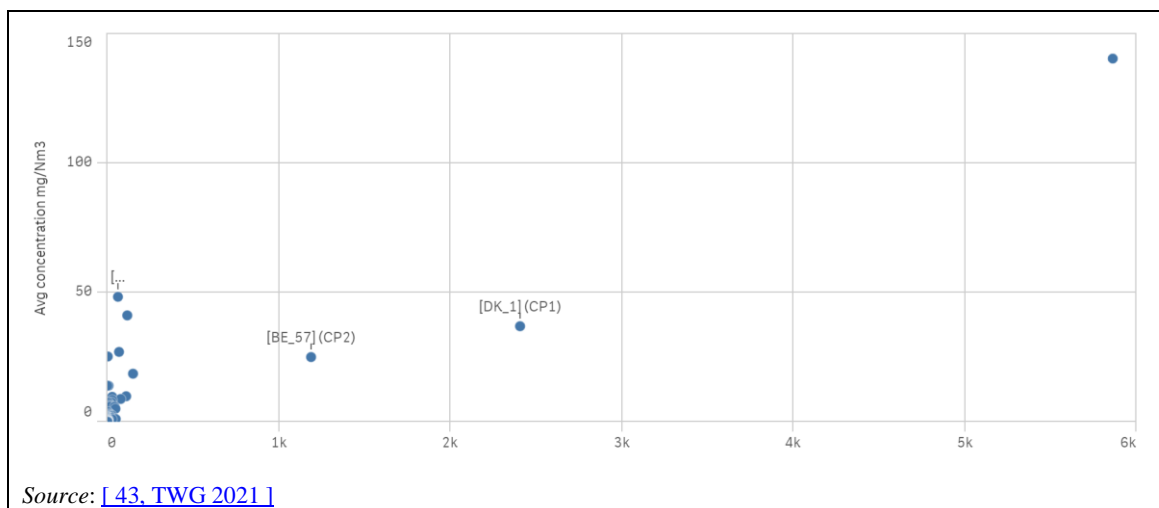
*Sulphur oxides*

Absorption is often reported as the main technique to remove sulphur oxides. Removal efficiencies for sulphur oxides typically range from 98 % to more than 99 % [43, TWG 2021].

Figure 3.17 and Figure 3.18 show sulphur oxides concentration versus mass flow when absorption is used as the final waste gas treatment technique. Figure 3.17 shows data from emission points with a mass flow of less than 200 g/h and Figure 3.18 shows data from emission points with a concentration of less than 150 mg/Nm<sup>3</sup>.



**Figure 3.17: Sulphur oxides concentration versus mass flow, for mass flows < 200 g/h when absorption is used as the final waste gas treatment**



**Figure 3.18: Sulphur oxides concentration versus mass flow, for concentrations < 150 mg/Nm<sup>3</sup> when absorption is used as the final waste gas treatment**

Further information is provided in the CWW BREF [13, COM 2016].

**Cross-media effects**

Absorption generates a spent scrubbing liquid that usually requires further treatment or disposal. Further information is provided in the CWW BREF [13, COM 2016].

**Technical considerations relevant to applicability**

Generally, there are no technical restrictions to the applicability of this technique. The use of absorption is subject to the availability of a suitable scrubbing liquid. Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

**Economics**

Absorption is relatively inexpensive in comparison with some other techniques, e.g. thermal oxidation. There is also the potential benefit of material recovery which depends on the concentration of the compound concerned in the waste gas. Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

**Driving force for implementation**

- Environmental legislation.
- Economic benefits due to material recovery.

**Example plants**

The technique is widely used in the chemical sector, for example in the production of organic and inorganic substances, pharmaceuticals, plant protection products, biocides and explosives.

**Reference literature**

[\[ 13, COM 2016 \]](#), [\[ 12, COM 2017 \]](#), [\[ 43, TWG 2021 \]](#).

**3.3.2.2 Adsorption****Description**

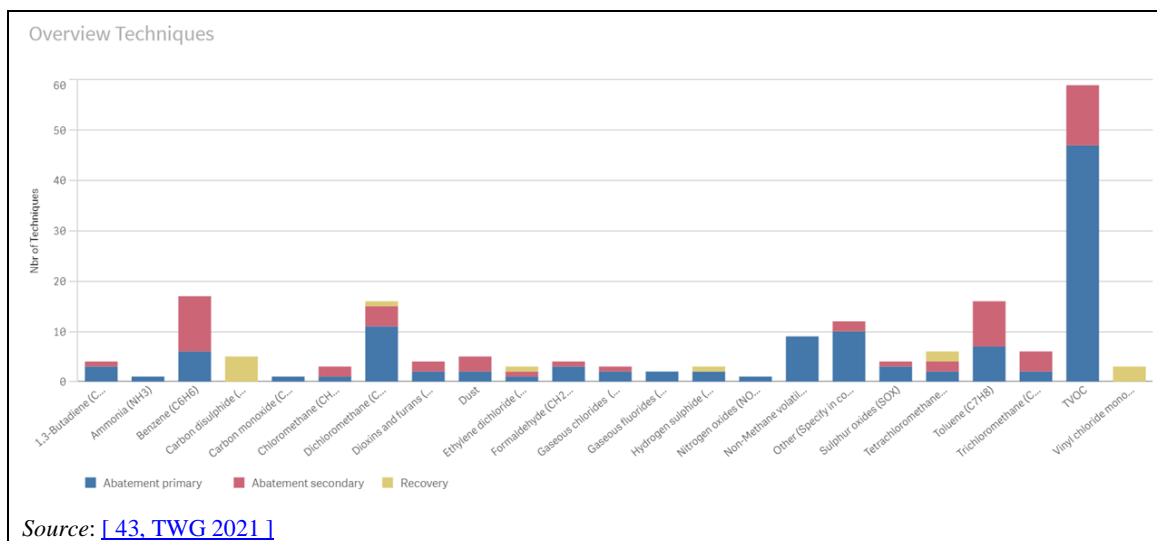
The removal of pollutants from a process off-gas or waste gas stream by retention on a solid surface (activated carbon is typically used as the adsorbent). Adsorption may be regenerative or non-regenerative.

In non-regenerative adsorption, the spent adsorbent is not regenerated but disposed of. In regenerative adsorption, the adsorbate is subsequently desorbed, e.g. with steam (often on site), for reuse or disposal and the adsorbent is reused. For continuous operation, typically more than two adsorbers are operated in parallel, one of them in desorption mode.

**Technical description**

Adsorption is typically used to remove organic and inorganic compounds.

Adsorption is mostly used as an abatement technique, although it is sometimes also used to recover organic compounds (e.g. vinyl chloride monomer) and inorganic compounds (e.g. carbon disulphide) (see Figure 3.19). Fixed-bed adsorbers and activated carbon as the adsorbent are typically used to remove organic and inorganic compounds.



**Figure 3.19: Use of adsorption for abatement or recovery**

Further information is provided in the CWW BREF [13, COM 2016] and the LVOC BREF [12, COM 2017].

#### Achieved environmental benefits

- Reduced pollutant load sent to final waste gas treatment.
- Reduced emissions to air.
- Possible material recovery.

#### Environmental performance and operational data

Adsorption is used alone or in combination with other waste gas treatment techniques (e.g. combined with pretreatment by condensation and post-treatment by thermal oxidation).

Reported waste gas flows for adsorption are shown in Table 3.3.

**Table 3.3: Reported waste gas flows for adsorption**

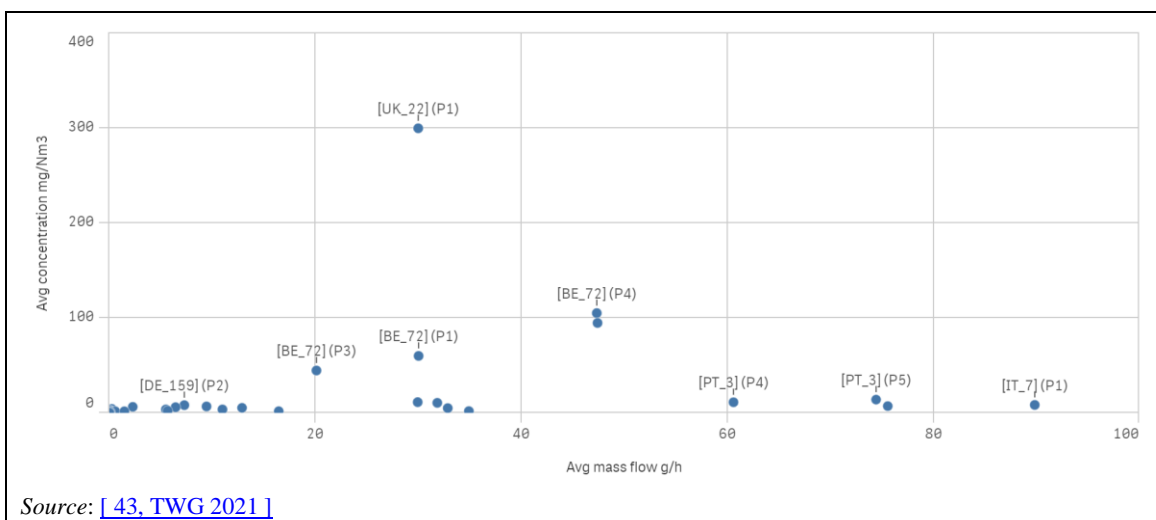
Type	Waste gas flows (Nm <sup>3</sup> /h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	1	20	1 000	35 000	215 000	113

Source: [43, TWG 2021]

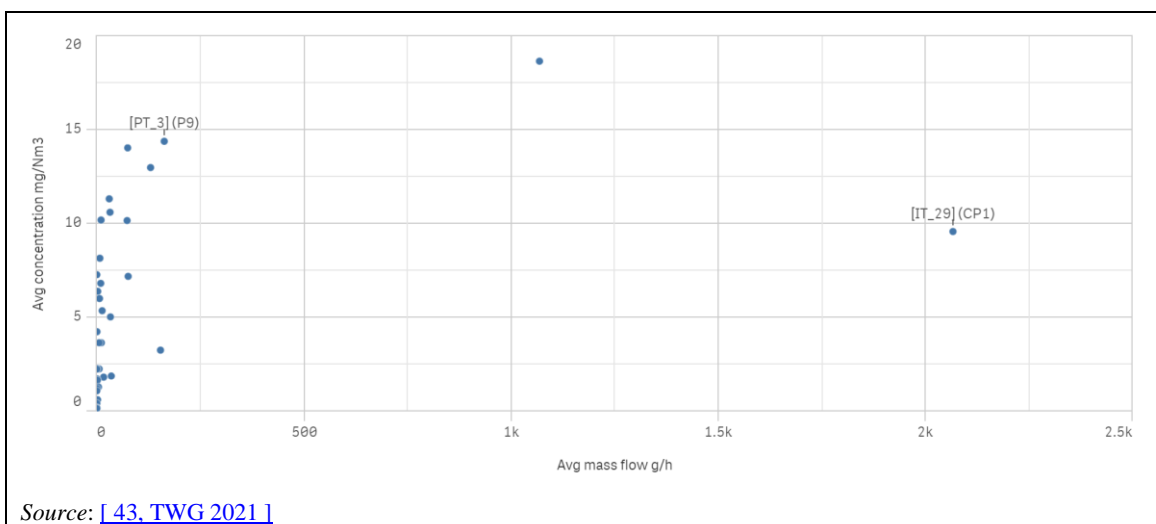
### Organic compounds

In the case of organic compounds, adsorption may be combined with a pretreatment by condensation and/or absorption and a post-treatment by thermal oxidation. Removal efficiencies for organic compounds typically range from 90 % to more than 99 % [43, TWG 2021].

Figure 3.20 and Figure 3.21 show TVOC concentration versus mass flow when adsorption is used as the final waste gas treatment technique and thermal oxidation is not used. Figure 3.20 shows data from emission points with a mass flow of less than 100 g/h and Figure 3.21 shows data from emission points with a concentration of less than 20 mg/Nm<sup>3</sup>.



**Figure 3.20: TVOC concentration versus mass flow, for mass flows < 100 g/h when adsorption is used as the final waste gas treatment**

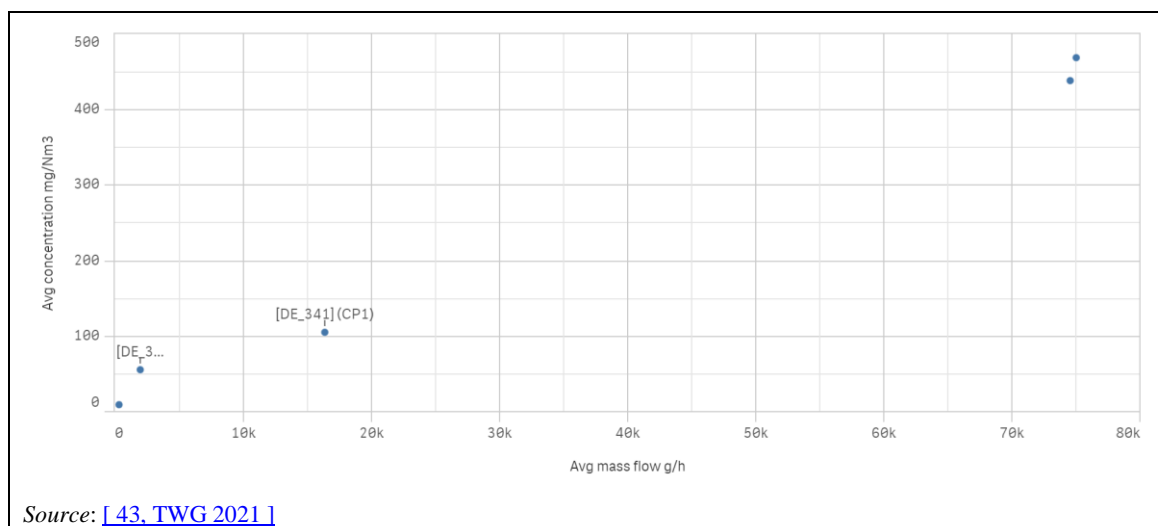


**Figure 3.21: TVOC concentration versus mass flow, for concentrations < 20 mg/Nm<sup>3</sup> when adsorption is used as the final waste gas treatment**

### *Carbon disulphide*

In the case of viscose production, adsorption is reported as a recovery and final abatement technique. Removal efficiencies for carbon disulphide typically range from 95 % to 98 % [43, TWG 2021].

Figure 3.22 shows carbon disulphide concentration versus mass flow when adsorption is used as the final waste gas treatment technique.



**Figure 3.22: Carbon disulphide concentration versus mass flow when adsorption is used as the final waste gas treatment**

Further information is provided in the CWW BREF [13, COM 2016].

- Cross-media effects
- For non-regenerative adsorption: disposal of spent adsorbent.
- For regenerative adsorption: energy consumption, usually in the form of steam. Disposal of the recovered substance, if it is not used.

Further information is provided in the CWW BREF [13, COM 2016].

### **Technical considerations relevant to applicability**

Generally, there are no technical restrictions to the applicability of this technique. The use of adsorption is subject to the availability of a suitable adsorbent. Further information is provided in the CWW BREF [13, COM 2016].

### **Economics**

Adsorption is relatively inexpensive in comparison with some other techniques, e.g. thermal oxidation. There is also the potential benefit of material recovery which depends on the concentration of the compound concerned in the waste gas. Further information is provided in the CWW BREF [13, COM 2016].

### **Driving force for implementation**

- Environmental legislation.
- Economic benefits due to material recovery.

### **Example plants**

The technique is widely used in the chemical sector, for example in the production of organic and inorganic substances, pharmaceuticals, plant protection products, biocides and explosives.

**Reference literature**

[ [13, COM 2016](#) ], [ [12, COM 2017](#) ], [ [43, TWG 2021](#) ].

**3.3.2.3 Biofilter**

Technical information is provided in the CWW BREF [ [13, COM 2016](#) ]. The use of bioprocesses for the abatement of volatile organic substances was reported by 10 reference plants. The data collection includes 14 EPs related to biofilters, 9 of which refer to biofiltration, 3 to biotrickling and 2 to bioscrubbing.

**Example plants**

Plants BE\_4, CZ\_11, DE\_51, DE\_215, DE\_278, DE\_380, FR\_16, FR\_18, FR\_45 reported several chemical activities to treat volatile organic compounds.

Plants FI\_4, FR\_48, DE\_383 producing food casings (viscose using CS<sub>2</sub>) reported treating CS<sub>2</sub> and H<sub>2</sub>S.

Plant BE\_4 producing synthetic rubbers reported a combination of biotrickling and biofiltration for waste gases with low calorific value to treat chloromethane.

**3.3.2.4 Choice of fuel****Description**

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).

**Technical description**

This technique involves the use of fuel gas instead of liquid fuels. Fuel gas usually has a low content of nitrogen and sulphur compounds, and complete combustion is achieved more easily than with liquid fuels.

Fuel gases can be natural gas or by-products from the chemical processes.

Further information is provided in the LVOC BREF [ [12, COM 2017](#) ].

**Achieved environmental benefits**

- Low emissions of SO<sub>2</sub> and dust.
- Change from liquid to gaseous fuels may also lead to lower NO<sub>x</sub> emissions.
- Potential to improve combustion, with reduction of emissions of VOCs and CO.
- Reduction of consumption of energy by use of by-products as fuels.

**Environmental performance and operational data**

SO<sub>2</sub> emissions are generally totally dependent upon the quantity of sulphur present in the fuel.

**Cross-media effects**

The combustion of hydrogen-rich gas from chemical processes has the potential to result in higher NO<sub>x</sub> emissions.

**Technical considerations relevant to applicability**

The switch from liquid to gaseous fuels may be restricted by the design of the burners in the case of existing plants.

**Economics**

Increased resource and energy efficiency from the use of process gas from chemical processes.

### Driving force for implementation

Increased resource and energy efficiency from the use of process gas from chemical processes.

### Example plants

Many plants use natural gas as fuel gas. Some plants also reported the use of process gases or by-products from chemical processes, for example containing methane and hydrogen, e.g. DE\_124, ES\_11, ES\_59, FI\_3, IT\_18, IT\_19, IT\_24, IT\_34 and PL\_12.

### Reference literature

[12, COM 2017].

## 3.3.2.5 Condensation

### Description

The removal of vapours of organic and inorganic compounds from a process off-gas or waste gas stream by reducing its temperature below its dew point so that the vapours liquefy. Depending on the operating temperature range required, different cooling media are used, e.g. water or brine.

In cryogenic condensation, liquid nitrogen is used as a cooling medium.

### Technical description

Condensation is typically used to remove organic compounds and may in some cases also remove inorganic compounds. Condensation is used both as a recovery and as an abatement technique for organic compounds (e.g. dichloromethane, TVOC, vinyl chloride monomer) (see Figure 3.23).

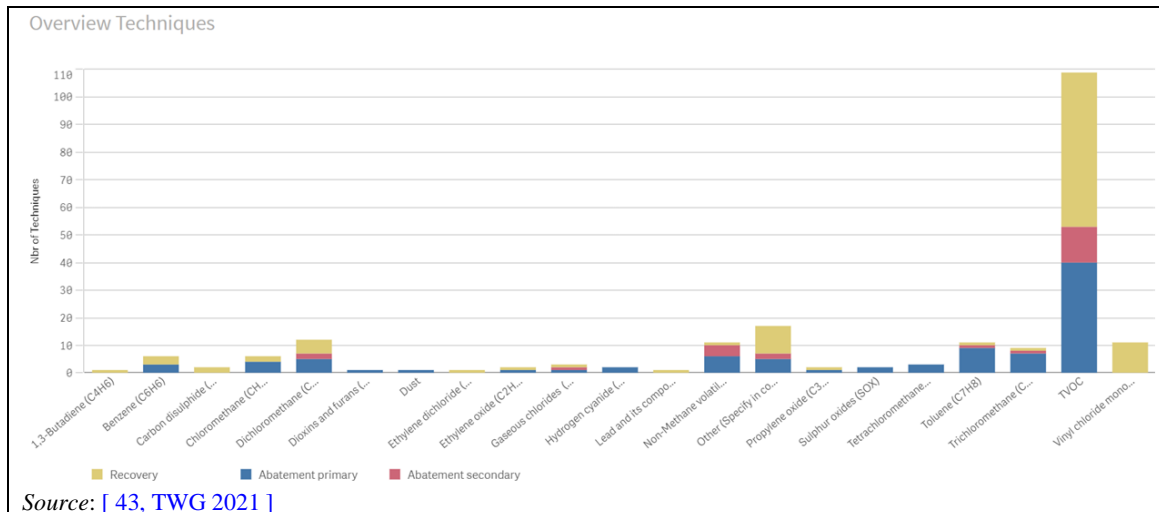


Figure 3.23: Use of condensation for abatement or recovery

Further information is provided in the CWW BREF [13, COM 2016] and the LVOC BREF [12, COM 2017].

### Achieved environmental benefits

- Possible material recovery.
- Reduced pollutant load sent to final waste gas treatment.
- Reduced emissions to air.



### Environmental performance and operational data

Condensation is often used in combination with other waste gas treatment techniques (e.g. combined with post-treatment by absorption, adsorption or thermal oxidation). Removal efficiencies for organic compounds typically range from 90 % to more than 99 % [43, TWG 2021].

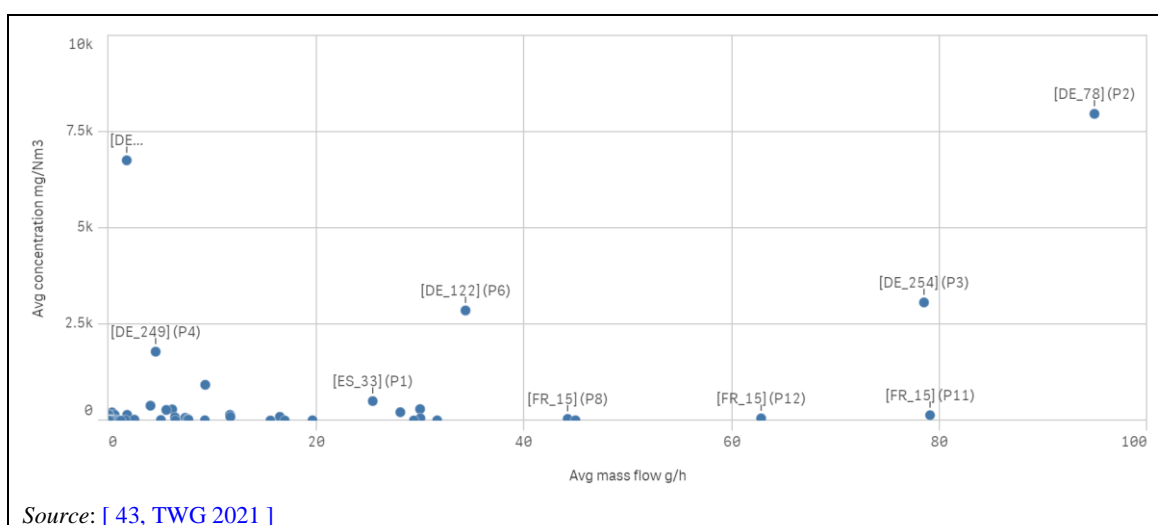
Reported waste gas flows for condensation are shown in Table 3.4.

**Table 3.4: Reported waste gas flows for condensation**

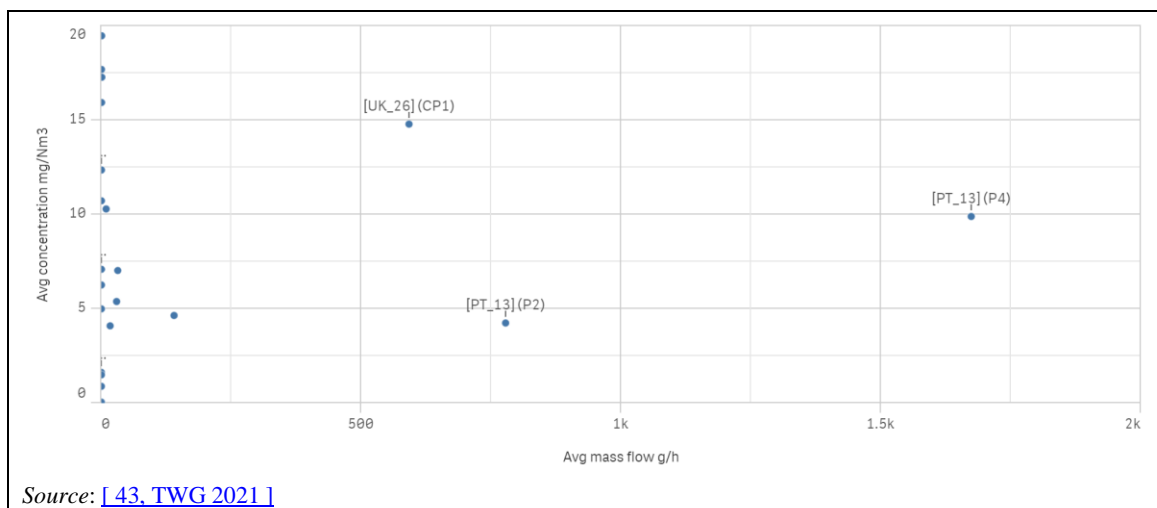
Type	Waste gas flows (Nm <sup>3</sup> /h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
Condenser	0.2	1	40	3 000	62 000	79
Cryogenic condenser	3.7	10	140	650	3 800	26

Source: [43, TWG 2021]

Figure 3.24 and Figure 3.25 show TVOC concentration versus mass flow when condensation is used as the only waste gas treatment technique. Figure 3.24 shows data from emission points with a mass flow of less than 100 g/h and Figure 3.25 shows data from emission points with a concentration of less than 20 mg/Nm<sup>3</sup>.



**Figure 3.24: TVOC concentration versus mass flow, for mass flows < 100 g/h when condensation is used as the only waste gas treatment technique**



**Figure 3.25: TVOC concentration versus mass flow, for concentrations < 20 mg/Nm<sup>3</sup> when condensation is used as the only waste gas treatment technique**

Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

### Cross-media effects

- Consumption of energy.
- Consumption and emissions of refrigerants (e.g. water).

Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

### Technical considerations relevant to applicability

Generally, there are no technical restrictions to the applicability of this technique.

Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

### Economics

Condensation is usually a low-cost technique. There is also the potential benefit of material recovery which depends on the concentration of the compound concerned in the waste gas. Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

### Driving force for implementation

- Environmental legislation.
- Economic benefits due to material recovery.

### Example plants

The technique is widely used in the chemical sector, for example in the production of organic and inorganic substances as well as of plant protection products and biocides.

### Reference literature

[\[ 13, COM 2016 \]](#), [\[ 12, COM 2017 \]](#), [\[ 43, TWG 2021 \]](#).

### 3.3.2.6 Cyclone

#### Description

Equipment for the removal of dust from a process off-gas or waste gas stream based on imparting centrifugal forces, usually within a conical chamber.

#### Technical description

Cyclones are used to remove dust, both as a recovery and as an abatement technique (see Figure 3.26).

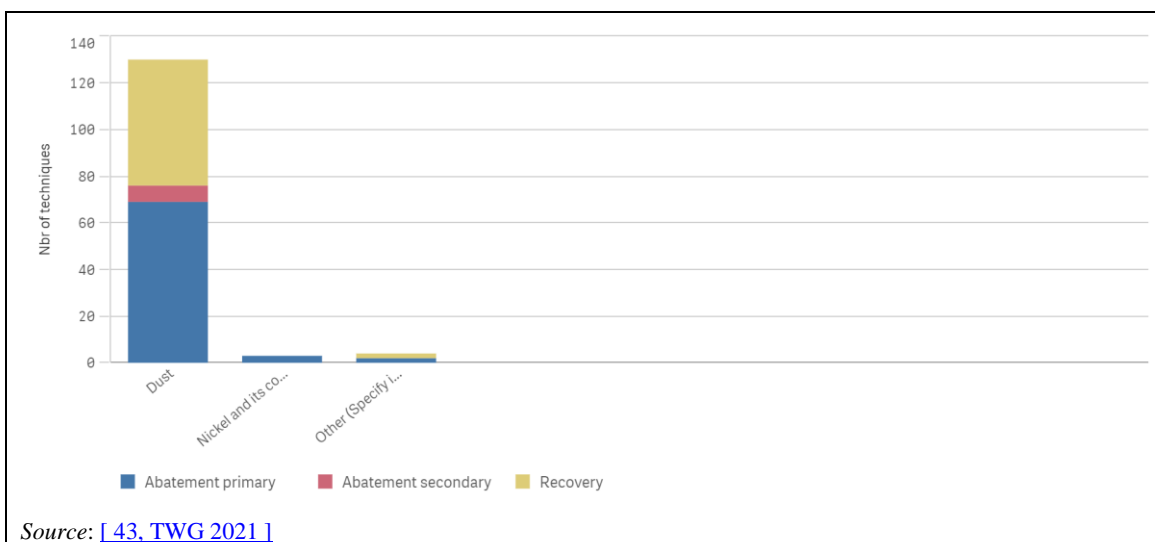


Figure 3.26: Use of cyclones for abatement or recovery

#### Achieved environmental benefits

- Possible material recovery.
- Reduced pollutant load sent to final waste gas treatment.
- Reduced emissions to air.

#### Environmental performance and operational data

Cyclones can be used alone, but are often used in combination with other waste gas treatment techniques (e.g. combined with post-treatment by absorption or filtration). Removal efficiencies for dust typically range from 90 % to more than 99 % [43, TWG 2021].

Reported waste gas flows for cyclones are shown in Table 3.5.

Table 3.5: Reported waste gas flows for cyclones

Type	Waste gas flows (Nm <sup>3</sup> /h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	5	1 000	9 000	95 000	240 000	126

Source: [43, TWG 2021]

Figure 3.27 and Figure 3.28 show dust concentration versus mass flow when cyclones are used as the final waste gas treatment technique. Figure 3.27 shows data from emission points with a mass flow of less than 50 g/h and Figure 3.28 shows data from emission points with a concentration of less than 5 mg/Nm<sup>3</sup>.

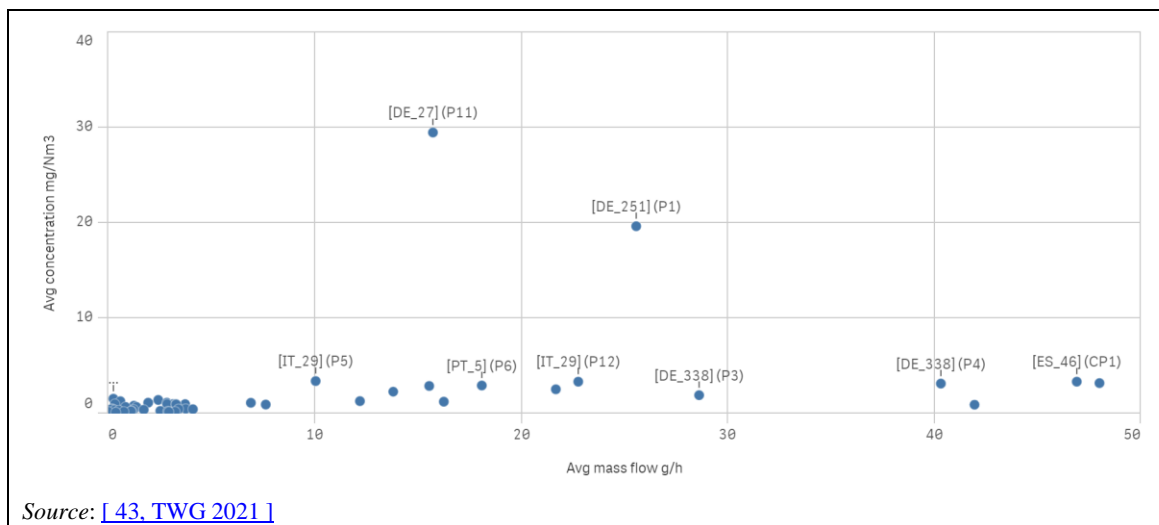


Figure 3.27: Dust concentration versus mass flow, for mass flows < 50 g/h when cyclones are used as the final waste gas treatment

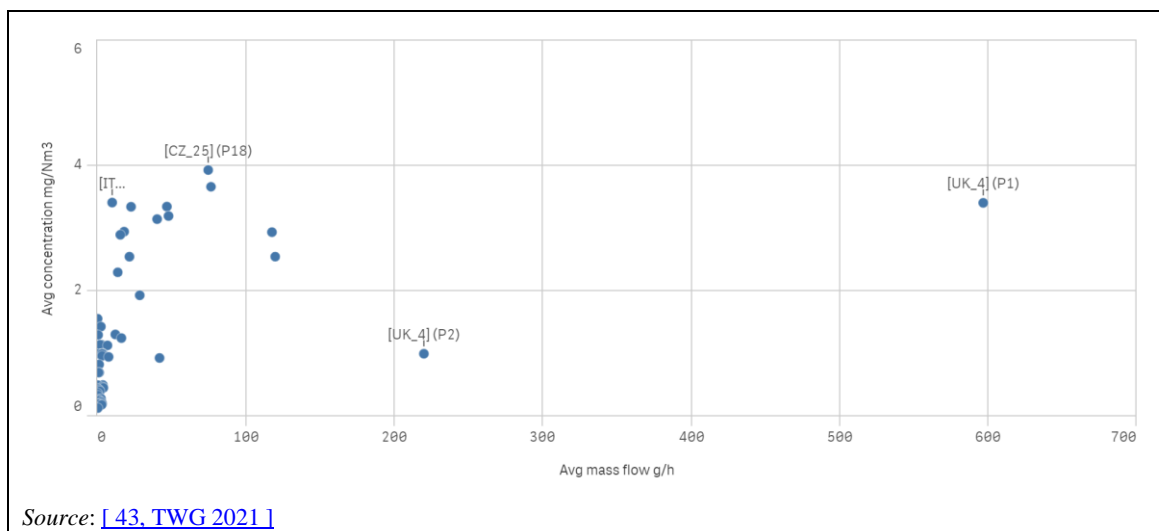


Figure 3.28: Dust concentration versus mass flow, for concentrations < 5 mg/Nm<sup>3</sup> when cyclones are used as the final waste gas treatment

**Cross-media effects**

Disposal of the dust, if it is not used. Further information is provided in the CWW BREF [ 13, COM 2016 ].

**Technical considerations relevant to applicability**

Generally, there are no technical restrictions to the applicability of this technique. Further information is provided in the CWW BREF [ 13, COM 2016 ].

### Economics

Cyclones are a low-cost technique. There is also the potential benefit of material recovery which depends on the dust concentration in the waste gas. Further information is provided in the CWW BREF [13, COM 2016].

### Driving force for implementation

- Environmental legislation.
- Economic benefits due to material recovery.

### Example plants

The technique is widely used in the chemical sector, for example in the production of polymers and inorganic compounds such as metal oxides and non-metals.

### Reference literature

[13, COM 2016], [43, TWG 2021].

## 3.3.2.7 Electrostatic precipitation

### Description

Particles to be removed are charged and separated under the influence of an electrical field. Electrostatic precipitators are capable of operating under a wide range of conditions. The abatement efficiency may depend on the number of fields, residence time (size), and upstream particle removal devices. They generally include between two and five fields. Electrostatic precipitators can be of the dry or of the wet type depending on the technique used to collect the dust from the electrodes. Wet electrostatic precipitators are typically used at the polishing stage to remove residual dust and droplets after absorption.

### Technical description

Electrostatic precipitation is used to remove dust, both as a recovery and as an abatement technique (see Figure 3.29). Removal efficiencies for dust typically range from 97 % to more than 99 % [13, COM 2016].

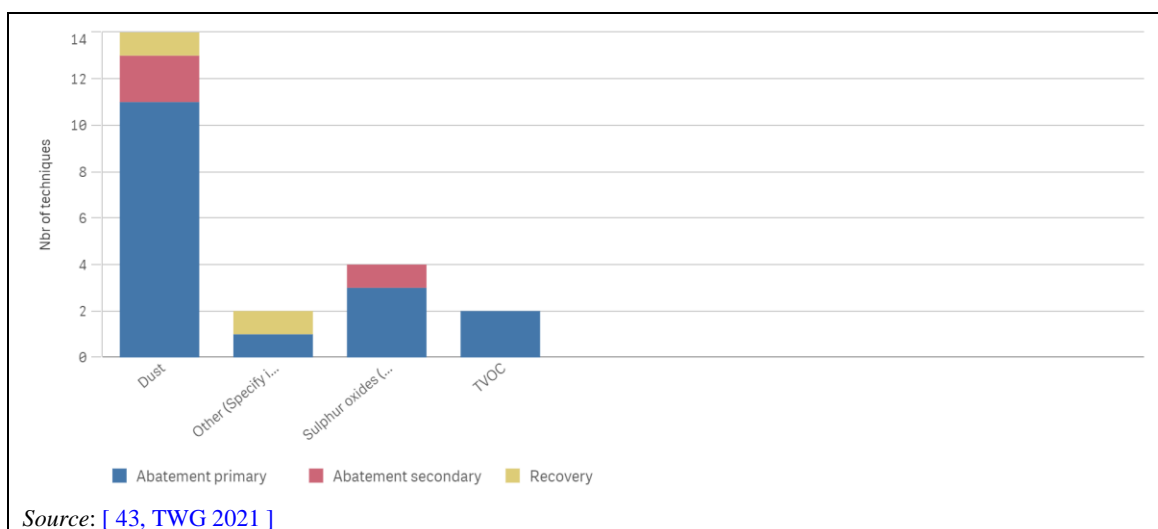


Figure 3.29: Use of electrostatic precipitation for abatement or recovery

Further information is provided in the CWW BREF [13, COM 2016].

### Achieved environmental benefits

- Reduced pollutant load sent to final waste gas treatment.
- Reduced emissions to air.
- Possible material recovery.

### Environmental performance and operational data

Electrostatic precipitation is used alone or in combination with other waste gas treatment techniques.

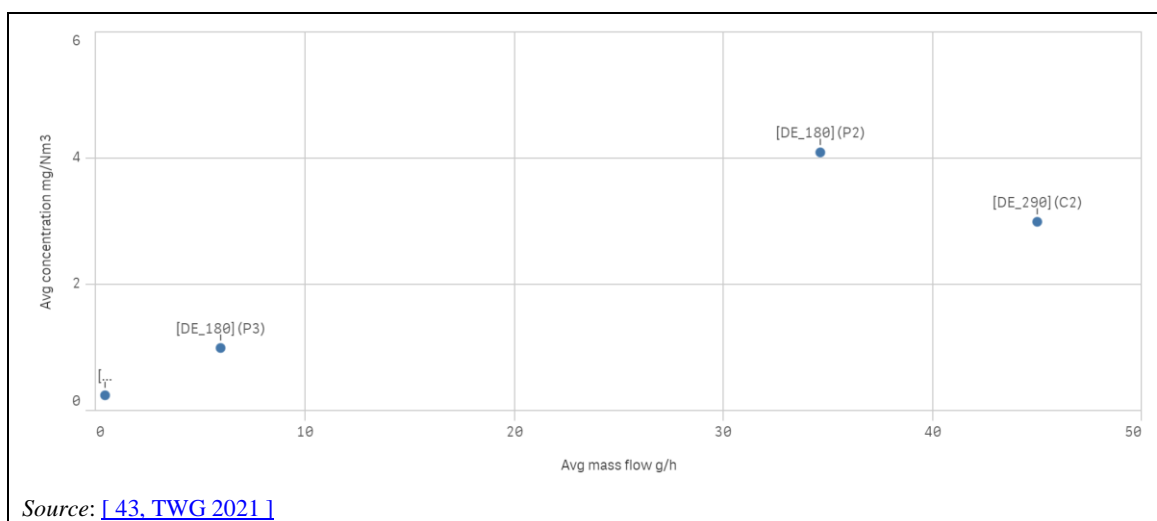
Reported waste gas flows for electrostatic precipitation are shown in Table 3.6.

**Table 3.6: Reported waste gas flows for electrostatic precipitation**

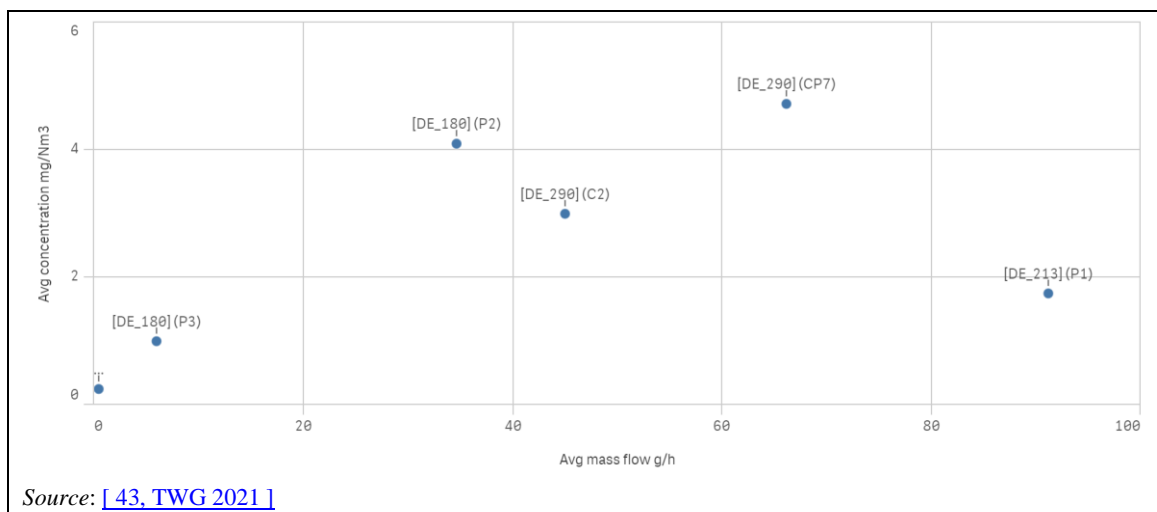
Type	Waste gas flows (Nm <sup>3</sup> /h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	900	1 800	11 500	53 000	800 000	20

Source: [43, TWG 2021]

Figure 3.30 and Figure 3.31 show dust concentration versus mass flow when electrostatic precipitation is used as the final waste gas treatment technique. Figure 3.30 shows data from emission points with a mass flow of less than 50 g/h and Figure 3.31 shows data from emission points with a concentration of less than 5 mg/Nm<sup>3</sup>.



**Figure 3.30: Dust concentration versus mass flow, for mass flows < 50 g/h when electrostatic precipitation is used as the final waste gas treatment technique**



**Figure 3.31: Dust concentration versus mass flow, for concentrations < 5 mg/Nm<sup>3</sup> when electrostatic precipitation is used as the final waste gas treatment technique**

Further information is provided in the CWW BREF [13, COM 2016 ].

#### Cross-media effects

- Energy consumption.
- Disposal of the dust, if it is not used.

Further information is provided in the CWW BREF [13, COM 2016 ].

#### Technical considerations relevant to applicability

Generally, there are no technical restrictions to the applicability of this technique. Further information is provided in the CWW BREF [13, COM 2016 ].

#### Economics

The potential benefit of material recovery depends on the dust concentration in the waste gas. Further information is provided in the CWW BREF [13, COM 2016 ].

#### Cross-media effects

- Energy consumption.
- Disposal of the dust, if it is not used.

Further information is provided in the CWW BREF [13, COM 2016 ].

#### Example plants

The technique is sometimes used in the production of non-metals, metal oxides or other inorganic compounds (IED activity 4.2e).

#### Reference literature

[13, COM 2016 ], [43, TWG 2021 ].

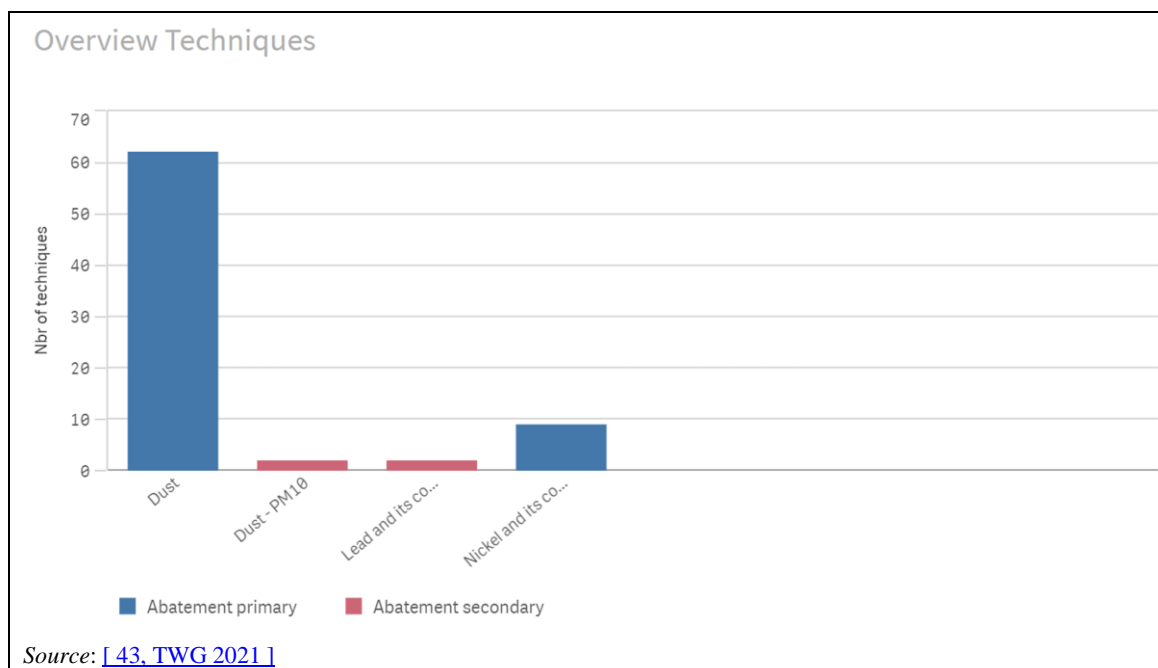
### 3.3.2.8 Absolute filter

#### Description

Absolute filters, also referred to as high-efficiency particle air (HEPA) filters or ultra-low penetration air (ULPA) filters, are constructed from glass cloth or fabrics of synthetic fibres through which gases are passed to remove particles. Absolute filters show higher efficiencies than fabric filters. The classification of HEPA and ULPA filters according to their performance is given in EN 1822-1 [5, CEN 2019].

#### Technical description

Absolute filters are used to remove dust (including  $PM_{10}$  and  $PM_{2.5}$ ) and particulate-bound metals, both as a recovery and as an abatement technique (see Figure 3.32). Removal efficiencies for dust typically range from 99 % to more than 99.9 % [43, TWG 2021].



**Figure 3.32: Use of absolute filters for abatement or recovery**

Further information is provided in the CWW BREF [13, COM 2016].

#### Achieved environmental benefits

- Reduced pollutant load sent to final waste gas treatment.
- Reduced emissions to air.
- Possible material recovery.

#### Environmental performance and operational data

Absolute filters are used alone or in combination with other waste gas treatment techniques.



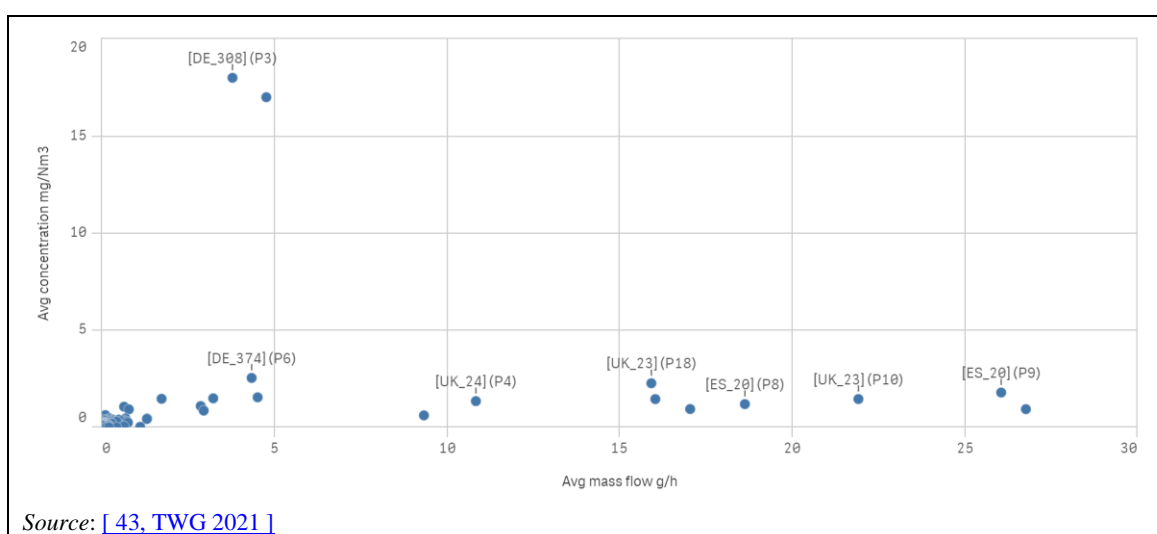
Reported waste gas flows for absolute filters are shown in Table 3.7.

**Table 3.7: Reported waste gas flows for absolute filters**

Type	Waste gas flows (Nm <sup>3</sup> /h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	150	300	1 400	15 000	38 000	62

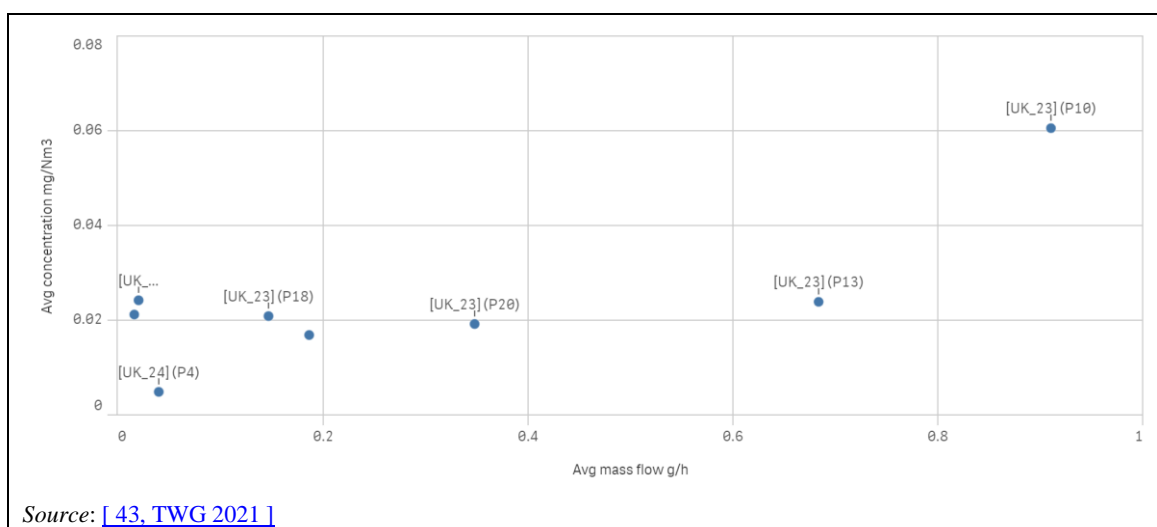
Source: [43, TWG 2021]

Figure 3.33 shows dust concentration versus mass flow when an absolute filter is used as the final waste gas treatment technique.



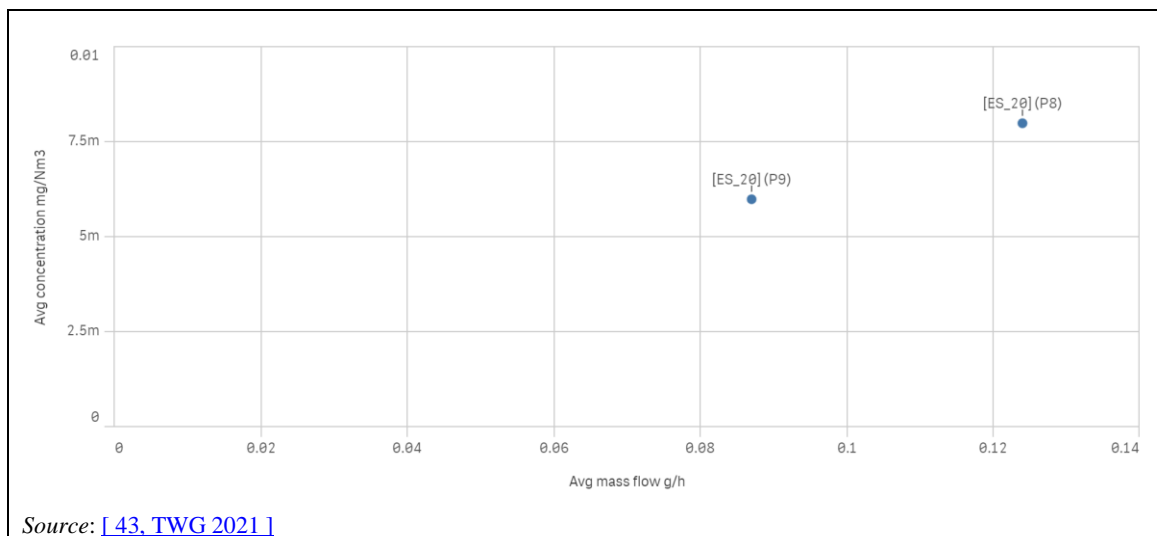
**Figure 3.33: Dust concentration versus mass flow when an absolute filter is used as the final waste gas treatment technique**

Figure 3.34 shows nickel concentration versus mass flow when an absolute filter is used as the final waste gas treatment technique.



**Figure 3.34: Nickel concentration versus mass flow when an absolute filter is used as the final waste gas treatment technique**

Figure 3.35 shows lead concentration versus mass flow when an absolute filter is used as the final waste gas treatment technique.



**Figure 3.35: Lead concentration versus mass flow when an absolute filter is used as the final waste gas treatment technique**

Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

### Technical considerations relevant to applicability

- Absolute filters are not suitable for sticky dusts because of the risk of filter clogging.
- The fabric used needs to be compatible with the waste gas temperature. Absolute filters are typically operated up to a temperature of 150 °C [\[ 43, TWG 2021 \]](#).

Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

### Economics

The potential benefit of material recovery depends on the dust concentration in the waste gas. Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

### Cross-media effects

- Energy consumption.
- Disposal of the dust, if it is not used.

Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

### Example plants

The technique is widely used in the chemical sector, for example in the production of pharmaceutical products (IED activity 4.5) and the production of non-metals, metal oxides or other inorganic compounds (IED activity 4.2e).

### Reference literature

[\[ 5, CEN 2019 \]](#), [\[ 13, COM 2016 \]](#), [\[ 43, TWG 2021 \]](#).

### 3.3.2.9 High-efficiency air filter (HEAF)

#### Description

A flat-bed filter in which aerosols combine into droplets. Highly viscous droplets remain on the filter fabric rolls to be disposed of, which contain the contaminants separated into droplets, aerosols and dust. A HEAF is particularly suitable for treating highly viscous droplets.

#### Technical description

High-efficiency air filters are used to remove dust.

High-efficiency air filters are used as an abatement technique for dust (reported by 127 emission points). Removal efficiencies are typically around 99 % for droplets and aerosols [13, COM 2016].

Further information is provided in the CWW BREF [13, COM 2016].

#### Achieved environmental benefits

Reduced dust emissions to air.

#### Environmental performance and operational data

High-efficiency air filters are generally used alone.

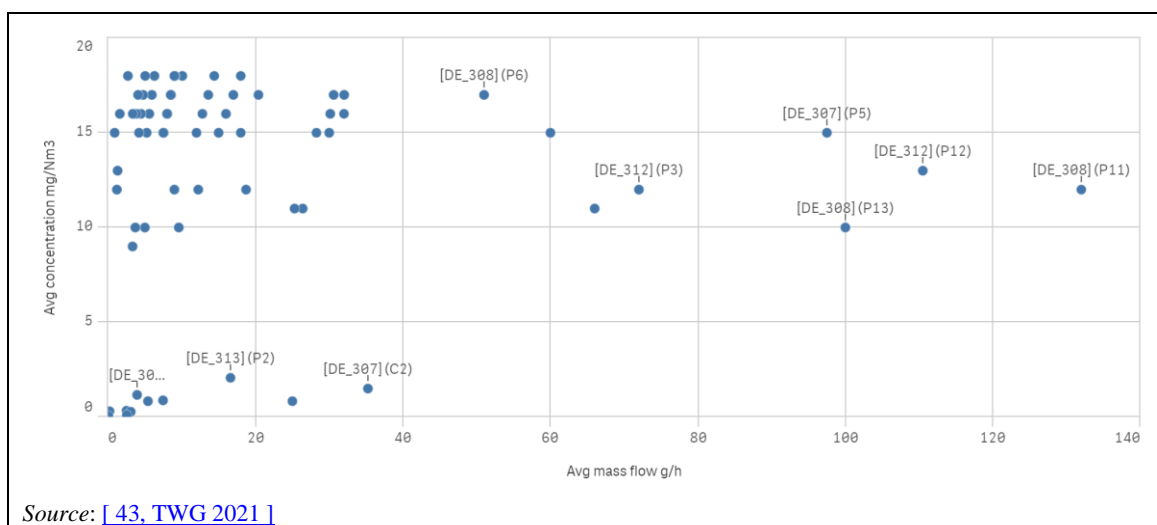
Reported waste gas flows for high-efficiency air filters are shown in Table 3.8.

**Table 3.8: Reported waste gas flows for high-efficiency air filters**

Type	Waste gas flows (Nm <sup>3</sup> /h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	60	280	504	6 000	30 000	127

Source: [43, TWG 2021]

Figure 3.36 shows dust concentration versus mass flow when a high-efficiency air filter is used as the final waste gas treatment technique.



**Figure 3.36: Dust concentration versus mass flow when a HEAF is used as the final waste gas treatment technique**

### Technical considerations relevant to applicability

High-efficiency air filters are normally applied to remove aerosols.

### Economics

Information is provided in the CWW BREF [ 13, COM 2016 ].

### Cross-media effects

The loaded filter rolls, which contain the contaminants separated as droplets, aerosols and dust, need to be disposed of as chemical or hazardous waste and are usually sent to waste incineration.

### Example plants

The technique is widely used in the production of zeolite (IED activity 4.2e).

### Reference literature

[ 13, COM 2016 ], [ 43, TWG 2021 ].

#### 3.3.2.10 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. 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 [ 5, CEN 2019 ].

##### Technical description

Fabric filters are used to remove dust (including PM<sub>10</sub> and PM<sub>2.5</sub>) and particulate-bound metals, both as a recovery and as an abatement technique (see Figure 3.37). Removal efficiencies for dust typically range from 95 % to more than 99.9 % [ 43, TWG 2021 ].

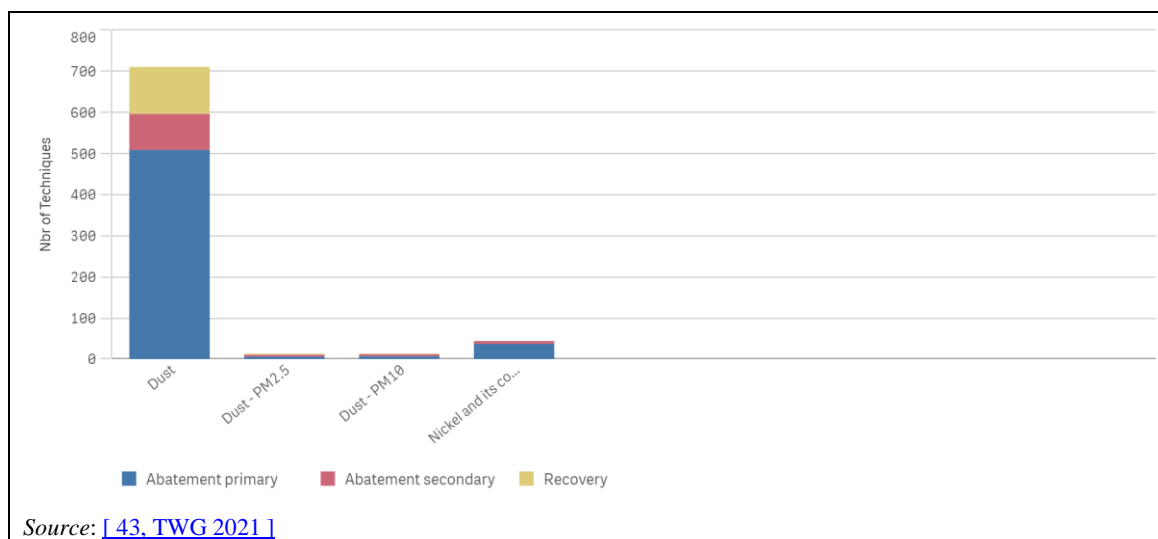


Figure 3.37: Use of fabric filters for abatement or recovery

Further information is provided in the CWW BREF [ 13, COM 2016 ].

### Achieved environmental benefits

- Possible material recovery.
- Reduced pollutant load sent to final waste gas treatment.
- Reduced emissions to air.

### Environmental performance and operational data

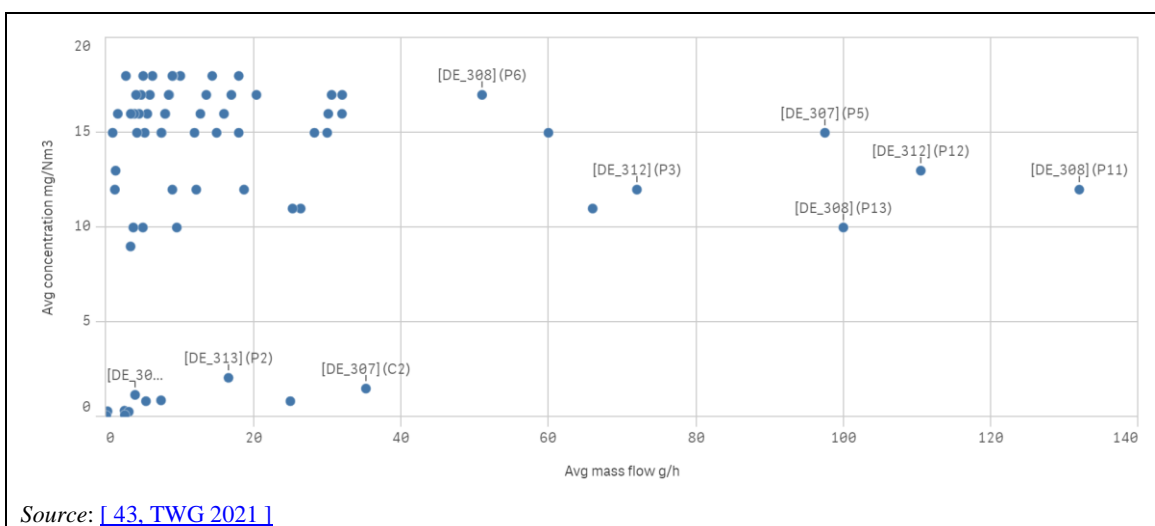
Fabric filters are used alone or in combination with other waste gas treatment techniques.

Reported waste gas flows for fabric filters are shown in Table 3.9.

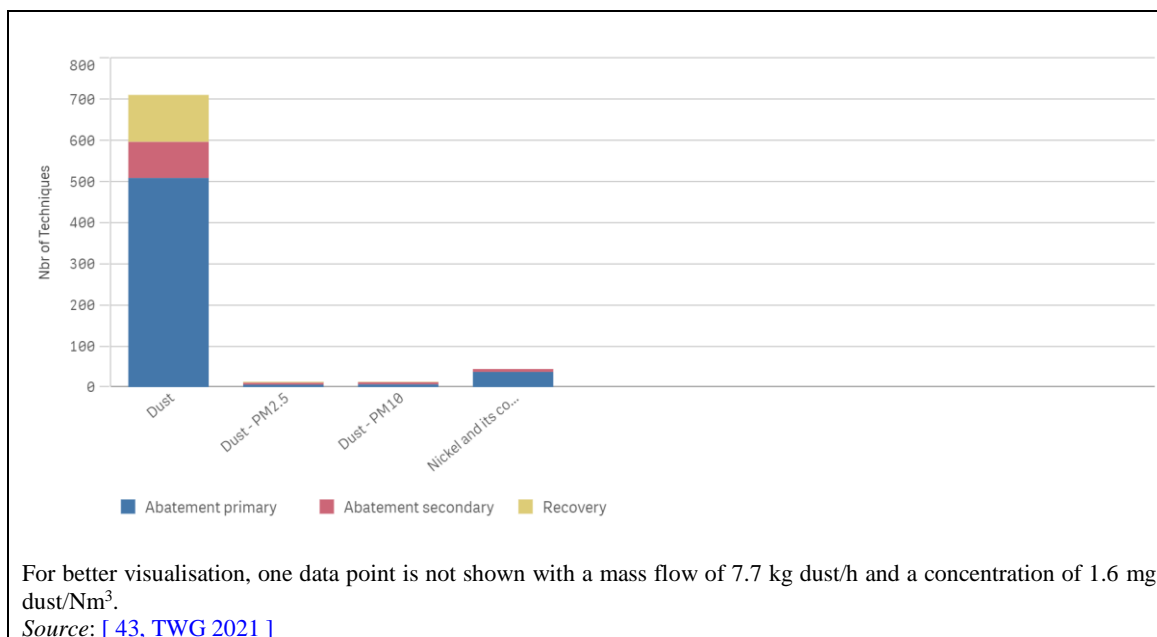
**Table 3.9: Reported waste gas flows for fabric filters**

Type	Waste gas flows (Nm <sup>3</sup> /h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	2	300	2 000	19 000	5 000 000	734
Source: [ 43, TWG 2021 ]						

Figure 3.38 and Figure 3.39 show dust concentration versus mass flow when a fabric filter is used as the final waste gas treatment technique. Figure 3.38 shows data from emission points with a mass flow of less than 50 g/h and Figure 3.39 shows data from emission points with a concentration of less than 5 mg/Nm<sup>3</sup>.

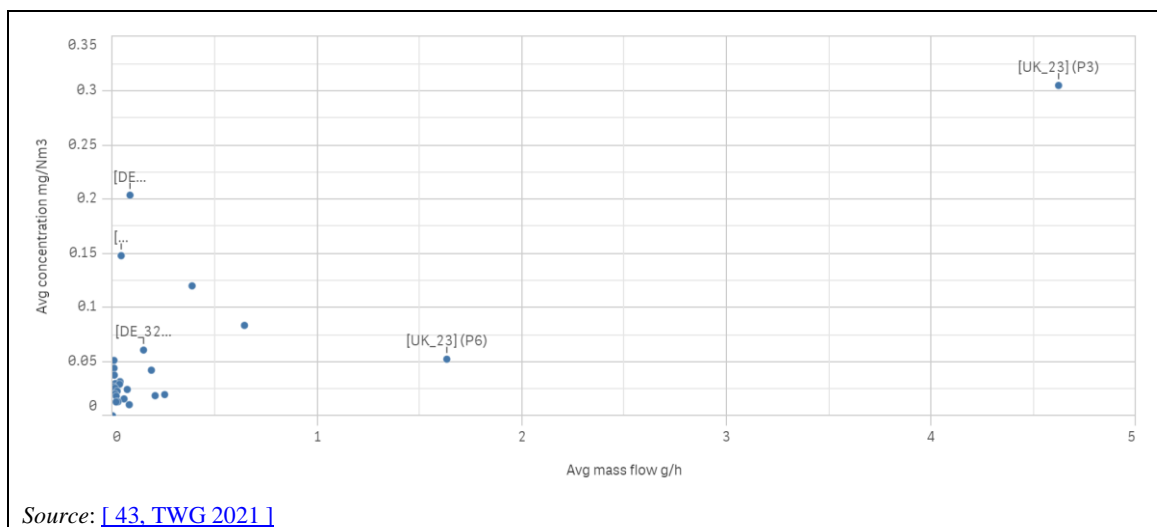


**Figure 3.38: Dust concentration versus mass flow, for mass flows < 50 g/h when a fabric filter is used as the final waste gas treatment technique**



**Figure 3.39: Dust concentration versus mass flow, for concentrations < 5 mg/Nm<sup>3</sup> when a fabric filter is used as the final waste gas treatment technique**

Figure 3.40 shows nickel concentration versus mass flow when a fabric filter is used as the final waste gas treatment technique.



**Figure 3.40: Nickel concentration versus mass flow when a fabric filter is used as the final waste gas treatment technique**

Further information is provided in the CWW BREF [ 13, COM 2016 ].

#### Cross-media effects

- Energy consumption.
- Disposal of the dust, if it is not used.

Further information is provided in the CWW BREF [ 13, COM 2016 ].

**Technical considerations relevant to applicability**

- Fabric filters are not suitable for sticky dusts because of the risk of filter clogging.
- The fabric used needs to be compatible with the waste gas temperature. Fabric filters are typically operated up to a temperature of 250 °C [\[43, TWG 2021\]](#).

Further information is provided in the CWW BREF [\[13, COM 2016\]](#).

**Economics**

The potential benefit of material recovery depends on the dust concentration in the waste gas. Further information is provided in the CWW BREF [\[13, COM 2016\]](#).

**Cross-media effects**

- Energy consumption.
- Disposal of the dust, if it is not used.

Further information is provided in the CWW BREF [\[13, COM 2016\]](#).

**Example plants**

The technique is widely used in the chemical sector, for example in the production of plastic materials such as polymers, synthetic fibres and cellulose-based fibres (IED activity 4.1h) and in the production of non-metals, metal oxides or other inorganic compounds (IED activity 4.1h).

**Reference literature**

[\[5, CEN 2019\]](#), [\[13, COM 2016\]](#), [\[43, TWG 2021\]](#).

**3.3.2.11 Low-NO<sub>x</sub> burner****Description**

The technique (including ultra-low-NO<sub>x</sub> burner) is based on the principles 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<sub>x</sub> and the formation of thermal NO<sub>x</sub>, while maintaining high combustion efficiency. The design of ultra-low-NO<sub>x</sub> burners includes (air/)fuel staging and exhaust/flue-gas recirculation.

**Technical description**

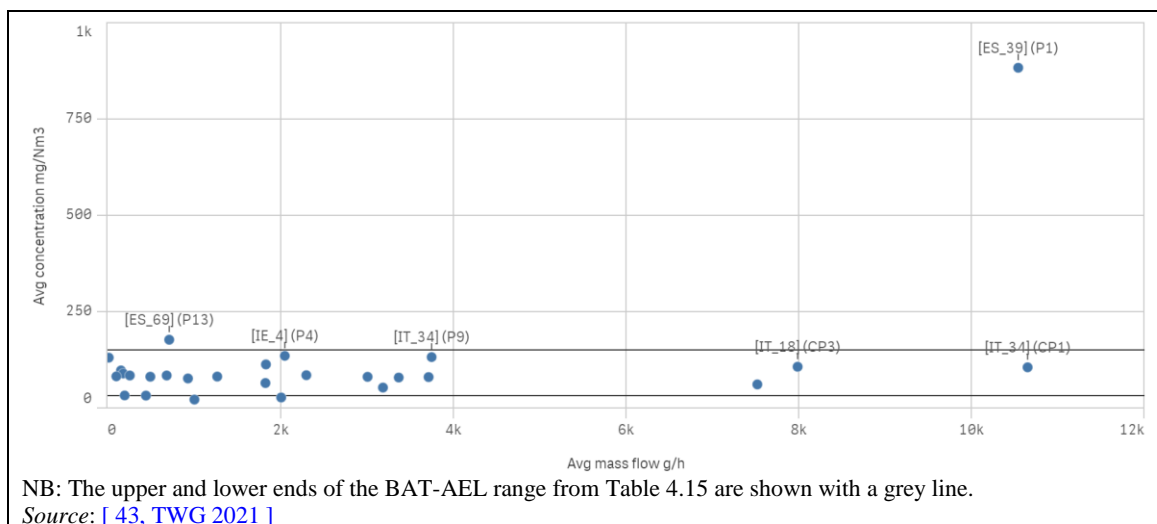
Descriptions of low-NO<sub>x</sub> burners used for conventional fuels are given in the LCP BREF [\[17, COM 2017\]](#) (note: these may require specific modifications for use in chemical processes).

**Achieved environmental benefits**

Reduced NO<sub>x</sub> emissions to air.

**Environmental performance and operational data**

Figure 3.41 shows NO<sub>x</sub> concentration versus mass flow when a low-NO<sub>x</sub> burner is used for process furnaces/heaters.



**Figure 3.41: NO<sub>x</sub> concentration versus mass flow when a low-NO<sub>x</sub> burner is used for process furnaces/heaters**

### Cross-media effects

None reported.

### Technical considerations relevant to applicability

For existing process furnaces/heaters, the applicability may be restricted by their design.

### Economics

No information provided.

### Driving force for implementation

Environmental legislation.

### Example plants

The technique is sometimes used in the chemical sector, for example in the production of simple hydrocarbons (IED activity 4.1a).

### Reference literature

[\[ 17, COM 2017 \]](#), [\[ 43, TWG 2021 \]](#).

## 3.3.2.12 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. Combustion conditions control is based on the continuous monitoring and automated control of appropriate combustion parameters (e.g. O<sub>2</sub>, CO, fuel to air ratio, and unburnt substances).

### Technical description

Further information is provided in the LVOC BREF [\[ 12, COM 2017 \]](#).

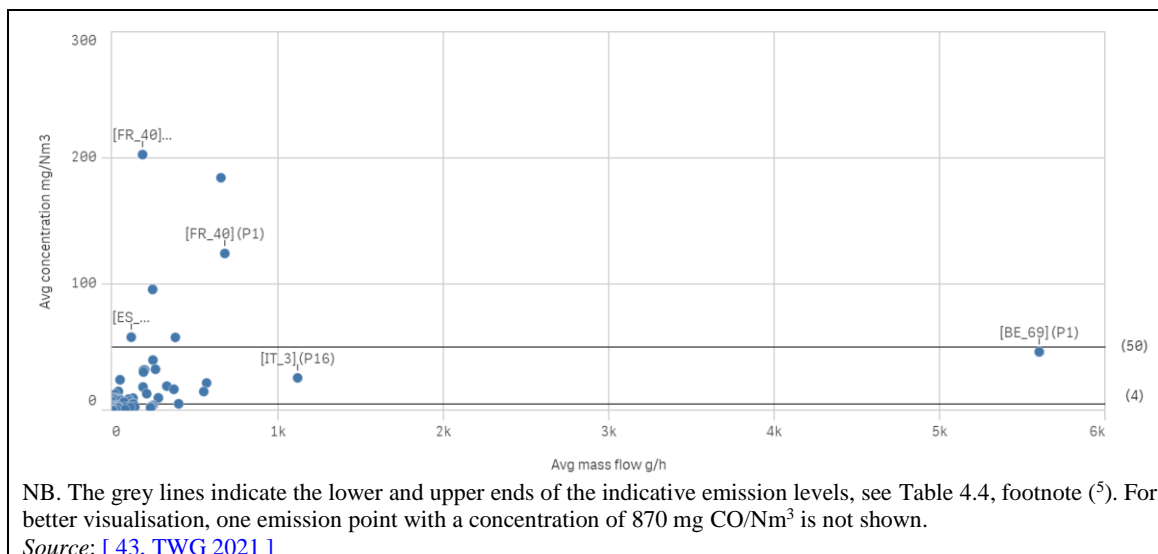
### Achieved environmental benefits

Reduced emissions to air of CO and VOCs.



### Environmental performance and operational data

Figure 3.42 shows CO concentration versus mass flow when optimised combustion is used for process furnaces/heaters.



**Figure 3.42: CO concentration versus mass flow when optimised combustion is used for process furnaces/heaters**

#### Cross-media effects

None reported.

#### Technical considerations relevant to applicability

No information provided.

#### Economics

No information provided.

#### Driving force for implementation

Environmental legislation.

#### Example plants

The technique is sometimes used in the chemical sector, for example in the production of simple hydrocarbons (IED activity 4.1a) and in the production of non-metals, metal oxides or other inorganic compounds (IED activity 4.2e).

#### Reference literature

[ 12, COM 2017 ], [ 43, TWG 2021 ].

### 3.3.2.13 Sending process off-gases to a combustion unit

#### Description

Process off-gases with a high calorific value are burnt as a fuel in a combustion unit (gas engine, boiler, etc.) and the heat is recovered as steam or for electricity generation. Alternatively, they may be burnt in a process heater or furnace to provide heat to the process.

#### Technical description

Process off-gases may have a high calorific value due to the presence of organic solvents, unreacted organic raw materials, by-products or flammable diluents. The process off-gas is

channelled to a gas engine or boiler where it is burnt to produce electricity and/or steam. The boiler may also use a conventional fuel, in which case the off-gases may require separate burners to ensure efficient combustion.

For process off-gases with low VOC concentrations (e.g.  $< 1 \text{ g/Nm}^3$ ), pre-concentration steps may be applied using adsorption (rotor or fixed bed, with activated carbon or zeolites), in order to increase the calorific value of the process off-gases.

Molecular sieves ('smoothers'), typically composed of zeolites, may be used to level down high variations (e.g. concentration peaks) of VOC concentrations in the process off-gases [47, DE 2021 ], [48, SE 2021 ].

### **Achieved environmental benefits**

- Reduced emissions of VOCs to air.
- Improved energy efficiency: lower energy consumption for steam production or electricity generation on site.

### **Environmental performance and operational data**

The usage of gas engines is reported by the data collection for the abatement of VOCs in five cases. All emission levels reported for volatile organic compounds were below 100 g TVOC/h and in three cases below 10 mg TVOC/Nm<sup>3</sup>. One gas engine reported benzene emissions below 2.5 g/h and 2 mg/Nm<sup>3</sup>. Furthermore, external treatment is reported by the data collection which may include treatment of waste gases with a high calorific value.

### **Cross-media effects**

No information provided.

### **Technical considerations relevant to applicability**

Sending process off-gases to a combustion unit may be restricted due to the presence of contaminants or due to safety considerations.

### **Economics**

Significant benefits from steam and/or electricity generation.

### **Driving force for implementation**

- Environmental legislation.
- Cost reduction.

### **Example plants**

Plants reporting gas engines in the data collection: DE\_49, DE\_36, DE\_346, FR\_14 and NL\_32. Plants reporting external treatment: DE\_382, [41, EIPPCB 2018 ].

### **Reference literature**

[43, TWG 2021 ], [41, EIPPCB 2018 ].

#### **3.3.2.14 Catalytic oxidation**

##### **Description**

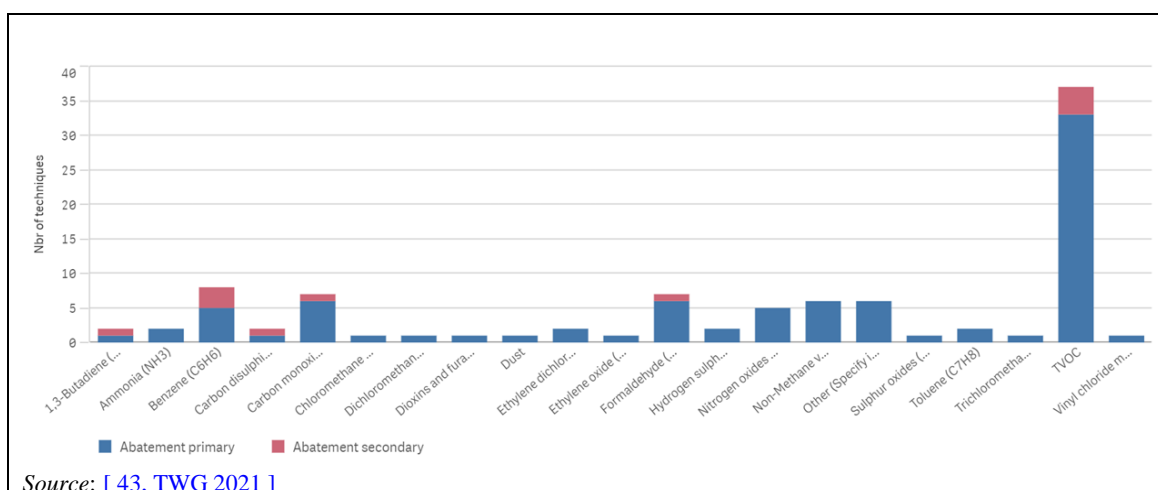
Abatement technique which oxidises combustible compounds in a waste gas stream with air or oxygen in a catalyst bed. The catalyst enables oxidation at lower temperatures and in smaller equipment compared to thermal oxidation. The typical oxidation temperature is between 200 °C and 600 °C.

For process off-gases with low VOC concentrations (e.g.  $< 1 \text{ g/Nm}^3$ ), pre-concentration steps may be applied using adsorption (rotor or fixed bed, with activated carbon or zeolites). VOCs adsorbed in the concentrator are desorbed by using heated ambient air or heated waste gas, and the resulting volume flow with higher VOC concentration is directed to the oxidiser.

Molecular sieves ('smoothers'), typically composed of zeolites, may be used before the concentrators or the oxidiser to level down high variations of VOC concentrations in the process off-gases [ 47, DE 2021 ] [ 48, SE 2021 ].

### Technical description

Catalytic oxidation is used as an abatement technique to reduce emissions of organic compounds (e.g. TVOC, benzene) (see Figure 3.43).



Source: [ 43, TWG 2021 ]

**Figure 3.43: Use of catalytic oxidation for abatement**

Further information is provided in the CWW BREF [ 13, COM 2016 ] and the LVOC BREF [ 12, COM 2017 ].

### Achieved environmental benefits

- Reduced emissions to air.
- Possible energy recovery.

### Environmental performance and operational data

Catalytic 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 99.9 % [ 43, TWG 2021 ].

Reported waste gas flows for catalytic oxidation are shown in Table 3.10.

**Table 3.10: Reported waste gas flows for catalytic oxidation**

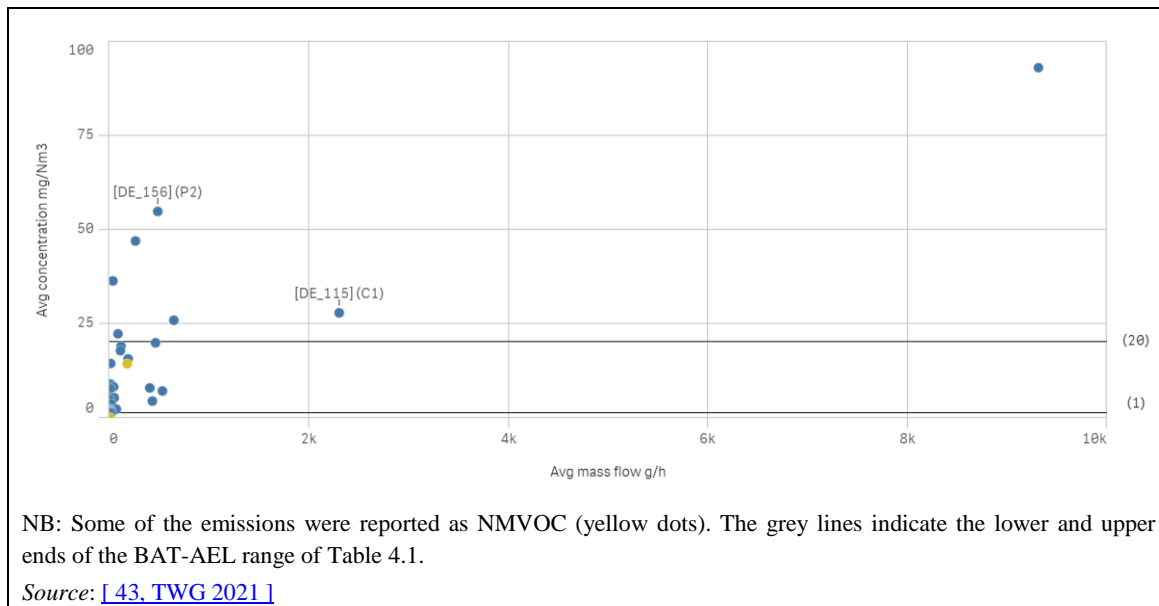
Type	Waste gas flows (Nm <sup>3</sup> /h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	700	1 000	6 000	80 000	100 000	31

Source: [ 43, TWG 2021 ]

### Chapter 3

The combustion temperature reported by the data collection is typically between 200 °C and 600 °C. Some plants reported heat recovery.

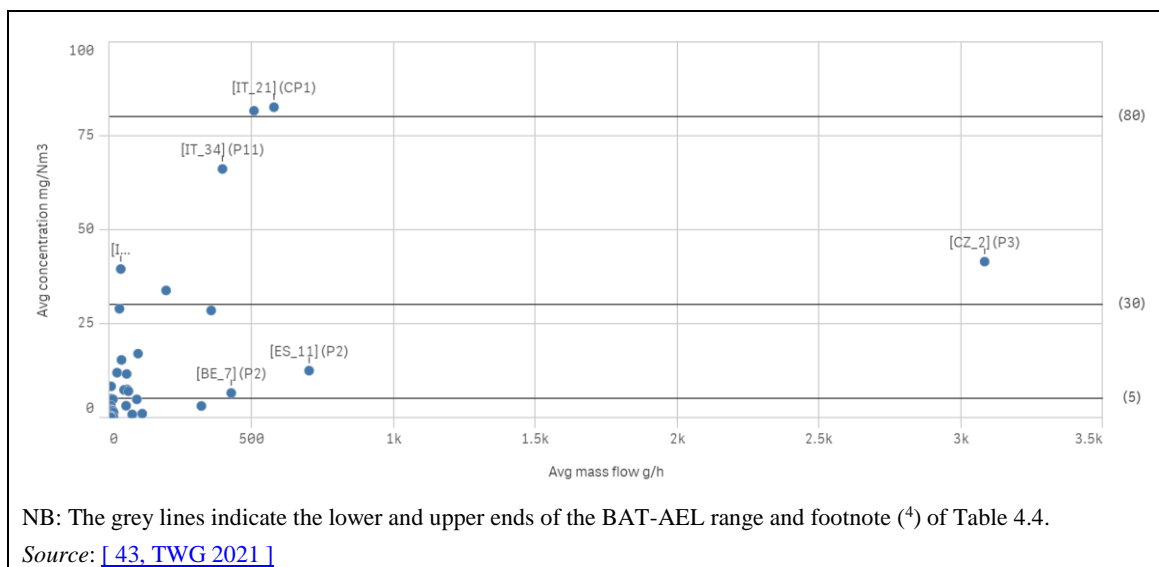
Figure 3.44 shows TVOC concentration versus mass flow when catalytic oxidation is used.



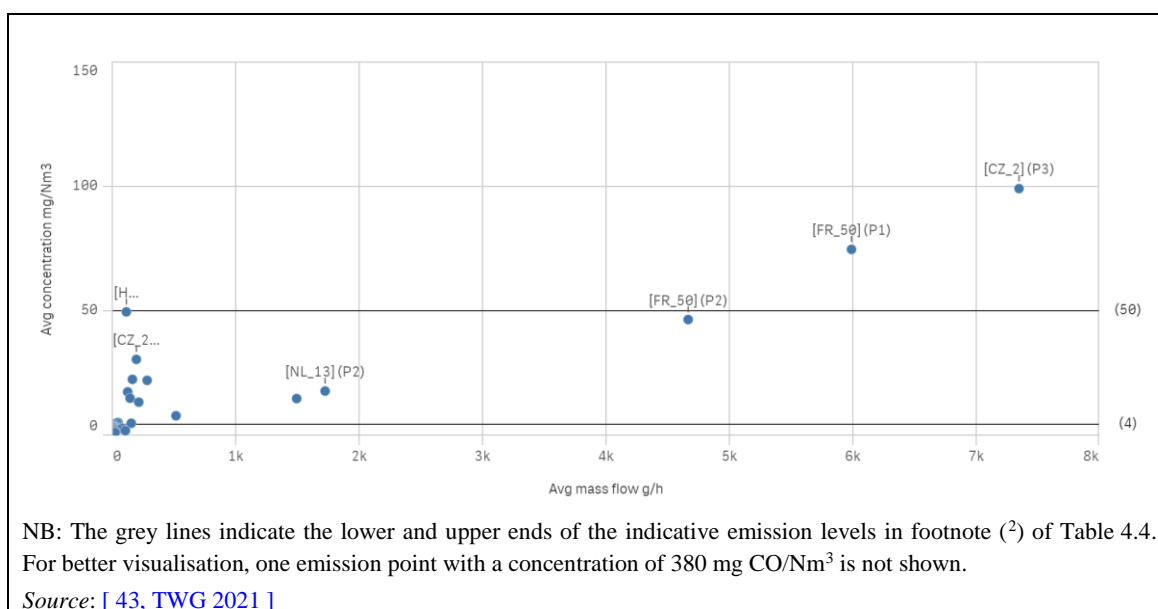
**Figure 3.44: TVOC concentration versus mass flow when catalytic oxidation is used**

TVOC emissions from catalytic oxidation tend to be higher than those from thermal oxidation, particularly when compared with straight thermal oxidation (see Section 3.3.2.15).

The use of catalytic oxidation leads to the generation of NO<sub>x</sub> and CO. Figure 3.45 and Figure 3.46 respectively shows NO<sub>x</sub> concentration and CO concentration versus mass flow when catalytic oxidation is used.



**Figure 3.45: NO<sub>x</sub> concentration versus mass flow when catalytic oxidation is used**



**Figure 3.46: CO concentration versus mass flow when catalytic oxidation is used**

NO<sub>x</sub> emission levels from catalytic oxidation are generally lower than those from thermal oxidation (see Section 3.3.2.15).

Optimisation of the catalytic oxidation can reduce the emissions of NO<sub>x</sub> 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 catalytic oxidation (e.g. absorption).

Further information is provided in the CWW BREF [\[13, COM 2016\]](#).

#### **Cross-media effects**

- Generation of NO<sub>x</sub> and CO and potentially of other pollutants (e.g. HCl, SO<sub>2</sub>, PCDD/F).
- Consumption of fuel in the case of non-autothermal operation.

#### **Technical considerations relevant to applicability**

The use of the technique may be hampered by catalyst poisons in the waste gases. Further information is provided in the CWW BREF [\[13, COM 2016\]](#).

### **Economics**

Catalytic oxidation is relatively expensive in comparison with some other techniques, e.g. absorption or adsorption. Investment costs are higher than for thermal oxidation. Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

### **Driving force for implementation**

Environmental legislation.

### **Example plants**

The technique is sometimes used in the chemical sector, for example in the production of organic substances, plant protection products, biocides and pharmaceuticals.

### **Reference literature**

[\[ 13, COM 2016 \]](#), [\[ 12, COM 2017 \]](#), [\[ 43, TWG 2021 \]](#).

### **3.3.2.15 Thermal oxidation**

#### **Description**

Abatement technique which oxidises combustible compounds in a waste gas stream with air or oxygen. The waste gas stream is heated above its auto-ignition point in a combustion chamber and maintained 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:

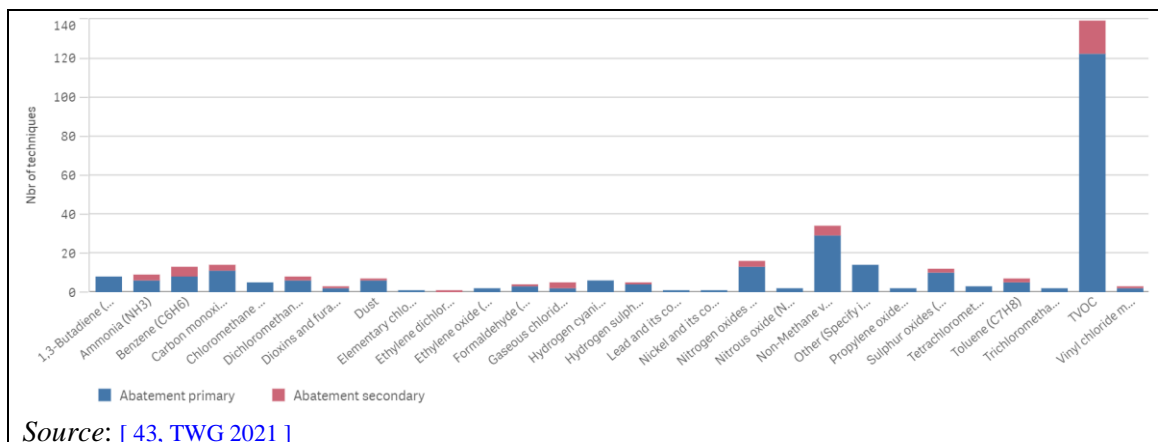
- Straight thermal oxidation: thermal oxidation without energy recovery from the combustion.
- Recuperative thermal oxidation: thermal oxidation using the heat of the waste gases by indirect heat transfer.
- Regenerative thermal oxidation: thermal oxidation where the incoming waste gas stream is heated 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.

For process off-gases with low VOC concentrations (e.g.  $< 1 \text{ g/Nm}^3$ ), pre-concentration steps may be applied using adsorption (rotor or fixed bed, with activated carbon or zeolites). VOCs adsorbed in the concentrator are desorbed by using heated ambient air or heated waste gas, and the resulting volume flow with higher VOC concentration is directed to the oxidiser.

Molecular sieves ('smoothers'), typically composed of zeolites, may be used before the concentrators or the oxidiser to level down high variations of VOC concentrations in the process off-gases.

### Technical description

Thermal oxidation is used as an abatement technique to reduce emissions of organic compounds (e.g. TVOC, benzene) (see Figure 3.47).



**Figure 3.47: Use of thermal oxidation for abatement**

Further information is provided in the CWW BREF [13, COM 2016] and the LVOC BREF [12, COM 2017].

### 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 % [43, TWG 2021].

Reported waste gas flows for thermal oxidation are shown in Table 3.11.

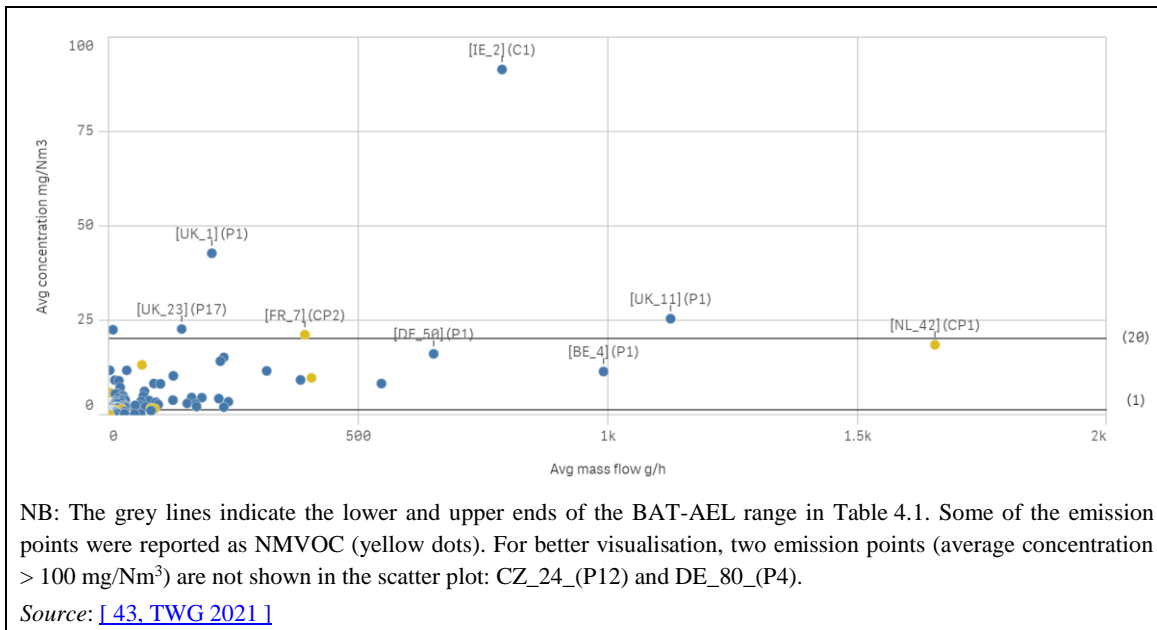
**Table 3.11: Reported waste gas flows for thermal oxidation**

Type	Waste gas flows (Nm <sup>3</sup> /h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
Straight thermal oxidation	150	1 000	5 000	21 000	170 000	66
Recuperative thermal oxidation	340	1 500	12 000	75 000	110 000	35
Regenerative thermal oxidation	100	4 000	21 000	70 000	190 000	51

Source: [43, TWG 2021]

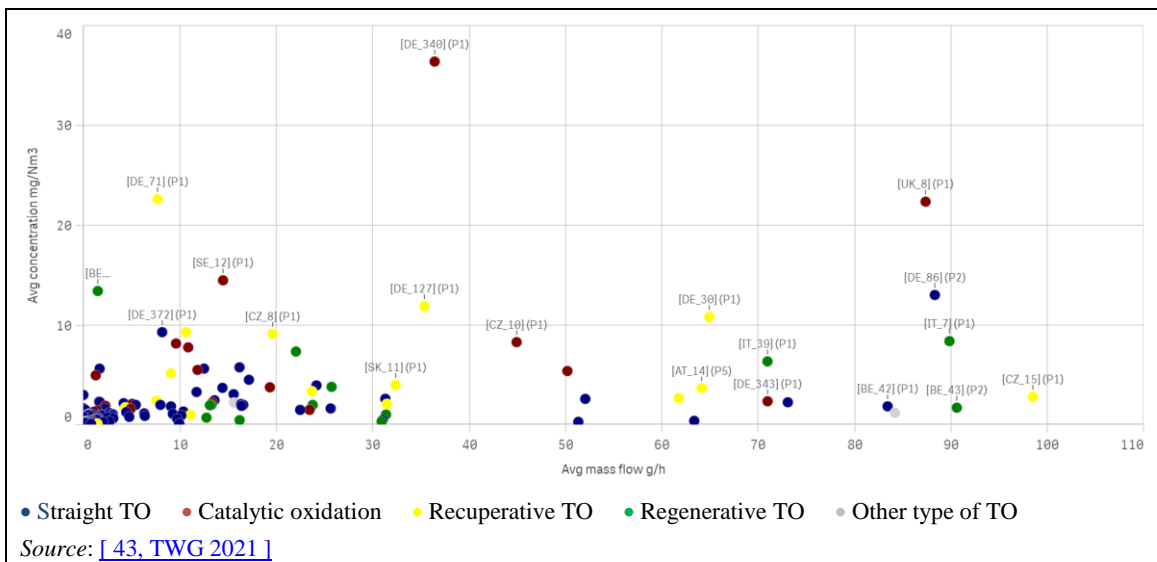
The combustion temperature reported by the data collection is typically between 600 °C and 1 200 °C.

Figure 3.48 shows TVOC concentration versus mass flow when thermal oxidation is used.



**Figure 3.48: TVOC concentration versus mass flow when thermal oxidation is used**

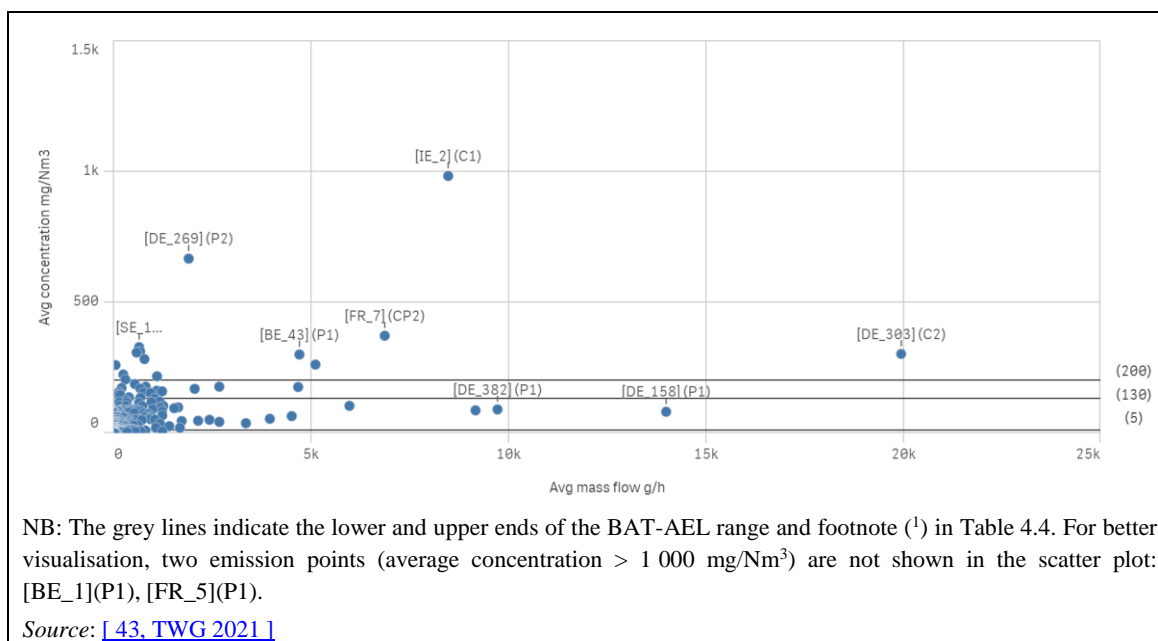
TVOC emission levels from straight thermal oxidation are generally lower than those from recuperative or regenerative thermal oxidation. TVOC emissions from catalytic oxidation tend to be higher than those from thermal oxidation (see Figure 3.49).



**Figure 3.49: Comparison of TVOC emission levels from catalytic oxidation and different types of thermal oxidation**

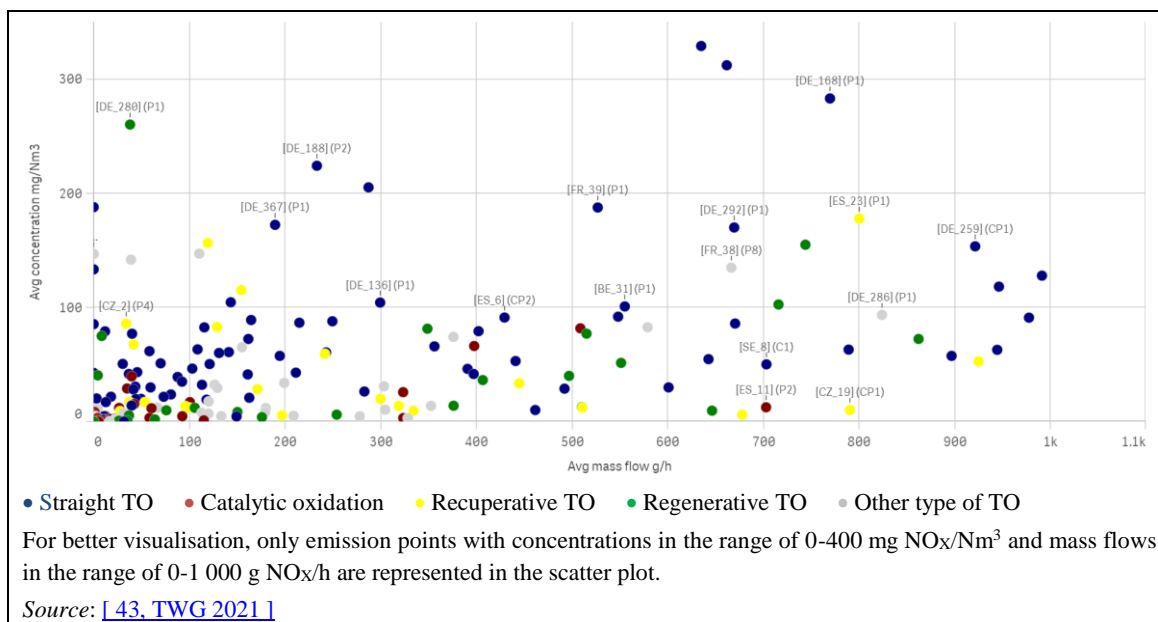


The use of thermal oxidation leads to the generation of  $\text{NO}_x$  and CO. Figure 3.50 shows  $\text{NO}_x$  concentration versus mass flow when thermal oxidation is used.



**Figure 3.50:  $\text{NO}_x$  concentration versus mass flow when thermal oxidation is used**

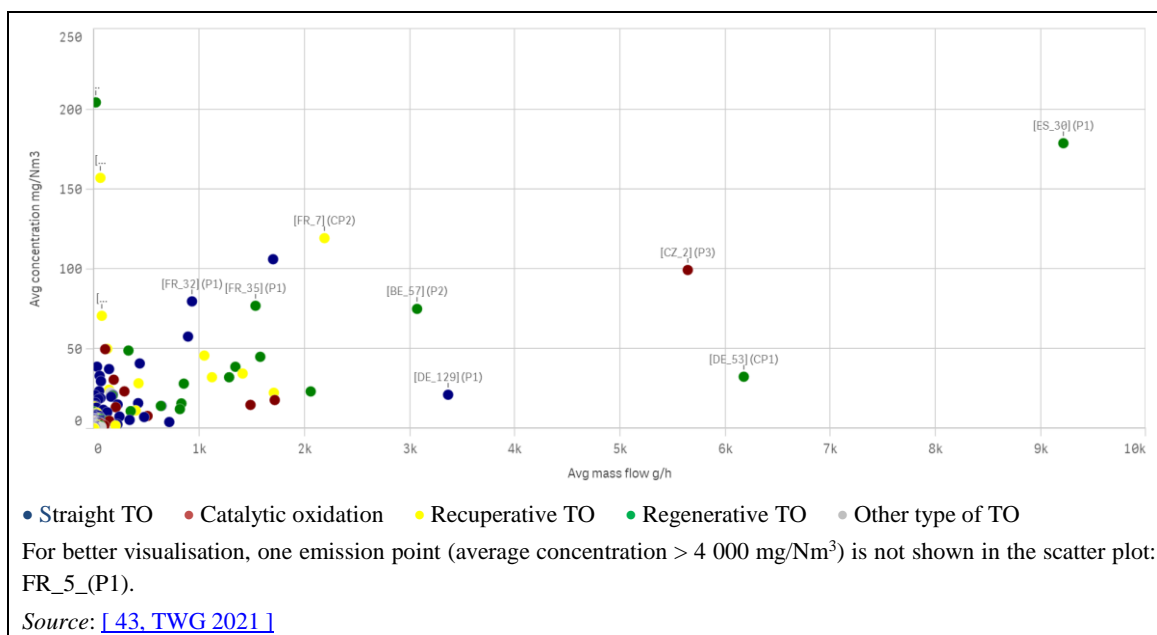
$\text{NO}_x$  emission levels from thermal oxidation are generally higher than those from catalytic oxidation (see Figure 3.51).



**Figure 3.51: Comparison of  $\text{NO}_x$  emission levels from catalytic oxidation and different types of thermal oxidation (TO)**

If preheating of waste gases and combustion air is necessary, regenerative and recuperative thermal oxidisers will show overall lower  $\text{NO}_x$  emissions than straight thermal oxidisers because of energy savings (indirect effect).

Figure 3.52 shows CO concentration versus mass flow when thermal oxidation is used.



**Figure 3.52: Comparison of CO emission levels from catalytic oxidation and different types of thermal oxidation**

Optimisation of thermal oxidation can reduce the emissions of NO<sub>x</sub> 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 [13, COM 2016].

### Cross-media effects

- Generation of NO<sub>x</sub> and CO and potentially of other pollutants (e.g. HCl, SO<sub>2</sub>, PCDD/F).
- Consumption of fuel in the case of non-autothermal operation.

**Technical considerations relevant to applicability**

Generally, there are no technical restrictions to the applicability of straight thermal oxidation. The applicability of recuperative and regenerative thermal oxidation to existing units may be restricted by design and/or operational constraints. Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

**Economics**

Thermal oxidation is relatively expensive in comparison with some other techniques, e.g. absorption or adsorption. Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

**Driving force for implementation**

Environmental legislation.

**Example plants**

The technique is widely used in the chemical sector, for example in central waste gas treatment as well as in the production of organic substances, plant protection products, biocides and pharmaceuticals. The use of the technique was also reported in the production of inorganic compounds such as metal oxides and non-metals.

**Reference literature**

[\[ 13, COM 2016 \]](#), [\[ 12, COM 2017 \]](#), [\[ 43, TWG 2021 \]](#).

**3.3.2.16 Selective catalytic reduction (SCR)****Description**

Selective reduction of nitrogen oxides with ammonia or urea in the presence of a catalyst. The technique is based on the reduction of NO<sub>x</sub> to nitrogen in a catalytic bed by reaction with ammonia at an optimum operating temperature that is typically around 200-450 °C. In general, ammonia is injected as an aqueous solution; the ammonia source can also be anhydrous ammonia or a urea solution. Several layers of catalyst may be applied. A higher NO<sub>x</sub> reduction is achieved with the use of a larger catalyst surface, installed as one or more layers. 'In-duct' or 'slip' SCR combines SNCR with downstream SCR which reduces the ammonia slip from SNCR.

**Technical description**

SCR is used as an abatement technique to reduce NO<sub>x</sub> emissions (reported by 20 emission points).

Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#) and the LVOC BREF [\[ 12, COM 2017 \]](#).

**Achieved environmental benefits**

Reduced emissions to air. An adequate catalyst surface of the SCR system also contributes to the partial reduction of the emissions of PCDD/F.

**Environmental performance and operational data**

SCR is typically used in combination with other waste gas treatment techniques (e.g. combined with pretreatment to remove dust). Removal efficiencies for NO<sub>x</sub> typically range from 50 % to more than 99 % [\[ 43, TWG 2021 \]](#).

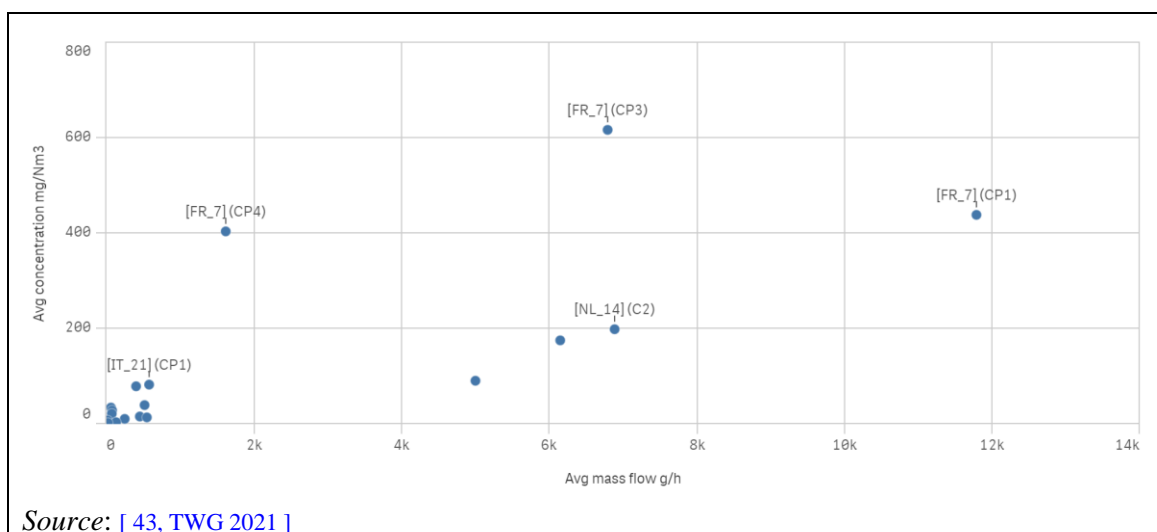
Reported waste gas flows for SCR are shown in Table 3.12.

**Table 3.12: Reported waste gas flows for SCR**

Type	Waste gas flows (Nm <sup>3</sup> /h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	1 800	2 500	20 000	37 000	55 000	20

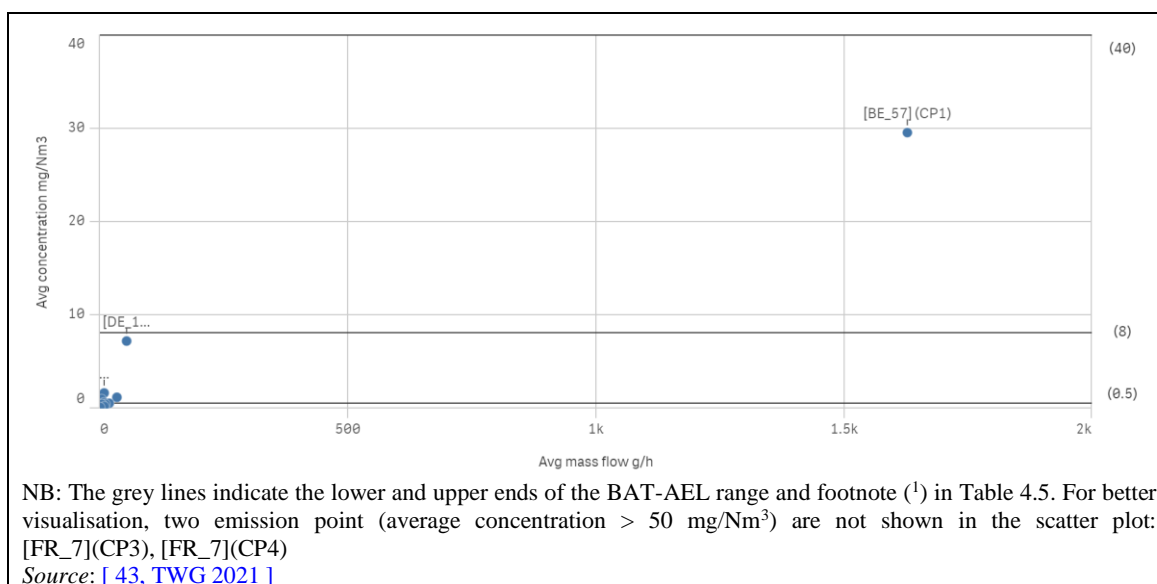
Source: [43, TWG 2021]

Figure 3.53 shows NO<sub>x</sub> concentration versus mass flow when SCR is used.



**Figure 3.53: NO<sub>x</sub> concentration versus mass flow when SCR is used**

The use of SCR leads to the generation of ammonia. Figure 3.54 shows ammonia concentration versus mass flow when SCR is used.



**Figure 3.54: Ammonia concentration versus mass flow when SCR is used**

Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

#### **Cross-media effects**

- Consumption of ammonia or urea.
- Emissions of ammonia ('ammonia slip').
- Consumption of energy if the waste gas needs to be reheated.

#### **Technical considerations relevant to applicability**

SCR requires considerable space which might not be available in existing plants. Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

#### **Economics**

Investment costs are high compared to SNCR. Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

#### **Driving force for implementation**

Environmental legislation.

#### **Example plants**

The technique is used in some parts of the chemical sector, for example in the production of non-metals, metal oxides and other inorganic compounds (IED activity 4.2e) and in the production of nitrogenous hydrocarbons (IED activity 4.1d).

#### **Reference literature**

[\[ 13, COM 2016 \]](#), [\[ 12, COM 2017 \]](#), [\[ 43, TWG 2021 \]](#).

### **3.3.2.17 Selective non-catalytic reduction (SNCR)**

#### **Description**

Selective reduction of nitrogen oxides to nitrogen with ammonia or urea at high temperatures and without catalyst. The operating temperature window is maintained between 800 °C and 1 000 °C for optimal reaction.

#### **Technical description**

SNCR is used as an abatement technique to reduce NO<sub>x</sub> emissions (reported by eight emission points).

Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#) and the LVOC BREF [\[ 12, COM 2017 \]](#).

#### **Achieved environmental benefits**

Reduced emissions to air.

#### **Environmental performance and operational data**

SNCR is typically used in combination with other waste gas treatment techniques (e.g. combined with pretreatment to remove dust). Removal efficiencies for NO<sub>x</sub> typically range from 30 % to 80 % [\[ 43, TWG 2021 \]](#).

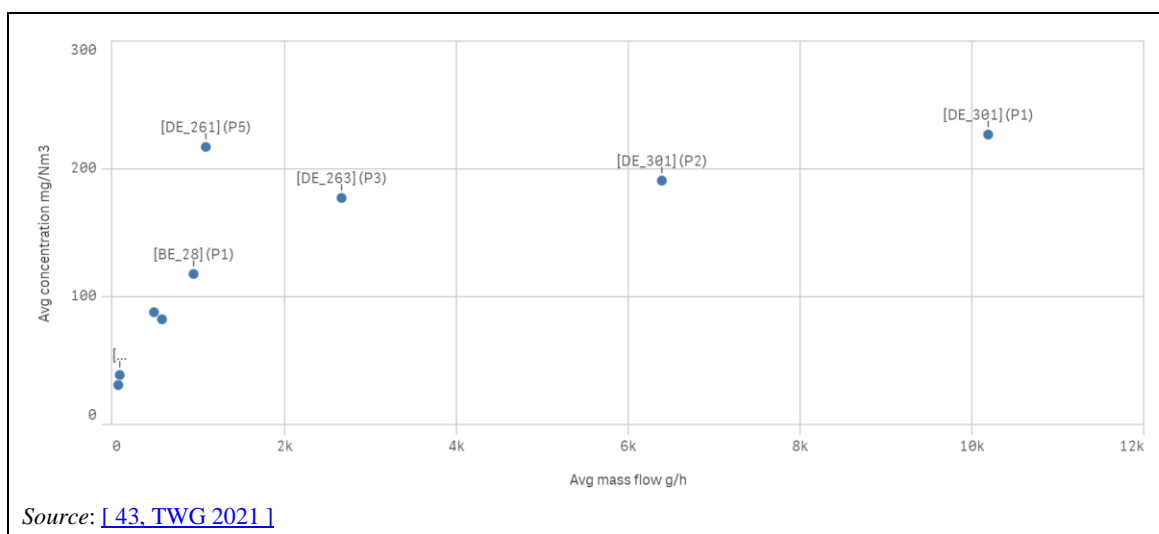
Reported waste gas flows for SNCR are shown in Table 3.13.

**Table 3.13: Reported waste gas flows for SNCR**

Type	Waste gas flows (Nm <sup>3</sup> /h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	1 500	2000	5 500	36 000	45000	9

Source: [43, TWG 2021]

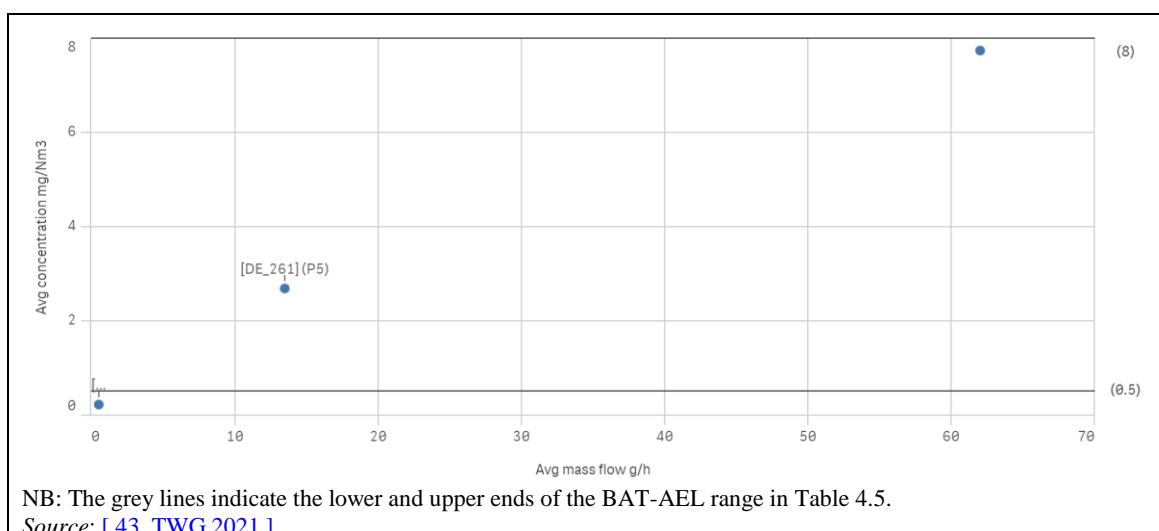
Figure 3.55 shows NO<sub>x</sub> concentration versus mass flow when SNCR is used.



Source: [43, TWG 2021]

**Figure 3.55: NO<sub>x</sub> concentration versus mass flow when SNCR is used**

The use of SNCR can lead to the generation of ammonia. Figure 3.56 shows ammonia concentration versus mass flow when SNCR is used.



NB: The grey lines indicate the lower and upper ends of the BAT-AEL range in Table 4.5.

Source: [43, TWG 2021]

**Figure 3.56: Ammonia concentration versus mass flow when SNCR is used**

Further information is provided in the CWW BREF [13, COM 2016].

**Cross-media effects**

- Consumption of ammonia or urea.
- Emissions of ammonia ('ammonia slip').
- Consumption of energy if the waste gas needs to be reheated.

**Technical considerations relevant to applicability**

The residence time of the waste gas is decisive for the efficiency of the SNCR. Optimisation in existing plants might be difficult. Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

**Economics**

Investment costs are lower than for SCR. Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#).

**Driving force for implementation**

Environmental legislation.

**Example plants**

The technique is rarely used in the chemical sector, for example in the production of nitrogenous hydrocarbons (IED activity 4.1d) and inorganic gases (IED activity 4.2a).

**Reference literature**

[\[ 13, COM 2016 \]](#), [\[ 12, COM 2017 \]](#), [\[ 43, TWG 2021 \]](#).

### 3.4 Diffuse VOC emissions to air

Diffuse emissions are not released via specific emission points such as stacks (i.e. diffuse emissions are non-channelled emissions). In chemical production sites, diffuse emissions can arise from:

- ‘area’ sources such as container-filling areas and waste water treatment facilities;
- ‘point’ sources such as pipe flanges, valves, pumps and other pressurised components on a process plant.

There are two categories of diffuse emissions: fugitive and non-fugitive emissions.

Fugitive emissions are characterised as random occurrences, and are typically due to:

- the relaxation or progressive wear and tear of sealing elements of particular equipment;
- poor construction/installation, operation, maintenance or design;
- the failure of equipment.

Fugitive emissions may occur continuously under normal operating conditions. For example, gaskets and flanges are never perfectly tight; however, their leak rate can be minimised to guarantee the lowest possible emissions [36, Riedl 2017]. Particular operating conditions imposed by the process (e.g. high temperature, high pressure, vibrations) may also increase the likelihood and/or quantity of fugitive emissions.

Fugitive emissions can arise from the following:

- Moving equipment, such as agitators, compressors, pumps, valves (manual and automatic). Occurrence of fugitive emissions is generally increased for moving equipment because of the vibration induced by the movement.
- Static equipment, such as flanges and other connections, open-ended lines, sampling points.

Non-fugitive emissions are diffuse emissions other than fugitive emissions. Non-fugitive emissions can arise from atmospheric vents, bulk storage, loading/unloading systems, vessels and tanks (on opening), open gutters, sampling systems, tank venting, waste, sewers, or waste water treatment plants.

Taken individually, the quantities emitted per source of fugitive emission are generally small. However, a chemical plant generally counts thousands or tens of thousands of fugitive emission sources and the sum of all these small losses can lead to significant quantities of diffuse emissions. In the case of non-fugitive emissions, few emission sources may contribute significantly to the total emissions of a plant.

Diffuse VOC emissions are particularly of concern in the chemical industry, mainly in the production of organic compounds. Some VOCs are classified as CMR (e.g. benzene, vinyl chloride monomer, ethylene dichloride). In addition, VOCs are one of the major contributors (along with NO<sub>x</sub> and CO under sunny conditions) to the formation of tropospheric ozone, which can be harmful to health. Some VOCs are also a problem as a result of their ozone depletion and/or global warming potential.



### 3.4.1 Management system for diffuse VOC emissions

#### Description

The management system for diffuse VOC emissions is a formal system aiming at establishing environmental objectives to prevent or reduce diffuse VOC emissions.

#### Technical description

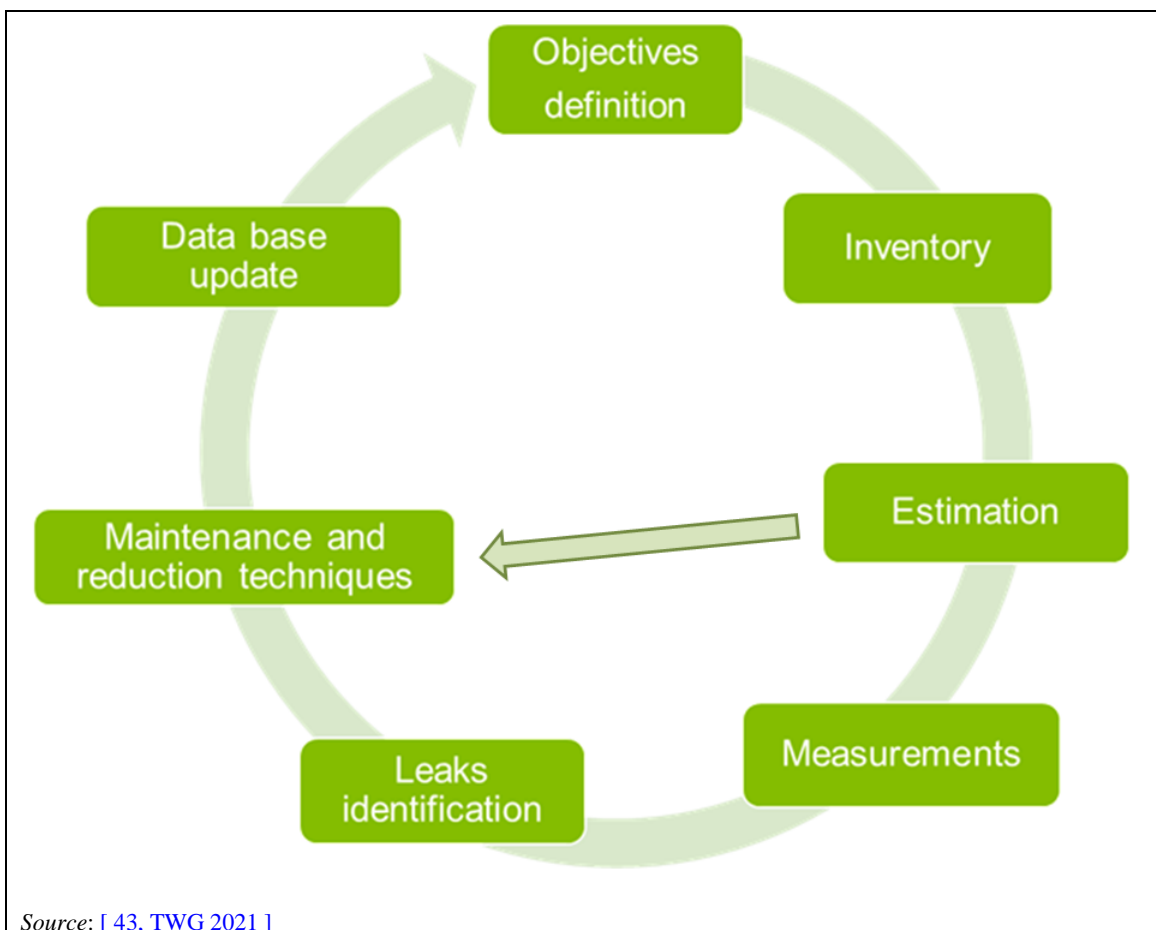
The management system for diffuse VOC emissions is a technique allowing operators of installations to address diffuse VOC emissions in a systematic way as well as to set up a strategy to reduce or prevent them.

The management system for diffuse VOC emissions consists of the following:

- i. Estimating (by calculation) the annual quantity of diffuse VOC emissions.
- ii. Monitoring diffuse VOC emissions from the use of solvents by compiling a solvent mass balance.
- iii. Establishing and implementing a leak detection and repair (LDAR) programme for fugitive VOC emissions. The LDAR programme typically lasts from 1 to 5 years depending on the nature, scale and complexity of the plant (5 years may correspond to large plants with a high number of emission sources).
  - I. The LDAR programme includes all of the following features:
    - a. Listing of equipment identified as relevant fugitive VOC sources in the inventory of diffuse VOC emissions.
    - b. Definition of criteria associated with the following:
      - Leaky equipment. Typical criteria could be a leak threshold, above which equipment is considered leaky, and/or the visualisation of a leak with OGI cameras. This depends on the characteristics of the emission source (e.g. accessibility) and the hazardous properties of the emitted substance(s).
      - Maintenance and repair actions to be carried out ('maintenance threshold'). A typical criterion could be a VOC concentration threshold triggering the maintenance or repair action (maintenance/repair threshold). The maintenance/repair threshold is generally equal to or higher than the leak threshold. This depends on the characteristics of the emission source (e.g. accessibility) and the hazardous properties of the emitted substance(s). For the first LDAR programme, it is generally not higher than 5 000 ppmv for VOCs other than VOCs classified as CMR 1A or 1B, and 1000 ppmv for VOCs classified as CMR 1A or 1B. For subsequent LDAR programmes, the maintenance/repair threshold is lowered (see point vi.a.) and not higher than 1000 ppmv for VOCs other than VOCs classified as CMR 1A or 1B, and 500 ppmv for VOCs classified as CMR 1A or 1B, targeting 100 ppmv.
    - c. Measuring fugitive VOC emissions from equipment listed under point iii.a.
    - d. Carrying out maintenance and/or repair actions, as soon as possible and where necessary according to the criteria defined in point iii.b. Maintenance and/or repair actions are prioritised according to the hazardous properties of the emitted substance(s), the significance of the emissions and/or operational constraints. The effectiveness of the maintenance and/or repair actions is verified according to point iii.c., leaving enough time after the intervention (e.g. 2 months).
    - e. Filling in the database mentioned in point v.
  - iv. Establishing and implementing a detection and reduction programme for non-fugitive VOC emissions that includes all of the following features:
    - a. Listing of equipment identified as relevant non-fugitive VOC emission sources in the inventory of diffuse VOC emissions.
    - b. Monitoring non-fugitive VOC emissions from equipment listed under point a.
    - c. Planning and implementing techniques to reduce non-fugitive VOC emissions. The planning and implementation of techniques are prioritised according to the hazardous properties of the emitted substance(s), the significance of the emissions and/or operational constraints.

- v. Establishing and maintaining a data base for diffuse VOC emission sources that are identified in the inventory of diffuse emissions, for keeping record of:
  - a. equipment design specifications (including date and description of any design changes);
  - b. the equipment maintenance, repair, upgrade, or replacement actions, performed or planned, and their date of implementation;
  - c. the equipment that could not be maintained, repaired, upgraded or replaced due to operational constraints;
  - d. the results of the measurements or monitoring, including the concentration(s) of the emitted substance(s), the calculated leak rate (in kg/year), the recording from OGI cameras (e.g. from the last LDAR programme) and the date of the measurements or monitoring;
  - e. the annual quantity of diffuse VOC emissions (as fugitive and non-fugitive emissions), including information on non-accessible sources and accessible sources not monitored during the year.
- vi. Reviewing and updating the LDAR programme periodically. This may include the following:
  - a. lowering the leak and/or maintenance/repair thresholds (see point iii.b.);
  - b. reviewing the prioritisation of equipment to be monitored, giving higher priority to (the type of) equipment identified as leaky during the previous LDAR programme;
  - c. planning the maintenance, repair, upgrade or replacement of equipment that could not be performed during the previous LDAR programme due to operational constraints.
- vii. Reviewing and updating the detection and reduction programme for non-fugitive VOC emissions. This may include the following:
  - a. monitoring non-fugitive VOC emissions from equipment where maintenance, repair, upgrade or replacement actions were implemented, in order to determine if those actions were successful;
  - b. planning the maintenance, repair, upgrade or replacement actions that could not be performed due to operational constraints.

All effective management system for diffuse VOC emissions incorporate the concept of continuous improvement, meaning that it is an ongoing process, not a project which eventually comes to an end. There are various process designs, but the management system for diffuse VOC emissions is generally based on the plan-do-check-act cycle. The cycle is an iterative dynamic model, where the completion of one cycle flows into the beginning of the next.



**Figure 3.57: Continuous improvement in a management system for diffuse VOC emissions**

A cycle typically lasts from 1 to 5 years. For some plants, the duration of a cycle may be aligned with the plant turnaround cycle, which means that one iteration of the management system for diffuse VOC emissions is established for the time between two consecutive turnarounds of the plant.

#### **Achieved environmental benefits**

Reduction of diffuse VOC emissions.

#### **Environmental performance and operational data**

Plant FR\_29 implemented a management system for diffuse VOC emissions in 1998. For the first LDAR campaign, the thresholds were set to 500 ppmv for the leak threshold and 5 000 ppmv for the maintenance threshold. The maintenance threshold was progressively lowered to 1 000 ppmv in 2005, then 500 ppmv in 2008 and 350 ppmv in 2015 (0 ppmv for CMR substances). Overall, Plant FR\_29 reduced its diffuse VOC emissions by more than 90 % between 1998 and 2018 [42, EIPPCB 2019].

#### **Cross-media effects**

None reported.

#### **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 management system for diffuse VOC emissions 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 management system for diffuse VOC emissions.

### Driving force for implementation

- Environmental legislation.
- Reduction in material losses.
- Minimisation of the environmental impact of diffuse VOC emissions.
- Health and safety for employees.

### Example plants

Plant FR\_29.

### Reference literature

[\[ 42, EIPPCB 2019 \]](#).

## 3.4.2 Monitoring of diffuse VOC emissions

### 3.4.2.1 Estimation by using emission factors

#### Description

Emission factors are numbers that can be multiplied by an activity rate (e.g. the production output, hours of operation) in order to estimate the emissions from the installation or from a piece of equipment. They are applied under the assumption that all industrial units of the same product line have similar emission patterns. These factors are widely used for the estimation of diffuse VOC emissions (fugitive emissions and non-fugitive emissions).

#### Technical description

Emission factors are generally derived through the testing of a population of similar process equipment (e.g. pumps, agitators) or process steps for a specific chemical sector. This information can be used to relate the quantity of material emitted to some general measure of the scale of activity (e.g. for equipment such as pumps, emission factors are generally based on the quantity of VOCs emitted per hour and per source). In the absence of other information, default emission factors (e.g. literature values) can be used to provide an estimate of the emission.

Emission factors require activity rates, which are combined with the emission factor to determine the emission rate. The generic formula is:

$$\text{Emission Rate} = \text{Emission Factor} \times \text{Activity Rate}$$

The emission rate is generally expressed as mass per unit of time, the emission factor as mass per unit of throughput and the activity rate as throughput per unit of time.

Further information is provided in the CWW BREF [\[ 13, COM 2016 \]](#) and the ROM [\[ 16, COM 2018 \]](#).

#### Achieved environmental benefits

Estimation of diffuse VOC emissions in order to derive strategies to tackle and to achieve reductions in diffuse VOC emissions to air.

#### Environmental performance and operational data

The reliability of an emission factor in a given application depends on the quality of the factor, the specific pollutants of interest, and the type of source.

#### Cross-media effects

None reported.

**Technical considerations relevant to applicability**

The technique is generally applicable.

**Economics**

Involvement of personnel.

**Driving force for implementation**

- Reporting requirements imposed by authorities.
- Reduction in material losses.
- Minimisation of the environmental impact of diffuse VOC emissions.

**Example plants**

Emission factors are widely used by plants producing large volumes of organic chemicals and polymers.

**Reference literature**

[ 16, COM 2018 ], [ 7, CONCAWE 2015 ], [ 32, IMPEL 2000 ], [ 38, US EPA 1995 ], [ 40, US EPA 1995 ], [ 39, US EPA 1999 ].

**3.4.2.2 Estimation by using a mass balance****Description**

Mass balances are one basis for understanding the processes on a site and the development of improvement strategies. For a complete mass balance, the inputs must equal the outputs. Table 3.14 shows the typical elements of a mass balance. Not every output path is relevant in every case.

**Table 3.14: Typical elements of a mass balance**

Input	Output
- Withdrawal from stock - Purchases - Production - Recycling/reuse from other processes	- Deposit in stock - Consumption - Destruction - Recycling/reuse in other processes - Losses to air - Losses to water - Losses in finished products - Losses in waste - Disposal

A solvent management plan according to Part 7 of Annex VII to the IED [ 25, EU 2010 ] constitutes an example of a mass balance.

**Achieved environmental benefits**

Mass balances are essential for understanding on-site processes and the development of improvement strategies.

**Environmental performance and operational data**

No information provided.

**Cross-media effects**

None reported.

### **Technical considerations relevant to applicability**

This technique can in some cases provide useful insights into a process. Mass balances are very time-consuming and this is a limitation to their use. Mass balances are generally not sufficiently accurate to quantify emissions from a chemical plant. They allow the estimation of the overall emissions of a chemical site (apart from the uncertainties) but they do not allow the identification of the emission sources. The technique may not apply to the production of polyolefins, PVC or synthetic rubbers.

### **Economics**

Additional measurements are required (hence costs) and, therefore, additional staff are needed.

### **Driving force for implementation**

- Reporting requirements imposed by authorities.
- Reduction in material losses.
- Minimisation of the environmental impact of diffuse VOC emissions.

### **Example plants**

Solvent mass balances are widely used in France, and by plants producing pharmaceuticals.

### **Reference literature**

[ [25, EU 2010](#) ].

### **3.4.2.3 Estimation by thermodynamic models**

#### **Description**

The laws of thermodynamics can be used to estimate diffuse VOC emissions from a type of equipment (e.g. tanks) or a particular step of a production process.

#### **Technical description**

Chemical production processes may significantly vary from one industrial sector to another (e.g. substances used, production volumes, batch or continuous production). However, diffuse VOC emissions will generally arise from the following:

- loading/unloading;
- changes of pressure and/or temperature in storage tanks;
- cleaning operations (e.g. with inert gases);
- evaporation from open surfaces (e.g. waste water treatment plant);
- solvent regeneration;
- final product (e.g. product transfer, packaging);
- other than normal operating conditions (OTNOC, e.g. accidental spillage).

Estimation by thermodynamic models usually uses equations from the main laws of thermodynamics, mainly the ideal gas law and the vapour-liquid equilibrium. These models will generally use the following input data:

- chemical properties of substances used (e.g. vapour pressure, molecular mass);
- process operational data (e.g. operating time, product quantity, ventilation);
- characteristics of the source (e.g. tank diameter, colour, shape).

#### **Achieved environmental benefits**

Estimation of diffuse VOC emissions in order to derive strategies to tackle and to achieve reductions in diffuse VOC emissions to air.

**Environmental performance and operational data**

Assumptions and approximations are generally used to simplify the equations and may lead to overestimation or underestimation of the real quantity of diffuse VOC emissions emitted.

**Cross-media effects**

None reported.

**Technical considerations relevant to applicability**

Thermodynamic models are particularly relevant to estimate emissions from manufacturing, cleaning, loading/unloading, storage and OTNOC.

**Economics**

Involvement of personnel.

**Driving force for implementation**

- Reporting requirements imposed by authorities.
- Reduction in material losses.
- Minimisation of the environmental impact of diffuse VOC emissions.

**Example plants**

[ 50, EIPPCB 2021 ].

**Reference literature**

[ 33, INERIS 2017 ].

**3.4.2.4 Portable VOC analyser****Description**

A VOC analyser is a hand-held device used to measure the concentration of organic compounds at the leak interface of a piece of equipment. A pump within the instrument draws a continuous sample of gas from the leak interface area to the instrument detector.

**Technical description**

Method EN 15446, also referred to as ‘sniffing’

This method, particularly relevant for plants, where large amounts of VOC are handled, in the case of fugitive VOC emissions, identifies leaking components by measuring the concentration of hydrocarbon vapours (in ppm) in the immediate vicinity of the leak with a handheld VOC analyser. The instrument response is a screening value (i.e. a relative measure of concentration level). The screening value is in units of parts per million by volume (ppmv). The screening value does not necessarily indicate the actual total concentration at the leak interface of the compound(s) being detected since the sensitivity of instruments vary depending on the compound. A correction factor, also called response factor, is therefore applied to the screening value. The correction factor relates the actual concentration to the measured concentration of a given compound. The most common types of detectors are the flame ionisation detector (FID) and the photo-ionisation detector (PID). They are usually calibrated with methane (for FID) or isobutene (for PID) to operate between 10 ppmv and 100 000 ppmv. The selection of the most suitable type of detector depends on the nature of the substance to be detected.

**Bagging**

Bagging is another technique using a VOC analyser that can be applied to quantify the mass flow of fugitive VOC emissions. This technique consists of measuring the emission rate of a piece of equipment by isolating the component from ambient air to collect any leaking VOCs. A bag made of material impermeable to the VOC(s) of interest is wrapped around the leak interface of the piece of equipment. The gas contained in the bag is evacuated at a constant measured flow rate and analysed to determine the concentration of leaking VOC(s). The



concentration can be measured directly using VOC analysers or off site in a laboratory. Two methods are generally employed in sampling source enclosures: the vacuum method and the blow-through method. In the vacuum method, a vacuum pump is used to pull air through the bag. In the blow-through method, an inert carrier gas (e.g. nitrogen) is blown into the bag.

However, as bagging is quite a burdensome operation and is not always possible, mathematical correlation curves can be derived from statistical results obtained from a sufficiently large number of previous measurements of both leak concentration and mass flow taken on similar components.



Source: [ 2, Bureau Veritas 2019 ]

**Figure 3.58: Bagging of a leaking valve**

### Flux chamber

The flux chamber technique can be applied to measure non-fugitive VOC emissions from surfaces. This technique is similar to bagging and consists of collecting gaseous emissions from an isolated surface area with an enclosure device (the flux chamber). The gaseous emissions are swept through an exit port where the concentration is measured with a VOC analyser. The emission rate is calculated based on the isolated surface area, the sweep air flow rate, and the gaseous concentration measured. Based on statistical sampling of a defined area, an average emission rate can be calculated and used to estimate the emissions from the total area.





Source: [ 2, Bureau Veritas 2019 ]

**Figure 3.59: Flux chamber**

#### **Achieved environmental benefits**

Measurement of the concentration of diffuse VOC emissions in order to reduce the uncertainties of the estimation (see Sections 3.4.2.1, 3.4.2.2 and 3.4.2.3).

#### **Environmental performance and operational data**

To check each potentially leaky component with a hand-held VOC analyser is time- and cost-intensive as the concentration is measured at every potential leak point. The VOC analyser needs to be within 1-2 cm of the point where a leak may occur. A VOC analyser is able to detect very low concentrations (a few ppmv), depending on the substance to be detected.

The occurrence of false positives (small leak with high concentration) and false negatives (significant leak with low concentration) is sometimes reported. When using sniffing, 100 to 500 components per day can be checked.

Monitoring concentrations by sniffing requires careful preparation (e.g. inventory of all sources to be monitored) and is usually executed in campaigns that cover a specific portion of the plant or a specific type of equipment. Some companies have therefore developed a ‘targeted monitoring’ approach in which additional emphasis is put on components with a higher tendency to leak.

#### **Cross-media effects**

None reported.

#### **Technical considerations relevant to applicability**

This technique is generally applicable. However, some leaking points in a plant might be difficult or impossible to access with the hand-held detectors to obtain a measurement (inaccessible sources, e.g. under insulation). New systems using drones are currently under development and could improve the accessibility of emission sources [ 44, SENSIA 2019 ].

### Economics

A portable VOC analyser costs between EUR 5 000 and EUR 20 000.

### Driving force for implementation

- Reporting requirements imposed by authorities.
- Reduction in material losses.
- Minimisation of the environmental impact of diffuse VOC emissions.

### Example plants

Plants FR\_28 and FR\_29.

### Reference literature

[ 2, Bureau Veritas 2019 ], [ 42, EIPPCB 2019 ], [ 7, CONCAWE 2015 ], [ 44, SENSIA 2019 ].

### 3.4.2.5 Optical gas imaging (OGI)

#### Description

Optical gas imaging uses hand-held and fixed infrared (IR) cameras which enable the visualisation of gas leaks in real time, as they appear as ‘smoke’ on a video recorder together with the image of the component concerned.

#### Technical description

OGI cameras are passive mid-wave infrared cameras equipped with a filter to selectively detect radiation at a specific C-H absorption band (e.g.: 3.2-3.4  $\mu\text{m}$ ; 10-11  $\mu\text{m}$ ). Each existing camera has a specific C-H absorption band and there is no camera capable of detecting all VOCs (e.g. pure 1,3-butadiene cannot be detected with a C-H absorption band of 3.2-3.3  $\mu\text{m}$ : it is possible only with a camera with a C-H absorption band of 10-11  $\mu\text{m}$ ). However, VOCs that can absorb infrared radiation in the spectral range 3.2-3.3  $\mu\text{m}$  include a large number of aliphatic and aromatic compounds. OGI shows the VOC leak as a plume coming from the emitting source, thus facilitating the remote detection of sources otherwise not accessible to the operator. Alternative applications include combining several IR cameras with FTIR (Fourier transform infrared) spectroscopy for remote and autonomous monitoring, detecting and quantifying leaks to map large industrial sites, scanning up to several kilometres away. New systems using drones are currently under development and could improve the accessibility of emission sources [ 44, SENSIA 2019 ].

Depending on the type of OGI camera and the spectral filter methods it may not be possible to directly provide the concentration of the emitted VOC. OGI cameras only allow to detect leaks above the detection limit of the camera (depending on real measurement conditions). OGI cameras give information about leak or no-leak. Knowing the detection limit of the camera may give an indication of the leak rate. Usually, the OGI camera detection limit is between 1 g/h and 10 g/h (under certain measurement conditions, the detection limit may be less than 1 g/h), depending on the VOC to be identified and the surroundings (e.g. the detection accuracy may be reduced if the temperature of the leaking gases and the temperature of the equipment or background are similar). If a leak is not being emitted at a sufficient rate it will not be visible using the imaging equipment.



Leak on vent

The picture on the left is taken with a normal camera. The picture on the right is taken with an OGI camera.

Source: [[2. Bureau Veritas 2019](#)]

**Figure 3.60: Optical gas imaging**

#### **Achieved environmental benefits**

Identification from a distance of leaks above the detection limit (without information about concentration of VOC emitted) is a benefit. OGI is particularly suitable in facilities with a significant number of potential leak points under insulation or that are not easily accessible. OGI is particularly suitable as a complement to sniffing:

- in facilities with a significant number of potential leak points under insulation or that are not easily accessible;
- before a turnaround to quickly detect significant leaks in order to provide the replacement of equipment during the shutdown;
- after a turnaround to quickly detect significant leaks before restarting the installations (the thermal and pressure cycling of equipment or other equipment adjustments for the purpose of shutting down or starting up typically results in an increase in the number of leaking components).

#### **Environmental performance and operational data**

The detection limit of the OGI depends on the nature of the substance(s) to be detected and on real measurement conditions.

Each camera has a specific C-H absorption band and there is no camera capable of detecting all VOCs (e.g. pure 1,3-butadiene cannot be detected with a C-H absorption band of 3.2-3.3  $\mu\text{m}$ ; it is possible only with a camera with a C-H absorption band of 10-11  $\mu\text{m}$ ). However, VOCs that can absorb infrared radiation in the spectral range 3.2-3.3  $\mu\text{m}$  include a large number of aliphatic and aromatic compounds. To compare, a portable VOC analyser like FID (see Section 3.4.2.4) can detect all VOCs.

For aliphatic hydrocarbons and benzene, the limit of detection of a leak typically ranges from 1 g/h to 10 g/h. A team of two people can generally monitor 1 500 to 2 000 components per day. To compare, the limit of detection of a FID is approximately 0.01 g/h (on average) and 500 components per day per surveyor can be monitored. The limit of detection of an OGI camera is a constraint for plants handling highly toxic substances for which very small leaks must be detected.

The use of an infrared camera allows the detection of leaking sources in a qualitative way and is complementary to the use of a portable VOC analyser (see Section 3.4.2.4).

### **Cross-media effects**

None reported.

### **Technical considerations relevant to applicability**

Generally, there are no technical restrictions to the applicability of this technique.

### **Economics**

An OGI camera costs between EUR 70 000 and EUR 100 000.

### **Driving force for implementation**

- Reporting requirements imposed by authorities.
- Reduction in material losses.
- Minimisation of the environmental impact of diffuse VOC emissions.

### **Example plants**

Plants FR\_28, FR\_29.

### **Reference literature**

[ 42, EIPPCB 2019 ], [ 7, CONCAWE 2015 ], [ 44, SENSIA 2019 ].

## **3.4.2.6 Other techniques**

### **Description**

In order to assess the effectiveness of all the techniques applied to prevent/reduce diffuse VOC emissions, three monitoring methods are available for use as described below.

### **Technical description**

#### Differential absorption LIDAR (DIAL) method

The DIAL method operates in the infrared and ultraviolet spectral region using laser sources for the detection and quantification of emissions of specified VOCs. DIAL is a technique which uses pulses of laser light transmitted into the atmosphere to determine the concentration and location of a target gas (in this case VOCs) in the atmosphere. The technique is able to determine the spatial concentration over an area of typically up to 500 m to 800 m with a spatial resolution of approximately 10 m. Combining the concentration with wind information enables the determination of emission rates.

DIAL is typically mounted on a mobile platform and, because it is an active system, it is able to operate under most environmental conditions. It is primarily used to detect and quantify emissions from separate sections of an industrial site, measuring one or more sections at a time, combining these to provide total site emissions. The spatial mapping information enables the location of emissions within measured sections and the discrimination of emissions from other sections of the site. It targets one or two species at a time and is typically not sensitive to emissions which have been dispersed over a long distance. DIAL provides mapping and quantification data from site scale down to individual emission sources.

Typical expanded uncertainty in emission rate: A DIAL measurement consisting of a set of at least 4 DIAL scans targeting individual sources, main equipment and units have an expanded uncertainty between 5 % and 25 % [ 58, EN17628 (CEN/TC 264) 2022 ]

#### Solar occultation flux (SOF) method

The solar occultation flux (SOF) method is used to map and quantify gas emissions from the scale of a site down to individual pieces of the main equipment. It is able to efficiently screen

large sections of the site and identify significant sources. The SOF technique is dependent on direct sunlight. SOF monitors solar radiation over a broad spectral region for the detection and quantification of emissions of the specified VOCs. The SOF technique uses FTIR spectrometry to analyse sunlight passing through the atmosphere and detected from a mobile system. By driving downwind of the VOC sources, and intersecting the plume with the measurement path an integrated concentration profile is obtained. The measurements are generally carried out by measuring around the perimeter of the emission sources, making it possible to subtract the upwind component from the downwind measurement after combining the respective path-integrated concentrations with wind information to determine emission rates.

Typical expanded uncertainty in emission rate: 20 % to 40 % [[58, EN17628 \(CEN/TC 264\) 2022](#)].

#### Tracer correlation

The tracer correlation (TC) method is used for two-dimensional mapping of concentrations and emissions detection on an industrial site and quantification of gas emissions from individual components, main equipment (e.g. tanks) and in some cases sections on a site, if spatially separated. TC relies on the controlled release of a known rate of a tracer gas, for example C<sub>2</sub>H<sub>2</sub> or N<sub>2</sub>O. The concentration of the tracer is measured downwind, usually with a mobile monitor, with simultaneous measurement of the source gas concentration. From the known release rate of the tracer gas (kg/h) and the measured mass concentration (mg/m<sup>3</sup>) in the emission plume of both the tracer gas and the source gas, the emission rate of the source gas can be retrieved. The technique assumes the tracer is subject to the same dispersion and transport in the atmosphere as the source gas emissions. The tracer technique is typically used to quantify emissions from known or suspected sources (source areas), on a source-by-source basis.

Typical expanded uncertainty in emission rate: 20 % to 40 % [[58, EN17628 \(CEN/TC 264\) 2022](#)].

#### **Achieved environmental benefits**

The facilitation of the prevention and reduction of diffuse VOC emissions.

#### **Cross-media effects**

None.

#### **Operational data**

In Belgium, the methods have been used to monitor the emissions in the Port of Antwerp and the Zwijndrecht industrial area. SOF measurements of alkenes were conducted to identify and quantify the largest emission sources in Texas during September 2006 [[56, Mellqvist et al. 2010](#)].

#### **Applicability**

Generally applicable to plants where large amounts of VOCs are handled.

#### **Economics**

No information provided.

#### **Driving force for implementation**

- Reporting requirements imposed by authorities.
- Reduction in material losses.
- Minimisation of the environmental impact of diffuse VOC emissions.

#### **Example plants**

Petrochemical installations and refineries in Sweden.

#### **Reference literature**

[[13, COM 2016](#)], [[29, FluxSense 2010](#)] [[28, FluxSense 2016](#)].



### 3.4.3 Techniques to minimise the uncertainty of the solvent mass balance data

#### 3.4.3.1 Full identification and quantification of the relevant solvent inputs and outputs, including the associated uncertainty

##### Description

This includes:

- identification and documentation of solvent inputs and outputs (e.g. emissions in waste gases, emissions from each diffuse VOC emission sources, solvent output in waste);
- substantiated quantification of each relevant solvent input and output and recording of the methodology used (e.g. measurement, calculation using emission factors, estimation based on operational parameters);
- identification of the main sources of uncertainty of the quantification and implementation of corrective actions to reduce the uncertainty;
- regular update of solvent input and output data.

The characterisation and quantification of the relevant solvent inputs and outputs is done by a person/persons with sufficient expertise in compiling a solvent mass balance, depending on the complexity of the processes, sources of emissions, applied abatement techniques, and other conditions influencing the accuracy.

The analysis of the inaccuracies of the methodology used is followed by a judgment on whether these inaccuracies are acceptable, meaning they have no effect on the decision as to whether the installation complies with its emission limit values or not. If the inaccuracies are not acceptable, more information must be gathered to improve the level of accuracy (e.g. use of emission factors or direct measurement of diffuse VOC emissions rather than subtraction of destroyed or captured emissions from the solvent input).

##### Technical description

The accuracy of the calculated source figures for a mass balance needs to be determined. Typical sources of inaccuracy include the following:

##### Estimation

Inaccuracy is often the result of making estimates instead of using measured values. For example, this could be the case with the solvent content of waste or the quantity of solvent recycled within the plant.

##### Measurement

Inaccuracy also occurs as the result of a single measurement, or a limited number of measurements, being extrapolated and used to determine the annual emissions or annual consumption. For example, this might be the case if the solvent concentration in stack emissions is used to calculate the annual emissions in waste gases.

##### Calculation

Inaccuracy also occurs if two numbers which are more or less equal and accurate in themselves are subtracted one from the other. The small difference between the two figures contains the sum of the possible errors in the original two numbers. The inaccuracy can be of the same order of magnitude as the result of the calculation.

Where the maximum error in any source has no effect on the objective of the mass balance, no further work is necessary to make the estimate more precise. However, if the inaccuracies are too large to meet the objective of the mass balance (e.g. verify compliance with the emission limit values), more information must be gathered to improve the level of accuracy. A quick way

to assess if detailed analysis of emission sources is needed is to start with a worst-case approach, which estimates the highest possible level of diffuse VOC emissions, considering the inaccuracies of measurements and estimations.

The choice of a suitable method is dependent on the type and size of the installation. There are different options to improve the quantification of diffuse VOC emission sources, such as direct measurement. An example is to use a combination of passive samplers and flow characteristics of diffuse VOC emission sources in the case of a closed workspace.

#### **Achieved environmental benefits**

Accurate identification, characterisation and quantification of the relevant solvent inputs and outputs allows better determination and control of diffuse VOC emissions. In this way, it enables the reduction of actual solvent emissions.

#### **Environmental performance and operational data**

No information provided.

#### **Cross-media effects**

None reported.

#### **Technical considerations relevant to applicability**

This technique is generally applicable. The required level of detail of characterisation and quantification depends on the complexity of the installation and the ability to meet the objective of the mass balance (e.g. to verify compliance with emission limit values).

#### **Economics**

Costs are dependent on the level of sampling and analysis required. A good characterisation and quantification of solvent inputs and outputs can enable targeted, efficient abatement of emissions, reducing the risk of costs for over-dimensioning, inefficient resource use, etc.

#### **Driving force for implementation**

- Reporting requirements imposed by authorities.
- Better knowledge of emissions/outputs.
- Assessment of necessary actions.

#### **Example plants**

No information provided.

#### **Reference literature**

No reference literature provided.

### **3.4.3.2 Implementation of a solvent tracking system**

#### **Description**

The solvent tracking system controls both the used and unused quantities of solvents (e.g. by weighing unused quantities returned to storage from the application area).

#### **Technical description**

The factor I1 (quantity of solvents / solvent mixtures purchased which are used in the processes) is used in the mass balance exercise. In practice, it is difficult to establish the volume of solvent used over a reference period, due to the difficulty of having the following:

- A perfect inventory in a business where hundreds of drums are used, sometimes stored and reused. In order to have— as precise as possible — a quantification of quantities used, and depending on the raw material distribution system (e.g. central automated distribution

system or manual delivery using containers), various processes could be used such as: computer-based registration of quantities delivered to the application, weighting of drums returning to storage after use, etc.

- Detailed knowledge of the precise solvent and solids content of the purchased materials. Usually material technical specifications (and/or safety data sheets) provide the dry content by weight as a range and there is no clear relation between dry content by volume and by weight. In addition, methodologies for the indirect estimation of the solvent content (as the difference of the dry content by weight) may suffer from the impact of removal of other volatile by-products of the chemical reactions that occur at such a high temperature and over such a long time. Various standard methods for the determination of non-volatile compounds exist but may not be followed in all cases.

### **Achieved environmental benefits**

Enabling better control of diffuse VOC emissions by more accurate establishment of the solvent mass balance.

### **Environmental performance and operational data**

No information provided.

### **Cross-media effects**

None reported.

### **Technical considerations relevant to applicability**

Generally, there are no technical restrictions to the applicability of this technique.

### **Economics**

Involvement of personnel.

### **Driving force for implementation**

No information provided.

### **Example plants**

No information provided.

### **Reference literature**

[ [55, COM 2020](#) ].

### **3.4.3.3 Monitoring of changes that may influence the uncertainty of the solvent mass balance data**

#### **Description**

Any change that could influence the uncertainty of the solvent mass balance data system is recorded, such as:

- malfunctions of the waste gas treatment system: date and duration are recorded;
- changes that may influence air/gas flow rates, e.g. replacement of fans, motors; the date and type of change are recorded.

#### **Technical description**

As an example, the waste gas treatment system performance can be monitored through pressure and temperature measurements at specific points, namely at the inlet off-gas and downstream waste gas stream. The results should be kept and controlled.

The monitoring system can send automatic alerts in case of detection of any pressure and/or temperature outside predefined levels.



**Achieved environmental benefits**

Improved accuracy of solvent mass balance calculations.

**Environmental performance and operational data**

No information provided.

**Cross-media effects**

None reported.

**Technical considerations relevant to applicability**

Generally, there are no technical restrictions to the applicability of this technique.

**Economics**

Involvement of personnel.

**Driving force for implementation**

No information provided.

**Example plants**

No information provided.

**Reference literature**

No reference literature provided.

### 3.4.4 Leak detection and repair (LDAR) programme and detection and reduction programme for fugitive VOC emissions

**Description**

Diffuse VOC emissions can be reduced by the detection and subsequent repair, replacement or upgrade of identified sources of emissions.

This is achieved by adopting a structured approach, usually risk-based and that includes three fundamental steps:

- identification of the sources of diffuse VOC emissions;
- prioritisation of the maintenance actions depending on the hazardous properties of the substance(s) and/or the significance of the emissions;
- carrying out maintenance actions: repair, replacement or upgrade of identified sources in order to minimise diffuse VOC emissions.

In the case of fugitive VOC emissions, this structured approach is commonly known as ‘leak detection and repair (LDAR) programme’.

**Technical description**

Different methods are available to detect diffuse VOC emissions, and each method has its individual strengths and weaknesses (see Section 3.4.2). It is therefore necessary to decide on the purpose behind a detection or measurement exercise when selecting the method. In some circumstances, methods might need to be combined to fully understand emission levels. For example, large-scale methods may quickly locate the major emission areas but might not be able to identify individual sources of diffuse VOC emissions. To that end, a sniffing campaign may be conducted with OGI campaign in addition for the inaccessible sources and after a turnaround.

Further information is provided in the REF BREF [\[21, COM 2015\]](#) and the CWW BREF [\[13, COM 2016\]](#).

### **Achieved environmental benefits**

The main environmental benefit is the reduction of diffuse VOC emissions.

### **Environmental performance and operational data**

Maintenance operations, and replacement or upgrade of equipment can be better anticipated. The application of a LDAR programme allows more precise tracking of leaking equipment and quicker detection of major leaks.

Some plants reported that the application of a LDAR programme, conducted in several cycles, contributed to the reduction of fugitive VOC emissions by more than 90 %.

### **Cross-media effects**

None reported.

### **Technical considerations relevant to applicability**

Generally, there are no technical restrictions to the applicability of this technique.

### **Economics**

Plant FR\_29 reported a cost of around EUR 60 000 per monitoring cycle using Method EN 15446 and OGI (around 35 000 sources of fugitive VOC emissions).

### **Driving force for implementation**

- Environmental legislation.
- Reduction in material losses.
- Health and safety for employees.

### **Example plants**

Plants FR\_29 and PT\_5.

Complementary to LDAR, some plants such as DE\_335, DE\_336, DE\_337 and PT\_5 reported the use of VCM gas detectors to detect leaks [\[ 50, EIPPCB 2021 \]](#) [\[ 59, EIPPCB 2018 \]](#).

### **Reference literature**

[\[ 21, COM 2015 \]](#), [\[ 7, CONCAWE 2015 \]](#), [\[ 38, US EPA 1995 \]](#), [\[ 40, US EPA 1995 \]](#), [\[ 39, US EPA 1999 \]](#).

## **3.4.5 Techniques to prevent or reduce diffuse VOC emissions to air**

### **Description**

Techniques to reduce diffuse VOC emissions can be considered during both process design and plant design.

#### Process design

Process design conditions (e.g. the process temperature and pressure, the vapour pressure of the process fluid) can influence the level of diffuse VOC emissions. However, they are not chosen independently; they depend on other parameters (e.g. catalyst activity) as well. For example, many process streams in petrochemical plants are 'light' (containing at least 20 % of substances with a vapour pressure greater than 0.3 kPa at 20 °C) and are used at high pressure (1 500-3 000 kPa), conditions which increase the occurrence of diffuse VOC emissions. On the other hand, in some operations with lower operating temperatures and pressures where the fluid vapour pressures are lower, diffuse VOC emissions are relatively lower [\[ 13, COM 2016 \]](#).

#### Plant design

The selection of plant components, and the manner in which they are configured and assembled, can both greatly influence the extent of diffuse VOC emissions. For new plants, there is a significant opportunity during the initial design phase to incorporate a wide range of techniques to reduce diffuse VOC emissions. For existing plants, efforts can be made to incorporate many of these techniques over time as part of a process of continuous improvement.

Techniques to reduce diffuse VOC emissions resulting from process design fall within the scopes of the other chemical BREFs (e.g. CWW BREF, LVOC BREF, POL BREF and OFC BREF).

### **Technical description**

For fugitive VOC emissions, reduction and prevention techniques include the following:

#### ***Limiting or reducing the number of potential emission sources:***

- minimising pipe lengths;
- reducing the number of pipe connectors (e.g. flanges) and valves;
- using welded fittings and connections;
- using compressed air or gravity for material transfer.

#### ***Facilitating access to potentially leaky equipment, in order to ease maintenance activities.***

#### ***Selecting and using high-integrity equipment:***

- Bellow valves or valves with double packing seals or equally effective equipment are especially recommended to handle highly toxic substances. The equivalence can be proven through a type approval verification test that shows the normal functioning in the long term of the sealing system and shows the limited leak rate. The number of valve movements that was the basis for the verification test has to correspond with the number of movements that is expected in practice (e.g. according to ISO 15848).
- Magnetically driven or canned pumps/compressors/agitators, or pumps/compressors/agitators using double seals and a liquid barrier.
- Certified high-quality gaskets (e.g. according to EN 13555) that are tightened according to EN 1591-4 and using the designed gasket stress [[36, Riedl 2017](#)].
- Corrosion-resistant equipment.

#### ***Tightening:***

- intervention such as tightening bolts to eliminate leaks from valve stems or flanges;
- installing tight caps on open ends.

#### ***Replacement of leaky equipment parts:***

- gaskets;
- sealing elements (e.g. tank lids);
- packing material (e.g. valve stem packing material).

For non-fugitive VOC emissions, reduction and prevention techniques include the following:

#### ***Reviewing and updating operating conditions:***

- to reduce openings of vessels and reactors;
- to ensure that all equipment (e.g. gaskets) is selected appropriately for each process application;
- to ensure the airtightness of vessels, pipes and vacuum distillations by regular checking all openings (and where necessary sealing) until the vessel keeps an applied pressure or vacuum;
- to avoid corrosion by appropriate selection of material of construction;
- to prevent corrosion by lining or coating of equipment, by painting pipes to prevent external corrosion and by using corrosion inhibitors of materials in contact with equipment.

### ***Reviewing and updating process design:***

- to optimise the catalyst system, reactor design and physical parameters to minimise the formation of volatile side products (e.g. optimisation of the chemistry for the direct synthesis in the production of silicones to avoid the formation of light hydrocarbons);
- to reduce the use of volatile compounds and to use products with lower vapour pressure and higher odour thresholds, e.g. in the production of OFC substances [\[19, COM 2006\]](#);
- to lower the operating temperature in order to minimise the evaporation of volatile organic compounds;
- to carry out solid/liquid separation (e.g. the liquid is the solvent) in such a way as to minimise VOC emissions, e.g. using centrifuges, keeping the system closed for subsequent operations (e.g. further processing or drying);
- to treat waste water streams which contain (mixtures of) VOCs by stripping, rectification and extraction, or combinations of these techniques, in order to remove the solvents that could contribute to diffuse VOC emissions in further treatment operations (e.g. central waste water treatment plants) and enable their reuse.

### ***Using closed systems:***

- to apply vapour balancing: the technique vapour balancing can be used for fixed-roof tanks, vessels and containers, and where these are fitted with pressure/vacuum relief valves for loading/unloading or pumping from one container to another;
- to minimise emissions during sampling by using closed sampling systems or in-line analysers;
- to enclose (partially or completely) liquid effluent drainage systems and tanks used for liquid effluent storage/treatment;
- to install a maintenance drain-out system to eliminate open discharges from drains.

### ***Minimising emissions from surfaces:***

- to install oil creaming systems on basin surfaces;
- to periodically skim open surfaces (removing floating matter);
- to install anti-evaporation floating elements;
- to install fixed-roof tanks;
- to install floating roof tanks with high-efficiency seals.

### ***Collecting and treating emissions:***

- conveying collectable emissions from leaky equipment (e.g. compressor seals, vents and purge lines) to a waste gas treatment;
- covering sewers, waste water treatment plant, open storage and convey the collected waste gases to a waste gas treatment.

### **Achieved environmental benefits**

Prevention and reduction of diffuse VOC emissions.

### **Environmental performance and operational data**

Diffuse VOC emissions can be estimated during process and plant design using a technique that counts the number of potential emission point sources (flanges, valves, pumps, etc.) and applies standard emission factors relating to the contained fluid. The reliability of an emission factor in a given application depends on the quality of the factor, the specific pollutants of interest, and the type of source.

**Cross-media effects**

The collection and containment of diffuse VOC emissions can lead to explosive limits being reached as a consequence of the build-up of VOCs. This issue is addressed by the ATEX Directives [ 23, EC 1999 ] [ 26, EU 2014 ].

**Technical considerations relevant to applicability**

The techniques to reduce diffuse VOC emissions related to process and plant design are generally applicable to all new chemical production plants. For existing plants, applicability may be limited due to operability constraints and efforts should be made to incorporate these techniques over time as part of the process of continuous improvement.

**Economics**

The cost of techniques to reduce diffuse VOC emissions related to process and plant design depends on each installation. The costs are expected to be lower for new plants. In the long run, the use of high-integrity equipment can reduce maintenance costs and time dedicated to monitoring.

Reduction of diffuse VOC emissions often provides opportunities for raw material savings or avoiding the loss of final products, both of which result in economic benefits.

**Driving force for implementation**

- Environmental legislation.
- Reduction in material losses.
- Health and safety for employees.

**Example plants**

All new chemical plants. Polymer plants (e.g. polyolefins, PVC) [ 50, EIPPCB 2021 ].

**Reference literature**

[ 13, COM 2016 ], [ 23, EC 1999 ], [ 26, EU 2014 ], [ 36, Riedl 2017 ].

### 3.4.6 Vapour balancing

**Description**

Also referred to as back-venting. Vapours of solvents or creosote which are displaced from the receiving tank during filling are collected and returned to the tank or truck from which the liquid is delivered.

**Technical description**

Emissions to air, especially VOCs, are controlled by back-venting displaced air to the delivery tank during filling of tanks (also referred to as vapour balancing). Vapours of solvents or creosote which are displaced from the 'receiving tank' during filling are collected and returned to the tank or truck from which the liquid is delivered ('delivery tank'). Such balancing systems require the receiving and delivery tanks to be of the fixed-roof type to permit vapour collection and transfer.

More details are given in the EFS BREF. [ 14, COM 2006 ].

**Achieved environmental benefits**

Vapour balancing greatly reduces the vapour volumes emitted to atmosphere.

**Environmental performance and operational data**

Where explosive mixtures can occur, safeguards should be implemented to limit the risk of ignition and ignition propagation.

### **Cross-media effects**

None reported.

### **Technical considerations relevant to applicability**

Not all vapours can be collected. This technique may affect loading rates and operational flexibility. Tanks which may contain incompatible vapours cannot be linked. This technique can only be used where the product is pumped out of a fixed-roof tank fitted with pressure/vacuum relief valves.

### **Economics**

No information provided.

### **Driving force for implementation**

Environmental legislation.

### **Example plants**

No information provided.

### **Reference literature**

[\[ 14, COM 2006 \]](#).

## 3.5 Techniques to reduce emissions to air from polymer production

Further information concerning the techniques to reduce emissions from polymer production is provided in the POL BREF [\[18, COM 2007\]](#).

### 3.5.1 Polyolefins

#### 3.5.1.1 Monitoring of volatile organic compounds in polyolefin grades

##### Description

Pellet samples of polyolefin grades are taken at the point of transition from the closed to the open system where the polyolefin comes into contact with the atmosphere to measure residual volatile organic compounds.

##### Technical description

The measurement technique is headspace gas chromatography. EN standards are not available. In this case, the measurement technique needs to take into account the specific volatile organic compounds which are being emitted.

##### Achieved environmental benefit

Monitoring as such has no direct environmental benefit. It is, however, the prerequisite for corrective action.

##### Environmental performance and operational data

Information on monitoring was collected through the plant-specific questionnaires as yearly averages and by site visits and is summarised in Chapter 2 in the sections on contextual information. Statistical models taking into account the polymer grade and the production rate can be used to estimate the emission of volatile organic compounds from non-fugitive emission sources, e.g. from drying and blending as well as the transfer, handling and storage of the polyolefins. Data were provided as yearly averages for polyolefin grades within a reference year.

##### Cross-media effects

Some equipment, ancillary materials and energy are required for the monitoring.

##### Technical considerations relevant to applicability

No information provided.

##### Economics

No information provided.

##### Driving force for implementation

Environmental legislation.

##### Example plants

The technique is widely used in the polyolefins sector.

##### Reference literature

[\[49, CEFIC 2020\]](#) [\[50, EIPPCB 2021\]](#).

### 3.5.1.2 Selection of chemical agents

#### Description

Solvents and suspension agents with low boiling points are used.

#### Technical description

A solvent is needed as the carrier for catalyst or initiator feeds or as the reactor diluent for the solution and slurry suspension processes, while a comonomer is used to control the polymer density of the final product. At the end of the process, the comonomer and the solvent are separated from the final polymer product. Selecting chemical agents with low boiling points will facilitate the separation from the polymer since the more volatile the hydrocarbon solvent and comonomer are, the easier the separation from the polymer will be.

Further information is provided in the POL BREF [\[ 18, COM 2007 \]](#).

#### Achieved environmental benefits

Low-boiling solvents and suspension agents can be removed from the product more easily and with less consumption of energy, leading to a reduction of the VOC emissions from storage.

#### Environmental performance and operational data

Reduction of VOC emissions to air.

#### Cross-media effects

The volatility of the hydrocarbon solvent and comonomer is a key parameter in the separation from the polymer. In principle, the less volatile the hydrocarbon solvent and comonomer are, the more difficult the separation from the polymer will be.

#### Technical considerations relevant to applicability

For some speciality products, such as PP for capacitor films, less volatile diluents are used to guarantee the product quality.

Further information concerning technical considerations relevant to applicability is provided in the POL BREF [\[ 18, COM 2007 \]](#).

#### Economics

No information provided.

#### Driving force for implementation

Environmental legislation.

#### Example plants

No information provided.

#### Reference literature

[\[ 18, COM 2007 \]](#).



### 3.5.1.3 Lowering the VOC content in the polymer

#### Description

The VOC content in the polymer is lowered by using low-pressure separation, stripping or closed-loop nitrogen purge systems. The techniques for lowering the VOC content depend on the type of product and process.

#### Technical description

Depending on the polyethylene process, several ways can be identified to lower the residual VOC content:

- High-pressure polyethylene processes: operation of the low-pressure separator (LPS) vessel at minimum pressure by lowering the pressure drop in the so-called low-pressure recycle section between the LPS and the suction side of the booster compressor, while maintaining a stable polymer feed to the extruder.
- Gas phase and slurry processes (HDPE and LLDPE): application of closed-loop nitrogen purge systems to remove monomers and/or solvents from polymer particles. Removed monomers can be collected and sent to a thermal oxidation unit.
- LLDPE solution process: devolatilisation of polymer at a lower pressure and/or vacuum level.
- HDPE and PP suspension processes: the deactivation and stripping is carried out in a stirred steamer. By subsequent condensation, the stripped monomer is recovered and after purification recycled back into the process.

Further information is provided in the POL BREF [\[18, COM 2007\]](#).

#### Achieved environmental benefits

- Reduction of VOC emissions from product silos.
- Reduction of monomer in the product and reuse of the monomer.

#### Environmental performance and operational data

No information provided.

#### Cross-media effects

None reported.

#### Technical considerations relevant to applicability

No information provided.

#### Economics

No information provided.

#### Driving force for implementation

Environmental legislation.

#### Example plants

[\[50, EIPPCB 2021\]](#).

#### Reference literature

[\[18, COM 2007\]](#).

## 3.5.2 PVC

### 3.5.2.1 Monitoring of VCM in PVC grades

#### Description

Pellet samples of PVC grades are taken at the point of transition from the closed to the open system where the PVC slurry/latex comes into contact with the atmosphere to measure residual VCM.

#### Technical description

The determination of vinyl chloride monomer in homopolymer and copolymer resins of vinyl chloride and compounded materials is carried out with the standard EN ISO 6401. The method is based on sample dissolution and headspace gas chromatography.

#### Achieved environmental benefit

Monitoring as such has no direct environmental benefit. It is, however, the prerequisite for corrective action.

#### Environmental performance and operational data

Information on monitoring was collected through the plant-specific questionnaires and by site visits and is summarised in Chapter 2 in the sections on contextual information. Statistical models taking into account the PVC grade and the production rate can be used to estimate the emission of VCM from non-fugitive emission sources, e.g. from drying and blending of the PVC as well as the transfer, handling and storage of PVC. Data were provided as yearly averages for PVC grades within a reference year.

#### Cross-media effects

Some equipment, ancillary materials and energy are required for the monitoring.

#### Technical considerations relevant to applicability

No information provided.

#### Economics

No information provided.

#### Driving force for implementation

Environmental legislation.

#### Example plants

The technique is widely used in the PVC sector.

#### Reference literature

[\[ 50, EIPPCB 2021 \]](#) [\[ 51, ISO 2008 \]](#).

### 3.5.2.2 Appropriate VCM storage facilities

#### Description

VCM feedstock is, in general, supplied by pipeline from nearby production facilities. Plants need storage facilities for VCM. These tanks must be designed and maintained to prevent leaks and the resulting soil and water pollution. VCM is alternatively stored in:

- refrigerated tanks at atmospheric pressure; or
- pressurised tanks at ambient temperature.

Off-gas only occurs when there is an excess of inert gases (typically nitrogen) introduced, or from vapour return from loading operations. Emissions are prevented by using tanks:

- equipped with refrigerated reflux condensers;
- connected to the VCM recovery system or to appropriate vent treatment equipment.

Further information is provided in the POL BREF [\[18, COM 2007\]](#).

#### **Achieved environmental benefits**

Prevention or reduction of emissions of VCM from storage.

#### **Environmental performance and operational data**

No information provided.

#### **Cross-media effects**

None reported.

#### **Technical considerations relevant to applicability**

Generally applicable to all PVC processes.

#### **Economics**

No information provided.

#### **Driving force for implementation**

Environmental legislation.

#### **Example plants**

Plant PT\_5.

#### **Reference literature**

[\[18, COM 2007\]](#).

### **3.5.2.3 Minimisation of emissions of residual VCM from equipment**

#### **Description**

In the case of batch production, the residual VCM remaining in the reactor is emitted on reactor opening. Such a residual emission can be prevented by reducing the frequency with which the reactor is opened and by degassing and steam-flushing the reactor before opening.

#### **Technical description**

The final emission level is determined by a combination of opening frequency and steam-flushing efficiency. Procedures for effective minimisation of residual VCM from reactors are:

- depressurising the reactor by venting to VCM recovery;
- draining the liquid contents to closed vessels;
- rinsing and cleaning the reactor with water;
- draining this water to the stripping system;
- steaming and/or flushing the reactor with inert gas to remove residual traces of VCM, with transfer of the gases to VCM recovery; the use of an extractor may also be considered.

During the venting operation, particular care needs to be taken to control foaming, and to stop foam from leaving the autoclave. This is carried out by careful control of the speed of valve opening, which is controlled by a computer. During venting, foaming is also limited by the

addition of chemical defoamers. In E-PVC plants, systems must exist to catch and contain any latex leaving the reactor during venting; this latex is either fed to the latex or waste water stripping systems.

Further information is provided in the POL BREF [\[ 18, COM 2007 \]](#).

### **Achieved environmental benefits**

Prevention and/or minimisation of VCM emissions from reactors.

### **Environmental performance and operational data**

No information provided.

### **Cross-media effects**

None reported.

### **Technical considerations relevant to applicability**

Generally applicable.

### **Economics**

No information provided.

### **Driving force for implementation**

- Reduction of VCM emissions to air;
- Health and safety for employees.

### **Example plants**

[\[ 50, EIPPCB 2021 \]](#).

### **Reference literature**

[\[ 18, COM 2007 \]](#).

## **3.5.2.4 Stripping**

### **Description**

A low VCM content in the suspension or latex is obtained during steam stripping by a suitable combination of temperature, pressure and residence time and by maximising the ratio of free latex surface to total latex volume.

### **Technical description**

See Section 12.4.4 of the POL BREF [\[ 18, COM 2007 \]](#).

### **Achieved environmental benefits**

- Removal of VCM from the latex and slurry.
- Prevention of VCM emissions to air during the drying stage.
- Prevention of VCM emissions from the final product.

Further information is provided in the POL BREF [\[ 18, COM 2007 \]](#).

### **Environmental performance and operational data**

No information provided.

### **Cross-media effects**

None reported.

**Technical considerations relevant to applicability**

Generally applicable for all suspension and emulsion PVC-producing processes.

**Economics**

No information provided.

**Driving force for implementation**

- Reduction of VCM emissions to air.
- Health and safety for employees.

**Example plants**

[ 50, EIPPCB 2021 ].

**Reference literature**

[ 18, COM 2007 ].

### 3.5.3 Synthetic rubbers

#### 3.5.3.1 Monitoring of volatile organic compounds in polyolefin grades

**Description**

Pellet samples of synthetic rubber grades are taken at the point of transition from the closed to the open system where the polyolefin comes into contact with the atmosphere to measure residual volatile organic compounds.

**Technical description**

The measurement technique is headspace gas chromatography. No EN standards are available. In this case, the measurement technique needs to take into account the specific volatile organic compounds which are being emitted.

**Achieved environmental benefit**

Monitoring as such has no direct environmental benefit. It is, however, the prerequisite for corrective action.

**Environmental performance and operational data**

Information on monitoring was collected through the plant-specific questionnaires as yearly averages and by site visits and is summarised in Chapter 2 in the sections on contextual information. Statistical models taking into account the polymer grade and the production rate can be used to estimate the emission of volatile organic compounds from non-fugitive emission sources, e.g. from drying and blending as well as the transfer, handling and storage of the polyolefins. Data were provided as yearly averages for synthetic rubber grades within a reference year.

**Cross-media effects**

Some equipment, ancillary materials and energy are required for the monitoring.

**Technical considerations relevant to applicability**

Measurements do not apply to production processes only made up of a closed system.

**Economics**

No information provided.

**Driving force for implementation**

Environmental legislation.

### Example plants

The technique is used in the synthetic rubbers sector.

### Reference literature

[ 52, CEFIC 2020 ].

### 3.5.3.2 Devolatilising extrusion

#### Description

Solvent-devolatilising extrusion is used for rubbers with a high melt index, a high tendency to stick, or which can be easily pelletised. Pelletised products offer the advantage of being easily processed by pneumatic and/or automated solid materials handling systems, since they tend to be free-flowing without effects like bridging in the process equipment.

#### Technical description

The rubber solution is first pre-concentrated from typically 15-30 wt-% to typically 50-85 wt-% using a pre-concentrator. The concentrated rubber solution is then further processed by an extruder, equipped with vents, for eliminating the residual solvent.

At the end of the extruder, the rubber is extruded through a dieplate and pelletised. The pellets are cooled down by means of spray water, or by using underwater pelletisers. In this way, sticking of the pellets is avoided.

Typical residual solvent levels of the rubber pellets are lower than 0.3 wt-%. The solvent vapours coming from the vent domes of the extruder are compressed and condensed. The vent domes operate between almost atmospheric pressure (first vent) down to 60 mbar (last vent).

Further information is provided in the POL BREF [ 18, COM 2007 ].

#### Achieved environmental benefits

Removal of residual solvents in the product and reduction of diffuse VOC emissions.

#### Environmental performance and operational data

No information provided.

#### Cross-media effects

None reported.

#### Technical considerations relevant to applicability

Generally, there are no technical restrictions to the applicability of this technique.

#### Economics

No information provided.

#### Driving force for implementation

Environmental legislation.

### Example plants

[ 52, CEFIC 2020 ].

### Reference literature

[ 18, COM 2007 ].

## 3.5.4 Viscose

### 3.5.4.1 Housing of the spinning lines for viscose production

#### Description

Spinning frames are one of the sources of CS<sub>2</sub> emissions. These emissions can be avoided by housing the spinning lines. The housing has to be equipped with leak-proof sliding windows. To avoid the accumulation of harmful and explosive gases, suction systems are installed in the housing and the waste gases are sent to a recovery facility where CS<sub>2</sub> is recycled.

Further information is provided in the POL BREF [[18, COM 2007](#)].

#### Achieved environmental benefits

Minimisation of CS<sub>2</sub> emissions from spinning.

#### Environmental performance and operational data

No information provided.

#### Cross-media effects

Recovery of CS<sub>2</sub> reduces the amount of fresh chemicals needed in the process.

#### Technical considerations relevant to applicability

Machines for filament yarn production (textile and technical Rayon) have a large number of spinning positions, which produce wet bobbins or dry bobbins. Due to the occurrence of spin breaks, these spinning positions need constant monitoring and maintenance. Thus, the spinning positions need to be accessible for manual interventions. The concentrations of hazardous substances in the machines must not exceed the exposure limits. Therefore, a complete encapsulation of the machine and a higher concentration of CS<sub>2</sub> is not possible.

#### Economics

No information provided.

#### Driving force for implementation

- Environmental legislation.
- Reduction of CS<sub>2</sub> emissions to air.
- Reduction of CS<sub>2</sub> consumption through recycling.

#### Example plants

Plants AT\_8, AT\_10 and AT\_9.

#### Reference literature

[[18, COM 2007](#)].





## 4 BEST AVAILABLE TECHNIQUES (BAT) CONCLUSIONS FOR COMMON WASTE GAS MANAGEMENT AND TREATMENT SYSTEMS IN THE CHEMICAL SECTOR

### Scope

These BAT conclusions concern the following activity specified in Annex I to Directive 2010/75/EU: 4. Chemical industry (i.e. all production processes included in the categories of activities listed in points 4.1 to 4.6 of Annex I, unless specified otherwise).

More specifically, these BAT conclusions focus on emissions to air from the aforementioned activity.

These BAT conclusions do not address the following:

1. Emissions to air from the production of chlorine, hydrogen, and sodium/potassium hydroxide by the electrolysis of brine. This is covered by the BAT conclusions for the Production of Chlor-alkali (CAK).
2. Channelled emissions to air from the production of the following chemicals in continuous processes where the total production capacity of those chemicals exceeds 20 kt/yr:
  - lower olefins using the steam cracking process;
  - formaldehyde;
  - ethylene oxide and ethylene glycols;
  - phenol from cumene;
  - dinitrotoluene from toluene, toluene diamine from dinitrotoluene, toluene diisocyanate from toluene diamine, methylene diphenyl diamine from aniline, methylene diphenyl diisocyanate from methylene diphenyl diamine;
  - ethylene dichloride (EDC) and vinyl chloride monomer (VCM);
  - hydrogen peroxide.

This is covered by the BAT conclusions for the Production of Large Volume Organic Chemicals (LVOC).

However, channelled emissions to air of nitrogen oxides (NO<sub>x</sub>) and carbon monoxide (CO) from thermal treatment of waste gases originating from the aforementioned production processes are included in the scope of these BAT conclusions.

3. Emissions to air from the production of the following inorganic chemicals:
  - ammonia;
  - ammonium nitrate;
  - calcium ammonium nitrate;
  - calcium carbide;
  - calcium chloride;
  - calcium nitrate;
  - carbon black;
  - ferrous chloride;
  - ferrous sulphate (i.e. copperas and related products, such as chloro-sulphates);
  - hydrofluoric acid;

- inorganic phosphates;
- nitric acid;
- nitrogen-, phosphorus- or potassium-based fertilisers (simple or compound fertilisers);
- phosphoric acid;
- precipitated calcium carbonate;
- sodium carbonate (i.e. soda ash);
- sodium chlorate;
- sodium silicate;
- sulphuric acid;
- synthetic amorphous silica;
- titanium dioxide and related products;
- urea;
- urea-ammonium nitrate.

This may be covered by the BAT conclusions for the Production of Large Volume Inorganic Chemicals (LVIC).

4. Emissions to air from steam reforming as well as from the physical purification and reconcentration of spent sulphuric acid, provided that these processes are directly associated with a production process listed under the aforementioned points 2 or 3.
5. Emissions to air from the production of magnesium oxide using the dry process route. This may be covered by the BAT conclusions for the Production of Cement, Lime and Magnesium Oxide (CLM).
6. Emissions to air from the following:
  - Combustion units other than process furnaces/heaters. This may be covered by the BAT conclusions for Large Combustion Plants (LCP), the BAT conclusions for the Refining of Mineral Oil and Gas (REF) and/or by Directive (EU) 2015/2193 of the European Parliament and of the Council<sup>4</sup>.
  - Process furnaces/heaters with a total rated thermal input below 1 MW.
  - Process furnaces/heaters used in lower olefins, ethylene dichloride and/or vinyl chloride monomer production referred to in point 2 above. This is covered by the BAT conclusions for the production of Large Volume Organic Chemicals (LVOC).
7. Emissions to air from waste incineration plants. This may be covered by the BAT conclusions for Waste Incineration (WI).
8. Emissions to air from the storage, transfer and handling of liquids, liquefied gases and solids, where these are not directly associated with the activity specified in Annex I to Directive 2010/75/EU: 4. Chemical industry. This may be covered by the BAT conclusions for Emissions from Storage (EFS).

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<sup>4</sup> 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).

However, emissions to air from the storage, transfer and handling of liquids, liquefied gases and solids are included in the scope of these BAT conclusions provided that these processes are directly associated with the chemical production process specified in the scope of these BAT conclusions.

9. Emissions to air from indirect cooling systems. This may be covered by the BAT conclusions for Industrial Cooling Systems (ICS).

Other BAT conclusions which are complementary for the activities covered by these BAT conclusions include Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (CWW).

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

- Production of Chlor-alkali (CAK);
- Manufacture of Large Volume Inorganic Chemicals – Ammonia, Acids and Fertilisers (LVIC-AAF);
- Manufacture of Large Volume Inorganic Chemicals – Solids and Others Industry (LVIC-S);
- Production of Large Volume Organic Chemicals (LVOC);
- Manufacture of Organic Fine Chemicals (OFC);
- Production of Polymers (POL);
- Production of Speciality Inorganic Chemicals (SIC);
- Refining of Mineral Oil and Gas (REF);
- Economics and Cross-media Effects (ECM);
- Emissions from Storage (EFS);
- Energy Efficiency (ENE);
- Industrial Cooling Systems (ICS);
- Large Combustion Plants (LCP);
- Monitoring of Emissions to Air and Water from IED installations (ROM);
- Waste Incineration (WI);
- Waste Treatment (WT).

These BAT conclusions apply without prejudice to other relevant legislation, e.g. on the registration, evaluation, authorisation and restriction of chemicals (REACH), on classification, labelling and packaging of substances and mixtures (CLP).

## Definitions

For the purposes of these BAT conclusions, the following definitions apply:

<b>General terms</b>	
<b>Term used</b>	<b>Definition</b>
Channelled emissions to air	Emissions of pollutants to air through an emission point such as a stack.
Combustion unit	Any technical apparatus in which fuels are oxidised in order to use the heat thus generated. Combustion units include boilers, engines, turbines and process furnaces/heaters, but do not include thermal or catalytic oxidisers.
Complex inorganic pigments	A stable crystal lattice of different metal cations. The most important host-lattices are rutile, spinel, zircon, and haematite/corundum, but other stable structures exist.
Continuous measurement	Measurement using an automated measuring system permanently installed on site.
Continuous process	A process in which the raw materials are fed continuously into the reactor with the reaction products then fed into connected downstream separation and/or recovery units.
Diffuse emissions	Non-channelled emissions to air. Diffuse emissions include fugitive and non-fugitive emissions.
Emissions to air	Generic term for emissions of pollutants to air including both channelled and diffuse emissions.
Ethanolamines	Collective term for monoethanolamine, diethanolamine and triethanolamine, or mixtures thereof.
Ethylene glycols	Collective term for monoethylene glycol, diethylene glycol and triethylene glycol, or mixtures thereof.
Existing plant	A plant that is not a new plant.
Existing process furnace/heater	A process furnace/heater that is not a new process furnace/heater.
Flue-gas	The exhaust gas exiting a combustion unit.
Fugitive emissions	Non-channelled emissions to air caused by loss of tightness of equipment which is designed or assembled to be tight. Fugitive emissions can arise from: <ul style="list-style-type: none"> <li>• moving equipment, such as agitators, compressors, pumps, valves (manual and automatic);</li> <li>• static equipment, such as flanges and other connections, open-ended lines, sampling points.</li> </ul>
Lower olefins	Collective term for ethylene, propylene, butylene and butadiene, or mixtures thereof.
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 units and associated equipment.
Mass flow	The mass of a given substance or parameter which is emitted over a defined period of time.
New plant	A plant first permitted on 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.
New process furnace/heater	A process furnace/heater in a plant first permitted following the publication of these BAT conclusions or a complete replacement of a process furnace/heater following the publication of these BAT conclusions.
Non-fugitive emissions	Diffuse emissions other than fugitive emissions. Non-fugitive emissions may arise from, for example, atmospheric vents, bulk storage, loading/unloading systems, vessels and tanks (on opening), open gutters, sampling systems, tank venting, waste, sewers and water treatment plants.

NO <sub>x</sub> precursors	Nitrogen-containing compounds (e.g. acrylonitrile, ammonia, nitrous gases, nitrogen-containing organic compounds) in the input to thermal or catalytic oxidation that lead to NO <sub>x</sub> emissions. Elemental nitrogen is not included.
Operational constraint	Limitation or restriction connected, for example, to: <ul style="list-style-type: none"> <li>• substances used (e.g. substances that cannot be substituted, very corrosive substances);</li> <li>• operating conditions (e.g. very high temperature or pressure);</li> <li>• the functioning of the plant;</li> <li>• resource availability (e.g. availability of spare parts when replacing a piece of equipment, availability of qualified manpower);</li> <li>• expected environmental benefits (e.g. giving priority to maintenance, repair or replacement actions with the highest environmental benefit).</li> </ul>
Periodic measurement	Measurement at specified time intervals using manual or automated methods.
Polymer grade	For each type of polymer, there are different product qualities (i.e. grades) which vary in structure and molecular mass, and are optimised for specific applications. In the case of polyolefins, these may vary regarding the use of co-polymers such as EVA. In the case of PVC, they may vary in the average length of the polymer chain and in the porosity of the particles.
Process furnace/heater	Process furnaces or heaters are: <ul style="list-style-type: none"> <li>• combustion units used for the treatment of objects or feed material through direct contact, e.g. in drying processes or chemical reactors; or</li> <li>• combustion units whose radiant and/or conductive heat is transferred to objects or feed material through a solid wall without using an intermediary heat transfer fluid, e.g. furnaces or reactors heating a process stream used in the (petro-) chemical industry.</li> </ul> <p>As a consequence of the application of good energy recovery practices, some of the process furnaces/heaters may have an associated steam/electricity generation system. This is an integral design feature of the process furnace/heater that cannot be considered in isolation.</p>
Process off-gas	The gas leaving a process which is further treated for recovery and/or abatement.
Solvent	Organic solvent as defined in Article 3(46) of Directive 2010/75/EU.
Solvent consumption	Consumption of solvent as defined in Article 57(9) of Directive 2010/75/EU.
Solvent input	The total quantity of organic solvents used as defined in Part 7 of Annex VII to Directive 2010/75/EU.
Solvent mass balance	A mass balance exercise conducted at least on an annual basis according to Part 7 of Annex VII to Directive 2010/75/EU.
Thermal treatment	Treatment of waste gases using thermal or catalytic oxidation.
Total emissions	The sum of channelled and diffuse emissions.
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.

<b>Substances/Parameters</b>	
<b>Term used</b>	<b>Definition</b>
Cl <sub>2</sub>	Elemental chlorine.
CO	Carbon monoxide.
CS <sub>2</sub>	Carbon disulphide.
Dust	Total particulate matter (in air). Unless specified otherwise, dust includes PM <sub>2.5</sub> and PM <sub>10</sub> .
EDC	Ethylene dichloride (1,2-Dichloroethane).
HCl	Hydrogen chloride.
HCN	Hydrogen cyanide.
HF	Hydrogen fluoride.
H <sub>2</sub> S	Hydrogen sulphide.
NH <sub>3</sub>	Ammonia.
Ni	Nickel.
N <sub>2</sub> O	Dinitrogen oxide (also referred to as nitrous oxide).
NO <sub>x</sub>	The sum of nitrogen monoxide (NO) and nitrogen dioxide (NO <sub>2</sub> ), expressed as NO <sub>2</sub> .
Pb	Lead.
PCDD/F	Polychlorinated dibenzo- <i>p</i> -dioxins and -furans.
PM <sub>2.5</sub>	Particulate matter which passes through a size-selective inlet with a 50 % efficiency cut-off at 2.5 µm aerodynamic diameter as defined in Directive 2008/50/EC <sup>(1)</sup> .
PM <sub>10</sub>	Particulate matter which passes through a size-selective inlet with a 50 % efficiency cut-off at 10 µm aerodynamic diameter as defined in Directive 2008/50/EC.
SO <sub>2</sub>	Sulphur dioxide.
SO <sub>x</sub>	The sum of sulphur dioxide (SO <sub>2</sub> ), sulphur trioxide (SO <sub>3</sub> ), and sulphuric acid aerosols, expressed as SO <sub>2</sub> .
TVOC	Total volatile organic carbon, expressed as C.
VCM	Vinyl chloride monomer.
VOC	Volatile organic compound as defined in Article 3(45) of Directive 2010/75/EU.
<sup>(1)</sup> Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe (OJ L 152, 11.6.2008, p. 1).	

## Acronyms

For the purposes of these BAT conclusions, the following acronyms apply:

Acronym	Definition
CLP	Regulation (EC) No 1272/2008 of the European Parliament and of the Council <sup>(1)</sup> on classification, labelling and packaging of substances and mixtures.
CMR	Carcinogenic, mutagenic or toxic for reproduction.
CMR 1A	CMR substance of category 1A as defined in Regulation (EC) No 1272/2008 as amended, i.e. carrying the hazard statements H340, H350, H360.
CMR 1B	CMR substance of category 1B as defined in Regulation (EC) No 1272/2008 as amended, i.e. carrying the hazard statements H340, H350, H360.
CMR 2	CMR substance of category 2 as defined in Regulation (EC) No 1272/2008 as amended, i.e. carrying the hazard statements H341, H351, H361.
DIAL	Differential absorption LIDAR.
EMS	Environmental Management System.
EPS	Expandable polystyrene.
E-PVC	PVC produced by emulsion polymerisation.
EVA	Ethylene-vinyl acetate.
GPPS	General-purpose polystyrene.
HDPE	High-density polyethylene.
HEAF	High-efficiency air filter.
HEPA	High-efficiency particle air.
HIPS	High-impact polystyrene.
IED	Directive 2010/75/EU on industrial emissions.
I-TEQ	International toxic equivalent – derived by using the equivalence factors in Part 2 of Annex VI to Directive 2010/75/EU.
LDAR	Leak detection and repair.
LDPE	Low-density polyethylene.
LIDAR	Light detection and ranging.
LLDPE	Linear low-density polyethylene.
OGI	Optical gas imaging.
OTNOC	Other than normal operating conditions.
PP	Polypropylene.
PVC	Polyvinyl chloride.
REACH	Regulation (EC) No 1907/2006 of the European Parliament and of the Council <sup>(2)</sup> concerning the registration, evaluation, authorisation and restriction of chemicals.
SCR	Selective catalytic reduction.
SNCR	Selective non-catalytic reduction.
SOF	Solar occultation flux.
S-PVC	PVC produced by suspension polymerisation.
ULPA	Ultra-low penetration air.
<p><sup>(1)</sup> 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).</p> <p><sup>(2)</sup> Regulation (EC) No 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).</p>	

## General considerations

### Best Available Techniques

The techniques 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.

Unless otherwise stated, the BAT conclusions are generally applicable.

### Emission levels associated with the best available techniques (BAT-AELs) and indicative emission levels for channelled emissions to air

The BAT-AELs and the indicative emission levels for channelled emissions to air given in these BAT conclusions refer to values of concentration, expressed as mass of emitted substance per volume of waste gas under standard conditions (dry gas at a temperature of 273.15 K, and a pressure of 101.3 kPa) and expressed in the unit mg/Nm<sup>3</sup>, µg/Nm<sup>3</sup> or ng I-TEQ/Nm<sup>3</sup>.

The reference oxygen levels used to express BAT-AELs and indicative emission levels in these BAT conclusions are shown in the table below.

Source of emissions	Reference oxygen level (O <sub>R</sub> )
Process furnace/heater using indirect heating	3 dry vol-%
All other sources	No correction for the oxygen level

For the cases where a reference oxygen level is given, the equation for calculating the emission concentration at the reference oxygen level is:

$$E_R = \frac{21 - O_R}{21 - O_M} \times E_M$$

where:

E<sub>R</sub>: emission concentration at the reference oxygen level O<sub>R</sub>;

O<sub>R</sub>: reference oxygen level in vol-%;

E<sub>M</sub>: measured emission concentration;

O<sub>M</sub>: measured oxygen level in vol-%.

The equation above does not apply if the process furnace(s)/heater(s) use(s) oxygen-enriched air or pure oxygen or when additional air intake for safety reasons brings the oxygen level in the waste gas very close to 21 vol-%. In this case, the emission concentration at the reference oxygen level of 3 dry vol-% is calculated differently.

For averaging periods of BAT-AELs and indicative emission levels 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 <sup>(1)</sup> .
<sup>(1)</sup> 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. For PCDD/F, one sampling period of 6 to 8 hours is used.		

For the purpose of calculating the mass flows in relation to BAT 11 (Table 4.1), BAT 14 (Table 4.3), BAT 18 (Table 4.6), BAT 29 (Table 4.9) and BAT 36 (Table 4.15), where waste gases with similar characteristics, e.g. containing the same (type of) substances/parameters, and discharged through two or more separate stacks could, in the judgement of the competent authority, be discharged through a common stack, these stacks shall be considered as a single stack.

#### **BAT-AELs for diffuse VOC emissions to air**

For diffuse VOC emissions from the use of solvents or the reuse of recovered solvents, the BAT-AELs in these BAT conclusions are given as a percentage of the solvent input, calculated on an annual basis according to Part 7 of Annex VII to Directive 2010/75/EU.

#### **BAT-AELs for total emissions to air for the production of polymers or synthetic rubbers**

##### Production of polyolefins or synthetic rubbers

For total emissions to air of VOCs from the production of polyolefins or synthetic rubbers, the BAT-AELs in these BAT conclusions are given as specific emission loads calculated on an annual basis by dividing the total VOC emissions by a sector-dependent production rate, expressed in the unit g C/kg of product.

##### Production of PVC

For total emissions to air of VCM from the production of PVC, the BAT-AELs in these BAT conclusions are given as specific emission loads calculated on an annual basis by dividing the total VCM emissions by a sector-dependent production rate, expressed in the unit g/kg of product.

For the purpose of calculating specific emission loads, total emissions include the VCM concentration in the PVC.

##### Production of viscose

For the production of viscose, the BAT-AEL in these BAT conclusions is given as a specific emission load calculated on an annual basis by dividing the total S emissions by the production rate of staple fibres or casing, expressed in the unit g S/kg of product.

## 4.1 General BAT conclusions

### 4.1.1 Environmental management systems

**BAT 1.** In order to improve the overall environmental performance, BAT is to elaborate and implement an environmental management system (EMS) that incorporates all of 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;
- iii. development of an environmental policy that includes the continuous improvement of the environmental performance of the installation;
- iv. establishing objectives and performance indicators in relation to significant environmental aspects, including safeguarding compliance with applicable legal requirements;
- 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;
- 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;
- 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;
- 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;
- xx. following and taking into account the development of cleaner techniques.

Specifically for the chemical sector, BAT is also to incorporate the following features in the EMS:

- xxi. an inventory of channelled and diffuse emissions to air (see BAT 2);
- xxii. an OTNOC management plan for emissions to air (see BAT 3);
- xxiii. an integrated waste gas management and treatment strategy for channelled emissions to air (see BAT 4);
- xxiv. a management system for diffuse VOC emissions to air (see BAT 19);
- xxv. a chemicals management system that includes an inventory of the hazardous substances and substances of very high concern used in the process(es); the potential for substitution of the substances that are listed in this inventory, focusing on those substances other than raw materials, is analysed periodically (e.g. annually) in order to identify possible new available and safer alternatives, with no or lower environmental impacts.

#### Note

Regulation (EC) No 1221/2009 of the European Parliament and of the Council<sup>5</sup> establishes the European Union eco-management and audit scheme (EMAS), which is an example of an EMS consistent with this BAT.

#### Applicability

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.

**BAT 2. In order to facilitate the reduction of emissions to air, BAT is to establish, maintain and regularly review (including when a substantial change occurs) an inventory of channelled and diffuse emissions to air, as part of the environmental management system (see BAT 1), that incorporates all of the following features:**

- i. information, as comprehensive as is reasonably possible, about the chemical production process(es), including:
  - a. chemical reaction equations, also showing side products;
  - b. simplified process flow sheets that show the origin of the emissions;
- ii. information, as comprehensive as is reasonably possible, about channelled emissions to air, such as:
  - a. emission point(s);
  - b. average values and variability of flow and temperature;
  - c. average concentration and mass flow values of relevant substances/parameters and their variability (e.g. TVOC, CO, NO<sub>x</sub>, SO<sub>x</sub>, Cl<sub>2</sub>, HCl);
  - d. presence of other substances that may affect the waste gas treatment system(s) or plant safety (e.g. oxygen, nitrogen, water vapour, dust);
  - e. techniques used to prevent and/or reduce channelled emissions to air;
  - f. flammability, lower and higher explosive limits, reactivity;
  - g. monitoring methods (see BAT 8);

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<sup>5</sup> Regulation (EC) No 1221/2009 of the European Parliament and of the Council of 25 November 2009 on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS), repealing Regulation (EC) No 761/2001 and Commission Decisions 2001/681/EC and 2006/193/EC (OJ L 342, 22.12.2009, p. 1).

- h. 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) 1272/2008 on classification, labelling and packaging (CLP).
- iii. information, as comprehensive as is reasonably possible, about diffuse emissions to air, such as:
  - a. identification of the emission source(s);
  - b. characteristics of each emission source (e.g. fugitive or non-fugitive; static or moving; accessibility of the emission source; included in an LDAR programme or not);
  - c. the characteristics of the gas or liquid in contact with the emission source(s), including:
    - 1) physical state;
    - 2) vapour pressure of the substance(s) in the liquid, pressure of the gas;
    - 3) temperature;
    - 4) composition (by weight for liquids or by volume for gases);
    - 5) hazardous properties of the substance(s) or mixtures, including substances or mixtures classified as CMR 1A, CMR 1B or CMR 2;
  - d. techniques used to prevent and/or reduce diffuse emissions to air;
  - e. monitoring (see BAT 20, BAT 21 and BAT 22).

### **Note for diffuse emissions**

The information about diffuse emissions to air is particularly relevant for activities using large amounts of organic substances or mixtures (e.g. production of pharmaceuticals, production of large volumes of organic chemicals or of polymers).

The information about fugitive emissions covers all emission sources in contact with organic substances with a vapour pressure greater than 0.3 kPa at 293.15 K.

Sources of fugitive emissions connected to pipes whose diameter is small (e.g. smaller than 12.7 mm, i.e. 0.5 inch) may be excluded from the inventory.

Equipment operated under subatmospheric pressure may be excluded from the inventory.

### **Applicability**

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.

## **4.1.2 Other than normal operating conditions (OTNOC)**

**BAT 3. In order to reduce the frequency of the occurrence of OTNOC and to reduce emissions to air during OTNOC, BAT is to set up and implement a risk-based OTNOC management plan as part of the environmental management system (see BAT 1) that includes all of the following features:**

- i. identification of potential OTNOC (e.g. failure of equipment critical to the control of channelled emissions to air, or equipment critical to the prevention of accidents or incidents that could lead to emissions to air ('critical equipment')), of their root causes and of their potential consequences;
- ii. appropriate design of critical equipment (e.g. equipment modularity and compartmentalisation, backup systems, techniques to obviate the need to bypass waste gas treatment during start-up and shutdown, high-integrity equipment, etc.);
- iii. set-up and implementation of a preventive maintenance plan for critical equipment (see BAT 1 xii.);

- iv. monitoring (i.e. estimating or, where this is possible, measuring) and recording of emissions and associated circumstances during OTNOC;
- v. periodic assessment of the emissions occurring during OTNOC (e.g. frequency of events, duration, amount of pollutants emitted as recorded in point iv.) 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. regular testing of backup systems.

### 4.1.3 Channelled emissions to air

#### 4.1.3.1 General techniques

**BAT 4.** In order to reduce channelled emissions to air, BAT is to use an integrated waste gas management and treatment strategy that includes, in order of priority, process-integrated recovery and abatement techniques.

##### Description

The integrated waste gas management and treatment strategy is based on the inventory in BAT 2. It takes into account factors such as greenhouse gas emissions and the consumption or reuse of energy, water and materials associated with the use of the different techniques.

**BAT 5.** In order to facilitate the recovery of materials and 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 production units).

Care is taken that the combination of waste gases does not lead to the dilution of emissions.

**BAT 6.** In order to reduce channelled emissions to air, BAT is to ensure that the waste gas treatment systems are appropriately designed (e.g. considering the maximum flow rate and pollutant concentrations), operated within their design ranges, and maintained (through preventive, corrective, regular and unplanned maintenance) so as to ensure optimal availability, effectiveness and efficiency of the equipment.

#### 4.1.3.2 Monitoring

**BAT 7.** BAT is to continuously monitor key process parameters (e.g. waste gas flow and temperature) of waste gas streams being sent to pretreatment and/or final treatment.

**BAT 8. 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.**

Substance/ Parameter <sup>(1)</sup>	Process(es)/ Source(s)	Emission points	Standard(s) <sup>(2)</sup>	Minimum monitoring frequency	Monitoring associated with
Ammonia (NH <sub>3</sub> )	Use of SCR/SNCR	Any stack	EN 21877	Once every 6 months <sup>(3)</sup> <sup>(4)</sup>	BAT 17
	All other processes/sources				BAT 18
Benzene	All processes/sources	Any stack	No EN standard available	Once every 6 months <sup>(3)</sup>	BAT 11
1,3-Butadiene	All processes/sources	Any stack	No EN standard available	Once every 6 months <sup>(3)</sup>	BAT 11
Carbon monoxide (CO)	Thermal treatment	Any stack with a CO mass flow of ≥ 2 kg/h	Generic EN standards <sup>(5)</sup>	Continuous	BAT 16
		Any stack with a CO mass flow of < 2 kg/h	EN 15058	Once every 6 months <sup>(3)</sup> <sup>(4)</sup>	
	Process furnaces/ heaters	Any stack with a CO mass flow of ≥ 2 kg/h	Generic EN standards <sup>(5)</sup>	Continuous <sup>(6)</sup>	BAT 36
		Any stack with a CO mass flow of < 2 kg/h	EN 15058	Once every 6 months <sup>(3)</sup> <sup>(4)</sup>	
	All other processes/sources	Any stack with a CO mass flow of ≥ 2 kg/h	Generic EN standards <sup>(5)</sup>	Continuous	BAT 18
		Any stack with a CO mass flow of < 2 kg/h	EN 15058	Once every year <sup>(3)</sup> <sup>(7)</sup>	
Chloromethane	All processes/sources	Any stack	No EN standard available	Once every 6 months <sup>(3)</sup>	BAT 11
CMR substances other than CMR substances covered elsewhere in this table <sup>(12)</sup>	All other processes/sources	Any stack	No EN standard available	Once every 6 months <sup>(3)</sup>	BAT 11
Dichloromethane	All processes/sources	Any stack	No EN standard available	Once every 6 months <sup>(3)</sup>	BAT 11
Dust	All processes/sources	Any stack with dust mass flow ≥ 3 kg/h	Generic EN standards <sup>(5)</sup> , EN 13284-1 and EN 13284-2	Continuous <sup>(8)</sup>	BAT 14

		Any stack with dust mass flow < 3 kg/h	EN 13284-1	Once every year ( <sup>3</sup> ) ( <sup>7</sup> )	
Elemental chlorine (Cl <sub>2</sub> )	All processes/sources	Any stack	No EN standard available	Once every year ( <sup>3</sup> ) ( <sup>7</sup> )	BAT 18
Ethylene dichloride (EDC)	All processes/sources	Any stack	No EN standard available	Once every 6 months ( <sup>3</sup> )	BAT 11
Ethylene oxide	All processes/sources	Any stack	No EN standard available	Once every 6 months ( <sup>3</sup> )	BAT 11
Formaldehyde	All processes/sources	Any stack	EN standard under development	Once every 6 months ( <sup>3</sup> )	BAT 11
Gaseous chlorides	All processes/sources	Any stack	EN 1911	Once every year ( <sup>3</sup> ) ( <sup>7</sup> )	BAT 18
Gaseous fluorides	All processes/sources	Any stack	No EN standard available	Once every year ( <sup>3</sup> ) ( <sup>7</sup> )	BAT 18
Hydrogen cyanide (HCN)	All processes/sources	Any stack	No EN standard available	Once every year ( <sup>3</sup> ) ( <sup>7</sup> )	BAT 18
Lead and its compounds	All processes/sources	Any stack	EN 14385	Once every 6 months ( <sup>3</sup> ) ( <sup>9</sup> )	BAT 14
Nickel and its compounds	All processes/sources	Any stack	EN 14385	Once every 6 months ( <sup>3</sup> ) ( <sup>9</sup> )	BAT 14
Nitrous oxide (N <sub>2</sub> O)	All processes/sources	Any stack	EN ISO 21258	Once every year ( <sup>3</sup> ) ( <sup>7</sup> )	–
Nitrogen oxides (NO <sub>x</sub> )	Thermal treatment	Any stack with a NO <sub>x</sub> mass flow of ≥ 2.5 kg/h	Generic EN standards ( <sup>5</sup> )	Continuous	BAT 16
		Any stack with a NO <sub>x</sub> mass flow of < 2.5 kg/h	EN 14792	Once every 6 months ( <sup>3</sup> ) ( <sup>4</sup> )	
	Process furnaces/heaters	Any stack with a NO <sub>x</sub> mass flow of ≥ 2.5 kg/h	Generic EN standards ( <sup>5</sup> )	Continuous ( <sup>6</sup> )	BAT 36
		Any stack with a NO <sub>x</sub> mass flow of < 2.5 kg/h	EN 14792	Once every 6 months ( <sup>3</sup> ) ( <sup>4</sup> )	
All other processes/sources	Any stack with a NO <sub>x</sub> mass flow of ≥ 2.5 kg/h	Generic EN standards ( <sup>5</sup> )	Continuous	BAT 18	



		Any stack with a NO <sub>x</sub> mass flow of < 2.5 kg/h	EN 14792	Once every 6 months ( <sup>3</sup> ) ( <sup>4</sup> )		
PCDD/F	Thermal treatment	Any stack	EN 1948-1, EN 1948-2, EN 1948-3	Once every 6 months ( <sup>3</sup> ) ( <sup>9</sup> )	BAT 12	
PM <sub>2.5</sub> and PM <sub>10</sub>	All processes/sources	Any stack	EN ISO 23210	Once every year ( <sup>3</sup> ) ( <sup>7</sup> )	BAT 14	
Propylene oxide	All processes/sources	Any stack	No EN standard available	Once every 6 months ( <sup>3</sup> )	BAT 11	
Sulphur dioxide (SO <sub>2</sub> )	Thermal treatment	Any stack with a SO <sub>2</sub> mass flow of ≥ 2.5 kg/h	Generic EN standards ( <sup>5</sup> )	Continuous	BAT 16	
		Any stack with a SO <sub>2</sub> mass flow of < 2.5 kg/h	EN 14791	Once every 6 months ( <sup>3</sup> ) ( <sup>4</sup> )		
	Process furnaces/heaters	Any stack with a SO <sub>2</sub> mass flow of ≥ 2.5 kg/h	Generic EN standards ( <sup>5</sup> )	Continuous ( <sup>6</sup> )	Once every 6 months ( <sup>3</sup> ) ( <sup>4</sup> )	BAT 18, BAT 36
		Any stack with a SO <sub>2</sub> mass flow of < 2.5 kg/h	EN 14791			
	All other processes/sources	Any stack with a SO <sub>2</sub> mass flow of ≥ 2.5 kg/h	Generic EN standards ( <sup>5</sup> )	Continuous	Once every 6 months ( <sup>3</sup> ) ( <sup>4</sup> )	BAT 18
		Any stack with a SO <sub>2</sub> mass flow of < 2.5 kg/h	EN 14791			
Tetrachloromethane	All processes/sources	Any stack	No EN standard available	Once every 6 months ( <sup>3</sup> )	BAT 11	
Toluene	All processes/sources	Any stack	No EN standard available	Once every 6 months ( <sup>3</sup> )	BAT 11	
Trichloromethane	All processes/sources	Any stack	No EN standard available	Once every 6 months ( <sup>3</sup> )	BAT 11	
Total volatile organic carbon (TVOC)	Production of polyolefins ( <sup>10</sup> )	Any stack with a TVOC mass flow of ≥ 2 kg C/h	Generic EN standards ( <sup>5</sup> )	Continuous	BAT 11, BAT 25	



		Any stack with a TVOC mass flow of < 2 kg C/h	EN 12619	Once every 6 months <sup>(3)</sup> <sup>(4)</sup>	
	Production of synthetic rubbers <sup>(11)</sup>	Any stack with a TVOC mass flow of $\geq 2$ kg C/h	Generic EN standards <sup>(5)</sup>	Continuous	BAT 11, BAT 32
		Any stack with a TVOC mass flow of < 2 kg C/h	EN 12619	Once every 6 months <sup>(3)</sup> <sup>(4)</sup>	
	All other processes/sources	Any stack with a TVOC mass flow of $\geq 2$ kg C/h	Generic EN standards <sup>(5)</sup>	Continuous	BAT 11
		Any stack with a TVOC mass flow of < 2 kg C/h	EN 12619	Once every 6 months <sup>(3)</sup> <sup>(4)</sup>	

(1) The monitoring only applies when the substance/parameter concerned is identified as relevant in the waste gas stream based on the inventory given in BAT 2.

(2) Measurements are carried out according to EN 15259.

(3) To the extent possible, the measurements are carried out at the highest expected emission state under normal operating conditions.

(4) The minimum monitoring frequency may be reduced to once every year or once every 3 years if the emission levels are proven to be sufficiently stable.

(5) Generic EN standards for continuous measurements are EN 14181, EN 15267-1, EN 15267-2 and EN 15267-3.

(6) In the case of process furnaces/heaters with a total rated thermal input of less than 100 MW operated less than 500 hours per year, the minimum monitoring frequency may be reduced to once every year.

(7) The minimum monitoring frequency may be reduced to once every 3 years if the emission levels are proven to be sufficiently stable.

(8) The minimum monitoring frequency may be reduced to once every 6 months if the emission levels are proven to be sufficiently stable.

(9) The minimum monitoring frequency may be reduced to once every year if the emission levels are proven to be sufficiently stable.

(10) In the case of the production of polyolefins, the monitoring of TVOC emissions from finishing steps (e.g. drying, blending) and from polymer storage may be complemented by the monitoring in BAT 24 if it provides a better representation of the TVOC emissions.

(11) In the case of the production of synthetic rubbers, the monitoring of TVOC emissions from finishing steps (e.g. extrusion, drying, blending) and from synthetic rubber storage may be complemented by the monitoring in BAT 31 if it provides a better representation of the TVOC emissions.

(12) i.e. other than benzene, 1,3-butadiene, chloromethane, dichloromethane, ethylene dichloride, ethylene oxide, formaldehyde, propylene oxide, tetrachloromethane, toluene, trichloromethane.

#### 4.1.3.3 Organic compounds

**BAT 9. In order to increase resource efficiency and to reduce the mass flow of organic compounds sent to the final waste gas treatment, BAT is to recover organic compounds from process off-gases by using one or a combination of the techniques given below and to reuse them.**

Technique		Description
a.	Absorption (regenerative)	See Section 4.4.1.
b.	Adsorption (regenerative)	See Section 4.4.1.
c.	Condensation	See Section 4.4.1.

**Applicability**

Recovery may be restricted where the energy demand is excessive due to the low concentration of the compound(s) concerned in the process off-gas(es). Reuse may be restricted due to product quality specifications.

**BAT 10. In order to increase energy efficiency and to reduce the mass flow of organic compounds sent to the final waste gas treatment, BAT is to send process off-gases with a sufficient calorific value to a combustion unit that is, if technically possible, combined with heat recovery. BAT 9 has priority over sending process off-gases to a combustion unit.**

**Description**

Process off-gases with a high calorific value are burnt as a fuel in a combustion unit (gas engine, boiler, process heater or furnace) and the heat is recovered as steam or for electricity generation, or to provide heat to the process.

For process off-gases with low VOC concentrations (e.g.  $< 1 \text{ g/Nm}^3$ ), pre-concentration steps may be applied using adsorption (rotor or fixed bed, with activated carbon or zeolites), in order to increase the calorific value of the process off-gases.

Molecular sieves ('smoothers'), typically composed of zeolites, may be used to level down high variations (e.g. concentration peaks) of VOC concentrations in the process off-gases.

**Applicability**

Sending process off-gases to a combustion unit may be restricted due to the presence of contaminants or due to safety considerations.

**BAT 11. In order to reduce channelled emissions to air of organic compounds, BAT is to use one or a combination of the techniques given below.**

Technique		Description	Applicability
a.	Adsorption	See Section 4.4.1.	Generally applicable.
b.	Absorption	See Section 4.4.1.	Generally applicable.
c.	Catalytic oxidation	See Section 4.4.1.	Applicability may be restricted by the presence of catalyst poisons in the waste gases.
d.	Condensation	See Section 4.4.1.	Generally applicable.
e.	Thermal oxidation	See Section 4.4.1.	Applicability of recuperative and regenerative thermal oxidation to existing plants may be restricted by design and/or operational constraints. 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.
f.	Bioprocesses	See Section 4.4.1.	Only applicable to the treatment of biodegradable compounds.

**Table 4.1: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of organic compounds**

Substance/Parameter	BAT-AEL (mg/Nm <sup>3</sup> ) (Daily average or average over the sampling period) <sup>(1)</sup>
Total volatile organic carbon (TVOC)	< 1-20 <sup>(2)</sup> <sup>(3)</sup> <sup>(4)</sup> <sup>(5)</sup>
Sum of VOCs classified as CMR 1A or 1B	< 1-5 <sup>(6)</sup>
Sum of VOCs classified as CMR 2	< 1-10 <sup>(7)</sup>
Benzene	< 0.5-1 <sup>(8)</sup>
1,3-Butadiene	< 0.5-1 <sup>(8)</sup>
Ethylene dichloride	< 0.5-1 <sup>(8)</sup>
Ethylene oxide	< 0.5-1 <sup>(8)</sup>
Propylene oxide	< 0.5-1 <sup>(8)</sup>
Formaldehyde	1-5 <sup>(8)</sup>
Chloromethane	< 0.5-1 <sup>(9)</sup> <sup>(10)</sup>
Dichloromethane	< 0.5-1 <sup>(9)</sup> <sup>(10)</sup>
Tetrachloromethane	< 0.5-1 <sup>(9)</sup> <sup>(10)</sup>
Toluene	< 0.5-1 <sup>(9)</sup> <sup>(11)</sup>
Trichloromethane	< 0.5-1 <sup>(9)</sup> <sup>(10)</sup>
<p><sup>(1)</sup> For activities listed under points 8 and 10, Part 1 of Annex VII of the IED, the BAT-AEL ranges apply to the extent that they lead to lower emission levels than the emission limit values in part 2 and 4 of Annex VII to the IED.</p> <p><sup>(2)</sup> TVOC is expressed in mg C/Nm<sup>3</sup>.</p> <p><sup>(3)</sup> In the case of polymer production, the BAT-AEL may not apply to emissions from the finishing steps (e.g. extrusion, drying, blending) and from polymer storage.</p> <p><sup>(4)</sup> The BAT-AEL does not apply to minor emissions (i.e. when the TVOC mass flow is below e.g. 100 g C/h) if no CMR substances are identified as relevant in the waste gas stream based on the inventory given in BAT 2.</p> <p><sup>(5)</sup> The upper end of the BAT-AEL range may be higher and up to 30 mg C/Nm<sup>3</sup> when using techniques to recover materials (e.g. solvents, see BAT 9), if both of the following conditions are fulfilled:</p> <ul style="list-style-type: none"> <li>• the presence of substances classified as CMR 1A/1B or CMR 2 is identified as not relevant (see BAT 2);</li> <li>• the TVOC abatement efficiency of the waste gas treatment system is <math>\geq 95\%</math>.</li> </ul> <p><sup>(6)</sup> The BAT-AEL does not apply to minor emissions (i.e. when the mass flow of the sum of the VOCs classified as CMR 1A or 1B is below e.g. 1 g/h).</p> <p><sup>(7)</sup> The BAT-AEL does not apply to minor emissions (i.e. when the mass flow of the sum of the VOCs classified as CMR 2 is below e.g. 50 g/h).</p> <p><sup>(8)</sup> The BAT-AEL does not apply to minor emissions (i.e. when the mass flow of the substance concerned is below e.g. 1 g/h).</p> <p><sup>(9)</sup> The BAT-AEL does not apply to minor emissions (i.e. when the mass flow of the substance concerned is below e.g. 50 g/h).</p> <p><sup>(10)</sup> The upper end of the BAT-AEL range may be higher and up to 15 mg/Nm<sup>3</sup> when using techniques to recover materials (e.g. solvents, see BAT 9), if the abatement efficiency of the waste gas treatment system is <math>\geq 95\%</math>.</p> <p><sup>(11)</sup> The upper end of the BAT-AEL range may be higher and up to 20 mg/Nm<sup>3</sup> when using techniques to recover toluene (see BAT 9), if the abatement efficiency of the waste gas treatment system is <math>\geq 95\%</math>.</p>	

The associated monitoring is given in BAT 8.

**BAT 12.** In order to reduce channelled emissions to air of PCDD/F from thermal treatment of waste gases containing chlorine and/or chlorinated compounds, BAT is to use techniques a. and b., and one or a combination of techniques c. to e., given below.

Technique	Description	Applicability	
<i>Specific techniques to reduce PCDD/F emissions</i>			
a.	Optimised catalytic or thermal oxidation	See Section 4.4.1.	Generally applicable.
b.	Rapid waste-gas cooling	Rapid cooling of waste gases from temperatures above 400 °C to below 250 °C to prevent the <i>de novo</i> synthesis of PCDD/F.	Generally applicable.
c.	Adsorption using activated carbon	See Section 4.4.1.	Generally applicable.
d.	Absorption	See Section 4.4.1.	Generally applicable.
<i>Other techniques not primarily used to reduce PCDD/F emissions</i>			
e.	Selective catalytic reduction (SCR)	See Section 4.4.1. When SCR is used for NO <sub>x</sub> abatement, an adequate catalyst surface of the SCR system also provides for the partial reduction of the emissions of PCDD/F.	Applicability to existing plants may be restricted by space availability and/or by the presence of catalyst poisons in the waste gases.

**Table 4.2:** BAT-associated emission level (BAT-AEL) for channelled emissions to air of PCDD/F from thermal treatment of waste gases containing chlorine and/or chlorinated compounds

Substance/Parameter	BAT-AEL (ng I-TEQ/Nm <sup>3</sup> ) (Average over the sampling period)
PCDD/F	< 0.01-0.05

The associated monitoring is given in BAT 8.

#### 4.1.3.4 Dust (including PM<sub>10</sub> and PM<sub>2.5</sub>) and particulate-bound metals

**BAT 13.** In order to increase resource efficiency and to reduce the mass flow of dust and particulate-bound metals sent to the final waste gas treatment, BAT is to recover materials from process off-gases by using one or a combination of the techniques given below and to reuse them.

Technique		Description
a.	Cyclone	See Section 4.4.1.
b.	Fabric filter	See Section 4.4.1.
c.	Absorption	See Section 4.4.1.

#### Applicability

Recovery may be restricted where the energy demand for dust purification or decontamination is excessive. Reuse may be restricted due to product quality specifications.

**BAT 14.** In order to reduce channelled emissions to air of dust and particulate-bound metals, BAT is to use one or a combination of the techniques given below.

Technique		Description	Applicability
a.	Absolute filter	See Section 4.4.1.	Applicability may be limited in the case of sticky dust or when the temperature of the waste gases is below the dew point.
b.	Absorption	See Section 4.4.1.	Generally applicable.
c.	Fabric filter	See Section 4.4.1.	Applicability may be limited in the case of sticky dust or when the temperature of the waste gases is below the dew point.
d.	High-efficiency air filter	See Section 4.4.1.	Generally applicable.
e.	Cyclone	See Section 4.4.1.	Generally applicable.
f.	Electrostatic precipitator	See Section 4.4.1.	Generally applicable.

**Table 4.3: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of dust, lead and nickel**

Substance/Parameter	BAT-AEL (mg/Nm <sup>3</sup> ) (Daily average or average over the sampling period)
Dust	< 1-5 <sup>(1)</sup> <sup>(2)</sup> <sup>(3)</sup> <sup>(4)</sup>
Lead and its compounds, expressed as Pb	< 0.01-0.1 <sup>(5)</sup>
Nickel and its compounds, expressed as Ni	< 0.02-0.1 <sup>(6)</sup>

(<sup>1</sup>) The upper end of the range is 20 mg/Nm<sup>3</sup> when neither an absolute nor a fabric filter is applicable.  
(<sup>2</sup>) The BAT-AEL does not apply to minor emissions (i.e. when the dust mass flow is below e.g. 50 g/h) if no CMR substances are identified as relevant in the dust based on the inventory given in BAT 2.  
(<sup>3</sup>) In the case of the production of complex inorganic pigments using direct heating, and in the case of the drying step in the production of E-PVC, the upper end of the BAT-AEL range may be higher and up to 10 mg/Nm<sup>3</sup>.  
(<sup>4</sup>) Dust emissions are expected to be towards the lower end of the BAT-AEL range (e.g. below 2.5 mg/Nm<sup>3</sup>) when the presence of substances classified as CMR 1A or 1B, or CMR 2 in the dust is identified as relevant (see BAT 2).  
(<sup>5</sup>) The BAT-AEL does not apply to minor emissions (i.e. when the lead mass flow is below e.g. 0.1 g/h).  
(<sup>6</sup>) The BAT-AEL does not apply to minor emissions (i.e. when the Ni mass flow is below e.g. 0.15 g/h).

The associated monitoring is given in BAT 8.

#### 4.1.3.5 Inorganic compounds

**BAT 15. In order to increase resource efficiency and to reduce the mass flow of inorganic compounds sent to the final waste gas treatment, BAT is to recover inorganic compounds from process off-gases by using absorption and to reuse them.**

##### Description

See Section 4.4.1.

##### Applicability

Recovery may be restricted where the energy demand is excessive due to the low concentration of the compound(s) concerned in the process off-gas(es). Reuse may be restricted due to product quality specifications.

**BAT 16.** In order to reduce channelled emissions to air of CO, NO<sub>x</sub> and SO<sub>x</sub> from thermal treatment, BAT is to use technique c. and one or a combination of the other techniques given below.

Technique		Description	Main inorganic compounds targeted	Applicability
a.	Choice of fuel	See Section 4.4.1.	NO <sub>x</sub> , SO <sub>x</sub>	Generally applicable.
b.	Low-NO <sub>x</sub> burner	See Section 4.4.1.	NO <sub>x</sub>	Applicability to existing plants may be restricted by design and/or operational constraints.
c.	Optimisation of catalytic or thermal oxidation	See Section 4.4.1.	CO, NO <sub>x</sub>	Generally applicable.
d.	Removal of high levels of NO <sub>x</sub> precursors	Remove (if possible, for reuse) high levels of NO <sub>x</sub> precursors prior to thermal or catalytic oxidation, e.g. by absorption, adsorption or condensation.	NO <sub>x</sub>	Generally applicable.
e.	Absorption	See Section 4.4.1.	SO <sub>x</sub>	Generally applicable.
f.	Selective catalytic reduction (SCR)	See Section 4.4.1.	NO <sub>x</sub>	Applicability to existing plants may be restricted by space availability.
g.	Selective non-catalytic reduction (SNCR)	See Section 4.4.1.	NO <sub>x</sub>	Applicability to existing plants may be restricted by the residence time needed for the reaction.

**Table 4.4:** BAT-associated emission levels (BAT-AELs) for channelled emissions to air of NO<sub>x</sub> and indicative emission level for channelled emissions to air of CO from thermal treatment

Substance/Parameter	BAT-AEL (mg/Nm <sup>3</sup> ) (Daily average or average over the sampling period)
Nitrogen oxides (NO <sub>x</sub> ) from catalytic oxidation	5-30 <sup>(1)</sup>
Nitrogen oxides (NO <sub>x</sub> ) from thermal oxidation	5-130 <sup>(2)</sup>
Carbon monoxide (CO)	No BAT-AEL <sup>(3)</sup>

<sup>(1)</sup> The upper end of the BAT-AEL range may be higher and up to 80 mg/Nm<sup>3</sup> if the process off-gas(es) contain(s) high levels of NO<sub>x</sub> precursors.  
<sup>(2)</sup> The upper end of the BAT-AEL range may be higher and up to 200 mg/Nm<sup>3</sup> if the process off-gas(es) contain(s) high levels of NO<sub>x</sub> precursors.  
<sup>(3)</sup> As an indication, the emission levels for carbon monoxide are 4-50 mg/Nm<sup>3</sup>, as a daily average or average over the sampling period.

The associated monitoring is given in BAT 8.

The BAT-AEL for channelled emissions to air of SO<sub>2</sub> is given in Table 4.6.

**BAT 17.** In order to reduce channelled emissions to air of ammonia from the use of selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) for the abatement of NO<sub>x</sub> emissions (ammonia slip), BAT is to optimise the design and/or operation of SCR or SNCR (e.g. optimised reagent to NO<sub>x</sub> ratio, homogeneous reagent distribution and optimum size of the reagent drops).

**Table 4.5:** BAT-associated emission level (BAT-AEL) for channelled emissions to air of ammonia from the use of SCR or SNCR (ammonia slip)

Substance/Parameter	BAT-AEL (mg/Nm <sup>3</sup> ) (Average over the sampling period)
Ammonia (NH <sub>3</sub> ) from SCR/SNCR	< 0.5-8 <sup>(1)</sup>
<sup>(1)</sup> The upper end of the BAT-AEL range may be higher and up to 40 mg/Nm <sup>3</sup> in the case of process off-gases containing very high levels of NO <sub>x</sub> (e.g. above 5 000 mg/Nm <sup>3</sup> ) prior to treatment with SCR or SNCR.	

The associated monitoring is given in BAT 8.



**BAT 18.** In order to reduce channelled emissions to air of inorganic compounds other than channelled emissions to air of ammonia from the use of selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) for the abatement of NO<sub>x</sub> emissions), channelled emissions to air of CO, NO<sub>x</sub> and SO<sub>x</sub> from the use of thermal treatment, and channelled emissions to air of NO<sub>x</sub> from process furnaces/heaters, BAT is to use one or a combination of the techniques given below.

Technique	Description	Main inorganic compounds targeted	Applicability	
<i>Specific techniques to reduce emissions to air of inorganic compounds</i>				
a.	Absorption	See Section 4.4.1.	Cl <sub>2</sub> , HCl, HCN, HF, NH <sub>3</sub> , NO <sub>x</sub> , SO <sub>x</sub>	Generally applicable.
b.	Adsorption	See Section 4.4.1. For the removal of inorganic substances, the technique is often used in combination with a dust abatement technique (see BAT 14).	HCl, HF, NH <sub>3</sub> , SO <sub>x</sub>	Generally applicable.
c.	Selective catalytic reduction (SCR)	See Section 4.4.1.	NO <sub>x</sub>	Applicability to existing plants may be restricted by space availability.
d.	Selective non-catalytic reduction (SNCR)	See Section 4.4.1.	NO <sub>x</sub>	Applicability to existing plants may be restricted by the residence time needed for the reaction.
<i>Other techniques not primarily used to reduce emissions to air of inorganic compounds</i>				
e.	Catalytic oxidation	See Section 4.4.1.	NH <sub>3</sub>	Applicability may be restricted by the presence of catalyst poisons in the waste gases.
f.	Thermal oxidation	See Section 4.4.1.	NH <sub>3</sub> , HCN	Applicability of recuperative and regenerative thermal oxidation to existing plants may be restricted by design and/or operational constraints. The 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.

**Table 4.6: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of inorganic compounds**

Substance/Parameter	BAT-AEL (mg/Nm <sup>3</sup> ) (Daily average or average over the sampling period)
Ammonia (NH <sub>3</sub> )	2-10 <sup>(1)</sup> <sup>(2)</sup> <sup>(3)</sup>
Elemental chlorine (Cl <sub>2</sub> )	< 0.5-2 <sup>(4)</sup> <sup>(5)</sup>
Gaseous fluorides, expressed as HF	≤ 1 <sup>(4)</sup>
Hydrogen cyanide (HCN)	< 0.1-1 <sup>(4)</sup>
Gaseous chlorides, expressed as HCl	1-10 <sup>(6)</sup>
Nitrogen oxides (NO <sub>x</sub> )	10-150 <sup>(7)</sup> <sup>(8)</sup> <sup>(9)</sup> <sup>(10)</sup>
Sulphur oxides (SO <sub>2</sub> )	< 3-150 <sup>(11)</sup> <sup>(9)</sup>

<sup>(1)</sup> The BAT-AEL does not apply to channelled emissions to air of ammonia from the use of SCR or SNCR (ammonia slip). This is covered by BAT 17.

<sup>(2)</sup> The BAT-AEL does not apply to minor emissions (i.e. when the NH<sub>3</sub> mass flow is below e.g. 50 g/h).

<sup>(3)</sup> In the case of the drying step in the production of E-PVC, the upper end of the BAT-AEL range may be higher and up to 20 mg/Nm<sup>3</sup>, when the substitution of ammonium salts is not possible due to product quality specifications.

<sup>(4)</sup> The BAT-AEL does not apply to minor emissions (i.e. when the mass flow of the substance concerned is below e.g. 5 g/h).

<sup>(5)</sup> In the case of NO<sub>x</sub> concentrations above 100 mg/Nm<sup>3</sup>, the upper end of the BAT-AEL range may be higher and up to 3 mg/Nm<sup>3</sup> due to analytical interference

<sup>(6)</sup> The BAT-AEL does not apply to minor emissions (i.e. when the HCl mass flow is below e.g. 30 g/h).

<sup>(7)</sup> In the case of the production of explosives, the upper end of the BAT-AEL range may be higher and up to 220 mg/Nm<sup>3</sup> when regenerating or recovering nitric acid from the production process.

<sup>(8)</sup> The BAT-AEL does not apply to channelled emissions to air of NO<sub>x</sub> from the use of catalytic or thermal oxidation (see BAT 16) or from process furnaces/heaters (see BAT 36).

<sup>(9)</sup> The BAT-AEL does not apply to minor emissions (i.e. when the mass flow of the substance concerned is below e.g. 500 g/h).

<sup>(10)</sup> In the case of the production of caprolactam, the upper end of the BAT-AEL range may be higher and up to 200 mg/Nm<sup>3</sup> in the case of process off-gases containing very high levels of NO<sub>x</sub> (e.g. above 10 000 mg/Nm<sup>3</sup>) prior to treatment with SCR or SNCR, when the abatement efficiency of the SCR or SNCR is ≥ 99 %.

<sup>(11)</sup> The BAT-AEL does not apply in the case of physical purification or reconcentration of spent sulphuric acid.

The associated monitoring is given in BAT 8.

#### 4.1.4 Diffuse VOC emissions to air

##### 4.1.4.1 Management system for diffuse VOC emissions

**BAT 19.** In order to prevent or, where that is not practicable, to reduce diffuse VOC emissions to air, BAT is to elaborate and implement a management system for diffuse VOC emissions, as part of the environmental management system (see BAT 1), that includes all of the following features:

- i. Estimating the annual quantity of diffuse VOC emissions (see BAT 20).
- ii. Monitoring diffuse VOC emissions from the use of solvents by compiling a solvent mass balance, if applicable (see BAT 21).
- iii. Establishing and implementing a leak detection and repair (LDAR) programme for fugitive VOC emissions. The LDAR programme typically lasts from 1 to 5 years depending on the nature, scale and complexity of the plant (5 years may correspond to large plants with a high number of emission sources).

The LDAR programme includes all of the following features:

- a. Listing of equipment identified as relevant fugitive VOC emission sources in the inventory of diffuse VOC emissions (see BAT 2).
- b. Definition of criteria associated with the following:
  - o Leaky equipment. Typical criteria could be a leak threshold, above which equipment is considered leaky, and/or the visualisation of a leak with OGI cameras. This depends on the characteristics of the emission source (e.g. accessibility) and the hazardous properties of the emitted substance(s).
  - o Maintenance and/or repair actions to be carried out. A typical criterion could be a VOC concentration threshold triggering the maintenance or repair action (maintenance/repair threshold). The maintenance/repair threshold is generally equal to or higher than the leak threshold. This depends on the characteristics of the emission source (e.g. accessibility) and the hazardous properties of the emitted substance(s). For the first LDAR programme, it is generally not higher than 5 000 ppmv for VOCs other than VOCs classified as CMR 1A or 1B, and 1 000 ppmv for VOCs classified as CMR 1A or 1B. For subsequent LDAR programmes, the maintenance/repair threshold is lowered (see point vi. a.) and not higher than 1 000 ppmv for VOCs other than VOCs classified as CMR 1A or 1B, and 500 ppmv for VOCs classified as CMR 1A or 1B, targeting 100 ppmv.
- c. Measuring fugitive VOC emissions from equipment listed under point iii. a. (see BAT 22).
- d. Carrying out maintenance and/or repair actions (see BAT 23, techniques e. and f.), as soon as possible and where necessary according to the criteria defined in point iii. b. Maintenance and repair actions are prioritised according to the hazardous properties of the emitted substance(s), the significance of the emissions and/or operational constraints. The effectiveness of the maintenance and/or repair actions is verified according to point iii. c., leaving enough time after the intervention (e.g. 2 months).
- e. Filling in the database mentioned in point v.
- iv. Establishing and implementing a detection and reduction programme for non-fugitive VOC emissions that includes all of the following features:
  - a. Listing of equipment identified as relevant non-fugitive VOC emission sources in the inventory of diffuse VOC emissions (see BAT 2).
  - b. Monitoring non-fugitive VOC emissions from equipment listed under point iv. a. (see BAT 22).
  - c. Planning and implementing techniques to reduce non-fugitive VOC emissions (see BAT 23, techniques a., c. and g. to j.). The planning and implementation of the techniques are prioritised according to the hazardous properties of the emitted substance(s), the significance of the emissions and/or operational constraints.

- d. Filling in the database mentioned in point v.
- v. Establishing and maintaining a database, for diffuse VOC emissions sources that are identified in the inventory mentioned in BAT 2, for keeping record of:
  - a. equipment design specifications (including the date and description of any design changes);
  - b. the equipment maintenance, repair, upgrade, or replacement actions, performed or planned, and their date of implementation;
  - c. the equipment that could not be maintained, repaired, upgraded or replaced due to operational constraints;
  - d. the results of the measurements or monitoring, including the concentration(s) of the emitted substance(s), the calculated leak rate (as kg/year), the recording from OGI cameras (e.g. from the last LDAR programme) and the date of the measurements or monitoring;
  - e. the annual quantity of diffuse VOC emissions (as fugitive and non-fugitive emissions), including information on non-accessible sources and accessible sources not monitored during the year.
- vi. Reviewing and updating the LDAR programme periodically. This may include the following:
  - a. lowering the leak and/or maintenance/repair thresholds (see point iii. b.);
  - b. reviewing the prioritisation of equipment to be monitored, giving higher priority to (the type of) equipment identified as leaky during the previous LDAR programme;
  - c. planning the maintenance, repair, upgrade or replacement of equipment that could not be performed during the previous LDAR programme due to operational constraints.
- vii. Reviewing and updating the detection and reduction programme for non-fugitive VOC emissions. This may include the following:
  - a. monitoring non-fugitive VOC emissions from equipment where maintenance, repair, upgrade or replacement actions were implemented, in order to determine if those actions were successful;
  - b. planning the maintenance, repair, upgrade or replacement actions that could not be performed due to operational constraints.

### Applicability

The features points iii., iv., vi. and vii. are only applicable to sources of diffuse VOC emissions for which monitoring according to BAT 22 is applicable.

The level of detail of the management system for diffuse VOC emissions will be proportionate to the nature, scale and complexity of the plant, and the range of environmental impacts it may have.

#### 4.1.4.2 Monitoring

**BAT 20. BAT is to estimate fugitive and non-fugitive VOC emissions to air separately at least once every year by using one or a combination of the techniques given below, as well as to determine the uncertainty of this estimation. The estimation distinguishes between VOCs classified as CMR 1A or 1B and VOCs that are not classified as CMR 1A or 1B.**

#### Note

The estimation of the diffuse VOC emissions to air takes into account the results of the monitoring carried out according to BAT 21 and/or to BAT 22.

For the purpose of the estimation, channelled emissions may be counted as non-fugitive emissions when the inherent characteristics of the waste gas stream (e.g. low velocities, variability of the flow rate and concentration) do not allow an accurate measurement according to BAT 8.

The main sources of uncertainty of the estimation are identified, and corrective actions are implemented to reduce the uncertainty.

Technique		Description	Type of emissions
a.	Use of emission factors	See Section 4.4.2.	Fugitive and/or non-fugitive
b.	Use of a mass balance	Estimation based on the difference in the mass of the substance inputs to and outputs from the plant/production unit, taking into account the generation and destruction of the substance in the plant/production unit. A mass balance may also consist of measuring the concentration of VOCs in the product (e.g. raw material or solvent).	
c.	Use of thermodynamic models	Estimation using the laws of thermodynamics applied to equipment (e.g. tanks) or particular steps of a production process. The following data are generally used as input for the model: <ul style="list-style-type: none"> <li>• chemical properties of the substance (e.g. vapour pressure, molecular mass);</li> <li>• process operating data (e.g. operating time, product quantity, ventilation);</li> <li>• characteristics of the emission source (e.g. tank diameter, colour, shape).</li> </ul>	

**BAT 21.** BAT is to monitor diffuse VOC emissions from the use of solvents by compiling, at least once every year, a solvent mass balance of the solvent inputs and outputs of the plant, as defined in Part 7 of Annex VII to Directive 2010/75/EU and to minimise the uncertainty of the solvent mass balance data by using all of the techniques given below.

Technique		Description
a.	Full identification and quantification of the relevant solvent inputs and outputs, including the associated uncertainty	<p>This includes:</p> <ul style="list-style-type: none"> <li>• identification and documentation of solvent inputs and outputs (e.g. channelled and diffuse emissions to air, emissions to water, solvent output in waste);</li> <li>• substantiated quantification of each relevant solvent input and output and recording of the methodology used (e.g. measurement, estimation by using emission factors, estimation based on operational parameters);</li> <li>• identification of the main sources of uncertainty of the aforementioned quantification, and implementation of corrective actions to reduce the uncertainty;</li> <li>• regular update of solvent input and output data.</li> </ul>
b.	Implementation of a solvent tracking system	A solvent tracking system aims to keep control of both the used and unused quantities of solvents (e.g. by weighing unused quantities returned to storage from the application area).
c.	Monitoring of changes that may influence the uncertainty of the solvent mass balance data	<p>Any change that could influence the uncertainty of the solvent mass balance data is recorded, such as:</p> <ul style="list-style-type: none"> <li>• malfunctions of the waste gas treatment system: the date and period of time are recorded;</li> <li>• changes that may influence air/gas flow rates (e.g. replacement of fans): the date and type of change are recorded.</li> </ul>

### Applicability

This BAT may not apply to the production of polyolefins, PVC or synthetic rubbers.

This BAT may not be applicable to plants whose total annual consumption of solvents is lower than 50 tonnes. The level of detail of the solvent mass balance will be proportionate to the nature, scale and complexity of the plant, and the range of environmental impacts it may have, as well as to the type and quantity of solvents used.

**BAT 22. BAT is to monitor diffuse VOC 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.**

Type of sources of diffuse VOC emissions <sup>(1) (2)</sup>	Type of VOCs	Standard(s)	Minimum monitoring frequency
Sources of fugitive emissions	VOCs classified as CMR 1A or 1B	EN 15446 <sup>(8)</sup>	Once every year <sup>(3) (4) (5)</sup>
	VOCs not classified as CMR 1A or 1B		Once during the period covered by each LDAR programme (see BAT 19 point iii.) <sup>(6)</sup>
Sources of non-fugitive emissions	VOCs classified as CMR 1A or 1B	EN 17628	Once every year
	VOCs not classified as CMR 1A or 1B		Once every year <sup>(7)</sup>

(1) The monitoring only applies to emission sources that are identified as relevant in the inventory given in BAT 2.  
(2) The monitoring does not apply to equipment operated under subatmospheric pressure.  
(3) In the case of inaccessible sources of fugitive VOC emissions (e.g. if the monitoring requires the removal of insulation or the use of scaffolding), the monitoring frequency may be reduced to once during the period covered by each LDAR programme (see BAT 19 point iii.).  
(4) For the production of PVC, the minimum monitoring frequency may be reduced to once every 5 years if the plant uses VCM gas detectors to continuously monitor VCM emissions in a way that allows an equivalent level of detection of VCM leaks.  
(5) In the case of high-integrity equipment (see BAT 23 b.) in contact with VOCs classified as CMR 1A or 1B, a lower minimum monitoring frequency may be adopted, but in any case at least once every 5 years.  
(6) In the case of high-integrity equipment (see BAT 23 b.) in contact with VOCs other than VOCs classified as CMR 1A or 1B, a lower minimum monitoring frequency may be adopted, but in any case at least once every 8 years.  
(7) The minimum monitoring frequency may be reduced to once every 5 years if non-fugitive emissions are quantified by using measurements.  
(8) This standard may be complemented by EN 17628.

### Note

Optical gas imaging (OGI) is a useful complementary technique to the method EN 15446 ('sniffing') in order to identify sources of fugitive VOC emissions and is particularly relevant in the case of inaccessible sources (see Section 4.4.2). This technique is described in EN 17628.

In the case of non-fugitive emissions, measurements may be complemented by the use of thermodynamic models.

Where large amounts (e.g. above 80 t/yr) of VOCs are used/consumed, the quantification of VOC emissions from the plant with tracer correlation (TC) or with optical absorption-based techniques, such as differential absorption light detection and ranging (DIAL) or solar occultation flux (SOF), is a useful complementary technique (see Section 4.4.2). These techniques are described in EN 17628.

### Applicability

BAT 22 only applies when the annual quantity of diffuse VOC emissions from the plant estimated according to BAT 20 is greater than the following:

For fugitive emissions:

- 1 tonne of VOCs per year in the case of VOCs classified as CMR 1A or 1B; or
- 5 tonnes of VOCs per year in the case of other VOCs.

For non-fugitive emissions:

- 1 tonne of VOCs per year in the case of VOCs classified as CMR 1A or 1B; or
- 5 tonnes of VOCs per year in the case of other VOCs.

## 4.1.4.3 Prevention or reduction of diffuse VOC emissions

**BAT 23.** In order to prevent or, where that is not practicable, to reduce diffuse VOC emissions to air, BAT is to use a combination of the techniques given below with the following order of priority.

**Note**

The use of techniques to prevent or, where that is not practicable, to reduce diffuse VOC emissions to air is prioritised according to the hazardous properties of the emitted substance(s) and/or the significance of the emissions.

Technique	Description	Type of emissions	Applicability
<i>1. Prevention techniques</i>			
a.	Limiting the number of emission sources	Fugitive and non-fugitive emissions	Applicability may be restricted by operational constraints in the case of existing plants.
b.	Use of high-integrity equipment	Fugitive emissions	Applicability may be restricted by operational constraints in the case of existing plants. Generally applicable to new plants and major plant upgrades.



c.	Collecting diffuse emissions and treating off-gases	Collecting diffuse VOC emissions (e.g. from compressor seals, vents and purge lines) and sending them to recovery (see BAT 9 and BAT 10) and/or abatement (see BAT 11).	Fugitive and non-fugitive emissions	Applicability may be restricted: <ul style="list-style-type: none"> <li>for existing plants; and/or</li> <li>by safety concerns (e.g. avoiding concentrations close to the lower explosive limit).</li> </ul>
<b>2. Other techniques</b>				
d.	Facilitating access and/or monitoring activities	To ease maintenance and/or monitoring activities, the access to potentially leaky equipment is facilitated, e.g. by installing platforms, and/or drones are used for monitoring.	Fugitive emissions	Applicability may be restricted by operational constraints in the case of existing plants.
e.	Tightening	This includes: <ul style="list-style-type: none"> <li>tightening of gaskets by personnel that is qualified according to EN 1591-4 and using the designed gasket stress (e.g. calculated according to EN 1591-1);</li> <li>installing tight caps on open ends;</li> <li>using flanges selected and assembled according to EN 13555.</li> </ul>	Fugitive emissions	Generally applicable.
f.	Replacement of leaky equipment and/or parts	This includes the replacement of: <ul style="list-style-type: none"> <li>gaskets;</li> <li>sealing elements (e.g. tank lid);</li> <li>packing material (e.g. valve stem packing material).</li> </ul>	Fugitive emissions	Generally applicable.
g.	Reviewing and updating process design	This includes: <ul style="list-style-type: none"> <li>reducing the use of solvents and/or using solvents with lower volatility;</li> <li>reducing the formation of side products containing VOCs;</li> <li>lowering the operating temperature;</li> <li>lowering the VOC content in the final product.</li> </ul>	Non-fugitive emissions	Applicability may be restricted in the case of existing plants due to operational constraints.
h.	Reviewing and updating operating conditions	This includes: <ul style="list-style-type: none"> <li>reducing the frequency and duration of reactor and vessel openings;</li> <li>preventing corrosion by lining or coating of equipment, by painting pipes (for external corrosion) and by using corrosion inhibitors for materials in contact with equipment.</li> </ul>	Non-fugitive emissions	Generally applicable.

i.	Using closed systems	<p>This includes:</p> <ul style="list-style-type: none"> <li>• vapour balancing (see Section 4.4.3);</li> <li>• closed systems for solid/liquid and liquid/liquid phase separations;</li> <li>• closed systems for cleaning operations;</li> <li>• closed sewers and/or waste water treatment plants;</li> <li>• closed sampling systems;</li> <li>• closed storage areas.</li> </ul> <p>Off-gases from closed systems are sent to recovery (see BAT 9 and BAT 10) and/or abatement (see BAT 11).</p>	Non-fugitive emissions	Applicability may be restricted by operational constraints in the case of existing plants and/or by safety concerns.
j.	Using techniques to minimise emissions from surfaces	<p>This includes:</p> <ul style="list-style-type: none"> <li>• installing oil creaming systems on open surfaces;</li> <li>• periodically skimming open surfaces (e.g. removing floating matter);</li> <li>• installing anti-evaporation floating elements on open surfaces;</li> <li>• treating waste water streams to remove VOCs and send the VOCs to recovery (see BAT 9 and BAT 10) and/or abatement (see BAT 11);</li> <li>• installing floating roofs on tanks;</li> <li>• using fixed-roof tanks connected to a waste gas treatment.</li> </ul>	Non-fugitive emissions	Applicability may be restricted by operational constraints in the case of existing plants.

#### 4.1.4.4 BAT conclusions for the use of solvents or the reuse of recovered solvents

The emission levels for the use of solvents or the reuse of recovered solvents given below are associated with the general BAT conclusions given in Section 4.1 and Section 4.1.4.3.

**Table 4.7: BAT-associated emission level (BAT-AEL) for diffuse VOC emissions to air from the use of solvents or the reuse of recovered solvents**

Parameter	BAT-AEL (percentage of the solvent inputs) (yearly average) <sup>(1)</sup>
Diffuse VOC emissions	≤ 5 %
<sup>(1)</sup> The BAT-AEL does not apply to plants whose total annual consumption of solvents is lower than 50 tonnes.	

The associated monitoring is given in BAT 20, BAT 21 and BAT 22.

## 4.2 Polymers and synthetic rubbers

The BAT conclusions presented in this section apply to the production of certain polymers. They apply in addition to the general BAT conclusions given in Section 4.1.

### 4.2.1 BAT conclusions for the production of polyolefins

**BAT 24.** BAT is to monitor the TVOC concentration in polyolefin products, at least once every year for each representative polyolefin grade produced during the same year, 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.

Polyolefin product	Standard(s)	Monitoring associated with
HDPE, LDPE, LLDPE	No EN standard available	BAT 2, BAT 20, BAT 25
PP		
EPS, GPPS, HIPS		

#### Note

The measurement samples are taken at the point of transition from the closed to the open system where the polyolefin comes into contact with the atmosphere.

The closed system refers to the part of the production process where the materials (e.g. reactants, solvents, suspension agents) are not in contact with the atmosphere. It includes the polymerisation steps, the reuse and recovery of materials.

The open system refers to the part of the production process where the polyolefins come into contact with the atmosphere. It includes the finishing steps (e.g. drying, blending) as well as the transfer, handling and storage of polyolefins.

When the transition point between the open and the closed system cannot be clearly identified, the measurement samples are taken at an appropriate point.

#### Applicability

Measurements do not apply to production processes only made up of a closed system.

**BAT 25.** In order to increase resource efficiency and to reduce emissions to air of organic compounds, BAT is to use all of the techniques given below, as far as applicable.

Technique		Description	Applicability
a.	Chemical agents with low boiling points	Solvents and suspension agents with low boiling points are used.	Applicability may be restricted by operational constraints.
b.	Lowering the VOC content in the polymer	The VOC content in the polymer is lowered, e.g. by using low-pressure separation, stripping or closed-loop nitrogen purge systems, devolatilisation extrusion (see Section 4.4.3). The techniques for lowering the VOC content depend on the type of polymer product and production process.	Devolatilisation extrusion may be restricted by product specifications for the production of HDPE, LDPE and LLDPE.
c.	Collection and treatment of process off-gases	Process off-gases arising from the use of technique b. as well as from the finishing step, e.g. extrusion and degassing silos, are collected and sent to recovery (see BAT 9 and BAT 10) and/or abatement (see BAT 11).	Applicability may be restricted by operational constraints and/or due to safety concerns (e.g. avoiding concentrations close to the lower/upper explosive limit).

**Table 4.8:** BAT-associated emission levels (BAT-AELs) for total emissions to air of VOCs from the production of polyolefins expressed as specific emission loads

Polyolefin product	Unit	BAT-AEL (Yearly average)
HDPE	g C per kg of polyolefins produced	0.3-1.0 <sup>(1)</sup>
LDPE		0.1-1.4 <sup>(2)</sup> <sup>(3)</sup>
LLDPE		0.1-0.8
PP		0.1-0.9 <sup>(1)</sup>
GPPS and HIPS		< 0.1
EPS		< 0.6
<sup>(1)</sup> The lower end of the BAT-AEL range is typically associated with the gas-phase polymerisation process. <sup>(2)</sup> The upper end of the BAT-AEL range may be higher and up to 2.7 g C/kg in the case of the production of EVA or other copolymers (e.g. ethyl acrylate copolymers). <sup>(3)</sup> The upper end of the BAT-AEL range may be higher and up to 4.7 g C/kg if both of the following conditions are met: <ul style="list-style-type: none"> <li>• thermal oxidation is not applicable;</li> <li>• EVA or other copolymers (e.g. ethyl acrylate copolymers) are produced.</li> </ul>		

The associated monitoring is given in BAT 8, BAT 20, BAT 22 and BAT 24. The monitoring of TVOC emissions to air includes all emissions from the following process steps, where the emissions are identified as relevant in the inventory given in BAT 2: storage and handling of raw materials, polymerisation, recovery of materials and pollutant abatement, finishing of the polymer (e.g. extrusion, drying, blending) as well as the transfer, handling and storage of polymers.

## 4.2.2 BAT conclusions for the production of polyvinyl chloride (PVC)

**BAT 26.** 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.

Substance	Emission points	Standard(s)	Minimum monitoring frequency <sup>(1)</sup>	Monitoring associated with
VCM	Any stack with a VCM mass flow of $\geq 25$ g/h	Generic EN standards <sup>(2)</sup>	Continuous <sup>(3)</sup>	BAT 29
	Any stack with a VCM mass flow of $< 25$ g/h	No EN standard available	Once every 6 months <sup>(4)</sup> <sup>(5)</sup>	

<sup>(1)</sup> The monitoring of VCM emissions from finishing steps (e.g. drying, blending) as well as from the transfer, handling and storage of PVC may be replaced by the monitoring in BAT 27.

<sup>(2)</sup> Generic EN standards for continuous measurements are EN 14181, EN 15267-1, EN 15267-2 and EN 15267-3.

<sup>(3)</sup> The minimum monitoring frequency may be reduced to once every 6 months if the emission levels are proven to be sufficiently stable.

<sup>(4)</sup> To the extent possible, the measurements are carried out at the highest expected emission state under normal operating conditions.

<sup>(5)</sup> The minimum monitoring frequency may be reduced to once every year if the emission levels are proven to be sufficiently stable.

**BAT 27.** BAT is to monitor the residual vinyl chloride monomer concentration in PVC slurry/latex, at least once every year for each representative PVC grade produced during the same year, in accordance with EN standards.

Substance	Standard(s)	Monitoring associated with
VCM	EN ISO 6401	BAT 30

### Note

The samples of the PVC slurry/latex are taken at the point of transition from the closed to the open system where the PVC slurry/latex comes into contact with the atmosphere.

The closed system refers to the part of the production process where the PVC slurry/latex is not in contact with the atmosphere. It generally includes the polymerisation steps, the reuse and recovery of VCM.

The open system is the part of the system where the PVC slurry/latex comes into contact with the atmosphere. It includes the finishing steps (e.g. drying and blending) as well as the transfer, handling and storage of PVC.

**BAT 28.** In order to increase resource efficiency and to reduce the mass flow of organic compounds sent to the final waste gas treatment, BAT is to recover the vinyl chloride monomer from process off-gases by using one or a combination of the techniques given below, and to reuse the recovered monomer.

Technique		Description
a.	Absorption (regenerative)	See Section 4.4.1.
b.	Adsorption (regenerative)	See Section 4.4.1.
c.	Condensation	See Section 4.4.1.

### Applicability

Recovery may be restricted where the energy demand is excessive due to the low concentration of the compound(s) concerned in the process off-gas(es).

**BAT 29.** In order to reduce channelled emissions to air of vinyl chloride monomer from the recovery of vinyl chloride monomer, BAT is to use one or a combination of the techniques given below.

	Technique	Description	Applicability
a.	Absorption	See Section 4.4.1.	Generally applicable
b.	Adsorption	See Section 4.4.1.	
c.	Condensation	See Section 4.4.1.	
d.	Thermal oxidation	See Section 4.4.1.	Applicability of recuperative and regenerative thermal oxidation to existing plants may be restricted by design and/or operational constraints. 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.

**Table 4.9:** BAT-associated emission level (BAT-AEL) for channelled emissions to air of VCM from the recovery of VCM

Substance	BAT-AEL (mg/Nm <sup>3</sup> ) (Daily average or average over the sampling period)
VCM	< 0.5-1 <sup>(1)</sup> <sup>(2)</sup>
<sup>(1)</sup> The BAT-AEL does not apply to minor emissions (i.e. when the VCM mass flow is below e.g. 1 g/h). <sup>(2)</sup> The upper end of the BAT-AEL range may be higher and up to 5 mg/Nm <sup>3</sup> if both of the following conditions are met: <ul style="list-style-type: none"> <li>• thermal oxidation is not applicable;</li> <li>• the plant is not directly associated to the production of EDC and VCM.</li> </ul>	

The associated monitoring is given in BAT 26.

**BAT 30.** In order to reduce emissions to air of vinyl chloride monomer, BAT is to use all of the techniques given below.

Technique		Description
a.	Appropriate VCM storage facilities	This includes: <ul style="list-style-type: none"> <li>storing VCM in refrigerated tanks at atmospheric pressure or in pressurised tanks at ambient temperature;</li> <li>using refrigerated reflux condensers or connecting tanks for VCM recovery (see BAT 28) and/or abatement (see BAT 29).</li> </ul>
b.	Vapour balancing	See Section 4.4.3.
c.	Minimisation of emissions of residual VCM from equipment	This includes: <ul style="list-style-type: none"> <li>reducing the frequency and duration of reactor openings;</li> <li>venting off-gases from latex storage tanks and from connections to VCM recovery (see BAT 28) and/or abatement (see BAT 29) prior to opening the reactor;</li> <li>flushing the reactor with inert gas prior to opening and venting off-gases to VCM recovery (see BAT 28) and/or abatement (see BAT 29);</li> <li>draining the liquid content of the reactor to closed vessels prior to opening the reactor;</li> <li>cleaning the reactor with water prior to opening and draining the water to the stripping system.</li> </ul>
d.	Lowering the VCM content in the polymer by stripping	See Section 4.4.3.
e.	Collection and treatment of process off-gases	Process off-gases from the use of technique d. are collected and sent to VCM recovery (see BAT 28) and/or abatement (see BAT 29).

**Table 4.10: BAT-associated emission levels (BAT-AELs) for total emissions to air of VCM from the production of PVC expressed as specific emission loads**

PVC type	Unit	BAT-AEL (Yearly average)
S-PVC	g VCM per kg of PVC produced	0.01-0.045
E-PVC		0.25-0.3 <sup>(1)</sup>
<sup>(1)</sup> The upper end of the BAT-AEL range may be higher and up to 0.5 g VCM per kg of PVC produced if both of the following conditions are met: <ul style="list-style-type: none"> <li>thermal oxidation is not applicable;</li> <li>the plant is not directly associated to the production of EDC and VCM.</li> </ul>		

The associated monitoring is given in BAT 20, BAT 22, BAT 26 and BAT 27. The monitoring of VCM emissions to air includes all emissions from the following process steps or equipment, where the emissions are identified as relevant in the inventory given in BAT 2: finishing, e.g. drying and blending; transfer, handling and storage; reactor openings; gasholders; waste water treatment plants; recovery and/or abatement of VCM.



**Table 4.11: BAT-associated emission levels (BAT-AELs) for the VCM concentration in the PVC slurry/latex**

PVC type	Unit	BAT-AEL (Yearly average)
S-PVC	g VCM per kg of PVC produced	0.01-0.03
E-PVC		0.2-0.4

The associated monitoring is given in BAT 27.

### 4.2.3 BAT conclusions for the production of synthetic rubbers

**BAT 31.** BAT is to monitor the TVOC concentration in synthetic rubbers, at least once every year for each representative synthetic rubber grade produced during the same year, 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.

Substance/Parameter	Standard(s)	Monitoring associated with
VOCs	No EN standard available	BAT 32

#### Note

The samples are taken after lowering the VOC content in the polymer (see BAT 32 a.) where the synthetic rubber comes into contact with the atmosphere.

#### Applicability

Measurements do not apply to production processes only made up of a closed system.

**BAT 32.** In order to reduce emissions to air of organic compounds, BAT is to use one or a combination of the techniques given below.

	Technique	Description
a.	Lowering the VOC content in the polymer	The VOC content in the polymer is lowered by using stripping or devolatilisation extrusion (see Section 4.4.3).
b.	Collection and treatment of process off-gases	Process off-gases are collected and sent to recovery (see BAT 9 and BAT 10) and/or abatement (see BAT 11).

**Table 4.12: BAT-associated emission level (BAT-AEL) for total emissions to air of VOC from the production of synthetic rubbers expressed as specific emission load**

Substance/Parameter	Unit	BAT-AEL (Yearly average)
TVOC	g C per kg of synthetic rubber produced	0.2-4.2

The associated monitoring is given in BAT 8, BAT 20, BAT 22 and BAT 31. The monitoring of TVOC emissions to air includes all emissions from the following process steps, where the emissions are identified as relevant in the inventory given in BAT 2: storage of raw materials, polymerisation, recovery of materials and abatement techniques, finishing of the polymer (e.g. extrusion, drying, blending) as well as the transfer, handling and storage of synthetic rubbers.

#### 4.2.4 BAT conclusions for the production of viscose using CS<sub>2</sub>

**BAT 33. 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.**

Substance <sup>(1)</sup>	Emission points	Standard(s)	Minimum monitoring frequency	Monitoring associated with
Carbon disulphide (CS <sub>2</sub> )	Any stack with a mass flow of ≥ 1 kg/h	Generic EN standards <sup>(2)</sup>	Continuous <sup>(3)</sup>	BAT 35
	Any stack with a mass flow of < 1 kg/h	No EN standard available	Once every year <sup>(4)</sup>	
Hydrogen sulphide (H <sub>2</sub> S)	Any stack with a mass flow of ≥ 50 g/h	Generic EN standards <sup>(2)</sup>	Continuous <sup>(3)</sup>	
	Any stack with a mass flow of < 50 g/h	No EN standard available	Once every year <sup>(4)</sup>	
<sup>(1)</sup> The monitoring only applies when the substance concerned is identified as relevant in the waste gas stream based on the inventory given in BAT 2. <sup>(2)</sup> Generic EN standards for continuous measurements are EN 14181, EN 15267-1, EN 15267-2 and EN 15267-3. <sup>(3)</sup> In the case of the production of casing, the minimum monitoring frequency may be reduced to once every month when continuous monitoring is not possible due to analytical interference. <sup>(4)</sup> To the extent possible, the measurements are carried out at the highest expected emission state under normal operating conditions.				

**BAT 34.** In order to increase resource efficiency and to reduce the mass flow of CS<sub>2</sub> and H<sub>2</sub>S sent to the final waste gas treatment, BAT is to recover CS<sub>2</sub> by using technique a. and/or technique b. or a combination of technique c. with technique(s) a. and/or b., given below and to reuse the CS<sub>2</sub>, or, alternatively, to use technique d.

Technique		Main substance targeted	Description	Applicability
a.	Absorption (regenerative)	H <sub>2</sub> S	See Section 4.4.1.	Generally applicable for the production of casing. For other products, applicability may be restricted where the energy demand is excessive due to high waste gas volume flows (above e.g. 120 000 Nm <sup>3</sup> /h) or low H <sub>2</sub> S concentration in the waste gas (below e.g. 0.5 g/Nm <sup>3</sup> ).
b.	Adsorption (regenerative)	H <sub>2</sub> S, CS <sub>2</sub>	See Section 4.4.1.	Applicability may be restricted where the energy demand for recovery is excessive if the concentration of CS <sub>2</sub> in the waste gas is below e.g. 5 g/Nm <sup>3</sup> .
c.	Condensation	H <sub>2</sub> S, CS <sub>2</sub>	See Section 4.4.1.	
d.	Production of sulphuric acid	H <sub>2</sub> S, CS <sub>2</sub>	Process off-gases containing CS <sub>2</sub> and H <sub>2</sub> S are used to produce sulphuric acid.	Applicability may be restricted if the concentration of CS <sub>2</sub> and/or H <sub>2</sub> S in the waste gas is below 5 g/Nm <sup>3</sup> .

**BAT 35.** In order to reduce channelled emissions to air of CS<sub>2</sub> and H<sub>2</sub>S, BAT is to use one or a combination of the techniques given below.

Technique		Main substance targeted	Description	Applicability
a.	Absorption	H <sub>2</sub> S	See Section 4.4.1.	Generally applicable.
b.	Bioprocesses	CS <sub>2</sub> , H <sub>2</sub> S	See Section 4.4.1.	Applicability may be restricted where the energy demand is excessive due to high waste gas volume flows (e.g. above 60 000 Nm <sup>3</sup> /h) or high CS <sub>2</sub> concentration in the waste gas (e.g. above 1 000 mg/Nm <sup>3</sup> ) or too low H <sub>2</sub> S concentration.
c.	Thermal oxidation	CS <sub>2</sub> , H <sub>2</sub> S	See Section 4.4.1.	Applicability of recuperative and regenerative thermal oxidation to existing plants may be restricted by design and/or operational constraints. 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.

**Table 4.13: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of CS<sub>2</sub> and H<sub>2</sub>S from the production of viscose using CS<sub>2</sub>**

Substance	BAT-AEL (mg/Nm <sup>3</sup> ) (Daily average or average over the sampling period) <sup>(1)</sup>
CS <sub>2</sub>	5-400 <sup>(2)</sup> <sup>(3)</sup>
H <sub>2</sub> S	1-10 <sup>(4)</sup>
<p><sup>(1)</sup> The BAT-AEL does not apply to the production of filament yarn.  <sup>(2)</sup> The upper end of the BAT-AEL range may be higher and up to 500 mg CS<sub>2</sub>/Nm<sup>3</sup> if:  a) both of the following conditions are fulfilled:  <ul style="list-style-type: none"> <li>• bioprocesses (see BAT 35 b) are not applicable;</li> <li>• the CS<sub>2</sub> recovery efficiency (see BAT 34) is ≥ 97 %; or</li> </ul> b) CS<sub>2</sub> recovery is not applicable.  <sup>(3)</sup> The lower end of the BAT-AEL range can be achieved by using thermal oxidation or technique d. in BAT 34.  <sup>(4)</sup> The upper end of the BAT-AEL range may be higher and up to 30 mg/Nm<sup>3</sup>, when the sum of H<sub>2</sub>S and CS<sub>2</sub> (expressed as Total S) is close to the lower end of the BAT-AEL range in Table 4.14.</p>	

The associated monitoring is given in BAT 33.

**Table 4.14: BAT-associated emission levels (BAT-AELs) for emissions to air of H<sub>2</sub>S and CS<sub>2</sub> from the production of staple fibres and casing expressed as specific emission loads**

Parameter	Process	Unit	BAT-AEL (Yearly average)
Sum of H <sub>2</sub> S and CS <sub>2</sub> (expressed as Total S) <sup>(1)</sup>	Production of staple fibres	g Total S per kg of product	6-9
	Casing		120-250
<sup>(1)</sup> Emissions to air refer to channelled emissions only.			

The associated monitoring is given in BAT 33.

### 4.3 Process furnaces/heaters

The BAT conclusions presented in this section apply when process furnaces/heaters with a total rated thermal input equal to or greater than 1 MW are used in the production processes included in the scope of these BAT conclusions. They apply in addition to the general BAT conclusions given in Section 4.1.

Where the waste gases of two or more separate process furnaces/heaters are, or could, in the judgement of the competent authority, be discharged through a common stack, the capacities of all individual furnaces/heaters shall be added together for the purpose of calculating the total rated thermal input.

**BAT 36. In order to prevent or, where that is not practicable, to reduce channelled emissions to air of CO, dust, NO<sub>x</sub> and SO<sub>x</sub>, BAT is to use technique c. and one or a combination of the other techniques given below.**

Technique	Description	Main inorganic compounds targeted	Applicability	
<i>Primary techniques</i>				
a.	Choice of fuel	See Section 4.4.1. This includes switching from liquid to gaseous fuels, taking into account the overall hydrocarbon balance.	NO <sub>x</sub> , SO <sub>x</sub> , dust	The switch from liquid to gaseous fuels may be restricted by the design of the burners in the case of existing process furnaces/heaters.
b.	Low-NO <sub>x</sub> burner	See Section 4.4.1	NO <sub>x</sub>	For existing process furnaces/heaters, the applicability may be restricted by their design.
c.	Optimised combustion	See Section 4.4.1.	CO, NO <sub>x</sub>	Generally applicable.
<i>Secondary techniques</i>				
d.	Absorption	See Section 4.4.1.	SO <sub>x</sub> , dust	Applicability may be restricted for existing process furnaces/heaters by space availability.
e.	Fabric filter or absolute filter	See Section 4.4.1.	Dust	Not applicable when only combusting gaseous fuels.
f.	Selective catalytic reduction (SCR)	See Section 4.4.1.	NO <sub>x</sub>	Applicability to existing process furnaces/heaters may be restricted by space availability.
g.	Selective non-catalytic reduction (SNCR)	See Section 4.4.1.	NO <sub>x</sub>	Applicability to existing process furnaces/heaters may be restricted by the temperature window (800-1100 °C) and the residence time needed for the reaction.

**Table 4.15: BAT-associated emission level (BAT-AEL) for channelled NO<sub>x</sub> emissions to air and indicative emission level for channelled CO emissions to air from process furnaces/heaters**

Parameter	BAT-AEL (mg/Nm <sup>3</sup> ) (Daily average or average over the sampling period)
Nitrogen oxides (NO <sub>x</sub> )	30-150 <sup>(1)</sup> <sup>(2)</sup> <sup>(3)</sup>
Carbon monoxide (CO)	No BAT-AEL <sup>(4)</sup>
<p><sup>(1)</sup> In the case of the production of complex inorganic pigments, the upper end of the BAT-AEL range may be higher and up to 400 mg/Nm<sup>3</sup> when condition b) below is met, and up to 1 000 mg/Nm<sup>3</sup> when conditions a) and b) below are met:  a) the combustion temperature is higher than 1 000°C;  b) oxygen-enriched air or pure oxygen is used.</p> <p><sup>(2)</sup> The BAT-AEL does not apply to minor emissions (i.e. when the NO<sub>x</sub> mass flow is below e.g. 500 g/h).</p> <p><sup>(3)</sup> The upper end of the BAT-AEL range may be higher and up to 200 mg/Nm<sup>3</sup> when direct heating is used.</p> <p><sup>(4)</sup> As an indication, the emission levels for carbon monoxide are 4-50 mg/Nm<sup>3</sup>, as a daily average or average over the sampling period.</p>	

The associated monitoring is given in BAT 8.

## 4.4 Description of techniques

### 4.4.1 Techniques to reduce channelled emissions to air

Technique	Description
Absorption	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). In the case of regenerative absorption, the compounds may be recovered from the liquid.
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. In non-regenerative adsorption, the spent adsorbent is not regenerated but disposed of. In the case of regenerative adsorption, the adsorbate is subsequently desorbed, e.g. with steam (often on site), for reuse or disposal and the adsorbent is reused. For continuous operation, typically more than two adsorbers are operated in parallel, one of them in desorption mode.
Bioprocesses	Bioprocesses include the following: <ul style="list-style-type: none"><li>• Biofiltration: 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.</li><li>• Bioscrubbing: the removal of the pollutant compounds from a waste gas stream using a combination of wet scrubbing (absorption) and biodegradation under aerobic conditions. The scrubbing water contains a population of microorganisms suitable to oxidise biodegradable gaseous compounds. The absorbed pollutants are degraded in aerated sludge tanks.</li><li>• Biotrickling: the removal of the pollutant compounds from a waste gas stream in a biological trickle-bed reactor. The pollutants are absorbed by the water phase and transported to the biofilm, where the biological transformation takes place.</li></ul>
Choice of fuel	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).
Condensation	The removal of vapours of organic and inorganic compounds from a process off-gas or waste gas stream by reducing its temperature below its dew point so that the vapours liquefy. Depending on the operating temperature range required, different cooling media are used, e.g. water or brine. In cryogenic condensation, liquid nitrogen is used as a cooling medium.
Cyclone	Equipment for the removal of dust from a process off-gas or waste gas stream based on imparting centrifugal forces, usually within a conical chamber.
Electrostatic precipitator	An electrostatic precipitator (ESP) is a particulate control device that uses electrical forces to move particles entrained within a waste gas stream onto collector plates. The entrained particles are given an electrical charge when they pass through a corona where gaseous ions flow. Electrodes in the centre of the flow lane are maintained at a high voltage and generate the electrical field that forces the particles to the collector walls. The pulsating DC voltage required is in the range of 20-100 kV.
Absolute filter	Absolute filters, also referred to as high-efficiency particle air (HEPA) filters or ultra-low penetration air (ULPA) filters, are constructed from glass cloth or fabrics of synthetic fibres through which gases are passed to remove particles. Absolute filters show higher efficiencies than fabric filters. The classification of HEPA and ULPA filters according to their performance is given in EN 1822-1.

High-efficiency air filter (HEAF)	A flat-bed filter in which aerosols combine into droplets. Highly viscous droplets remain on the filter fabric which contains the residues to be disposed of and separated into droplets, aerosols and dust. HEAFs are particularly suitable for treating highly viscous droplets.
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. 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.
Low-NO <sub>x</sub> burner	The technique (including ultra-low-NO <sub>x</sub> burner) is based on the principles 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 <sub>x</sub> and the formation of thermal NO <sub>x</sub> , while maintaining high combustion efficiency. The design of ultra-low-NO <sub>x</sub> burners includes (air/fuel) staging and exhaust/flue-gas recirculation.
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 the regular planned maintenance of the combustion system according to suppliers' recommendations. Combustion conditions control is based on the continuous monitoring and automated control of appropriate combustion parameters (e.g. O <sub>2</sub> , CO, fuel to air ratio, and unburnt substances).
Optimisation of catalytic or thermal oxidation	Optimisation of design and operation of catalytic or thermal oxidation to promote the oxidation of organic compounds including PCDD/F present in the waste gases, to prevent PCDD/F and the (re)formation of their precursors, as well as to reduce the generation of pollutants such as NO <sub>x</sub> and CO.
Catalytic oxidation	Abatement technique which oxidises combustible compounds in a waste gas stream with air or oxygen in 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. For process off-gases with low VOC concentrations (e.g. < 1 g/Nm <sup>3</sup> ), pre-concentration steps may be applied using adsorption (rotor or fixed bed, with activated carbon or zeolites). VOCs adsorbed in the concentrator are desorbed by using heated ambient air or heated waste gas, and the resulting volume flow with higher VOC concentration is directed to the oxidiser. Molecular sieves ('smoothers'), typically composed of zeolites, may be used before the concentrators or the oxidiser to level down high variations of VOC concentrations in the process off-gases.



Thermal oxidation	<p>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.</p> <p>Several types of thermal oxidation are operated:</p> <ul style="list-style-type: none"> <li>• Straight thermal oxidation: thermal oxidation without energy recovery from the combustion.</li> <li>• Recuperative thermal oxidation: thermal oxidation using the heat of the waste gases by indirect heat transfer.</li> <li>• 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.</li> </ul> <p>For process off-gases with low VOC concentrations (e.g. &lt;math&gt;&lt; 1 \text{ g/Nm}^3&lt;/math&gt;), pre-concentration steps may be applied using adsorption (rotor or fixed bed, with activated carbon or zeolites). VOCs adsorbed in the concentrator are desorbed by using heated ambient air or heated waste gas, and the resulting volume flow with higher VOC concentration is directed to the oxidiser.</p> <p>Molecular sieves ('smoothers'), typically composed of zeolites, may be used before the concentrators or the oxidiser to level down high variations of VOC concentrations in the process off-gases.</p>
Selective catalytic reduction (SCR)	<p>Selective reduction of nitrogen oxides with ammonia or urea in the presence of a catalyst. The technique is based on the reduction of <math>\text{NO}_x</math> to nitrogen in a catalytic bed by reaction with ammonia at an optimum operating temperature that is typically around 200-450 °C. In general, ammonia is injected as an aqueous solution; the ammonia source can also be anhydrous ammonia or a urea solution. Several layers of catalyst may be applied. A higher <math>\text{NO}_x</math> reduction is achieved with the use of a larger catalyst surface, installed as one or more layers. 'In-duct' or 'slip' SCR combines SNCR with downstream SCR which reduces the ammonia slip from SNCR.</p>
Selective non-catalytic reduction (SNCR)	<p>Selective reduction of nitrogen oxides to nitrogen with ammonia or urea at high temperatures and without catalyst. The operating temperature window is maintained between 800 °C and 1 000 °C for optimal reaction.</p>

#### 4.4.2 Techniques to monitor diffuse emissions to air

Technique	Description
Differential absorption LIDAR (DIAL)	A laser-based technique using differential absorption LIDAR (light detection and ranging), which is the optical analogue of radio-wave-based RADAR. The technique relies on the back-scattering of laser beam pulses by atmospheric aerosols, and the analysis of the spectral properties of the returned light collected with a telescope.
Emission factor	Emission factors are numbers that can be multiplied by an activity rate (e.g. the production output), in order to estimate the emissions from the installation. Emission factors are generally derived through the testing of a population of similar process equipment or process steps. This information can be used to relate the quantity of material emitted to some general measure of the scale of activity. In the absence of other information, default emission factors (e.g. literature values) can be used to provide an estimate of the emissions. Emission factors are usually expressed as the mass of a substance emitted divided by the throughput of the process emitting the substance.
Leak Detection and Repair (LDAR) programme	A structured approach to reduce fugitive VOC emissions by detection and subsequent repair or replacement of leaking components. The LDAR programme consists of one or more campaigns. A campaign is usually conducted over 1 year, where a certain percentage of the pieces of equipment is monitored.
Optical gas imaging (OGI) methods	Optical gas imaging uses small lightweight hand-held or fixed cameras which enable the visualisation of gas leaks in real time, so that they appear as 'smoke' on a video recorder together with the image of the equipment concerned, to easily and rapidly locate significant VOC leaks. Active systems produce an image with a back-scattered infrared laser light reflected on the equipment and its surroundings. Passive systems are based on the natural infrared radiation of the equipment and its surroundings.
Solar occultation flux (SOF)	The technique is based on the recording and spectrometric Fourier Transform analysis of a broadband infrared or ultraviolet/visible sunlight spectrum along a given geographical itinerary, crossing the wind direction and cutting through VOC plumes.

#### 4.4.3 Techniques to reduce diffuse emissions

Technique	Description
Devolatilisation extrusion	When the concentrated rubber solution is further processed by extrusion, the solvent vapours (commonly cyclohexane, hexane, heptane, toluene, cyclopentane, isopentane or mixtures thereof) coming from the vent hole of the extruder are compressed and sent to recovery.
Stripping	VOCs contained in the polymer are transferred to the gaseous phase (e.g. by using steam). The removal efficiency may be optimised by a suitable combination of temperature, pressure and residence time and by maximising the ratio of free polymer surface to total polymer volume.
Vapour balancing	The vapour from a piece of receiving equipment (e.g. a tank) that is displaced during the transfer of a liquid and is returned to the delivery equipment from which the liquid is delivered.

## 5 EMERGING TECHNIQUES

No information provided.



## 6 CONCLUDING REMARKS AND RECOMMENDATIONS FOR FUTURE WORK

### Timing of the process to draw up the WGC BREF

The key milestones of the process are summarised in Table 6.1.

**Table 6.1: Key milestones of the drawing up of the WGC BREF**

Key milestone	Date
Activation of the TWG	15 September 2016
Call for initial positions	20 January 2017
Kick-off meeting	25-29 September 2017
Interim meeting	14-15 March 2018
Data collection	27 July 2018-28 February 2019
First data assessment workshop	4-5 June 2019
Draft 1 (D1) of the WGC BREF	29 November 2019
End of commenting period (1 551 comments received)	28 February 2020
Second data assessment workshop	1-2 December 2020
Closed sessions on polymers production processes	9-10 March 2021
Revised proposals for the draft BAT conclusions and Background Paper for the Final TWG Meeting	30 April 2021
Final TWG meeting (conducted as a series of web-based sessions)	15 June-2 July 2021

During the process to draw up the WGC BREF, a total of 26 plants were visited in Austria, Belgium, France, Germany, Portugal, Spain and the Netherlands.

The physical Final TWG Meeting was replaced by a series of web-based sessions because of the severe travel restrictions and social distancing measures in place due to the COVID-19 pandemic.

### Sources of information and information gaps

The main sources of information for the drawing up process were:

- scientific and technical literature;
- 784 filled-in questionnaires (443 of which contained confidential business information) from operators of chemical plants;
- additional information from the TWG members;
- 1 551 comments on Draft 1 of the BREF;
- 477 comments on the revised version of the draft BAT conclusions (April 2021);
- information gathered from site visits;
- outcomes of the workshops mentioned above.

In total, approximately 600 documents have been posted in BATIS and taken into account for the drawing up of this document.

### Degree of consensus reached during the information exchange

At the Final TWG Meeting that took place as a series of web-based sessions during the period from 15 June to 2 July 2021, a high degree of consensus was reached on most of the BAT conclusions. However, 19 split views were expressed, which fulfil the conditions set out in Section 4.6.2.3.2 of Commission Implementing Decision 2012/119/EU. They are summarised in Table 6.2 below.

Table 6.2: Split views expressed

BAT conclusion/ Table number	Split view	Expressed by	Alternative proposed level (if any)
-	To delete in the section 'General considerations' the the expression 'in the judgement of the competent authorities'.	DE, EEB	NA
-	To delete in the section 'General considerations' the reference oxygen level for process furnaces/heaters using indirect heating.	CEFIC, supported by CZ	NA
BAT 8	Not to delete footnote <sup>(4)</sup> for all substances classified as CMR 1A or 1B or CMR 2 and to also add footnote <sup>(4)</sup> to the substances/parameters 'CMR substances other than CMR substances covered elsewhere in this table'.	CEFIC and ORGALIME, supported by CZ	NA
BAT 11/ Table 4.1	To increase the mass flow value for minor emissions of formaldehyde.	CEFIC and ORGALIME, supported by CZ and IT	5 g/h
	To increase the mass flow value for minor emissions of substances classified as CMR 1A or 1B.		2.5 g/h
	To increase the mass flow value for minor emissions for the parameter 'Sum of VOCs classified as CMR 1A or 1B'.		5 g/h
BAT 11/ Table 4.1	To change the parameters as follows: <ul style="list-style-type: none"> <li>'Sum of VOCs classified as CMR 1A or 1B' to 'Total volatile organic carbon (TVOC) containing substances classified as CMR 1A or 1B';</li> <li>'Sum of VOCs classified as CMR 2' to 'Total volatile organic carbon (TVOC) containing substances classified as CMR 2'.</li> </ul>	AT and DE	NA
BAT 11/ Table 4.1	To include a footnote, as follows: 'In the case of significant methane content in the emission, the methane content monitored according to EN ISO 25140 or EN ISO 25139 is subtracted from the result'.	CEFIC	NA
BAT 16/ Table 4.4	To introduce the following footnote, for both thermal and catalytic oxidation: 'The BAT-AEL does not apply when the NO <sub>x</sub> mass flow is below 1 000 g/h'.	IT	NA
BAT 16/ Table 4.4	To modify footnote <sup>(4)</sup> as follows: <sup>(4)</sup> The upper end of the BAT-AEL range may be higher and up to 100 mg/Nm <sup>3</sup> if the process off-gas(es) contain(s) high levels of NO <sub>x</sub> precursors.	IT	NA
BAT 16/ Table 4.4	To modify the upper end of the BAT-AEL range for NO <sub>x</sub> from thermal oxidation.	CEFIC	150 mg/Nm <sup>3</sup>
BAT 18/	To modify the BAT-AEL range for HF.	ES	< 1-2 mg/Nm <sup>3</sup>

Table 4.6	To add a footnote as follows: 'In the case of the production of complex inorganic pigments, the upper end of the BAT-AEL range may be higher and up to 5 mg/Nm <sup>3</sup> if the process off-gas(es) contain(s) high levels of HF precursors'.	CEFIC	NA
BAT 19	To delete the phrase 'targeting 100 ppmv'.	CEFIC	NA
BAT 22	To add a footnote to the table as follows: 'An EN standard to determine VOC fugitive and non-fugitive emissions into the atmosphere, including DIAL and SOF techniques, is under development' ( <i>at the time of the publication of these BAT Conclusions</i> )	BE, SE and EEB	NA
BAT 25/ Table 4.8	To reduce the higher end of the BAT-AEL range for LLDPE.	AT	0.7 g C/kg
BAT 25/ Table 4.8	To delete footnote (2 <sup>bis</sup> ).	AT and SE	NA
BAT 29/ Table 4.9	To increase the upper end of the BAT-AEL range in footnote (2).	CEFIC	10 mg/Nm <sup>3</sup>
BAT 30/ Table 4.10	To increase the upper end of the BAT-AEL range for E-PVC.	CEFIC	0.4 g VCM/kg of PVC produced
BAT 36/Table 4.15	To delete footnote (3)	AT and DE	NA
BAT 11/Table 4.1 BAT 14/Table 4.3 BAT 18/Table 4.6 BAT 29/Table 4.9 BAT 36/Table 4.15	To delete 'e.g.' in all footnotes where a mass flow value is indicated.	DE, DK, SE and EEB	NA

The TWG had extensive debates on the following topics on which a few TWG members raised dissenting views during the Final Meeting:

- Mass flow values used to distinguish between major and minor channelled emissions and whether BAT-AELs (in Table 4.1, Table 4.3, Table 4.6, Table 4.9 and Table 4.15) may apply only to major emissions. The conclusion was to provide example mass flow values as a guide to distinguish between major and minor emissions.
- The absence of a standardised methodology or approach to determine/calculate the mass flow values.

### Consultation of the Forum and subsequent formal adoption procedure of the BAT conclusions

In accordance with Article 13(3) of the Directive 2010/75/EU, the Forum delivered its opinion on the final draft of the Best Available Techniques (BAT) Reference Document for Common Waste Gas Management and Treatment Systems in the chemical sector (WGC BREF) in its meeting of 11 May 2022.

1. The Forum welcomed the draft of the WGC BREF as presented by the Commission.
2. The Forum acknowledged the discussions held at its meeting of 11 May 2022 and agreed that the changes to the draft of the WGC BREF, as proposed in Annex A of the publicly available Forum opinion, should be included in the final version of the document.
3. The Forum confirmed the comments included in Annex B of the publicly available Forum opinion as representing the views of certain members of the Forum, on which no consensus was reached within the Forum to include them in the final document.

Subsequently, the Commission took the opinion of the IED Article 13 Forum into account when preparing the draft Commission Implementing Decision establishing Best Available Techniques (BAT) conclusions for the Common Waste Gas Management and Treatment Systems in the chemical sector.

The IED Article 75 Committee, through a written procedure lasting until 28 September 2022, voted in favour of the draft Commission Implementing Decision establishing the BAT conclusions for the Waste Gas Management and Treatment Systems in the Chemical sector (WGC).

Subsequently, the Commission Implementing Decision (EU) establishing best available techniques (BAT) conclusions for Common Waste Gas Management and Treatment Systems in the chemical sector was adopted on 6 December 2022 and published in the Official Journal of the European Union (OJ L 318, 12.12.2022, p. 157 – 206).

### **Recommendations for future work**

The information exchange revealed a number of issues that should be addressed during the review of the WGC BREF. The recommendations for the review include the following tasks.

Related to emissions to air:

- To collect further information on the practical application of the concept of ‘minor emissions’ and on the methodology or approach used to determine/calculate the mass flow values (including information on relevant monitoring frequency).
- To track and evaluate the progress of the development of standardised methods to monitor VOC substances classified as CMR.
- To track and evaluate the progress of the development of standardised methods to monitor dust substances classified as CMR.
- To collect information about the energy demand associated with the use of the techniques listed in BAT 9, BAT 11, BAT 13, BAT 15, BAT 18 and BAT 34, and the minimum concentration of the compounds in the process off-gases sent for recovery or abatement.
- To collect information on the performance and the use of smoothers and concentrators in the chemical sector.
- To collect data and information on the actual/real operating hours of the processes (including the abatement techniques) for the purpose of calculating the yearly mass flow (e.g. for batch processes).
- To collect data and information on the performance of bioprocesses (including when CMR substances are present).
- To collect information on the use of bag filters and on their maintenance, especially in the cases where emission levels are above 5 mg/Nm<sup>3</sup>.
- To collect information on the use and performance of the following techniques:
  - a. choice of fuel;
  - b. low-NO<sub>x</sub> burner;
  - c. optimisation of catalytic or thermal oxidation;
  - d. removal of high levels of NO<sub>x</sub> precursors.
- To collect information on the variability of the NO<sub>x</sub> emissions from thermal treatments associated with batch processes.
- To collect information on process off-gas(es) containing high levels of NO<sub>x</sub> and SO<sub>x</sub> precursors (e.g. production of amino acids).
- To collect information on the fluctuation of the NH<sub>3</sub> concentration in the process off-gases, e.g. for batch production of metal catalysts.



- To collect information on the use and performance of the techniques to reduce HF emissions from batch processes (e.g. production of complex inorganic pigments).
- To collect information on the production of potassium sulphates via the Mannheim process.
- To collect information on the chemical production processes (e.g. including their boundaries) for which a solvent mass balance is implemented.
- To collect information on the calculation of the percentage of the solvent inputs.

Related to the production of polyolefins:

- To collect information on the monitoring of VOCs in the polyolefins, on the monitoring of total emissions from the production of polyolefins, and to develop a harmonised monitoring methodology.
- To collect information on the production of EVA copolymers and other types of copolymers.
- To develop a harmonised methodology for the purpose of calculating total emissions expressed as specific loads.

Related to the production of PVC, to collect information on the emission levels associated with the different PVC grades produced.

Related to the production of viscose, to collect information on the emission levels associated with the use of bioprocesses, and on the possible applicability restriction regarding low concentrations of H<sub>2</sub>S and high volumes of CS<sub>2</sub> in the waste gas.

Related to process furnace(s)/heater(s), to collect information on:

- the use of a reference oxygen level for process furnace(s)/heater(s);
- process furnace(s)/heater(s) using oxygen-enriched air or pure oxygen;
- the reasons, other than safety, why additional air intake brings the oxygen level in the waste gas very close to 21 vol-%;
- the calculation of the emission concentration in the cases above;
- process furnace(s)/heater(s) used in the chemical sector and burning refinery fuels;
- process furnace(s)/heater(s) used in the production of inorganic chemicals containing nitrogenous compounds, especially in the case of hydrogen cyanide;
- the use of hydrogen as fuel, or part of the fuel, for process furnace(s)/heater(s).

Related to monitoring of diffuse emissions, to track and evaluate the progress of the development of standardised methods using different types of techniques. It is noted that a new standard is available, the EN 17628 'Fugitive and diffuse emissions of common concern to industry sectors – Standard method to determine diffuse emissions of volatile organic compounds into the atmosphere'.

According to the aforementioned draft standard, the measurement methods DIAL and SOF allow the determination of (fugitive and/or non-fugitive) emissions from the entire site as well as from equipment (e.g. silo farm). Therefore, SOF and DIAL may be considered as useful monitoring methods for sources of non-fugitive emissions for which a periodic minimum monitoring frequency has been concluded.

Related to the assessment of cross-media effects resulting from the selection of waste gas treatment techniques, to collect information on the use of the life cycle assessment according to EN 14040 (e.g. in the case of stand-alone PVC plant).

Related to the adoption of chemicals management systems, to collect information on their practical applications.

### **Suggested topics for future R&D work**

The Commission is launching and supporting, through its Research and Technological Development programmes, a series of projects dealing with clean technologies, emerging effluent treatment and recycling technologies and management strategies. Potentially, these projects could provide a useful contribution to future BREF reviews. Readers are therefore invited to inform the European IPPC Bureau of any research results which are relevant to the scope of this document (see also the fifth section of the Preface of this document).

## 7 ANNEXES

### 7.1 Calculated concentrations and mass flows

The standardised questionnaire used for the data collection of the WGC BREF gave the possibility to report, per substance monitored and per emission point:

- up to 12 concentration values for 3 different years (36 values in total) in the case of periodic measurements;
- concentration values as daily averages (as 95<sup>th</sup> and 97<sup>th</sup> percentiles) and/or the yearly average, reported for 3 different years in the case of continuous measurements.

For each abatement technique, the volume flow could also be reported:

- as an average value if the waste gas properties did not vary significantly;
- as 12 different values if the waste gas properties varied significantly.

The data presented in Chapter 2 were obtained as explained in Table 7.1.

**Table 7.1: Description of the data related to channelled emissions from Chapter 2**

Data	Type of monitoring	Description
Avg. concentration	Continuous	Depending on the availability of the data, according to the following priority: <ol style="list-style-type: none"> <li>1. the average of all values reported as yearly averages over the 3 years;</li> <li>2. the average over the 3 years of all 97<sup>th</sup> percentile daily average values;</li> <li>3. the average over the 3 years of all 95<sup>th</sup> percentile daily average values;</li> <li>4. the average over the 3 years of all 97<sup>th</sup> percentile half-hourly average values;</li> <li>5. the average over the 3 years of all 95<sup>th</sup> percentile half-hourly average values.</li> </ol>
	Periodic	Average of all values reported over the 3 years.
Avg. volume flow	Continuous and periodic	<ul style="list-style-type: none"> <li>• Average of all volume flows if several values were reported; or</li> <li>• reported volume flow.</li> </ul>
Avg. mass flow	Continuous	$\frac{\text{Avg concentration} * \text{Avg volume flow}}{1000}$
	Periodic	

Table 7.2: Description of the data related to polymers and diffuse emissions from Chapter 2

Type of emission	Data	Description
Fugitive/ Non- Fugitive	Total VOC quantity in t/yr	If the quantity per equipment is not available then take the total quantity reported  Else $\sum_{\text{All equipments}} \text{quantities reported}$
	Total CMR 1A/1B substances quantity in t/yr	
	Total CMR 2 substances quantity in t/yr	
SMP	% diffused emissions / solvent input (indirect method)	$100 \frac{l_1 - (O_1 + O_5 + O_6 + O_7 + O_8)}{l_1 + l_2}$
Polyolefins	Average specific load in kg/t for KEI	$\frac{\sum \text{values reported}}{\text{Number of values reported}}$
PVC	Average specific load in kg/t for KEI	
Synthetic rubbers	Average specific load in kg/t for KEI	
Viscose	Average specific load in kg/t for KEI	

## 7.2 List of chemical installations/plants in EU Member States and the United Kingdom that participated in the data collection

Plant Code	Installation/plant	Company name	Country	City
[AT_1]	Boehringer Ingelheim RCV GMBH & Co KG	Boehringer Ingelheim RCV GMBH & Co KG	AT	Vienna
[AT_2]	Melamin	Borealis Agrolinz Melamine GmbH	AT	Linz
[AT_3]	Borealis Schwechat	Borealis Polyolefine GmbH	AT	Schwechat-Mannswörth
[AT_4]	Werk Arnoldstein	Chemson Polymer Additive AG	AT	Arnoldstein
[AT_5]	DIC Performance Resins GmbH	DIC Performance Resins GmbH	AT	Vienna
[AT_6]	Lenzing	Evonik Fibres GmbH	AT	Lenzing
[AT_7]	EPO-Plant	Evonik Peroxid GmbH	AT	Weißenstein
[AT_8]	Lenzing AG	Lenzing AG	AT	Lenzing
[AT_9]	Lyocell Production	Lenzing AG	AT	Lenzing
[AT_10]	Lyocell Production	Lenzing Fibers GmbH	AT	Heiligenkreuz
[AT_11]	Fischamend	Loba Feinchemie GmbH	AT	Fischamend
[AT_12]	CPL Linz	Nufarm GmbH & Co.KG	AT	Linz
[AT_13]	Linz	Patheon Austria GmbH & Co KG	AT	Linz
[AT_14]	Kundl	Sandoz GmbH	AT	Kundl
[AT_15]	Schaftenau	Sandoz GmbH	AT	Langkampfen
[AT_16]	Recycling1	Treibacher Industrie AG	AT	Althofen
[AT_17]	Selten Erden (SE)	Treibacher Industrie AG	AT	Althofen
[AT_18]	Vanadiumoxidanlage (VO)	Treibacher Industrie AG	AT	Althofen
[AT_19]	Waschmittelrohstoffproduktion (WR)	Treibacher Industrie AG	AT	Althofen
[AT_20]	Werk Arnoldstein	Tribotec GmbH	AT	Arnoldstein
[BE_1]	3M Belgium BVBA	3M	BE	Zwijndrecht
[BE_2]	Ajinomoto Omnichem Balen Plant	Ajinomoto Omnichem	BE	Balen
[BE_3]	Ajinomoto Omnichem Wetteren Plant	Ajinomoto Omnichem	BE	Wetteren

[BE_4]	Butyl rubber production plant	ARLANXEO Belgium nv	BE	Zwijndrecht
[BE_5]	Methylcellulose production	Ashland Specialties Belgium	BE	Beveren
[BE_6]	BE.VL.000000032	BASF Antwerp NV	BE	Antwerp
[BE_7]	BE.VL.000000033	BASF Antwerp NV	BE	Antwerp
[BE_8]	BE.VL.000000035	BASF Antwerp NV	BE	Antwerp
[BE_9]	BE.VL.000000036	BASF Antwerp NV	BE	Antwerp
[BE_10]	BE.VL.000000037	BASF Antwerp NV	BE	Antwerp
[BE_11]	BE.VL.000000038	BASF Antwerp NV	BE	Antwerp
[BE_12]	BE.VL.000000039	BASF Antwerp NV	BE	Antwerp
[BE_13]	BE.VL.000000041	BASF Antwerp NV	BE	Antwerp
[BE_14]	BE.VL.000000042	BASF Antwerp NV	BE	Antwerp
[BE_15]	BE.VL.000000043	BASF Antwerp NV	BE	Antwerp
[BE_16]	BE.VL.000000045	BASF Antwerp NV	BE	Antwerp
[BE_17]	BE.VL.000000049	BASF Antwerp NV	BE	Antwerp
[BE_18]	BE.VL.000000034-1	BASF Antwerp NV	BE	Antwerp
[BE_19]	BE.VL.000000034-2	BASF Antwerp NV	BE	Antwerp
[BE_20]	BE.VL.000000040-1	BASF Antwerp NV	BE	Antwerp
[BE_21]	BE.VL.000000040-2	BASF Antwerp NV	BE	Antwerp
[BE_22]	BE.VL.000000052	BASF DOW HPPO Production	BE	Antwerp
[BE_23]	Borealis ANTLD (reactor section)	Borealis Antwerpen N.V.	BE	Zwijndrecht
[BE_24]	Dehydrogenation unit (DEHY)	Borealis Kallo N.V.	BE	Kallo-Kieldrecht (Beveren)
[BE_25]	PP3 (polymerisation polypropylene)	Borealis Kallo N.V.	BE	Kallo-Kieldrecht (Beveren)
[BE_26]	Production Plant PP1	Borealis Polymers NV	BE	Beringen
[BE_27]	Production Plant PP2	Borealis Polymers NV	BE	Beringen
[BE_28]	Aniline/Nitrobenzene	Covestro NV	BE	Antwerp
[BE_29]	BPA	Covestro NV	BE	Antwerp
[BE_30]	Makrolon	Covestro NV	BE	Antwerp
[BE_31]	Polyether	Covestro NV	BE	Antwerp

[BE_40]	Production of Zinc Oxide and by-products Lead Sulphate and Zinc Chloride	Everzinc Belgium NV	BE	Heusden-Zolder
[BE_41]	ACA	Evonik Antwerpen	BE	Antwerp
[BE_42]	ACMC	Evonik Antwerpen	BE	Antwerp
[BE_43]	ME2	Evonik Antwerpen	BE	Antwerp
[BE_44]	PACM	Evonik Antwerpen	BE	Antwerp
[BE_45]	SL	Evonik Antwerpen	BE	Antwerp
[BE_46]	Antwerp Polymers Plant (APP)	ExxonMobil Petroleum & Chemical BVBA	BE	Zwijndrecht
[BE_47]	Meerhout Polymers Plant (MPP)	ExxonMobil Petroleum & Chemical BVBA	BE	Meerhout
[BE_48]	W5_BE.VL.000000650	FENZI BELGIUM	BE	Vilvoorde
[BE_49]	Ineos Manufacturing Belgium_Antwerpen	Ineos Manufacturing Belgium NV	BE	Antwerp
[BE_50]	INEOS Manufacturing Belgium_Geel	INEOS Manufacturing Belgium NV	BE	Geel
[BE_51]	ENB	Ineos Oxide	BE	Zwijndrecht
[BE_52]	ETOX	Ineos Oxide	BE	Zwijndrecht
[BE_53]	Ineos Phenol	INEOS Phenol Belgium NV	BE	Beveren
[BE_54]	INOVYN JEMEPPE-SUR-SAMBRE-VCM Production	INOVYN MANUFACTURING BELGIUM	BE	Jemeppe-Sur-Sambre
[BE_55]	INOVYN JEMEPPE-SUR-SAMBRE-PVC Production	INOVYN MANUFACTURING BELGIUM	BE	Jemeppe-Sur-Sambre
[BE_56]	Janssen Pharmaceutica Geel	Janssen Pharmaceutica NV	BE	Geel
[BE_57]	Caprolactam production plant	LANXESS nv (Lillo)	BE	Antwerp
[BE_58]	Incinerator	Lawter Kallo	BE	Kallo
[BE_59]	Monument Chemical	Monument Chemical bvba	BE	Beveren
[BE_60]	Akzo Nobel Chemicals	Nouryon	BE	Ghlin
[BE_61]	Polyol belgium Tertre	Polyol Belgium sprl	BE	Tertre
[BE_65]	Taminco 963	Taminco BVBA	BE	Ghent
[BE_66]	Taminco 964	Taminco BVBA	BE	Ghent
[BE_67]	Production FeCl3	Tessengerlo Group	BE	Tessengerlo
[BE_68]	Production NaHS/Na2S	Tessengerlo Group	BE	Tessengerlo

[BE_69]	TIMAC AGRO Belux	TIMAC AGRO Belux	BE	Marchienne au Pont
[BE_70]	NC2 & toluene unit	Total Olefins Antwerp	BE	Antwerp
[BE_71]	Total Petrochemicals Feluy SA	Total Petrochemicals Feluy SA	BE	Feluy
[BE_72]	BZC	Valtris AO Belgium nv	BE	Tessenderlo
[BE_73]	Production of cellulose casings for foodindustry	ViskoTeepak	BE	Lommel
[BE_74]	MVC	VYNOVA Belgium NV	BE	Tessenderlo
[BE_75]	Total Polymers Antwerp	Total Polymers Antwerp	BE	Antwerp
[BE_76]	EOC Belgium Oudenaarde	EOC Belgium Oudenaarde	BE	Oudenaarde
[BE_77]	EOC Belgium Latex Division II	EOC Belgium Latex Division II	BE	Evergem
[BE_78]	EOC Belgium Adhesive Division	EOC Belgium Adhesive Division	BE	Evergem
[BE_79]	EOC Surfactants	EOC Surfactants	BE	Evergem
[BE_80]	Proviron Functional Chemicals	Proviron	BE	Oostende
[BE_81]	Production chlorosulfonic acid (process CSA)	PVS Chemicals Belgium	BE	Ghent
[BE_82]	Pore Volume Impregnation Plant	Shell Catalysts & Technologies Belgium NV	BE	Ghent
[CZ_1]	Production of nitrobenzene	BorsodChem MCHZ, s.r.o.	CZ	Ostrava
[CZ_2]	Set of chemical productions	DEZA, a.s.	CZ	Vlašské Meziříčí; Otrokovice
[CZ_3]	31	FARMAK, a.s.	CZ	Olomouc
[CZ_4]	PJ 20.04	FARMAK, a.s.	CZ	Olomouc
[CZ_5]	PJ 20.08	FARMAK, a.s.	CZ	Olomouc
[CZ_6]	Production and processing of rayon and production of calcined sodium sulphate	Glanzstoff-Bohemia s.r.o.	CZ	Lovosice
[CZ_7]	PVC	SPOLANA a.s.	CZ	Neratovice
[CZ_8]	Production of low molecular epoxy resins	Spolek pro chemickou a hutní výrobu, akciová společnost	CZ	Ústí nad Labem
[CZ_9]	Production of Polyester resins	Spolek pro chemickou a hutní výrobu, akciová společnost	CZ	Ústí nad Labem
[CZ_10]	Production of synthetic resins (UP I)	Spolek pro chemickou a hutní výrobu, akciová společnost	CZ	Ústí nad Labem
[CZ_11]	Production of EPITETRA	Spolek pro chemickou a hutní výrobu, akciová společnost	CZ	Ústí nad Labem



[CZ_12]	Production of Epichlorohydrin	Spolek pro chemickou a hutní výrobu, akciová společnost	CZ	Ústí nad Labem
[CZ_13]	Production of nitrocellulose	Synthesia, a.s.	CZ	Pardubice
[CZ_14]	Ethylbenzene	SYNTHOS Kralupy a.s.	CZ	Litvínov
[CZ_15]	Expandable polystyrene production	SYNTHOS Kralupy a.s.	CZ	Kralupy nad Vltavou
[CZ_16]	General purpose polystyrene (GPPS) plant	Synthos Kralupy a.s.	CZ	Kralupy nad Vltavou
[CZ_17]	High Impact Polystyrene (HIPS) plant	SYNTHOS Kralupy a.s.	CZ	Kralupy nad Vltavou
[CZ_18]	Styrene	SYNTHOS Kralupy a.s.	CZ	Kralupy nad Vltavou
[CZ_19]	Styrenebutadiene rubber production plant	SYNTHOS Kralupy a.s.	CZ	Kralupy nad Vltavou
[CZ_20]	Polybutadiene rubber production plant	SYNTHOS PBR s.r.o.	CZ	Kralupy nad Vltavou
[CZ_21]	Ethylene Unit/LO	UNIPETROL RPA, s.r.o.	CZ	Litvínov Záluží
[CZ_22]	Ethylene Unit/A	UNIPETROL RPA, s.r.o.	CZ	Litvínov Záluží
[CZ_23]	Polypropylene and polyethylene production/PP	UNIPETROL RPA, s.r.o.	CZ	Litvínov Záluží
[CZ_24]	Polypropylene and polyethylene production/PE2	UNIPETROL RPA, s.r.o.	CZ	Litvínov Záluží
[CZ_25]	Polypropylene and polyethylene production/PO storage	UNIPETROL RPA, s.r.o.	CZ	Litvínov Záluží
[DE_1]	4061 - Anlage zur Herstellung von PU-Granulat - Bandanlagen (Gebäude B30)	BASF Polyurethanes GmbH	DE	Lemfoerde
[DE_2]	8E Anorganic Pigments	Merck KGaA	DE	Gernsheim
[DE_3]	301 M - Pearlescent pigment production plant	Merck KGaA	DE	Gernsheim
[DE_4]	G20 Multipurpose and multi-material plant for factory production of active pharmaceutical ingredients and fine chemicals	Merck KGaA	DE	Darmstadt
[DE_5]	G151 Anorganic Pigments	Merck KGaA	DE	Gernsheim
[DE_6]	J29 - Plant for the production of inorganic salts	Merck KGaA	DE	Darmstadt
[DE_7]	L21 plant for the production of ammonium salts and secondary products	Merck KGaA	DE	Darmstadt
[DE_8]	N5 - organic production for industrial chemicals	Merck KGaA	DE	Darmstadt

[DE_11]	Nabaltec AG	Process plant for production of aluminium hydroxide, alumina, boehmite and synthetically mullite (product P1).	DE	Schwandorf
[DE_13]	Anlage 003 - Eisen(III)salz-Anlagen	Nouryon	DE	Ibbenbüren
[DE_14]	Anlage 003 - Eisen(III)salz-Anlagen	Nouryon	DE	Ibbenbüren
[DE_15]	Sta	Olin Blue Cube	DE	Stade
[DE_16]	Sth	Olin Blue Cube	DE	Stade
[DE_17]	Stm	Olin Blue Cube	DE	Stade
[DE_18]	Stn	Olin Blue Cube	DE	Stade
[DE_19]	Stq	Olin Blue Cube	DE	Stade
[DE_20]	Stx	Olin Blue Cube	DE	Stade
[DE_21]	100_0990908_1000_V1	OXEA Production GmbH & Co.KG	DE	Oberhausen
[DE_22]	100_0990908_1300_V1	OXEA Production GmbH & Co.KG	DE	Oberhausen
[DE_23]	100_0990908_1420_V1	OXEA Production GmbH & Co.KG	DE	Oberhausen
[DE_24]	100_0990908_4000_V1	OXEA Produktion GmbH & Co.KG	DE	Oberhausen
[DE_25]	100_0990908_300_V1	OXEA Produktion GmbH & Co.KG	DE	Oberhausen
[DE_26]	Polymerisation of Polyamide	Performance Polyamides GmbH	DE	Freiburg
[DE_27]	PHP Fibers GmbH_06-09-676-4139-0001_Nylonkondensation	PHP Fibers GmbH	DE	Obernburg
[DE_28]	PHP Fibers GmbH_06-09-676-4139-0001_Nylonkondensation	PHP Fibers GmbH	DE	Obernburg
[DE_29]	Production of Celluloseacetate	Rhodia Acetow GmbH	DE	Freiburg
[DE_30]	Tränk- und Beschichtungsanlage mit thermischer Abluftreinigung	Roche Diagnostics GmbH	DE	Mannheim
[DE_31]	Crushing unit dedusting	RW silicium GmbH	DE	Pocking
[DE_32]	Dedusting equipment	RW silicium GmbH	DE	Pocking
[DE_33]	Raw material transport dedusting	RW silicium GmbH	DE	Pocking
[DE_34]	LEV 023 FFK	Saltigo GmbH	DE	Leverkusen
[DE_35]	LEV 058 DHA	Saltigo GmbH	DE	Leverkusen
[DE_36]	LEV 066 ZETO	Saltigo GmbH	DE	Leverkusen

[DE_37]	S1	Sasol	DE	Marl
[DE_38]	S2	Sasol	DE	Marl
[DE_39]	S3	Sasol	DE	Marl
[DE_40]	S4	Sasol	DE	Marl
[DE_41]	S5	Sasol	DE	Marl
[DE_42]	S6	Sasol	DE	Marl
[DE_43]	P2 Vielstoffanlage	Solenis Technologies Germany GmbH	DE	Krefeld
[DE_44]	P4 Polymerisationsanlage	Solenis Technologies Germany GmbH	DE	Krefeld
[DE_45]	TESIUM-TAREX	Tesium GmbH	DE	Holzminden
[DE_46]	TESIUM-Thermoreaktor- C413	Tesium GmbH	DE	Holzminden
[DE_47]	TESIUM-TAREX	Tesium GmbH	DE	Holzminden
[DE_48]	100_0991623_6010_V1	TOPAS Advanced Polymers GmbH	DE	Oberhausen
[DE_49]	Polykondensationsanlage mit HT-Anlage	Trevira GmbH	DE	Bobingen
[DE_50]	1,4 cis PB Plant	Trinseo Deutschland GmbH	DE	Schkopau
[DE_51]	ESBR Plant	Trinseo Deutschland GmbH	DE	Schkopau
[DE_52]	PS Plant	Trinseo Deutschland GmbH	DE	Schkopau
[DE_53]	Solution Elastomer Plant	Trinseo Deutschland GmbH	DE	Schkopau
[DE_54]	Ursa-Chemie GmbH	Ursa-Chemie GmbH	DE	Montabaur
[DE_55]	Schwefelsäurebetrieb	VENATOR Uerdingen GmbH	DE	Uerdingen
[DE_56]	100_0078370_5000_V1	Versalis Deutschland GmbH	DE	Oberhausen
[DE_57]	PVC	Vestolit	DE	Marl
[DE_58]	H 07 E-Polymer	Vinnolit GmbH & Co. KG	DE	Burgkirchen
[DE_59]	J02-Vinnol-S-Anlage	Vinnolit GmbH & Co. KG	DE	Burghausen
[DE_60]	J 03- Vinnol-E-Anlage BGH	Vinnolit GmbH & Co. KG	DE	Burghausen
[DE_61]	VINHEDC	Vinnolit GmbH & Co. KG	DE	Hürth
[DE_62]	VINHOXI	Vinnolit GmbH & Co. KG	DE	Hürth
[DE_63]	VINHPVCS	Vinnolit GmbH & Co. KG	DE	Hürth
[DE_64]	VINHVC	Vinnolit GmbH & Co. KG	DE	Hürth

[DE_65]	VINM_PVC-P	Vinnolit GmbH & Co. KG	DE	Cologne
[DE_66]	VINM_PVC-S	Vinnolit GmbH & Co. KG	DE	Cologne
[DE_67]	PVC-E-Anlage	Vinnolit Schkopau GmbH	DE	Schkopau
[DE_68]	PVC-Anlage	VYNOVA Wilhelmshaven GmbH	DE	Wilhelmshaven
[DE_70]	BGH_CT02TA6	Wacker Chemie AG	DE	Burghausen
[DE_71]	BGH_E14	Wacker Chemie AG	DE	Burghausen
[DE_72]	BGH_E26	Wacker Chemie AG	DE	Burghausen
[DE_73]	BGH_E 39	Wacker Chemie AG	DE	Burghausen
[DE_74]	BGH_E43	Wacker Chemie AG	DE	Burghausen
[DE_75]	BGH_E45	Wacker Chemie AG	DE	Burghausen
[DE_76]	BGH_L01	Wacker Chemie AG	DE	Burghausen
[DE_77]	BGH_L02	Wacker Chemie AG	DE	Burghausen
[DE_78]	BGH_N02	Wacker Chemie AG	DE	Burghausen
[DE_79]	BGH_N05	Wacker Chemie AG	DE	Burghausen
[DE_80]	BGH_N09	Wacker Chemie AG	DE	Burghausen
[DE_81]	EO-Betrieb Blow Down	Zschimmer & Schwarz GmbH & Co KG	DE	Lahnstein
[DE_82]	KS-Betrieb	Zschimmer & Schwarz GmbH & Co KG	DE	Lahnstein
[DE_83]	S/M Betrieb	Zschimmer & Schwarz GmbH & Co KG	DE	Lahnstein
[DE_84]	Z-Betrieb	Zschimmer & Schwarz GmbH & Co KG	DE	Lahnstein
[DE_85]	BMCR1	Dow	DE	Bomlitz
[DE_86]	LPE	Dow	DE	Leuna
[DE_87]	LU_23.05	BASF SE	DE	Ludwigshafen
[DE_88]	NC-B	Dow	DE	Bomlitz
[DE_89]	StB	Dow	DE	Stade
[DE_90]	StRW	Dow	DE	Stade
[DE_98]	ID1322 Lithium SOPRO	Albemarle Germany GmbH	DE	Langelshiem
[DE_103]	DCD-Anlage	AlzChem Trostberg GmbH	DE	Tacherting
[DE_104]	DO 0124 LP	Arlanxeo Deutschland GmbH	DE	Dormagen

[DE_105]	DO 0135 CP	Arlanxeo Deutschland GmbH	DE	Dormagen
[DE_108]	Petrochemische Anlage Münchsmünster	Basell Polyolefine GmbH	DE	Münchsmünster
[DE_109]	W0010 OT3	Basell Polyolefine GmbH	DE	Wesseling
[DE_110]	W0011 OM6	Basell Polyolefine GmbH	DE	Wesseling
[DE_111]	W0020 BD	Basell Polyolefine GmbH	DE	Wesseling
[DE_112]	W0022 OM4	Basell Polyolefine GmbH	DE	Wesseling
[DE_113]	W0025 ONC	Basell Polyolefine GmbH	DE	Wesseling
[DE_114]	W0033 OH	Basell Polyolefine GmbH	DE	Wesseling
[DE_115]	WEO KAOX Ost	Basell Polyolefine GmbH	DE	Wesseling
[DE_117]	9040 Produktionsgebäude	BASF Grenzach GmbH	DE	Grenzach-Wyhlen
[DE_118]	BTZ-Anlage	BASF Lampertheim GmbH	DE	Lampertheim
[DE_119]	Ester-HALS-Anlage	BASF Lampertheim GmbH	DE	Lampertheim
[DE_120]	FR-Anlage	BASF Lampertheim GmbH	DE	Lampertheim
[DE_121]	Irgafos-Anlage	BASF Lampertheim GmbH	DE	Lampertheim
[DE_122]	LS-Anlage	BASF Lampertheim GmbH	DE	Lampertheim
[DE_123]	MZ-Anlage	BASF Lampertheim GmbH	DE	Lampertheim
[DE_124]	Öladditiv-Anlage	BASF Lampertheim GmbH	DE	Lampertheim
[DE_125]	TAR-Anlage	BASF Lampertheim GmbH	DE	Lampertheim
[DE_126]	Plant 63: Sulfication H	BASF Personal Care and Nutrition GmbH	DE	Düsseldorf
[DE_127]	Plant No. 31: EO-Anlage	BASF Personal Care and Nutrition GmbH	DE	Düsseldorf
[DE_128]	LU_01.01	BASF SE	DE	Ludwigshafen
[DE_129]	LU_01.02	BASF SE	DE	Ludwigshafen
[DE_130]	LU_01.04	BASF SE	DE	Ludwigshafen
[DE_131]	LU_01.06	BASF SE	DE	Ludwigshafen
[DE_132]	LU_01.10	BASF SE	DE	Ludwigshafen
[DE_133]	LU_02.01	BASF SE	DE	Ludwigshafen
[DE_134]	LU_02.07	BASF SE	DE	Ludwigshafen
[DE_135]	LU_02.15	BASF SE	DE	Ludwigshafen

[DE_136]	LU_03.01	BASF SE	DE	Ludwigshafen
[DE_137]	LU_03.02	BASF SE	DE	Ludwigshafen
[DE_138]	LU_04.05	BASF SE	DE	Ludwigshafen
[DE_139]	LU_05.01	BASF SE	DE	Ludwigshafen
[DE_140]	LU_05.02	BASF SE	DE	Ludwigshafen
[DE_141]	LU_07.05	BASF SE	DE	Ludwigshafen
[DE_142]	LU_07.06	BASF SE	DE	Ludwigshafen
[DE_143]	LU_07.07	BASF SE	DE	Ludwigshafen
[DE_144]	LU_07.08	BASF SE	DE	Ludwigshafen
[DE_145]	LU_08.03	BASF SE	DE	Ludwigshafen
[DE_146]	LU_08.04	BASF SE	DE	Ludwigshafen
[DE_147]	LU_08.06	BASF SE	DE	Ludwigshafen
[DE_148]	LU_08.07	BASF SE	DE	Ludwigshafen
[DE_149]	LU_09.01	BASF SE	DE	Ludwigshafen
[DE_150]	LU_09.04	BASF SE	DE	Ludwigshafen
[DE_151]	LU_09.07	BASF SE	DE	Ludwigshafen
[DE_152]	LU_09.09	BASF SE	DE	Ludwigshafen
[DE_153]	LU_10.01	BASF SE	DE	Ludwigshafen
[DE_154]	LU_10.02	BASF SE	DE	Ludwigshafen
[DE_155]	LU_10.04	BASF SE	DE	Ludwigshafen
[DE_156]	LU_10.05	BASF SE	DE	Ludwigshafen
[DE_157]	LU_10.06	BASF SE	DE	Ludwigshafen
[DE_158]	LU_10.08	BASF SE	DE	Ludwigshafen
[DE_159]	LU_11.04	BASF SE	DE	Ludwigshafen
[DE_160]	LU_11.06	BASF SE	DE	Ludwigshafen
[DE_161]	LU_11.08	BASF SE	DE	Ludwigshafen
[DE_162]	LU_11.11	BASF SE	DE	Ludwigshafen
[DE_163]	LU_12.11	BASF SE	DE	Ludwigshafen

[DE_164]	LU_12.15	BASF SE	DE	Ludwigshafen
[DE_165]	LU_12.18	BASF SE	DE	Ludwigshafen
[DE_166]	LU_12.30	BASF SE	DE	Ludwigshafen
[DE_167]	LU_14.01	BASF SE	DE	Ludwigshafen
[DE_168]	LU_14.03	BASF SE	DE	Ludwigshafen
[DE_169]	LU_14.04	BASF SE	DE	Ludwigshafen
[DE_170]	LU_14.06	BASF SE	DE	Ludwigshafen
[DE_171]	LU_14.08	BASF SE	DE	Ludwigshafen
[DE_172]	LU_14.12	BASF SE	DE	Ludwigshafen
[DE_173]	LU_15.03	BASF SE	DE	Ludwigshafen
[DE_174]	LU_15.06	BASF SE	DE	Ludwigshafen
[DE_175]	LU_16.05	BASF SE	DE	Ludwigshafen
[DE_176]	LU_16.06	BASF SE	DE	Ludwigshafen
[DE_177]	LU_17.02	BASF SE	DE	Ludwigshafen
[DE_178]	LU_17.03	BASF SE	DE	Ludwigshafen
[DE_179]	LU_17.04	BASF SE	DE	Ludwigshafen
[DE_180]	LU_18.01	BASF SE	DE	Ludwigshafen
[DE_181]	LU_18.03	BASF SE	DE	Ludwigshafen
[DE_182]	LU_19.01	BASF SE	DE	Ludwigshafen
[DE_183]	LU_19.03	BASF SE	DE	Ludwigshafen
[DE_184]	LU_19.04	BASF SE	DE	Ludwigshafen
[DE_185]	LU_19.05	BASF SE	DE	Ludwigshafen
[DE_186]	LU_19.06	BASF SE	DE	Ludwigshafen
[DE_187]	LU_19.08	BASF SE	DE	Ludwigshafen
[DE_188]	LU_20.01	BASF SE	DE	Ludwigshafen
[DE_189]	LU_20.02	BASF SE	DE	Ludwigshafen
[DE_190]	LU_20.03	BASF SE	DE	Ludwigshafen
[DE_191]	LU_20.04	BASF SE	DE	Ludwigshafen

[DE_192]	LU_21.03	BASF SE	DE	Ludwigshafen
[DE_193]	LU_21.04	BASF SE	DE	Ludwigshafen
[DE_194]	LU_21.08	BASF SE	DE	Ludwigshafen
[DE_195]	LU_23.01	BASF SE	DE	Ludwigshafen
[DE_196]	LU_2601	BASF SE	DE	Ludwigshafen
[DE_197]	LU_2703	BASF SE	DE	Ludwigshafen
[DE_198]	LU_2801	BASF SE	DE	Ludwigshafen
[DE_199]	LU_2906	BASF SE	DE	Ludwigshafen
[DE_200]	LU_29.09	BASF SE	DE	Ludwigshafen
[DE_201]	LU_30.01	BASF SE	DE	Ludwigshafen
[DE_202]	LU_3002	BASF SE	DE	Ludwigshafen
[DE_203]	LU_3004	BASF SE	DE	Ludwigshafen
[DE_204]	LU_3103	BASF SE	DE	Ludwigshafen
[DE_205]	LU_3104	BASF SE	DE	Ludwigshafen
[DE_206]	LU_3108	BASF SE	DE	Ludwigshafen
[DE_207]	LU_3109	BASF SE	DE	Ludwigshafen
[DE_208]	LU_32.06	BASF SE	DE	Ludwigshafen
[DE_209]	LU_32.07	BASF SE	DE	Ludwigshafen
[DE_210]	LU_33.01	BASF SE	DE	Ludwigshafen
[DE_211]	LU_33.02	BASF SE	DE	Ludwigshafen
[DE_212]	LU_33.05	BASF SE	DE	Ludwigshafen
[DE_213]	LU_33.09	BASF SE	DE	Ludwigshafen
[DE_214]	LU_37.01	BASF SE	DE	Ludwigshafen
[DE_215]	LU_37.07	BASF SE	DE	Ludwigshafen
[DE_216]	LU_3708	BASF SE	DE	Ludwigshafen
[DE_217]	LU_37.39	BASF SE	DE	Ludwigshafen
[DE_218]	LU_70.11	BASF SE	DE	Ludwigshafen
[DE_219]	LU_70.34	BASF SE	DE	Ludwigshafen



[DE_221]	DO 0144 BAG CI	Bayer AG	DE	Dormagen
[DE_222]	DO 106 HB	Bayer AG	DE	Dormagen
[DE_223]	DO 0155 VZ	Bayer AG	DE	Dormagen
[DE_224]	Production Unit B	Bayer AG, Site Bergkamen	DE	Bergkamen
[DE_225]	Production Unit E	Bayer AG, Site Bergkamen	DE	Bergkamen
[DE_226]	Production Unit F	Bayer AG, Site Bergkamen	DE	Bergkamen
[DE_227]	DE_Boehringer Ingelheim_ING_4000_BfS	Boehringer Ingelheim Pharma GmbH & Co. KG	DE	Ingelheim
[DE_228]	DE_Boehringer Ingelheim_ING_2100_Synt hese 1	Boehringer Ingelheim Pharma GmbH & Co. KG	DE	Ingelheim
[DE_229]	DE_Boehringer Ingelheim_ING_2300_Synt hese 8	Boehringer Ingelheim Pharma GmbH & Co. KG	DE	Ingelheim
[DE_232]	2 Line Melamine Production	Borealis Agrolinz Melamine Deutschland GmbH	DE	Lutherstadt Wittenberg
[DE_233]	BU PP4	Borealis Polymere GmbH	DE	Burghausen
[DE_234]	BU PP6	Borealis Polymere GmbH	DE	Burghausen
[DE_235]	CABB_MCE	CABB GmbH	DE	Cologne
[DE_236]	CABB_NMCA	CABB GmbH	DE	Cologne
[DE_237]	CS2-Anlage	Carbosulf Chemische Werke GmbH	DE	Cologne
[DE_238]	249	Celanese Production Germany GmbH	DE	Frankfurt am Main
[DE_239]	274	Celanese Production Germany GmbH	DE	Frankfurt am Main
[DE_240]	289	Celanese Production Germany GmbH	DE	Frankfurt am Main
[DE_241]	356	Celanese Production Germany GmbH	DE	Frankfurt am Main
[DE_242]	359	Celanese Production Germany GmbH	DE	Frankfurt am Main
[DE_243]	368	Celanese Production Germany GmbH	DE	Frankfurt am Main
[DE_244]	1245	Celanese Production Germany GmbH	DE	Frankfurt am Main
[DE_246]	Reaktionsanlage zur Oberflächenbehandlung von Siliziumdioxid (Planetendisslover)	CHT Germany GmbH	DE	Geretsried
[DE_247]	Werk Dusslingen	CHT Germany GmbH	DE	Dusslingen
[DE_248]	B770, HPPS-B770	Clariant Plastics & Coatings (Deutschland) GmbH	DE	Frankfurt am Main
[DE_249]	C490 Azo IV	Clariant Plastics & Coatings (Deutschland) GmbH	DE	Frankfurt am Main

[DE_250]	C738, HPPS C738	Clariant Plastics & Coatings (Deutschland) GmbH	DE	Frankfurt am Main
[DE_251]	CLA Gh Anlage 2	Clariant Plastics & Coatings (Deutschland) GmbH Gersthofen	DE	Gersthofen
[DE_252]	CLA Gh Anlage 1	Clariant Plastics & Coatings (Deutschland) GmbH	DE	Gersthofen
[DE_253]	D 428 VP-4 Diketen	Clariant Plastics & Coatings (Deutschland) GmbH	DE	Frankfurt am Main
[DE_254]	D747 Azo II	Clariant Plastics & Coatings (Deutschland) GmbH	DE	Frankfurt am Main
[DE_255]	E751 W/O Vorprodukte1	Clariant Plastics & Coatings (Deutschland) GmbH	DE	Frankfurt am Main
[DE_256]	E751 W/O VP-1	Clariant Plastics & Coatings (Deutschland) GmbH	DE	Frankfurt am Main
[DE_257]	E751 W/O VP-1	Clariant Plastics & Coatings (Deutschland) GmbH	DE	Frankfurt am Main
[DE_259]	BRU Anlage 0010	Covestro Deutschland AG	DE	Brunsbüttel
[DE_260]	BRU Anlage 003 REB 1	Covestro Deutschland AG	DE	Brunsbüttel
[DE_261]	BRU Anlage 0029	Covestro Deutschland AG	DE	Brunsbüttel
[DE_262]	BRU Anlage 003 REB 3	Covestro Deutschland AG	DE	Brunsbüttel
[DE_263]	LEV Anlage 0150	Covestro Deutschland AG	DE	Leverkusen
[DE_264]	UER Anlage 0071	Covestro Deutschland AG	DE	Uerdingen
[DE_265]	OLD Systemhaus	Covestro Oldenburg GmbH & Co KG	DE	Oldenburg
[DE_266]	Anlage zur Herstellung von pharmazeutischen Wirkstoffen	Chemisch-pharmazeutisches Labor, Rolf Sachse GmbH	DE	Berlin
[DE_267]	Thermische Abluftreinigung TAR (waste gas incinerator TAR)	CU Chemie Uetikon GmbH	DE	Lahr
[DE_269]	Wes02	CyPlus	DE	Wesseling
[DE_270]	Acryl Fibre Production	Dolan GmbH	DE	Kelheim
[DE_271]	BACR	DOW	DE	Boehlen
[DE_272]	Sch7601	Dow	DE	Schkopau
[DE_273]	Sch7603	Dow	DE	Schkopau
[DE_274]	Acrylfaserwerk (Anlage zur Herstellung von Chemiefasern)	Dralon GmbH Lingen	DE	Lingen
[DE_275]	Produktion	Dralon GmbH	DE	Dormagen
[DE_277]	DOS01	Evonik	DE	Dossenheim
[DE_278]	Ess01	Evonik	DE	Essen

[DE_279]	Ess02	Evonik	DE	Essen
[DE_280]	Han03	Evonik	DE	Hanau
[DE_281]	Han04	Evonik	DE	Hanau
[DE_282]	Han011	Evonik	DE	Hanau
[DE_283]	Han012	Evonik	DE	Hanau
[DE_284]	Han013	Evonik	DE	Hanau
[DE_285]	Lue01	Evonik	DE	Niederkassel
[DE_286]	Lue02	Evonik	DE	Niederkassel
[DE_287]	Lue04	Evonik	DE	Niederkassel
[DE_288]	36951	Evonik	DE	Marl
[DE_289]	37316	Evonik	DE	Marl
[DE_290]	37681	Evonik	DE	Marl
[DE_291]	38047	Evonik	DE	Marl
[DE_292]	38412	Evonik	DE	Marl
[DE_293]	38777	Evonik	DE	Marl
[DE_294]	Rhe01	Evonik	DE	Rheinfelden
[DE_295]	Rhe02	Evonik	DE	Rheinfelden
[DE_296]	STNE	Evonik	DE	Steinau an der Straße
[DE_297]	STNK	Evonik	DE	Steinau an der Straße
[DE_298]	STNU	Evonik	DE	Steinau an der Strasse
[DE_299]	Wei01	Evonik	DE	Weiterstadt
[DE_300]	Wes01	Evonik	DE	Wesseling
[DE_301]	Wes03	Evonik	DE	Wesseling
[DE_302]	Wes04	Evonik	DE	Wesseling
[DE_303]	Wor01	Evonik	DE	Worms
[DE_304]	Wor02	Evonik	DE	Worms
[DE_305]	Microencapsulation Plant	Follmann Chemie GmbH	DE	Minden
[DE_306]	Polymerisation Plant	Follmann Chemie GmbH	DE	Minden

[DE_307]	Adsorbents-Anlage	Grace GmbH	DE	Worms
[DE_308]	Adsorbents-Anlage	Grace GmbH	DE	Worms
[DE_309]	FCC Anlage	Grace GmbH	DE	Worms
[DE_310]	FCC Anlage - Teilanlage 2	Grace GmbH	DE	Worms
[DE_311]	FCC Anlage - Teilanlage 3	Grace GmbH	DE	Worms
[DE_312]	FCC Anlage - Teilanlage 4	Grace GmbH	DE	Worms
[DE_313]	Zeolith Anlage	GRACE GmbH	DE	Worms
[DE_314]	Anlage 50	Henkel AG & Co. KGaA	DE	Düsseldorf
[DE_315]	Anlage 73	Henkel AG & Co. KGaA	DE	Düsseldorf
[DE_316]	Anlage 75	Henkel AG & Co. KGaA	DE	Düsseldorf
[DE_317]	Steam Generator	Heubach GmbH	DE	Langelsheim
[DE_318]	Production of pigment preparations wet (PPW)	Heubach GmbH	DE	Langelsheim
[DE_319]	Production of complex inorganic colored pigments (CIC) Part A	Heubach GmbH	DE	Langelsheim
[DE_320]	Production of complex inorganic colored pigments (CIC) Part B	Heubach GmbH	DE	Langelsheim
[DE_321]	Production of complex inorganic colored pigments (CIC) Part C	Heubach GmbH	DE	Langelsheim
[DE_322]	Production of pigment preparations dry (PPD)	Heubach GmbH	DE	Langelsheim
[DE_323]	Production of anti-corrosive pigments (ACO)	Heubach GmbH	DE	Langelsheim
[DE_324]	O08 Acrylnitrilanlage III, 0140	Ineos Manufacturing Deutschland GmbH	DE	Cologne
[DE_325]	O17 Acrylnitrilanlage II, 0013	Ineos Manufacturing Deutschland GmbH	DE	Cologne
[DE_326]	P14 Mehrprodukten-Anlage, 0260	Ineos Manufacturing Deutschland GmbH	DE	Cologne
[DE_327]	P16 Ethoxilatanlage, 0280	Ineos Manufacturing Deutschland GmbH	DE	Cologne
[DE_328]	Q20 Ethylenoxidanlage, 0180	Ineos Manufacturing Deutschland GmbH	DE	Cologne
[DE_329]	S03 Kracker V, 0200	Ineos Manufacturing Deutschland GmbH	DE	Cologne
[DE_330]	T02 Polyethylenanlage I, 0120	Ineos Manufacturing Deutschland GmbH	DE	Cologne
[DE_331]	T05 Polyethylenanlage II, 0210	Ineos Manufacturing Deutschland GmbH	DE	Cologne
[DE_332]	T07 Polyethylenanlage III, 0270	Ineos Manufacturing Deutschland GmbH	DE	Cologne

[DE_333]	T21 Kracker IV, 0110	Ineos Manufacturing Deutschland GmbH	DE	Cologne
[DE_334]	INEOS Phenol Gladbeck	INEOS Phenol GmbH	DE	Gladbeck
[DE_335]	VC-Anlage	NOVYN Deutschland GmbH	DE	Rheinberg
[DE_336]	Allylchlorid, Epichlorhydrin Glycerin (AEG) und	NOVYN Deutschland GmbH	DE	Rheinberg
[DE_337]	Rheinberg E-PVC	NOVYN Deutschland GmbH	DE	Rheinberg
[DE_338]	Rheinberg S-PVC	NOVYN Deutschland GmbH	DE	Rheinberg
[DE_339]	Endstufe	Jungbunzlauer Ladenburg GmbH	DE	Ladenburg
[DE_340]	Ester Anlage	Jungbunzlauer Ladenburg GmbH	DE	Ladenburg
[DE_341]	Viscose Staple Fibre Production	Kelheim Fibres GmbH	DE	Kelheim
[DE_342]	Production Vellmar	KEMPER SYSTEM GmbH & Co. KG	DE	Vellmar
[DE_343]	Formalin and Glue production unit	Kronospan	DE	Lampertswalde
[DE_344]	Resin production unit and impregnation	Kronospan	DE	Lampertswalde
[DE_345]	LEV 048 CLB	Lanxess Deutschland GmbH	DE	Leverkusen
[DE_346]	LEV 054 N	Lanxess Deutschland GmbH	DE	Leverkusen
[DE_347]	LEV 080 OF	Lanxess Deutschland GmbH	DE	Leverkusen
[DE_348]	LEV 086 GST	Lanxess Deutschland GmbH	DE	Leverkusen
[DE_349]	LEV 114 SSF	Lanxess Deutschland GmbH	DE	Leverkusen
[DE_350]	LEV 122 PFK	Lanxess Deutschland GmbH	DE	Leverkusen
[DE_351]	LEV 140 Hydr	Lanxess Deutschland GmbH	DE	Leverkusen
[DE_352]	UE 0002 CrOX	Lanxess Deutschland GmbH	DE	Krefeld
[DE_353]	UE 004 FeOX1 (a)	Lanxess Deutschland GmbH	DE	Krefeld
[DE_354]	UE 004 FeOX1	Lanxess Deutschland GmbH	DE	Krefeld
[DE_355]	UE 021 ADS	Lanxess Deutschland GmbH	DE	Krefeld
[DE_356]	LU_23.07	BASF SE	DE	Ludwigshafen
[DE_357]	ID1306 Li-carbonate	Albemarle Germany GmbH	DE	Langelsheim
[DE_358]	ID1302 Li-chloride	Albemarle Germany GmbH	DE	Langelsheim
[DE_359]	ID Lithiumspezialsalze 1304	Albemarle Germany GmbH	DE	Langelsheim

[DE_360]	ID1310 Lithium hydride	Albemarle Germany GmbH	DE	Langelsheim
[DE_361]	ID1312 Lithiumalkyle	Albemarle Germany GmbH	DE	Langelsheim
[DE_362]	ID1311 Lithiumamid	Albemarle Germany GmbH	DE	Langelsheim
[DE_363]	ID1321 Ex-Technikum und Grignard	Albemarle Germany GmbH	DE	Langelsheim
[DE_364]	ID1323 Lithiumalanat	Albemarle Germany GmbH	DE	Langelsheim
[DE_365]	ID1332 Metallprodukte	Albemarle Germany GmbH	DE	Langelsheim
[DE_366]	ID 1330 Cesium	Albemarle Germany GmbH	DE	Langelsheim
[DE_367]	Cyanamid-Anlage	AlzChem Trostberg GmbH	DE	Trostberg
[DE_368]	LEV 014 Therb	Arlanxeo Deutschland GmbH	DE	Leverkusen
[DE_369]	HDPE-Anlage Münchsmünster	Basell Polyolefine GmbH	DE	Münchsmünster
[DE_370]	Agrochemikalien 1 / Wirkstoffe	BASF Agricultural Solutions GmbH	DE	Frankfurt am Main
[DE_371]	Harzfabrik	BASF Coatings GmbH	DE	Münster
[DE_372]	Agrochemikalien 2	Bayer AG	DE	Franfurt am Main
[DE_373]	DE_Boehringer-Ingelheim_ING_5000_PW B	Boehringer Ingelheim Pharma GmbH & Co. KG	DE	Ingelheim
[DE_374]	DE_Boehringer Ingelheim_ING_1000_Alkaloid	Boehringer Ingelheim Pharma GmbH & Co. KG	DE	Ingelheim
[DE_375]	CHT Germany GmbH - Site Oyten	CHT Germany GmbH	DE	Oyten
[DE_376]	Cordenka GmbH & Co. KG_Technical Rayon Production_06-09-676-0081-0001	Cordenka GmbH & Co. KG	DE	Obernburg a.M.
[DE_377]	ENKA GmbH & Co. KG, Installation for textile rayon, 06-09-676-4111-0001	ENKA GmbH & Co. KG	DE	Obernburg
[DE_378]	Cellulosehydratbetriebe	Kalle GmbH	DE	Wiesbaden
[DE_379]	P24 - Hydrogenation and processing of organic chemicals	Merck KGaA	DE	Darmstadt
[DE_380]	Zuckerfabrik Klein Wanzleben - Bioethanolanlage	Nordzucker AG	DE	Stadt Wanzleben - Börde
[DE_381]	VCM-Anlage	VYNOVA Wilhelmshaven GmbH	DE	Wilhelmshaven
[DE_382]	DO 145 CUR TVA	Currenta	DE	Dormagen
[DE_383]	Viskase	Walsroder Casings GmbH	DE	Walsrode
[DK_1]	FMC Production Site Ronland	Cheminova A/S	DK	Harboore

[DK_2]	Fine Chemical Production	LEO Pharma A/S	DK	Ballerup
[ES_4]	Fabrica de Transformados de Arnao	Asturiana de Zinc, S.A.U.	ES	Castrillón
[ES_5]	Castellbisbal Site	BASF	ES	Castellbisbal (Barcelona)
[ES_6]	Site Tarragona	BASF	ES	Tarragona
[ES_7]	Zona Franca Site	BASF	ES	Barcelona
[ES_8]	BASF ESPAÑOLA S.L.U - SITE MARCHAMALO, GUADALAJARA	BASF ESPAÑOLA S.L	ES	Guadalajara
[ES_9]	Cepsa Química Palos	Cepsa	ES	Palos de la Frontera (Huelva)
[ES_11]	Refinería Gibraltar-San Roque	Cepsa (Compañía Española de Petróleos, S.A.U.)	ES	San Roque (Cádiz)
[ES_14]	Colores Ceramicos de Tortosa S.A.	Colores Ceramicos de Tortosa S.A.	ES	Tortosa
[ES_15]	Colores Ceramicos de Tortosa S.A.	Colores Ceramicos de Tortosa S.A.	ES	Tortosa
[ES_16]	Colores Ceramicos de Tortosa S.A.	Colores Ceramicos de Tortosa S.A.	ES	Tortosa
[ES_20]	COPLOSA	COPLOSA S.A.	ES	Barcelona
[ES_21]	Colorobbia España S.A.	Colorobbia España S.A.	ES	Vilafamés
[ES_23]	TAR MDI_MDA plant	Covestro S.L.	ES	La Canonja
[ES_24]	ZFR Resin	Covestro S.L.	ES	Zona Franca, Barcelona
[ES_25]	Olefins	Dow North	ES	La Pobla de Mafumet and Perafort (Tarragona)
[ES_26]	LDPE	Dow South	ES	La Canonja (Tarragona)
[ES_27]	Polyols	Dow South	ES	La Canonja (Tarragona)
[ES_28]	Solution	Dow South	ES	La Canonja (Tarragona)
[ES_29]	ENDEKA CERAMICS SA	ENDEKA CERAMICS SA	ES	Vall d'Alba (Castellón)
[ES_30]	Almussafes	ERCROS SA	ES	Almussafes
[ES_31]	ARANJUEZ	ERCROS, S.A.	ES	Aranjuez
[ES_32]	Cerdanyola	Ercros SA	ES	Cerdanyola del Vallès
[ES_33]	SABIÑÁNIGO	ERCROS SA	ES	Sabiñánigo
[ES_34]	Tortosa	Ercros, S.A.	ES	Tortosa (Tarragona)
[ES_35]	Vilaseca I	ERCROS, S.A.	ES	Tarragona

[ES_36]	Vilaseca II	ERCROS S.A.	ES	Vila-Seca (Tarragona)
[ES_37]	EXPAL Propellant Systems, S.A	EXPAL Propellant Systems, S.A	ES	Murcia
[ES_38]	FERRO SPAIN, S.A._ASPIRACIONES	FERRO SPAIN, S.A.	ES	Almassora
[ES_39]	FERRO SPAIN, S.A._COMBUSTION1MW	FERRO SPAIN, S.A.	ES	Almassora
[ES_42]	Fritta S.L.U.	Fritta S.L.U.	ES	Onda (Castellón)
[ES_43]	RUBBER CHEMICALS SAU	GRUPO DYANSOL	ES	Zubillaga Lantaron (Álava)
[ES_44]	DYNASOL ELASTÓMEROS S.A.U.	GRUPO DYNASOL	ES	Gajano (Marina de Cudeyo)
[ES_45]	INDUSTRIAS QUÍMICAS DEL EBRO S.A	INDUSTRIAS QUÍMICAS DEL EBRO S.A	ES	Zaragoza
[ES_46]	INOVYN MARTORELL-PVC Production	INOVYN ESPAÑA S.L.	ES	Martorell
[ES_49]	ITACA,S.A.U.	ITACA,S.A.U.	ES	Pobla Tornesa (Castellón)
[ES_52]	PANREAC QUIMICA S.L.U.	ITW REAGENTS	ES	Castellar del Vallès
[ES_53]	KEM ONE HERNANI	KEM ONE	ES	Hernani
[ES_54]	MANUEL VILASECA, S.A.	MANUEL VILASECA, S.A.	ES	Móra la Nova
[ES_55]	FABRICA DE PARAMO DE MASA	MAXAM EUROPE, S.A.	ES	Quintanilla Sobresierra (Burgos)
[ES_56]	Galdacano Factory	MAXAM EUROPE, S.A.	ES	Galdakao (Vizcaya)
[ES_57]	Galdacano Factory	MAXAM-UEB, S.L.	ES	Galdakao (Vizcaya)
[ES_58]	Planta de Olefinas Refinería de Tarragona	Repsol Petróleo	ES	Tarragona
[ES_59]	REPSOL PETRÓLEO PUERTOLLANO	REPSOL PETRÓLEO PUERTOLLANO	ES	Puertollano
[ES_60]	BUTADIENE	REPSOL QUÍMICA, S.A.	ES	La Pobla de Mafumet (Tarragona)
[ES_61]	Complejo Industrial Repsol Química Puertollano	Repsol Química S.A.	ES	Puertollano
[ES_62]	FLEXIBLE POLYOLS	REPSOL QUIMICA, S.A.	ES	La Pobla de Mafumet (Tarragona)
[ES_63]	HDPE	REPSOL QUIMICA, S.A.	ES	La Pobla de Mafumet (Tarragona)
[ES_64]	LDPE	REPSOL QUIMICA, S.A.	ES	La Pobla de Mafumet (Tarragona)
[ES_65]	POLYMERIC POLYOLS	REPSOL QUÍMICA, S.A.	ES	La Pobla de Mafumet (Tarragona)
[ES_66]	Polypropilene	REPSOL QUIMICA, S.A.	ES	La Pobla de Mafumet (Tarragona)
[ES_67]	PROPYLENE GLYCOL	REPSOL QUIMICA, S.A.	ES	La Pobla de Mafumet (Tarragona)
[ES_68]	Styrene coproduction with propylene oxide.	REPSOL QUIMICA, S.A.	ES	La Pobla de Mafumet (Tarragona)
[ES_69]	SABIC Innovative Plastics España S.C.P.A.	SABIC	ES	Cartagena



[ES_70]	TRANSFORMADORA DE ETILENO, AIE	TDE,AIE	ES	Tarragona
[ES_72]	ALFARBEN, S.A. <1 Mw	ALFARBEN, S.A.	ES	L'Alcora
[ES_73]	ALFARBEN, S.A., dust	ALFARBEN, S.A.	ES	L'Alcora
[ES_74]	ALFARBEN, S.A. up 1MW	ALFARBEN, S.A.	ES	L'Alcora
[ES_75]	CEPSA QUIMICA PUENTE MAYORGA	CEPSA (Compañía Española de Petróleos, S.A.U.)	ES	San Roque (Cádiz)
[ES_76]	COLORES CERAMICOS SA	COLORES CERAMICOS SA	ES	Onda
[ES_77]	COLORES CERAMICOS S.A.	COLORES CERAMICOS S.A.	ES	Onda
[ES_78]	COLOR ESMALT S.A.	COLOR ESMALT S.A.	ES	Alcora (Castellón)
[ES_79]	COLOR ESMALT S.A.	COLOR ESMALT S.A.	ES	Alcora (Castellón)
[ES_80]	Colorobbia España S.A.	Colorobbia España S.A.	ES	Vilafamés
[ES_81]	Colorobbia España S.A.	Colorobbia Esapaña S.A.	ES	Vilafames
[ES_82]	ENDEKA CERAMICS SA	ENDEKA CERAMICS SA	ES	Vall d'Alba (Castellón)
[ES_83]	Fritta S.L.U.	Fritta S.L.U.	ES	Onda (Castellón)
[ES_84]	Fritta S.L.U.	Fritta S.L.U.	ES	Onda (Castellón)
[ES_85]	ITACA,S.A.U.	ITACA,S.A.U.	ES	Pobla Tornesa (Castellón)
[ES_86]	ITACA,S.A.U.	ITACA,S.A.U.	ES	Pobla Tornesa (Castellón)
[ES_87]	ITACA,S.A.U.	ITACA,S.A.U.	ES	Pobla Tornesa (Castellón)
[ES_88]	ITACA,S.A.U.	ITACA,S.A.U.	ES	Pobla Tornesa (Castellón)
[FI_1]	Polyethylene plant PE2	Borealis Polymers Oy	FI	Porvoo
[FI_2]	Olefins unit	Borealis Polymers Oy	FI	Porvoo
[FI_3]	Phenol & aromatics	Borealis Polymers Oy	FI	Porvoo
[FI_4]	Production of fibrous casings for food industry	Oy ViskoTeepak Ab	FI	Hanko
[FI_5]	Potassium sulphate plant	Yara Suomi Oy Kokkola	FI	Kokkola
[FR_1]	ALFI_LACQ	Air Liquide France Industrie	FR	Lacq
[FR_2]	ALFI_LAVERA	Air Liquide France Industrie	FR	Lavera
[FR_3]	ALFI_LIMAY	Air liquide France Industrie	FR	Limay
[FR_4]	PIERRE BENITE	ARKEMA	FR	Pierre Benite

[FR_5]	MONT's Arkema plant	ARKEMA France	FR	Mont
[FR_50]	ARKEMA Saint-Avoid	ARKEMA France	FR	Saint-Avoid
[FR_6]	ASHLAND_ETAIN	ASHLAND	FR	Etain
[FR_7]	Axens_Salindres	Axens	FR	Salindres
[FR_8]	BUTADIENE EXTRACTION	BASELL POLYOLEFINES France SAS - BPO	FR	Berre l'Etang
[FR_9]	CRACKER	BASELL POLYOLEFINES France SAS - BPO	FR	Berre l'Etang
[FR_10]	POLYETHYLENE	BASELL POLYOLEFINES France SAS - BPO	FR	Berre l'Etang
[FR_11]	POLYPROPYLENE	BASELL POLYOLEFINES France SAS - BPO	FR	Berre l'Etang
[FR_12]	BIMA 83_CERNAY	BIMA 83	FR	Cernay
[FR_13]	Butachimie_Chalampé	Butachimie	FR	Chalampé
[FR_14]	Carboxylates Unit, HO HHOB2 Unit, Phenat Dithiophosphates de Zinc Traitment Unit	CHEVRON ORONITE SAS	FR	Gonfreville-l'Orcher
[FR_15]	CHIMEX Mourenx plant	CHIMEX	FR	Mourenx
[FR_16]	Dow agrosiences	Dow Agrosiences	FR	Drusenheim
[FR_17]	DRT Castets	DRT	FR	Castets
[FR_18]	Chauny	DSP SAS	FR	Chauny
[FR_19]	EURENCO SORGUES	EURENCO	FR	Sorgues
[FR_20]	EMCF Lillebonne	EXXONMOBIL CHEMICAL France	FR	Lillebonne
[FR_21]	EMCF Port Jerome Sur Seine	EXXONMOBIL CHEMICAL France	FR	Port Jerome Sur Seine
[FR_22]	Unité Formol 4	FORESA France	FR	Ambarés & Lagrave
[FR_23]	INEOS DERIVATIVES LAVERA_LAVERA	INEOS DERIVATIVES LAVERA	FR	Lavera
[FR_24]	INOVYN_TAVAU(39)	INOVYN France	FR	Tavaux
[FR_25]	Kem One Balan	Kem One	FR	Balan
[FR_26]	Lavera	KEM ONE France	FR	Martigues
[FR_27]	LA MESTA CHIMIE FINE	LA MESTA CHIMIE FINE	FR	Gilette
[FR_28]	POLYOLS	Lyondell Chimie France SAS	FR	Fos sur Mer
[FR_29]	PO/TBA-MTBE	Lyondell Chimie France SAS	FR	Fos sur Mer
[FR_30]	ORIL INDUSTRIE_BACLAIR	ORIL INDUSTRIE	FR	Bolbec

[FR_31]	ORIL INDUSTRIE_BOLBEC	ORIL INDUSTRIE	FR	Bolbec
[FR_32]	PIERRE FABRE MEDICAMENT_GAILLAC	PIERRE FABRE LABORATORIES	FR	Gaillac
[FR_33]	PITHIVIERS	PMC ISOCHEM	FR	Pithiviers
[FR_34]	Potasse et Produits Chimiques_Thann	Potasse et Produits Chimiques	FR	Thann
[FR_35]	SA ARKEMA FRANCE_MARSEILLE	SA ARKEMA France	FR	Marseille
[FR_36]	SISTERON	SANOFI CHIMIE	FR	Sisteron
[FR_37]	SIMOREP ET CIE	MICHELIN	FR	Bassens
[FR_38]	SNF Andrézieux	SNF SA	FR	Andrézieux- Bouthéon
[FR_39]	Thermal oxydiser	SOBEGI	FR	Mourenx
[FR_40]	RHODIA OPERATIONS LA ROCHELLE	SOLVAY	FR	La Rochelle
[FR_41]	SOLVAY OPERATIONS France, établissement de Tavaux	SOLVAY	FR	Tavaux
[FR_42]	Saint Fons Spécialités plant	RHODIA OPERATIONS	FR	Saint Fons
[FR_43]	Usine de Gonfreville	TOTAL	FR	Gonfreville L'Orcher
[FR_44]	Plateforme TotalPetrochemicals de Carling Saint-Avoid	TOTAL	FR	Saint-Avoid
[FR_45]	Notre-Dame	V.Mane.fils	FR	Le Bar-sur-Loup
[FR_46]	Etablissement Résines	VON ROLL France SA	FR	Meyzieu
[FR_47]	VYNOVA Mazingarbe	VYNOVA Mazingarbe SAS	FR	Mazingarbe
[HU_1]	LD-2 Unit	MOL Petrochemicals Plc.	HU	Tiszaújváros
[HU_2]	Olefin-1 Unit	MOL Petrochemicals Plc.	HU	Tiszaújváros
[HU_3]	Olefin-2 Unit	MOL Petrochemicals Plc.	HU	Tiszaújváros
[HU_4]	WWT-1 Unit	MOL Petrochemicals Plc.	HU	Tiszaújváros
[IE_1]	Aughinish Alumina Ltd	Aughinish Alumina Ltd	IE	Limerick
[IE_2]	Avara Shannon Pharmaceutical Services Ltd.	Avara Shannon Pharmaceutical Services Ltd.	IE	Shannon
[IE_3]	Eli Lilly Kinsale, IEL No. P0009-04	Eli Lilly Kinsale Limited	IE	Cork
[IE_4]	Hovione Ltd	Hovione Ltd	IE	Cork
[IE_5]	RHI Manesita Drogheda Plant AKA- Premier Periclase Ltd	Premier Periclase Ltd	IE	Drogheda

[IT_1]	Basell Poliolefine Italia S.r.l. Stabilimento di Brindisi	Basell Poliolefine Italia S.r.l.	IT	Brindisi
[IT_2]	Stabilimento di Ferrara	Basell Poliolefine Italia S.r.l.	IT	Ferrara
[IT_3]	Stabilimento di Sasso Marconi (loc. Pontecchio Marconi)	BASF Italia SpA	IT	Sasso Marconi (Bologna)
[IT_4]	U.P. Celanese Donegani	Celanese Production Italy SRL	IT	Ferrara
[IT_5]	C.O.I.M. s.p.a. Stabilimento di Offanengo (CR)	C.O.I.M. s.p.a.	IT	Offanengo
[IT_6]	Baranzate Site	Dipharma Francis srl	IT	Baranzate (Milano)
[IT_7]	Mereto	Dipharma Francis srl	IT	Mereto di Tomba (Udine)
[IT_8]	Stabilimento petrolchimico versalis di Brindisi	eni	IT	Brindisi
[IT_10]	Villadose Plant	FRESENIUS KABI iPSUM	IT	Villadose (Rovigo)
[IT_11]	INEOS MANUFACTURING ITALIA SpA	INEOS MANUFACTURING ITALIA SpA	IT	Rosignano Marittimo (Livorno)
[IT_12]	Lundbeck Pharmaceuticals Italy	Lundbeck Pharmaceuticals Italy S.p.A.	IT	Padova
[IT_13]	Mater-Biopolymer S.r.l.	Mater-Biopolymer S.r.l.	IT	Patrica (Frosinone)
[IT_14]	OPOCRIN SPA STABILIMENTO DI CORLO DI FORMIGINE	OPOCRIN SPA	IT	Modena
[IT_15]	OPOCRIN SPA STABILIMENTO DI CORLO DI NONANTOLA	OPOCRIN SPA	IT	Modena
[IT_16]	Plastipak Italia Preforme Srl	Plastipak Italia Preforme Srl	IT	Verbania
[IT_17]	Stabilimento di Terranova	Sasol Italy S.p.A.	IT	Terranova dei Passerini (Lodi)
[IT_18]	Stabilimento di Augusta	Sasol Italy S.p.A.	IT	Augusta (Siracusa)
[IT_19]	Stabilimento di Sarroch	Sasol Italy S.p.A.	IT	Sarroch (Cagliari)
[IT_20]	Ravenna Plant	SOL Gas Primari s.r.l.	IT	Ravenna
[IT_21]	SYNTHOMER s.r.l.	SYNTHOMER s.r.l.	IT	Filago
[IT_23]	Stabilimento di Ravenna	Versalis	IT	Ravenna
[IT_24]	Porto Marghera Plant	Versalis S.p.A.	IT	Marghera (Venice)
[IT_25]	STABILIMENTO VERSALIS DI PORTO TORRES	Versalis s.p.a.	IT	Porto Torres
[IT_26]	Stabilimento Versalis di Priolo	Versalis spa	IT	Priolo Gargallo (Siracusa)
[IT_27]	Stabilimento Versalis di Priolo	Versalis spa	IT	Priolo Gargallo (Siracusa)

[IT_28]	Stabilimento Versalis di Priolo	Versalis spa	IT	Priolo Gargallo (Siracusa)
[IT_29]	STABILIMENTO VERSALIS DI FERRARA	VERSALIS S.P.A.	IT	Ferrara
[IT_30]	Stabilimento Versalis di Sarroch	Versalis S.p.A.	IT	Sarroch (Cagliari)
[IT_34]	Versalis S.p.A. Mantova	Versalis S.p.A.	IT	Mantova
[IT_36]	Versalis S.p.A. Mantova	Versalis S.p.A.	IT	Mantova
[IT_37]	Versalis S.p.A. Mantova	Versalis S.p.A.	IT	Mantova
[IT_38]	Versalis S.p.A. Mantova	Versalis S.p.A.	IT	Mantova
[IT_39]	Sede Centrale - Via Ponte della Fabbrica, 3/a	Fidia Farmaeutici S.p.A.	IT	Abano Terme (Padua)
[IT_40]	Stabilimento di Ravenna	Versalis	IT	Ravenna
[IT_41]	STABILIMENTO VERSALIS DI RAGUSA	VERSALIS SPA	IT	Ragusa
[NL_1]	ACN, ZAV and HCN processing	AnQore B.V.	NL	Urmond
[NL_2]	EPT Fabrieken	ARLANXEO NETHERLANDS B.V.	NL	Geleen
[NL_3]	Plant	BASF Heerenveen	NL	Heerenveen (Nijehaske)
[NL_4]	BOREALIS Plastomers Geleen	Borealis	NL	Geleen
[NL_5]	Celanese Production Netherlands B.V.	Celanese Production Netherlands B.V.	NL	Geleen
[NL_6]	Dowlex	Dow Benelux B.V.	NL	Terneuzen
[NL_7]	Ethyleenamines	Dow Benelux B.V.	NL	Terneuzen
[NL_8]	LDPE	Dow Benelux B.V.	NL	Terneuzen
[NL_9]	Polyurethanen	Dow Benelux B.V.	NL	Terneuzen
[NL_10]	Katalic Oxydiser	DSM Coating Resins	NL	Waalwijk
[NL_11]	DSM Engineering Plastics Stanyl	DSM Engineering Plastics	NL	Geleen
[NL_12]	ZorF, fermentation and down stream processing of 7-ADCA	dsm-sinochem pharmaceuticals	NL	Delft
[NL_13]	Plasticizer Plant	ExxonMobil Chemical Holland BV	NL	Rotterdam
[NL_14]	Caprolactam plant	Fibrant BV	NL	Geleen
[NL_15]	Hexion B.V.	Hexion B.V.	NL	Rotterdam
[NL_17]	Kt2	OCI Nitrogen	NL	Geleen
[NL_18]	Melaminefabriek2	OCI Nitrogen	NL	Geleen

[NL_19]	Melaminefabriek4	OCI Nitrogen	NL	Geleen
[NL_20]	Ureumfabriek	OCI Nitrogen	NL	Geleen
[NL_21]	Chemelot, SMA Plant	Polyscope Polymers bv	NL	Geleen
[NL_22]	SABIC Innovative Plastics	SABIC	NL	Bergen op Zoom
[NL_23]	LD3/4 SABIC	SABIC Limburg BV	NL	Geleen
[NL_24]	LDPE SABIC	SABIC Limburg BV	NL	Geleen
[NL_25]	Olefins 3	SABIC Limburg BV	NL	Geleen
[NL_26]	Olefins 4	SABIC Limburg BV	NL	Geleen
[NL_27]	PPF3/6 SABIC	SABIC Limburg BV	NL	Geleen
[NL_28]	COD	Shell Nederland Chemie B.V. Locatie Pernis	NL	Hoogvliet (Rotterdam)
[NL_30]	SNC	Shell Nederland Chemie B.V. Locatie Pernis	NL	Pernis (Rotterdam)
[NL_32]	MFD	Shell Nederland Chemie B.V. Locatie Moerdijk	NL	Moerdijk
[NL_35]	SNC	Shell Nederland Chemie B.V. Locatie Moerdijk	NL	Moerdijk
[NL_36]	PVC Pernis	Shin-Etsu PVC B.V.	NL	Pernis (Rotterdam)
[NL_37]	Productie van alkyl-antrachinon, verdunnen en verpakken van waterstofperoxide, productie, verdunnen en verpakken van organische(ester)perzuren	Solvay Chemie	NL	Herten
[NL_38]	Latex	Trinseo	NL	Terneuzen
[NL_39]	VYNOVA Beek bv	VYNOVA Group	NL	Sittard-Geleen
[NL_40]	MEOD	Shell Nederland Chemie B.V. Locatie Moerdijk	NL	Moerdijk
[NL_41]	MLO	Shell Nederland Chemie B.V. Locatie Moerdijk	NL	Moerdijk
[NL_42]	MSPO	Shell Nederland Chemie B.V. Locatie Moerdijk	NL	Moerdijk
[NL_43]	CVP	Shell Nederland Chemie B.V. Locatie Pernis	NL	Hoogvliet (Rotterdam)
[NO_1]	GE Healthcare AS, Lindesnes Factories (GEHCLI)	GE Helthcare AS	NO	Lindesnes (Vest-Agder)
[NO_2]	Inovyn Norge AS, Klor/VCM-fabrikken	INEOS	NO	Rafnes
[NO_3]	Ineos Bamble AS - Polyethylene Plant	Ineos Bamble AS	NO	Stathelle
[NO_4]	INOVYN Norge AS, PVC-plant	INOVYN Norge AS	NO	Porsgrunn

[NO_5]	NOVYN Norge AS, PVC-plant	NOVYN Norge AS	NO	Porsgrunn
[NO_6]	Kemira Fredrikstad Norway	Kemira Chemicals AS	NO	Fredrikstad
[NO_7]	RHI Normag AS	RHI Magnesita	NO	Porsgrunn
[NO_8]	Saint-Gobain Ceramic Materials AS Lillesand	Saint-Gobain Ceramic Materials AS	NO	Lillesand
[NO_9]	S-anlegg	Unger Fabrikker AS	NO	Fredrikstad
[PL_1]	PVC production	ANWIL S.A.	PL	Włocławek
[PL_2]	Caprolactam	Grupa Azoty S.A.	PL	Tarnów
[PL_3]	Aldehydes and alcohols installation	Grupa Azoty Zakłady Azotowe Kędzierzyn S.A.	PL	Kędzierzyn-Koźle
[PL_4]	Continuous production of di-2-ethylhexyl terephthalate	Grupa Azoty Zakłady Azotowe Kędzierzyn S.A.	PL	Kędzierzyn-Koźle
[PL_5]	Cyclohexanone from phenol	Grupa Azoty S.A.	PL	Tarnów
[PL_6]	Formaline	Grupa Azoty S.A.	PL	Tarnów
[PL_7]	MELAMINE II	Grupa Azoty Puławy	PL	Puławy
[PL_8]	MELAMINE III	Grupa Azoty Puławy	PL	Puławy
[PL_9]	Melamine I plant	Grupa Azoty Zakłady Azotowe Puławy	PL	Puławy
[PL_10]	Polyamide II	Grupa Azoty S.A.	PL	Tarnów
[PL_11]	Tarnoform (polyoxymethylene)	Grupa Azoty S.A.	PL	Tarnów
[PL_12]	Styrene Production Installation	Synthos Dwory 7 Sp. z o. o. Sp.J.	PL	Oświęcim
[PT_1]	Bresfor, Indústria do Formol, S.A.	Bresfor, Indústria do Formol, S.A.	PT	Gafanha da Nazaré
[PT_3]	ASCENZA Agro, S.A.	ASCENZA Agro, S.A.	PT	Setúbal
[PT_4]	BONDALTI chemicals, S.A. (former CUF- Químicos Industriais, S.A.)	BONDALTI Chemicals, S.A. (former CUF-Químicos Industriais, S.A.)	PT	Estarreja
[PT_5]	Companhia Industrial de Resinas Sintéticas, CIRES, Lda.	Companhia Industrial de Resinas Sintéticas, CIRES, Lda. (Shin-Etsu Group)	PT	Estarreja
[PT_6]	Diamantino Malho & C <sup>a</sup> Lda	Diamantino Malho & C <sup>a</sup> Lda	PT	Albergaria dos Doze, Pombal
[PT_7]	EuroResinas - Industrias Químicas SA	EuroResinas - Industrias Químicas SA	PT	Sines
[PT_8]	Euro-Yser Produtos Químicos S.A.	Euro-Yser Produtos Químicos S.A.	PT	Aveiro
[PT_9]	InChemica, Indústria Química de Especialidades, SA	InChemica, Indústria Química de Especialidades, SA	PT	Azambuja
[PT_10]	Centro de Produção de Alenquer	Linde Portugal Lda	PT	Alenquer

[PT_11]	OMNOVA Solutions Portugal, S.A. (former Resiquímica - Resinas Químicas, S.A.)	OMNOVA Solutions Portugal, S.A. (former Resiquímica - Resinas Químicas, S.A.)	PT	Mem Martins
[PT_12]	Repsol Polímeros S.A. (Complexo Industrial de Sines)	Repsol Polímeros S.A.	PT	Sines
[PT_13]	SGL COMPOSITES, S.A (former FISIFE, S.A.)	SGL COMPOSITES, S.A (former FISIFE, S.A.)	PT	Lavradio
[PT_14]	Centro de Produção de Estarreja	Sociedade Portuguesa do Ar Líquido "ArLíquido", Lda (Air Liquide)	PT	Estarreja
[PT_15]	Solvay Portugal - Produtos Químicos	Solvay Portugal - Complexo Fabril da Póvoa de Santa Iria	PT	Póvoa de Santa Iria
[PT_16]	AQP – Aliada Química de Portugal, Lda.	AQP – Aliada Química de Portugal, Lda.	PT	Estarreja
[SE_1]	Pergopak plant	Akzo Nobel Adhesives AB	SE	Sundsvall
[SE_4]	Borealis_Cracker	Borealis AB	SE	Stenungsund
[SE_5]	Borealis_Polyeten	Borealis AB	SE	Stenungsund
[SE_6]	E-PVC	INOVYN Sverige AB	SE	Stenungsund
[SE_7]	S-PVC	INOVYN Sverige AB	SE	Stenungsund
[SE_8]	VCM production	INOVYN Sverige AB	SE	Stenungsund
[SE_9]	VOCSIDIZER model 0813-F2-E7. Serial no. 453	Nouryon, Legal entity: Akzo Nobel Functional Chemicals AB	SE	Örnsköldsvik
[SE_10]	Myrsyrafabriken	Perstorp Specialty Chemicals AB	SE	Perstorp
[SE_11]	Neofabriken	Perstorp Specialty Chemicals AB	SE	Perstorp
[SE_12]	Pentafabriken	Perstorp Specialty Chemicals AB	SE	Perstorp
[SE_13]	TMP-fabriken	Perstorp Specialty Chemicals AB	SE	Perstorp
[SE_14]	Expancel plant	Nouryon Pulp and Performance Chemicals AB	SE	Sundsvall
[SE_15]	Surface Chemistry	Nouryon Surface Chemistry AB	SE	Sundsvall
[SI_1]	AquafilSLO d.o.o.	AquafilSLO d.o.o.	SI	Ljubljana
[SI_2]	AquafilSLO d.o.o.	AquafilSLO d.o.o.	SI	Ljubljana
[SK_1]	Alkylamines production	Duslo, a.s.	SK	Šaľa
[SK_2]	Antioxidants production	Duslo, a.s.	SK	Šaľa
[SK_3]	Cyclohexylamine production	Duslo, a.s.	SK	Šaľa
[SK_4]	Magnesium compounds production	Duslo, a.s.	SK	Šaľa
[SK_5]	Sulphenamides production	Duslo, a.s.	SK	Bratislava



[SK_6]	Acetylene	FORTISCHEM a. s.	SK	Novaky
[SK_7]	Ethylene chlorohydrin and bis(2-chlorethoxy)metane and homologues	FORTISCHEM a. s.	SK	Novaky
[SK_8]	Aromatics extraction unit	Slovnaft, a.s.	SK	Bratislava
[SK_9]	Steam Cracker	Slovnaft a.s.	SK	Bratislava
[SK_10]	Desulphurization of coke oven gases by Claus technology - production of elemental sulphur	U. S. Steel Košice, s.r.o.	SK	Košice
[SK_11]	Formalin and resin plant	DIAKOL STRAZSKE, s.r.o.	SK	Strazske
[UK_1]	Aesica Pharmaceuticals Manufacturing Plant	Aesica Pharmaceuticals Limited	UK	Newcastle
[UK_2]	Bardyke Chemicals Ltd	Bardyke Chemicals Ltd	UK	Glasgow
[UK_3]	BASF Bradford	BASF	UK	Bradford, West Yorkshire
[UK_4]	Grimsby Chemical Works	BASF Plc	UK	Grimsby
[UK_5]	Campact	Campact Limited	UK	Hexham
[UK_6]	Croda Leek	Croda Europe Ltd	UK	Leek
[UK_7]	BR9685IX	Dow	UK	Barry
[UK_8]	DP3432RV	Dow	UK	Dewsbury
[UK_9]	Solutia UK Limited	Eastman Chemicals	UK	Newport
[UK_10]	Esseco UK Limited	Esseco UK Limited	UK	Wakefield
[UK_11]	Fawley Refinery Installation	ExxonMobil Chemical Limited	UK	Southampton
[UK_12]	Wigton Cellophane Plant	Futamura UK Limited	UK	Wigton
[UK_13]	GSK Worthing	GlaxoSmithKline	UK	Worthing
[UK_14]	Ulverston	GlaxoSmithKline	UK	Lancaster
[UK_15]	Barry Thermosets Plant	Hexion UK Ltd	UK	Barry
[UK_16]	ICoNiChem Widnes Ltd	ICoNiChem Widnes Ltd	UK	Widnes
[UK_17]	PP3/Innovene Grangemouth	<sup>4</sup> Ineos O&P UK	UK	Grangemouth
[UK_18]	EIP Plant	INOVYN Chlorvinyls Ltd	UK	Runcorn
[UK_19]	INOVYN Newton Aycliffe	INOVYN ChlorVinyls LTD	UK	Darlington
[UK_21]	International Paints Limited (Felling)	International Paints Limited / AkzoNobel	UK	Gateshead

## Annexes

[UK_22]	JM Scotland (Edinburgh)	JM Scotland	UK	Edinburgh
[UK_23]	Johnson Matthey Clitheroe	Johnson Matthey	UK	Clitheroe
[UK_24]	Johnson Matthey	Johnson Matthey	UK	Clitheroe
[UK_25]	Royston Site	Johnson Matthey Plc	UK	Royston (Cambridge)
[UK_26]	Cassel Site	Lucite International UK Ltd	UK	Billingham
[UK_27]	Lucite International Speciality Polymers & Resins	Lucite International Speciality Polymers & Resins	UK	Newton Aycliffe
[UK_28]	Makevale Acrylic Works	Makevale ltd	UK	Ware
[UK_29]	Wyke Lane Chemicals	Nufarm UK Ltd	UK	Bradford
[UK_30]	Sandwich Pharmaceuticals Pilot Plant	Pfizer Limited	UK	Sandwich
[UK_31]	Newton Aycliffe	Preferre Resins UK Ltd	UK	Newton Aycliffe
[UK_32]	HCl Synthesis	RUNCORN MCP Ltd	UK	Runcorn
[UK_33]	System 18 LDPE	SABIC UK Petrochemicals Ltd.	UK	Redcar
[UK_34]	Grangemouth Manufacturing Centre	Syngenta Ltd	UK	Grangemouth
[UK_35]	Huddersfield Manufacturing Centre	Syngenta Ltd	UK	Huddersfield
[UK_36]	Thomas Swan & Co Ltd	Thomas Swan & Co Ltd	UK	Consett
[UK_37]	Venator Pigments (UK) - Birtley	Venator Pigments (UK)	UK	Durham
[UK_39]	Wychem Ltd	Wychem Ltd	UK	Newmarket
[UK_40]	Runcorn Site - Cereclor	INOVYN Chlorvinyls	UK	Runcorn

## 8 GLOSSARY

This glossary is meant to facilitate the understanding of the information contained in this document. The definitions of terms in this glossary are not legal definitions (even if some of them may coincide with definitions given in European legislation), they are meant to help the reader understand some key terms in the context of their use in the specific sector covered by this document.

This glossary is divided into the following sections:

- I. ISO country codes
- II. Monetary units
- III. Unit prefixes, number separators and notations
- IV. Units and measures
- V. Chemical elements
- VI. Chemical formulae commonly used in this document
- VII. Acronyms
- VIII. Definitions

## I. ISO country codes

ISO code	Country
<i>Member States (*)</i>	
AT	Austria
BE	Belgium
CZ	Czech Republic
DE	Germany
DK	Denmark
ES	Spain
FI	Finland
FR	France
HU	Hungary
IE	Ireland
IT	Italy
NL	Netherlands
PL	Poland
PT	Portugal
SE	Sweden
SI	Slovenia
SK	Slovakia
<i>Non-member countries</i>	
NO	Norway
UK	United Kingdom
(*) The protocol order of the Member States is based on the alphabetical order of their geographical names in the original language(s).	

## II. Monetary units

Code <sup>(1)</sup>	Country/territory	Currency
<i>Member State currencies</i>		
EUR	Euro area <sup>(2)</sup>	euro (pl. euros)
<i>Other currencies</i>		
USD	United States	US dollar
<sup>(1)</sup> ISO 4217 codes.		
<sup>(2)</sup> Includes Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia and Spain.		

### III. Unit prefixes, number separators and notations

Numbers in this document are written using the '.' character as the decimal separator and the space as the separator for thousands.

The symbol ~ (around; about) is the notation used to indicate approximation.

The symbol  $\Delta$  (delta) is the notation used to indicate a difference.

The following table contains the frequently used prefixes:

Symbol	Prefix	$10^n$	Word	Decimal number
G	giga	$10^9$	Billion	1 000 000 000
M	mega	$10^6$	Million	1 000 000
k	kilo	$10^3$	Thousand	1 000
-----	-----	1	One	1
d	deci	$10^{-1}$	Tenth	0.1
c	centi	$10^{-2}$	Hundredth	0.01
m	milli	$10^{-3}$	Thousandth	0.001
$\mu$	micro	$10^{-6}$	Millionth	0.000 001
n	nano	$10^{-9}$	Billionth	0.000 000 001

## IV. Units and measures

Unit symbol	Unit name	Measure name (measure symbol)	Conversion and comment
atm	normal atmosphere	Pressure (P)	1 atm = 101 325 N/m <sup>2</sup>
bar	bar	Pressure (P)	1.013 bar = 100 kPa = 1 atm
°C	degree Celsius	Temperature (T) temperature difference ( $\Delta T$ )	–
d	day	Time	–
g	gram	Weight	–
h	hour	Time	–
K	Kelvin	Temperature (T) temperature difference ( $\Delta T$ )	0 °C = 273.15 K
kg	kilogram	Weight	–
kg/yr	kilogram per year	Mass flow Materials consumption	–
kPa	kilopascal	Pressure	–
kWh	kilowatt-hour	Energy	1 kWh = 3 600 kJ
l	litre	Volume	–
m	metre	Length	–
m <sup>2</sup>	square metre	Area	–
m <sup>3</sup>	cubic metre	Volume	–
mg	milligram	Weight	1 mg = 10 <sup>-3</sup> g
mm	millimetre	Length	1 mm = 10 <sup>-3</sup> m
min	minute	Time	–
MW <sub>e</sub>	megawatts electric (energy)	Electric energy	–
MW <sub>th</sub>	megawatts thermal (energy)	Thermal energy Heat	–
µm	micrometre	Length	1 µm = 10 <sup>-6</sup> m
nm	nanometre	Length	1 nm = 10 <sup>-9</sup> m
Nm <sup>3</sup>	normal cubic metre	Volume	at 101.325 kPa, 273.15 K
Pa	pascal	Pressure (P)	1 Pa = 1 N/m <sup>2</sup>
ppm	parts per million	Composition of mixtures	1 ppm = 10 <sup>-6</sup>
ppmv	parts per million by volume	Composition of mixtures	–
s	second	Time	–
t	metric tonne	Weight	1 t = 1 000 kg or 10 <sup>6</sup> g
t/d	tonnes per day	Mass flow Materials consumption	–
t/yr	tonnes per year	Mass flow Materials consumption	–
vol-% % v/v	percentage by volume	Composition of mixtures	–
wt-% % w/w	percentage by weight	Composition of mixtures	–
W	watt	Power	1 W = 1 J/s
yr	year	Time	–

## V. Chemical elements

Symbol	Name	Symbol	Name
Ac	Actinium	Mn	Manganese
Ag	Silver	Mo	Molybdenum
Al	Aluminium	N	Nitrogen
Am	Americium	Na	Sodium
Ar	Argon	Nb	Niobium
As	Arsenic	Nd	Neodymium
At	Astatine	Ne	Neon
Au	Gold	Ni	Nickel
B	Boron	No	Nobelium
Ba	Barium	Np	Neptunium
Be	Beryllium	O	Oxygen
Bi	Bismuth	Os	Osmium
Bk	Berkelium	P	Phosphorus
Br	Bromine	Pa	Protactinium
C	Carbon	Pb	Lead
Ca	Calcium	Pd	Palladium
Cd	Cadmium	Pm	Promethium
Ce	Cerium	Po	Polonium
Cf	Californium	Pr	Praseodymium
Cl	Chlorine	Pt	Platinum
Cm	Curium	Pu	Plutonium
Co	Cobalt	Ra	Radium
Cr	Chromium	Rb	Rubidium
Cs	Caesium	Re	Rhenium
Cu	Copper	Rf	Rutherfordium
Dy	Dysprosium	Rh	Rhodium
Er	Erbium	Rn	Radon
Es	Einsteinium	Ru	Ruthenium
Eu	Europium	S	Sulphur
F	Fluorine	Sb	Antimony
Fe	Iron	Sc	Scandium
Fm	Fermium	Se	Selenium
Fr	Francium	Si	Silicon
Ga	Gallium	Sm	Samarium
Gd	Gadolinium	Sn	Tin
Ge	Germanium	Sr	Strontium
H	Hydrogen	Ta	Tantalum
He	Helium	Tb	Terbium
Hf	Hafnium	Tc	Technetium
Hg	Mercury	Te	Tellurium
Ho	Holmium	Th	Thorium
I	Iodine	Ti	Titanium
In	Indium	Tl	Thallium
Ir	Iridium	Tm	Thulium
K	Potassium	U	Uranium
Kr	Krypton	V	Vanadium
La	Lanthanum	W	Tungsten
Li	Lithium	Xe	Xenon
Lr	Lawrencium	Y	Yttrium
Lu	Lutetium	Yb	Ytterbium
Md	Mendelevium	Zn	Zinc
Mg	Magnesium	Zr	Zirconium



## VI. Chemical formulae commonly used in this document

Chemical formula	Name (explanation)
NH <sub>3</sub>	Ammonia
C <sub>6</sub> H <sub>6</sub>	Benzene
C <sub>4</sub> H <sub>6</sub>	1,3-Butadiene
CS <sub>2</sub>	Carbon disulphide
CO	Carbon monoxide
CH <sub>3</sub> Cl	Chloromethane
CH <sub>2</sub> Cl <sub>2</sub>	Dichloromethane or methylene chloride (DCM)
Cl <sub>2</sub>	Elemental chlorine
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	Ethylene dichloride (EDC)
C <sub>2</sub> H <sub>4</sub> O	Ethylene oxide
CH <sub>2</sub> O	Formaldehyde
HCl	Hydrochloric acid
HF	Hydrofluoric acid
HCN	Hydrogen cyanide
H <sub>2</sub> S	Hydrogen sulphide
NaOH	Sodium hydroxide. Also called caustic soda
N <sub>2</sub> O	Nitrous oxide
NO <sub>x</sub>	Nitrogen oxides, the sum of nitrogen monoxide (NO) and nitrogen dioxide (NO <sub>2</sub> ), expressed as NO <sub>2</sub>
C <sub>3</sub> H <sub>6</sub> O	Propylene oxide
CCl <sub>4</sub>	Tetrachloromethane
C <sub>7</sub> H <sub>8</sub>	Toluene
CHCl <sub>3</sub>	Trichloromethane
C <sub>2</sub> H <sub>3</sub> Cl	Vinyl chloride. Also called vinyl chloride monomer (VCM)

## VII. Acronyms

Acronym	Definition
BAT	Best Available Techniques.
BAT-AEL	Best Available Techniques - associated emission level.
BREF	BAT reference document.
CLP	Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures.
CBI	Confidential business information.
CMR	Carcinogenic, mutagenic or toxic for reproduction.
CMR 1A	CMR substance of category 1A as defined in Regulation (EC) No 1272/2008 as amended, i.e. carrying the hazard statements H340, H350, H360.
CMR 1B	CMR substance of category 1B as defined in Regulation (EC) No 1272/2008 as amended, i.e. carrying the hazard statements H340, H350, H360.
CMR 2	CMR substance of category 2 as defined in Regulation (EC) No 1272/2008 as amended, i.e. carrying the hazard statements H341, H351, H361.
DIAL	Differential absorption LIDAR.
EDC	Ethylene dichloride.
EIPPCB	European Integrated Pollution Prevention and Control Bureau.
EMS	Environmental Management System.
EP	Emission point (refers to channelled emissions).
EPS	Expandable polystyrene.
E-PRTR	European Pollutant Release and Transfer Register.
E-PVC	PVC produced by emulsion polymerisation.
EU	European Union.
EVA	Ethylene-vinylacetate.
GPPS	General-purpose polystyrene.
HDPE	High-density polyethylene.
HEAF	High-efficiency air filter.
HEPA	High-efficiency particle air.
HIPS	High-impact polystyrene.
IED	Directive 2010/75/EU on industrial emissions.
I-TEQ	International toxic equivalent – derived by using the equivalence factors in Part 2 of Annex VI to Directive 2010/75/EU.
JRC	Joint Research Centre.
KEI	Key environmental issue.
KOM	Kick-off Meeting.
LDAR	Leak detection and repair.
LDPE	Low-density polyethylene.
LIDAR	Light detection and ranging.
LLDPE	Linear low-density polyethylene.
LPS	Low-pressure separator.
NM VOC	Non-methane volatile organic compound (see VOC).
NPK	Nitrogen-, phosphorus- or potassium-based fertilisers.
OGI	Optical gas imaging.
OTNOC	Other than normal operating conditions.
PCDD/F	Polychlorinated dibenzo-p-dioxins and -furans.
PP	Polypropylene.
PVC	Polyvinyl chloride.
REACH	Regulation (EC) No 1907/2006 concerning the registration, evaluation, authorisation and restriction of chemicals.
SCR	Selective catalytic reduction.
SNCR	Selective non-catalytic reduction.
SOF	Solar occultation flux.
S-PVC	PVC produced by suspension polymerisation.
TVOC	Total volatile organic carbon.
ULPA	Ultra-low penetration air.
VCM	Vinyl chloride monomer.
VOC	Volatile organic compound.

## VIII. Definitions

Term used	Definition
Channelled emissions	Emissions of pollutants to air through an emission point such as a stack.
Combustion unit	Any technical apparatus in which fuels are oxidised in order to use the heat thus generated. Combustion units include boilers, engines, turbines and process furnaces/heaters, but do not include thermal or catalytic oxidisers.
Complex inorganic pigments	A stable crystal lattice of different metal cations. The most important host-lattices are rutile, spinel, zircon, and haematite/corundum, but other stable structures exist.
Continuous measurement	Measurement using an automated measuring system permanently installed on site.
Continuous process	A process in which the raw materials are fed continuously into the reactor with the reaction products then fed into connected downstream separation and/or recovery units.
Diffuse emissions	Non-channelled emissions. Diffuse emissions include fugitive and non-fugitive emissions.
EU-27	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Ireland, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden.
Emissions to air	Generic term for emissions of pollutants to air including both channelled and diffuse emissions.
Ethanolamines	Collective term for monoethanolamine, diethanolamine and triethanolamine, or mixtures thereof.
Ethylene glycols	Collective term for monoethylene glycol, diethylene glycol and triethylene glycol, or mixtures thereof.
Existing plant	A plant that is not a new plant.
Existing process furnace/heater	A process furnace/heater that is not a new process furnace/heater.
Flue-gas	The exhaust gas exiting a combustion unit.
Fugitive emissions	Non-channelled emissions to air caused by loss of tightness of equipment which is designed or assembled to be tight. Fugitive emissions can arise from: <ul style="list-style-type: none"> <li>• moving equipment, such as agitators, compressors, pumps, valves (manual and automatic);</li> <li>• static equipment, such as flanges and other connections, open-ended lines, sampling points.</li> </ul>
IED Chemical Activities	Categories of activities listed in points 4.1 to 4.6 of Annex I to the IED.
Lower olefins	Collective term for ethylene, propylene, butylene and butadiene, or mixtures thereof.
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 units and associated equipment.
Mass flow	The mass of a given substance or parameter which is emitted over a defined period of time.
Nbr of EP	Number of emission points.
New plant	A plant first permitted on 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.
New process furnace/heater	A process furnace/heater in a plant first permitted following the publication of these BAT conclusions or a complete replacement of a process furnace/heater following the publication of these BAT conclusions.

Term used	Definition
Non-fugitive emissions	Diffuse emissions other than fugitive emissions. Non-fugitive emissions can arise from atmospheric vents, bulk storage, loading/unloading systems, vessels and tanks (on opening), open gutters, sampling systems, tank venting, waste, sewers and water treatment plants.
NO <sub>x</sub> precursors	Nitrogen-containing compounds (e.g. acrylonitrile, ammonia, nitrous gases and nitrogen-containing organic compounds) in the input to a thermal or catalytic oxidation that lead to NO <sub>x</sub> emissions. Elemental nitrogen is not included.
Operational constraint	Limitation or restriction connected, for example, to: <ul style="list-style-type: none"> <li>• substances used (e.g. substances that cannot be substituted, very corrosive substances);</li> <li>• operating conditions (e.g. very high temperature or pressure);</li> <li>• the functioning of the plant;</li> <li>• resource availability (e.g. availability of spare parts when replacing a piece of equipment, availability of qualified manpower);</li> <li>• expected environmental benefits (e.g. giving priority to maintenance, repair or replacement actions with the highest environmental benefit).</li> </ul>
Other than normal operating conditions (OTNOC)	Other than normal operating conditions. Article 14 (f) of the IED refers to other than normal operating conditions as start-up and shutdown operations, leaks, malfunctions, momentary stoppages and definitive cessation of operations.
Periodic measurement	Measurement at specified time intervals using manual or automated methods.
Polymer grade	For each type of polymer, there are different product qualities (i.e. grades) which vary in structure and molecular mass, and are optimised for specific applications. In the case of polyolefins, these may vary regarding the use of co-polymers such as EVA. In the case of PVC, they may vary in the average length of the polymer chain and in the porosity of the particles.
Process furnace/heater	Process furnaces or heaters are: <ul style="list-style-type: none"> <li>• combustion units used for the treatment of objects or feed material through direct contact, e.g. in drying processes or chemical reactors; or</li> <li>• combustion units whose radiant and/or conductive heat is transferred to objects or feed material through a solid wall without using an intermediary heat transfer fluid, e.g. furnaces or reactors heating a process stream used in the (petro-)chemical industry.</li> </ul> As a consequence of the application of good energy recovery practices, some of the process furnaces/heaters may have an associated steam/electricity generation system. This is an integral design feature of the process furnace/heater that cannot be considered in isolation.
Process off-gas	The gas leaving a process which is further treated for recovery and/or abatement.
Solvent	Organic solvent as defined in Article 3(46) of Directive 2010/75/EU.
Solvent consumption	Consumption of solvent as defined in Article 57(9) of Directive 2010/75/EU.
Solvent input	The total quantity of organic solvents used as defined in Part 7 of Annex VII to Directive 2010/75/EU.
Solvent mass balance	A mass balance exercise conducted at least on an annual basis according to Part 7 of Annex VII to Directive 2010/75/EU.
Thermal treatment	Treatment of waste gases using thermal or catalytic oxidation.
Total emissions	The sum of channelled and diffuse emissions.

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Term used	Definition
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.



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