European Commission

JRC SCIENCE FOR POLICY REPORT

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

Colour code:

The text highlighted in yellow will not appear in the BREF; it is used to:

- remind the TWG of the conclusions reached at the kick-off meeting;
- indicate information missing that TWG members are invited to collect and submit;
- indicate information to be updated;
- make clarifications to the TWG.

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

JOINT RESEARCH CENTRE
Directorate B – Growth and Innovation
Circular Economy and Industrial Leadership Unit
European IPPC Bureau

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Joint Research Centre

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

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

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

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 document is a working draft of the European IPPC Bureau (of the Commission’s Joint Research Centre). It is not an official publication of the European Union and does not necessarily reflect the position of the European Commission.

2. Participants in the information exchange

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

Forum members have nominated technical experts constituting the technical working group (TWG) that was the main source of information for drafting this document. The work of the TWG was led by 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 emissions 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.

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

Chapter 5 presents information on ‘emerging techniques’ as defined in Article 3(14) of the Directive.

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 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 best available techniques (BAT), their associated emission levels (and other environmental performance levels) and the associated monitoring for this sector according to Article 3(10) of, and Annex III to, the Directive.

Expert judgement by 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.

6. Contact information

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

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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.

More specifically, this BREF addresses 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;
   - aromatics: production of benzene, toluene, ortho-, meta- and para-xylene as well as cyclohexane from the pygas by-product of steam crackers and from reformate/naphtha produced in catalytic reformers;
   - ethlybenzene using either the zeolite- or $AlCl_3$-catalysed alkylation process;
   - styrene monomer either by ethylbenzene dehydrogenation or by co-production with propylene oxide;
   - formaldehyde;
   - ethylene oxide and ethylene glycols;
   - phenol from cumene;
   - ethanolamines;
   - 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_X) 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);
   - 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;
  - urea.

  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 may be covered by the BREF for Large Combustion Plants (LCP), the BREF for the Refining of Mineral Oil and Gas and/or by Directive (EU) 2015/2193 of the European Parliament and of the Council[1].
   - Process furnaces/heaters with a total rated thermal input below 1 MW.

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 materials. This may be covered by the BREF for Emissions from Storage (EFS).

   However, emissions to air from the storage, transfer and handling of materials are included in the scope of this BREF when these processes are directly associated with the chemical production process.

9. Emissions to air from indirect cooling systems. This may be covered by the BREF for Industrial Cooling Systems (ICS).

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.

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[1] 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).

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

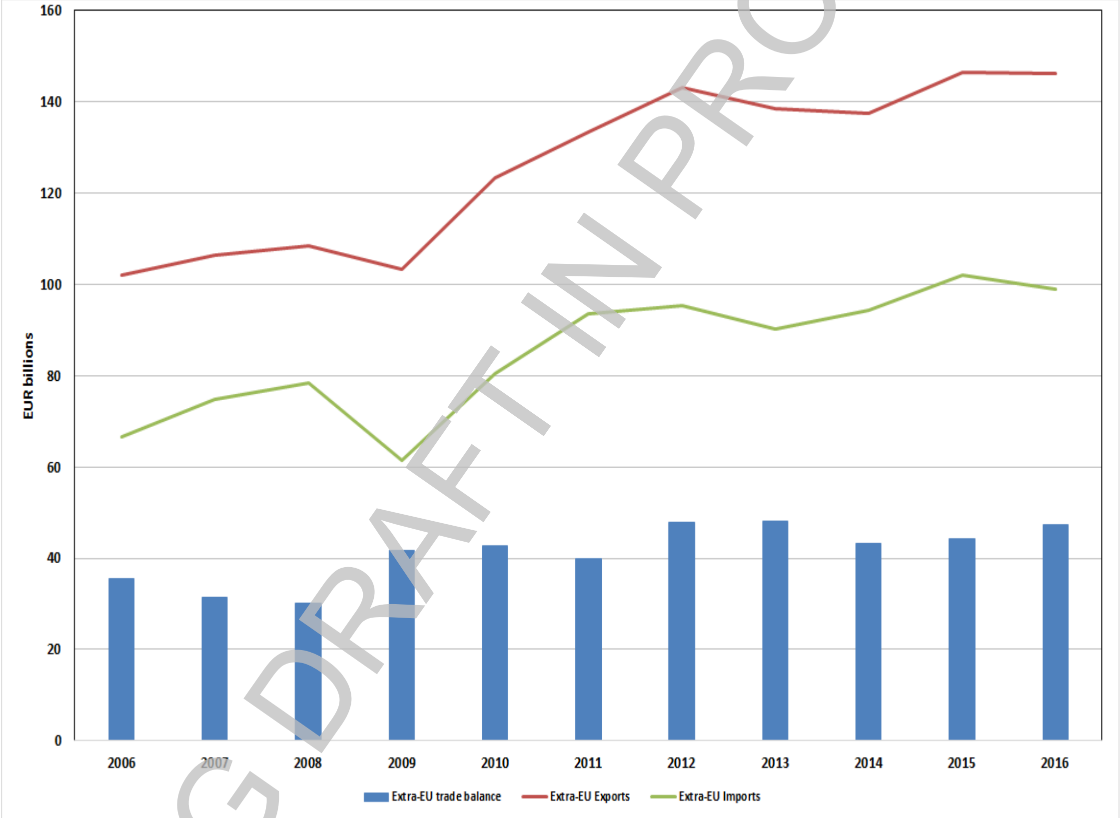
- Production of Chlor-alkali (CAK);
- Manufacture of Large Volume Inorganic Chemicals – Ammonia, Acids and Fertilisers (LVIC-AAF);
- Manufacture of Large Volume Inorganic Chemicals – Solids and Others Industry (LVIC-S);
- Production of Large Volume Organic Chemicals (LVOC);
- Manufacture of Organic Fine Chemicals (OFC);
- Production of Polymers (POL);
- Production of Speciality Inorganic Chemicals (SIC);
- 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).

1 GENERAL INFORMATION

1.1 The chemical industry in Europe

1.1.1 Industrial and economic development

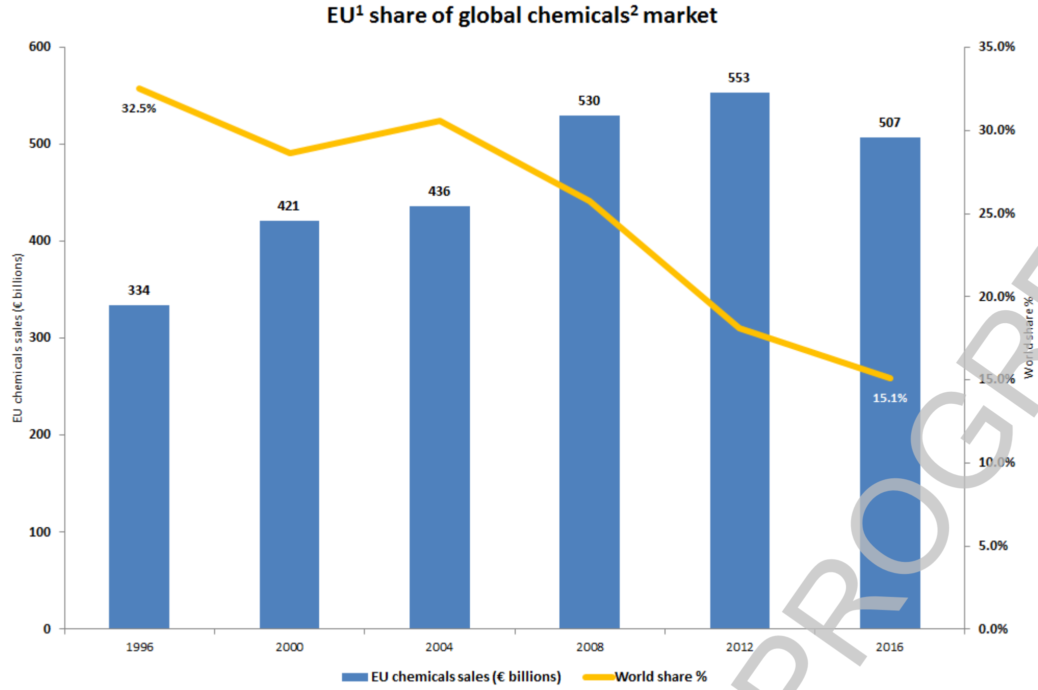
The EU chemical industry provides a significant contribution to the EU economy. It is one of its most international and competitive industries, connected to a wide field of processing and manufacturing activities. Its output covers a wide range of chemical products, and supplies virtually all sectors of the economy. Figure 1.1 shows that the EU-28 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].



(^{1}) EU refers to EU-28.
(^{2}) Excluding pharmaceuticals.
Source: [45, EIPPCB 2018] based on data from [4, CEFIC 2018]

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

Figure 1.2 shows that the European chemical market grew continuously from 1996 to 2012 (and decreased by 8 % in 2016). In 2016, the total chemical sales (excluding pharmaceuticals) in the EU-28 amounted to EUR 507 billion. With 15.1 % of the global sales in terms of value, the European chemical industry ranks second, followed by the United States (14.2 %), but after China which holds the top ranking in sales (39.6 %) [4, CEFIC 2018].

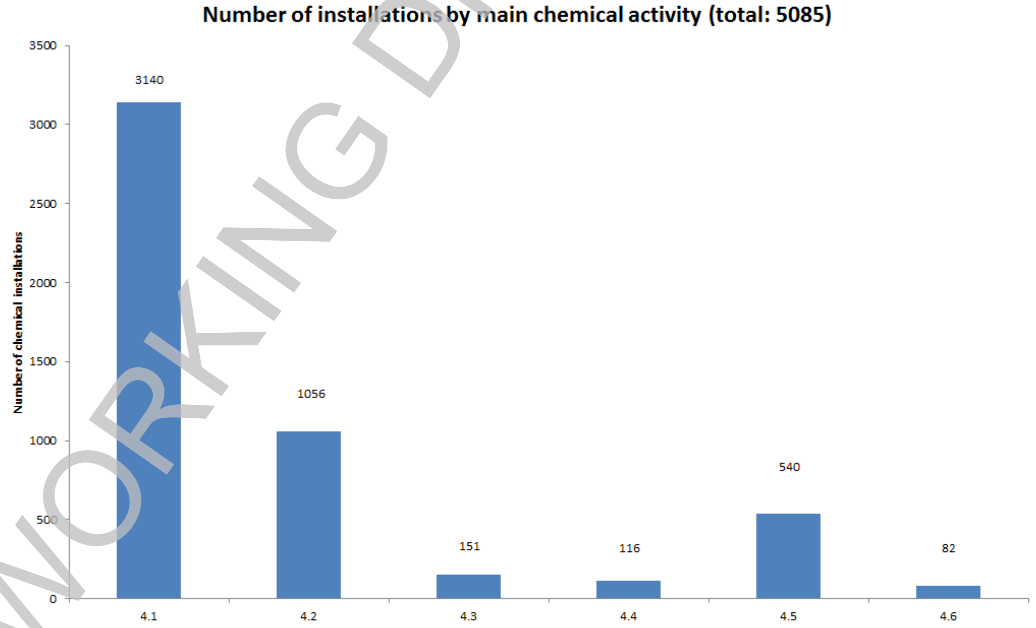


(¹) EU refers to EU-28.
(²) Excluding pharmaceuticals.
Source: [45, EIPPCB 2018] based on data from [4, CEFIC 2018]

Figure 1.2: EU share of global markets

The chemical sector in the EU-28 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.



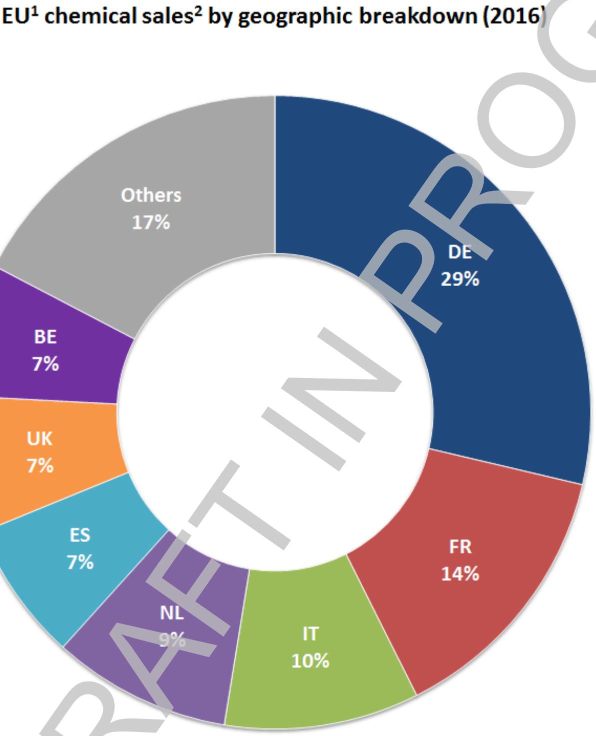
Source: [8, DG ENV 2015]

Figure 1.3: EU-27: 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.

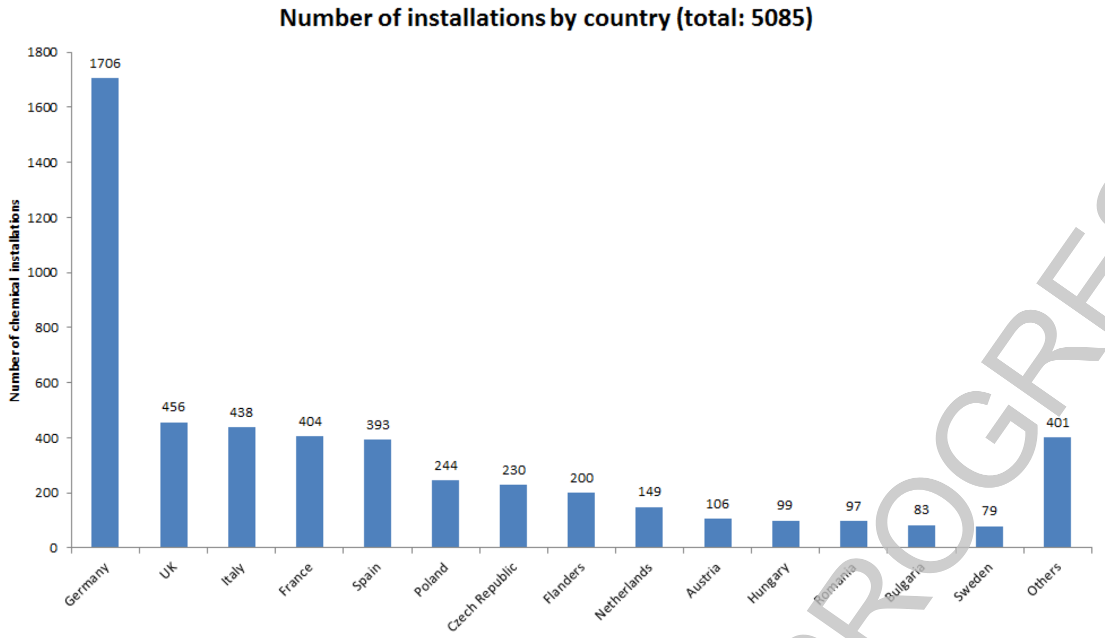
The share rises to 82.6 %, or EUR 419 billion, when including Spain, the United Kingdom and Belgium. The remaining EU Member States accounted for 17.4 % of European chemical sales in 2016, valued at EUR 88 billion. Poland and Austria are the two largest contributors to that Member States bloc.



(1) EU refers to EU-28.
(2) Excluding pharmaceuticals.
Source: [45, EIPPCB 2018] based on data from [4, CEFIC 2018]

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.



Source: [8, DG ENV 2015]

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

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.

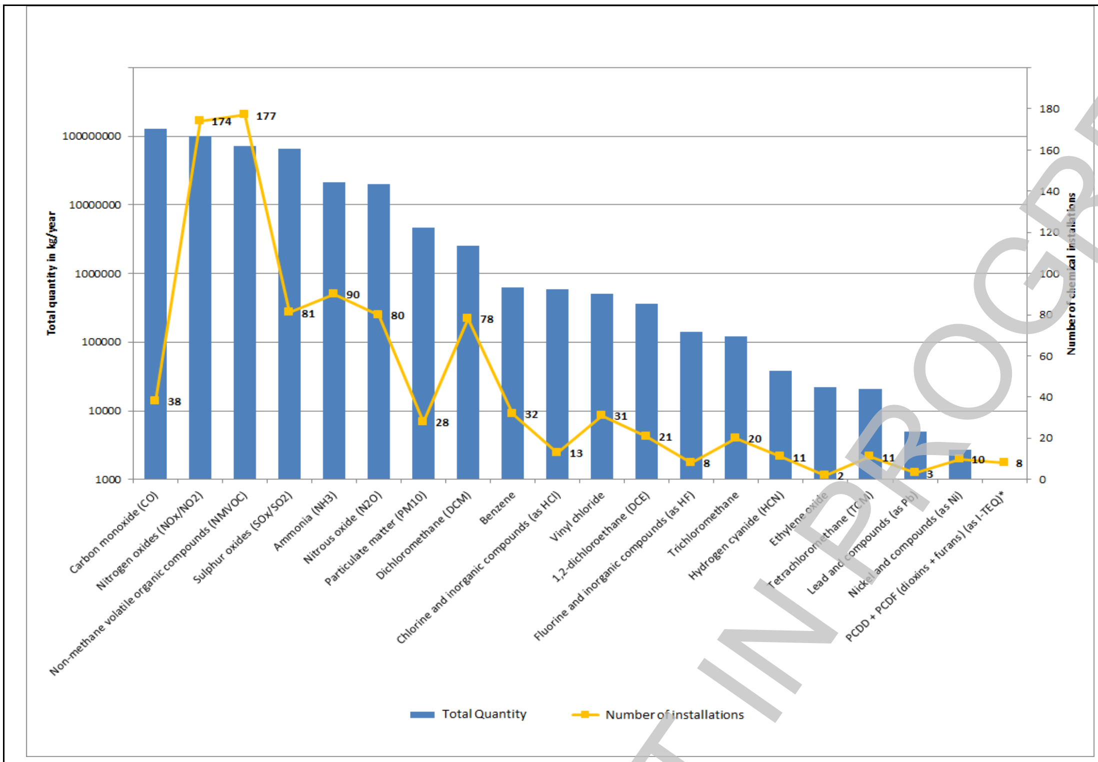
The following substances/parameters were defined as KEIs for the WGC BREF [6, EIPPCB 2017]:

- 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/Fs (dioxins and furans);
- greenhouse gases: nitrous oxide;
- ozone-depleting substances: tetrachloromethane;
- volatile organic compounds (VOCs): 1,3-butadiene, chloromethane, dichloromethane, ethylene dichloride, ethylene oxide, formaldehyde, propylene oxide, toluene, trichloromethane and vinyl chloride monomer;
- other gases: ammonia, carbon disulphide, elementary 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-28 plus Norway and Serbia in 2016, 1 437 reported a chemical production as their main activity [9, E-PRTR 2018]. Figure 1.6 gives an overview of emissions to air reported by those facilities.



* PCDD + PCDF total quantity: 21 g I-TEQ/year.
Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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 a 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).

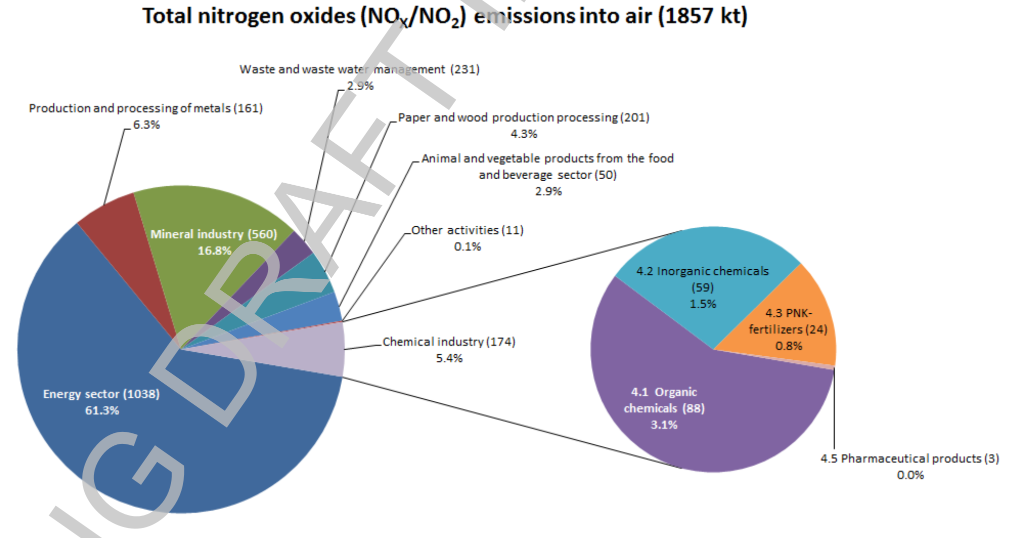
1.2.2 European air quality standards substances

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 ($PM_{2.5}$) or particulate matter (PM_{10}), 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_X)

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.

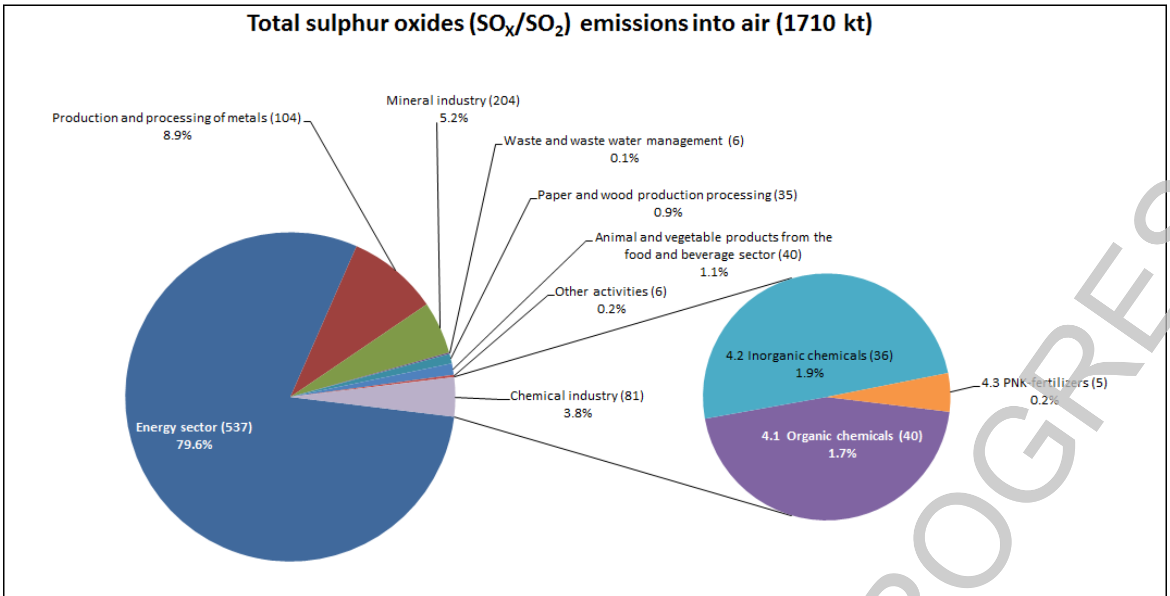


Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

Figure 1.7: Emissions of nitrogen oxides to air by industrial sector/activity in Europe 2016

1.2.2.2 Sulphur oxides (SO_X)

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.

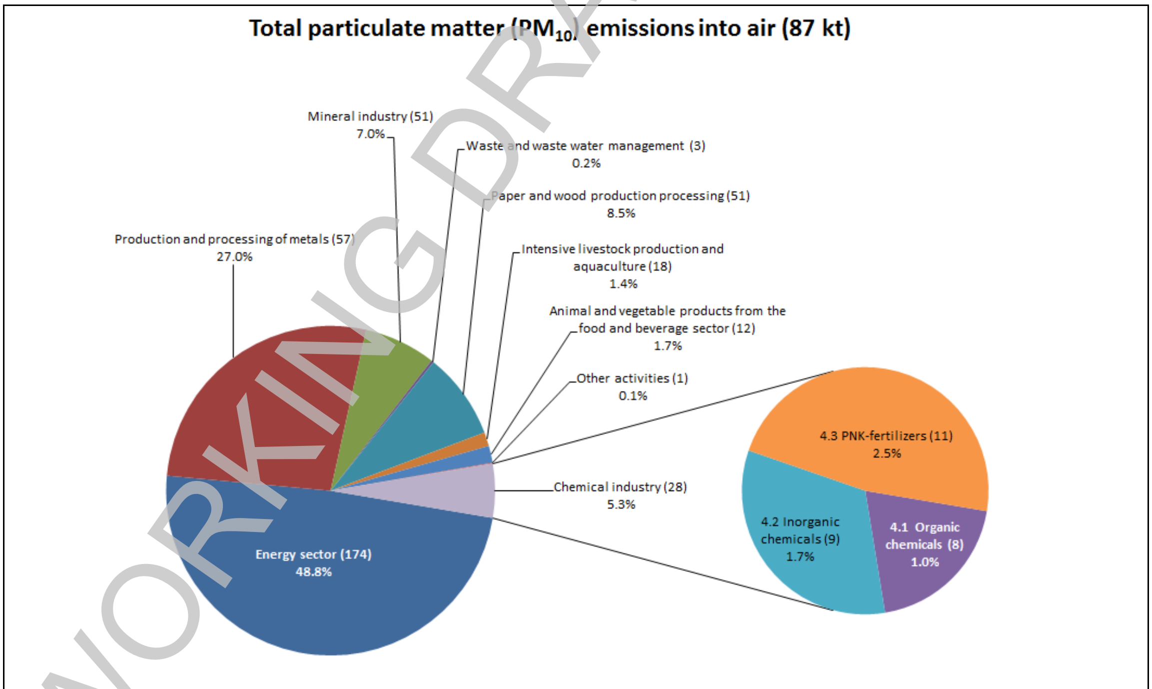


Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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

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.

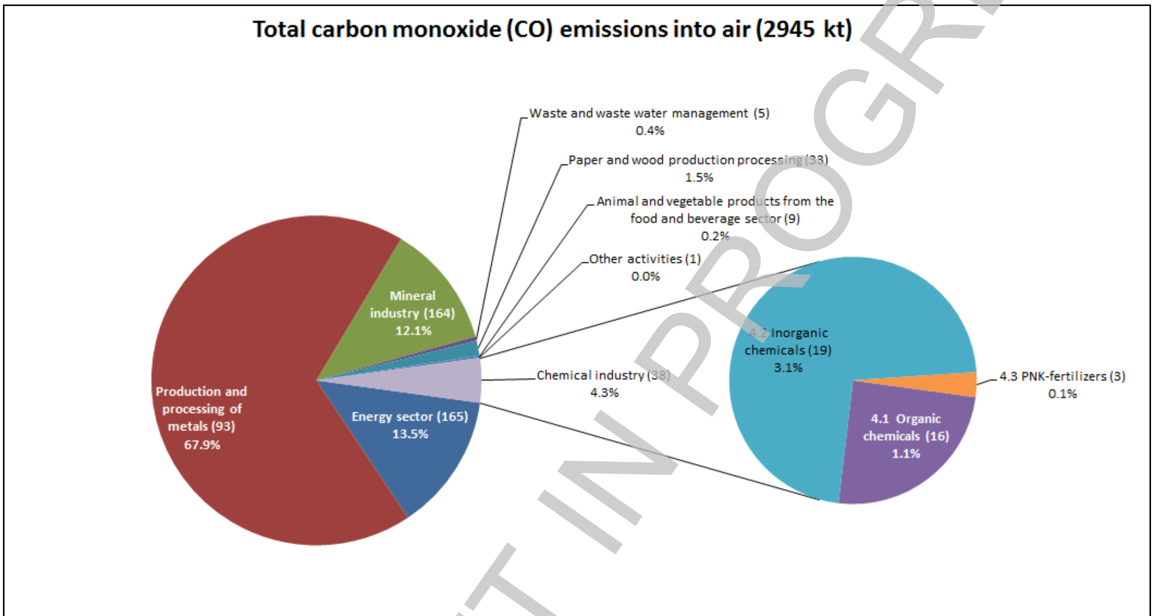


Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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

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 3.9 % 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.

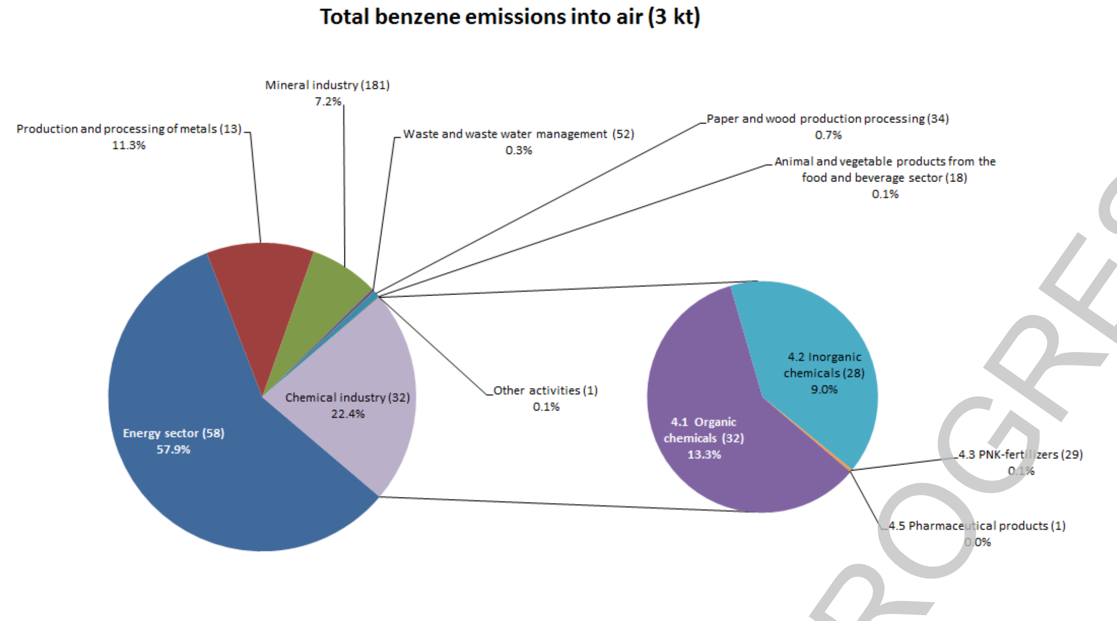


Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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.

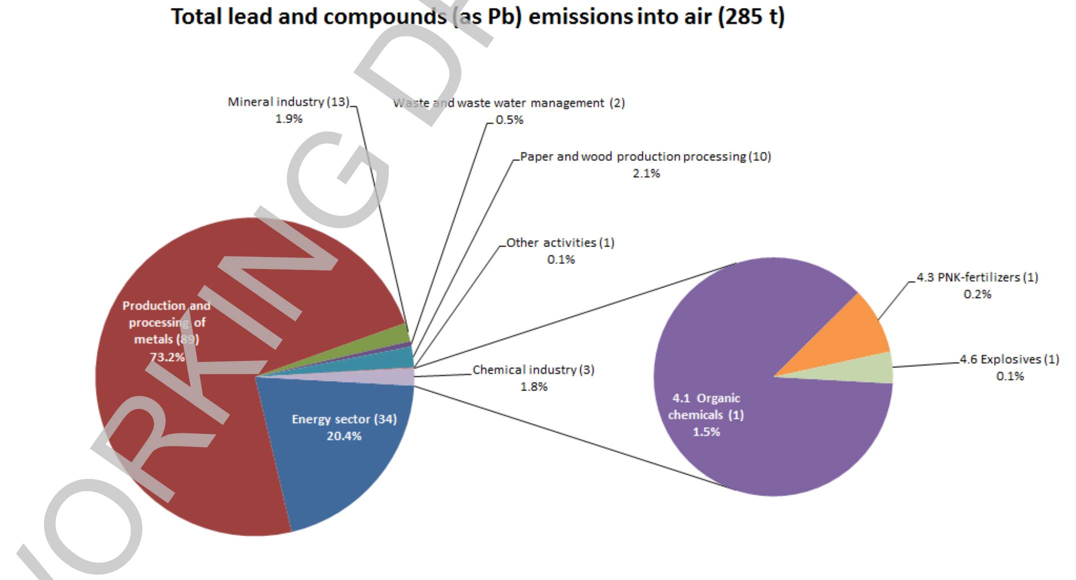


Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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.

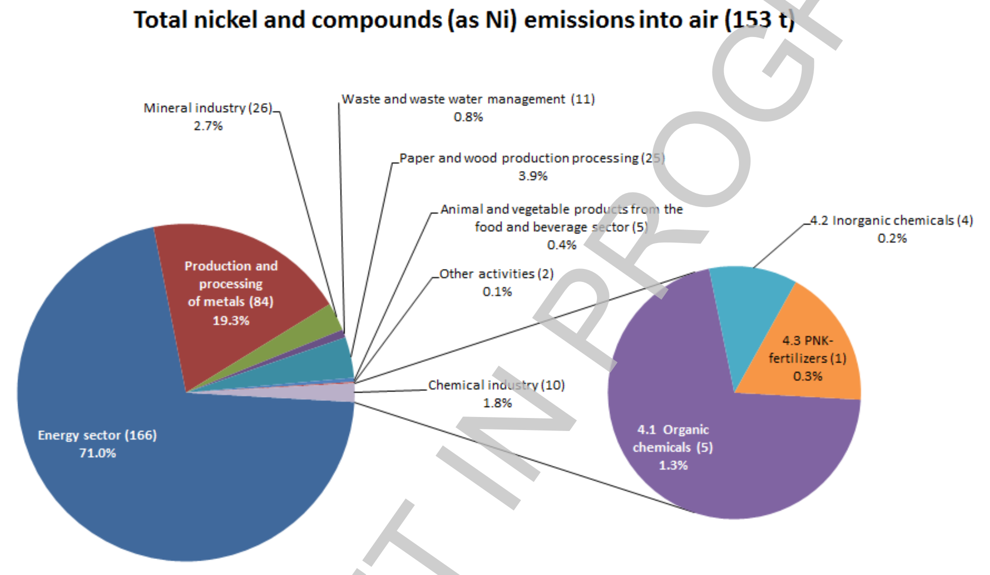


Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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.



Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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

1.2.3 Stockholm Convention substances

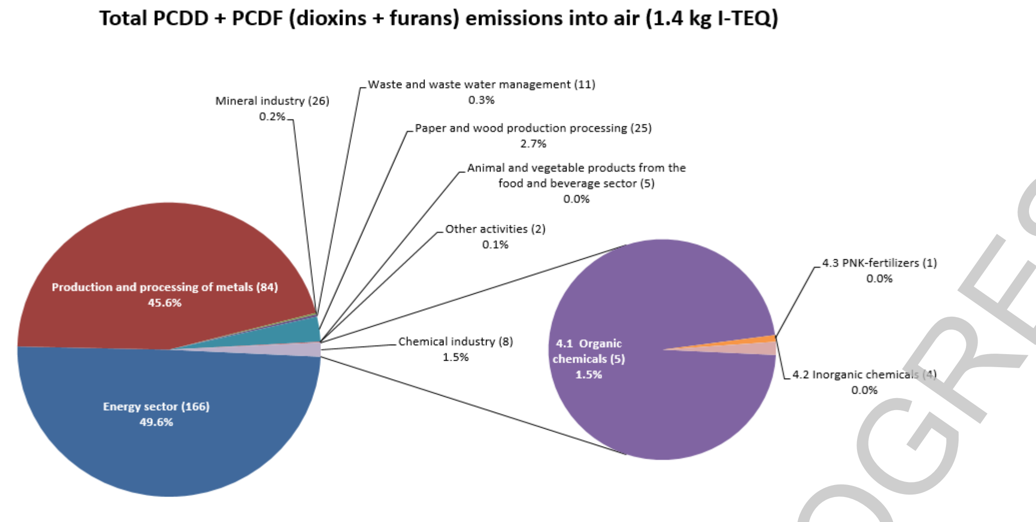
Under the Stockholm Convention on Persistent Organic Pollutants, Parties shall promote in some cases, and require in others, the use of best available techniques as well as the application of best environmental practices.

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) among other chemicals.

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

1.2.3.1 PCDD/Fs (dioxins and furans)

Emissions of PCDD/Fs 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/Fs 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/Fs.



Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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

1.2.4 Greenhouse gases

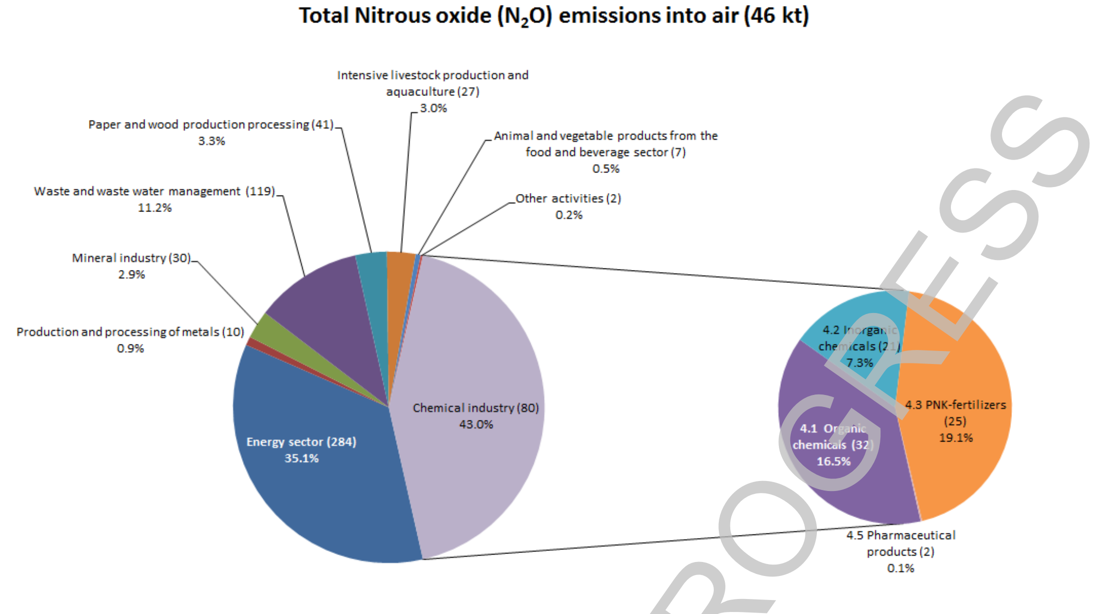
According to Article 9(1) of the Directive [25, EU 2010], the permit shall not include an emission limit value for direct emissions of greenhouse gas originating from activities listed in Annex I to Directive 2003/87/EC (greenhouse gas emission allowance trading scheme). Consequently, BAT-AELs may not 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_2O)

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.



Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

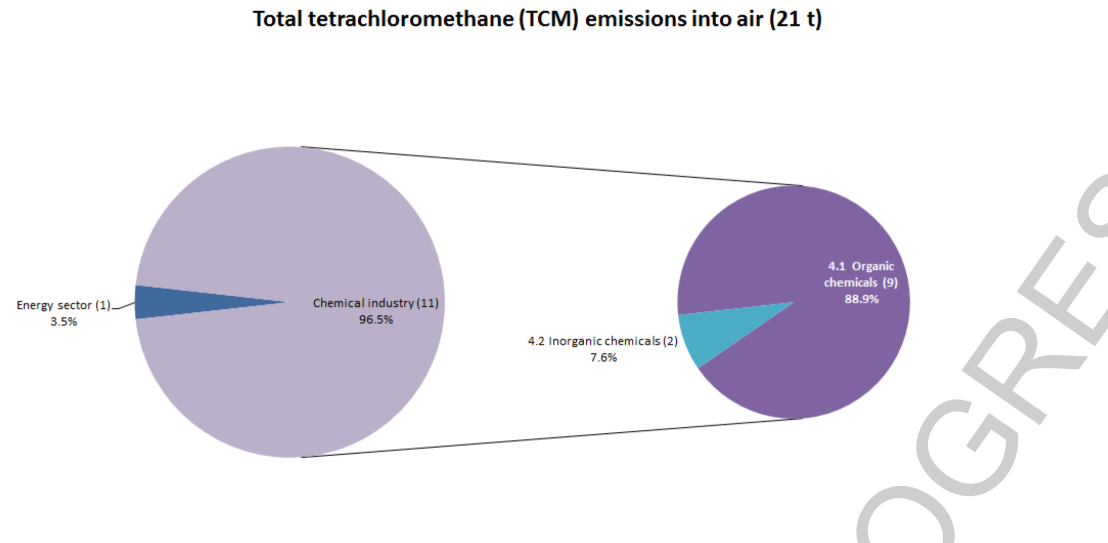
Figure 1.15: Emissions of nitrous oxide to air by industrial sector/activity

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_4)

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.



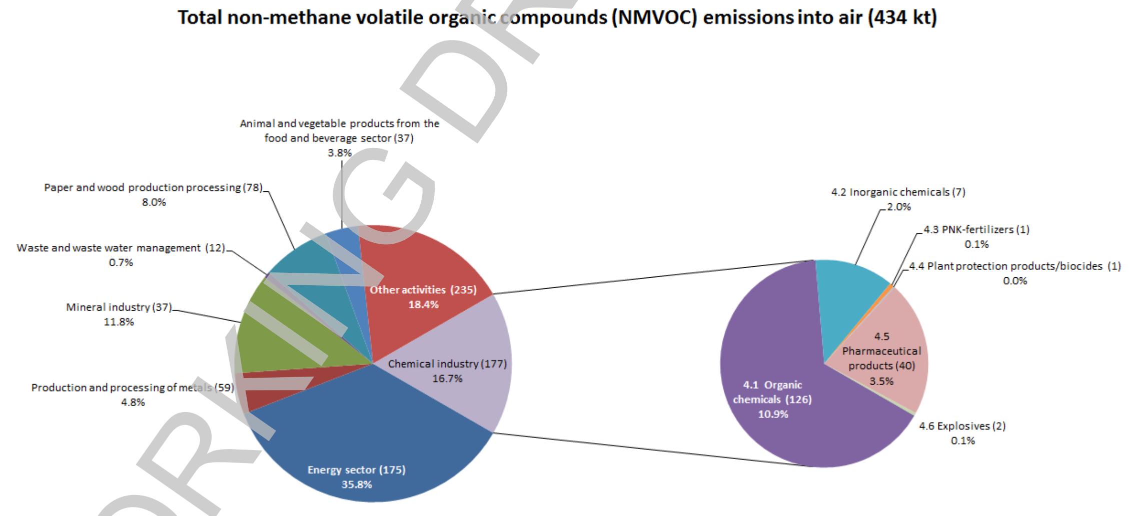
Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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 tonnes 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. 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.



Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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

1.2.6.2 Formaldehyde

Formaldehyde is not in 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 [37, UBA 2016]. Emissions to air are measured in the production of organic chemicals, and more particularly, the production of plastic materials.

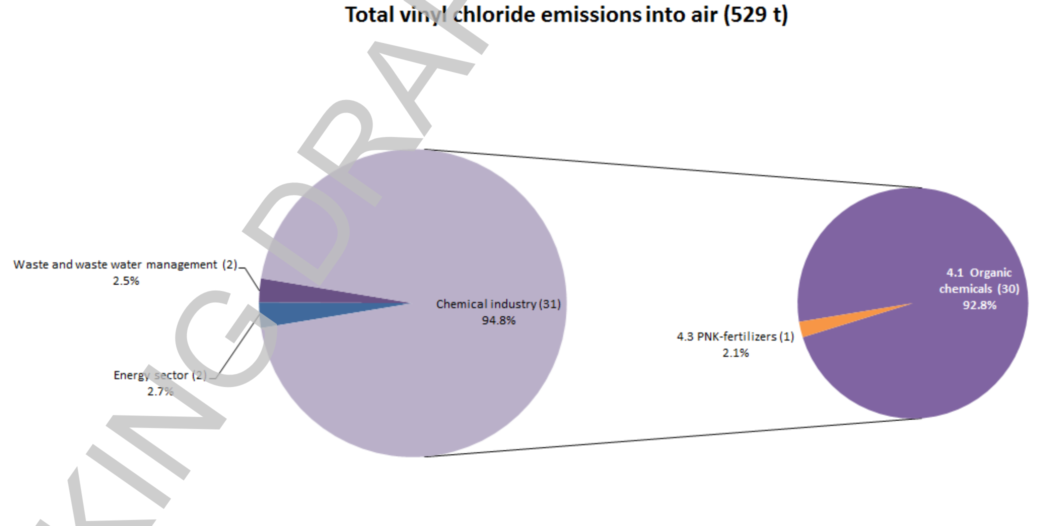
Formaldehyde emissions are also reported from industrial sites, including chemical installations, in Belgium [29, FluxSense 2010] [28, FluxSense 2016]:

- 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.

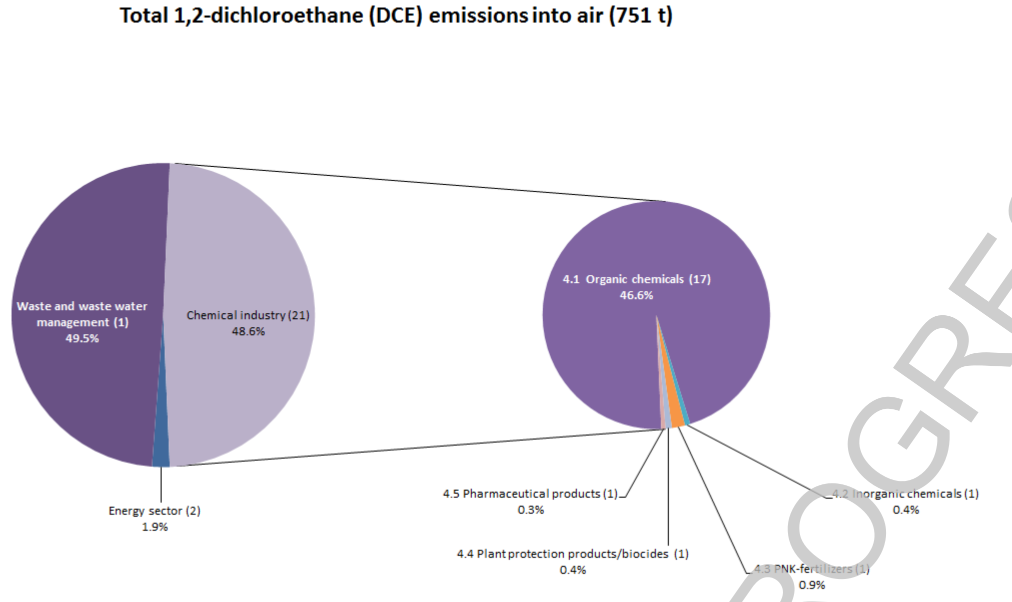


Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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.

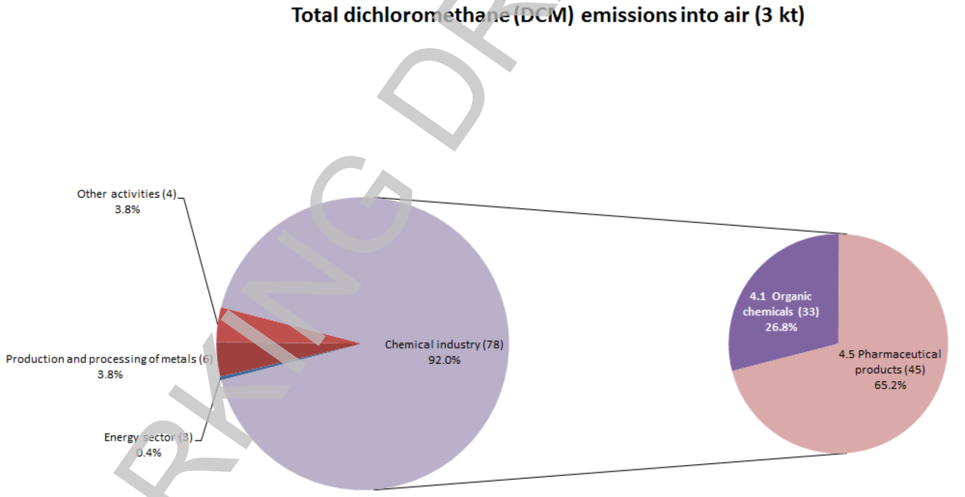


Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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.

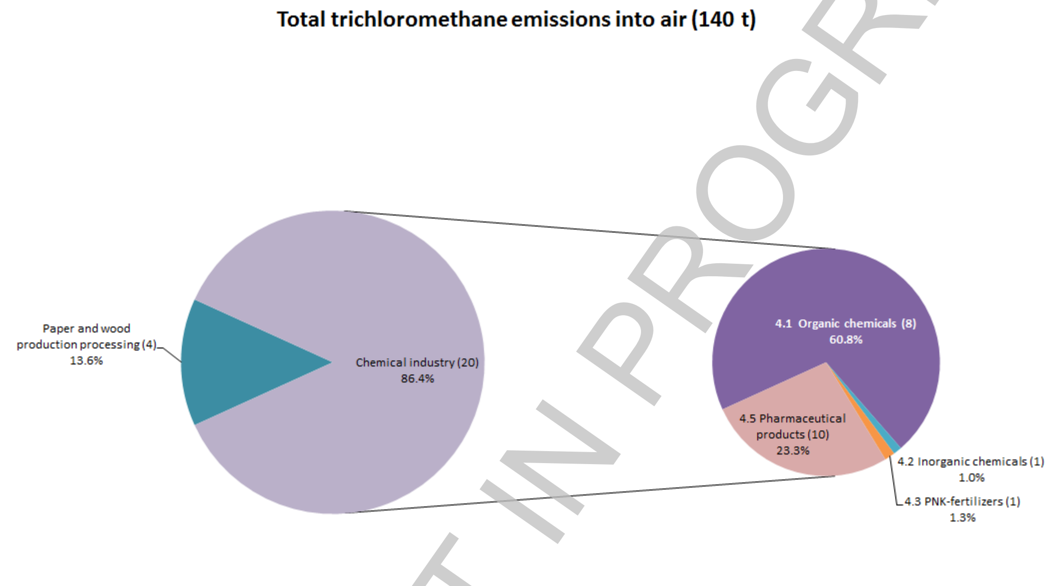


Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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, 78 installations of the chemical industry emitted around 162 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.



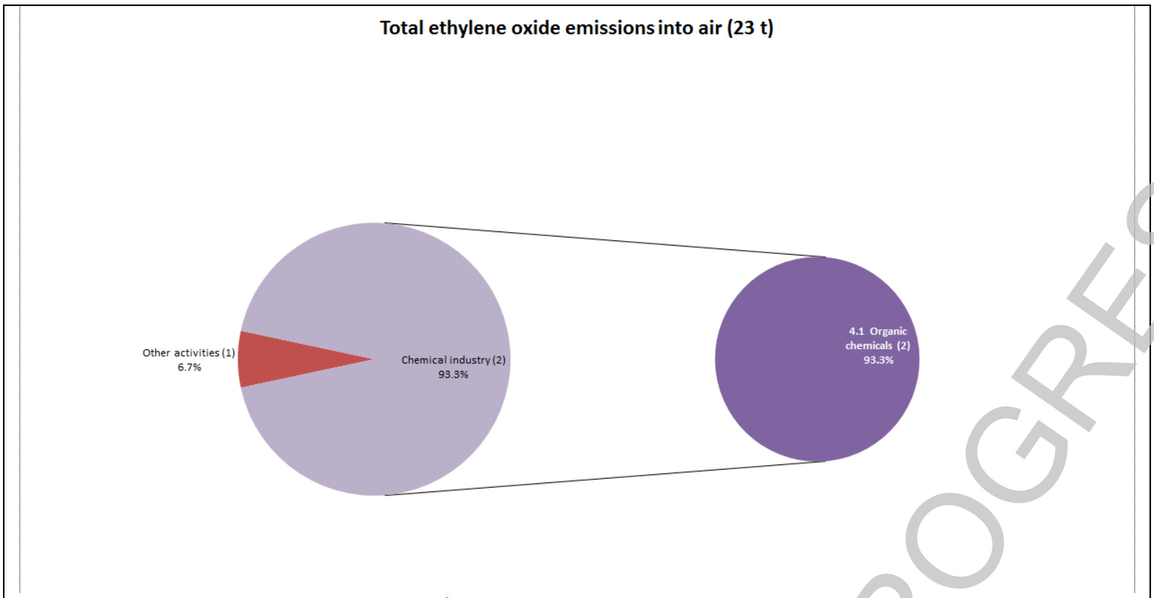
Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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.



Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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

1.2.6.8 Toluene

Toluene is not in 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 of 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 in 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].

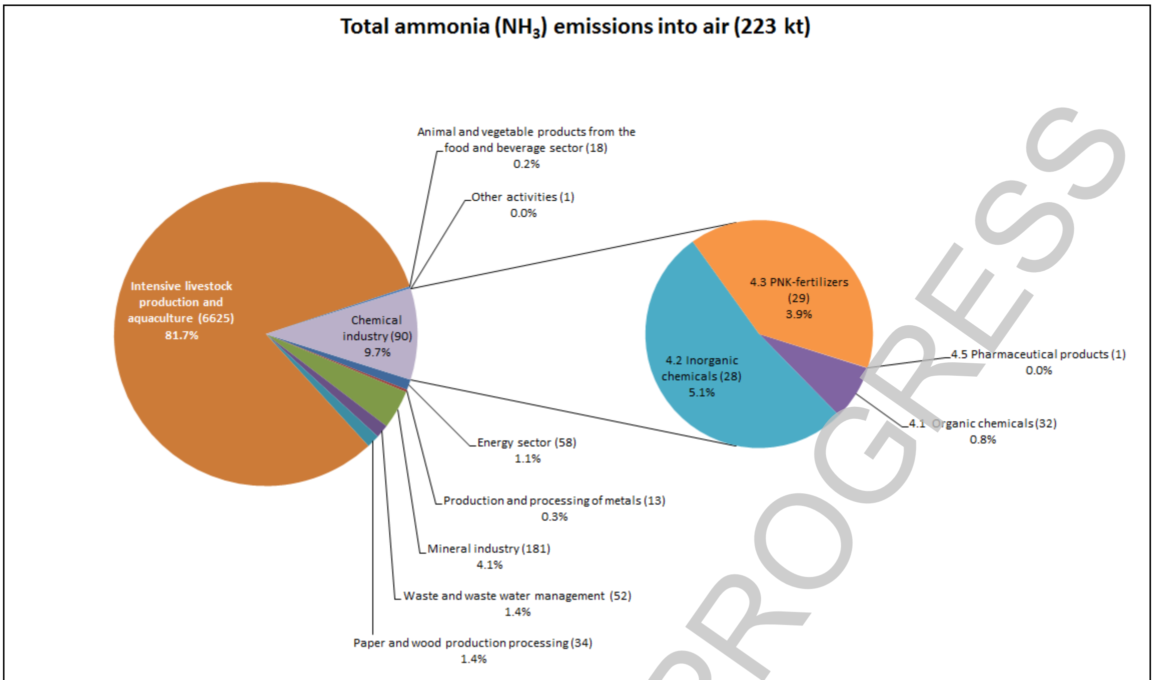
France [30, FR 2017] reported emissions of 75.5 tonnes of 1,3-butadiene from French chemical facilities in 2015.

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_3)

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.

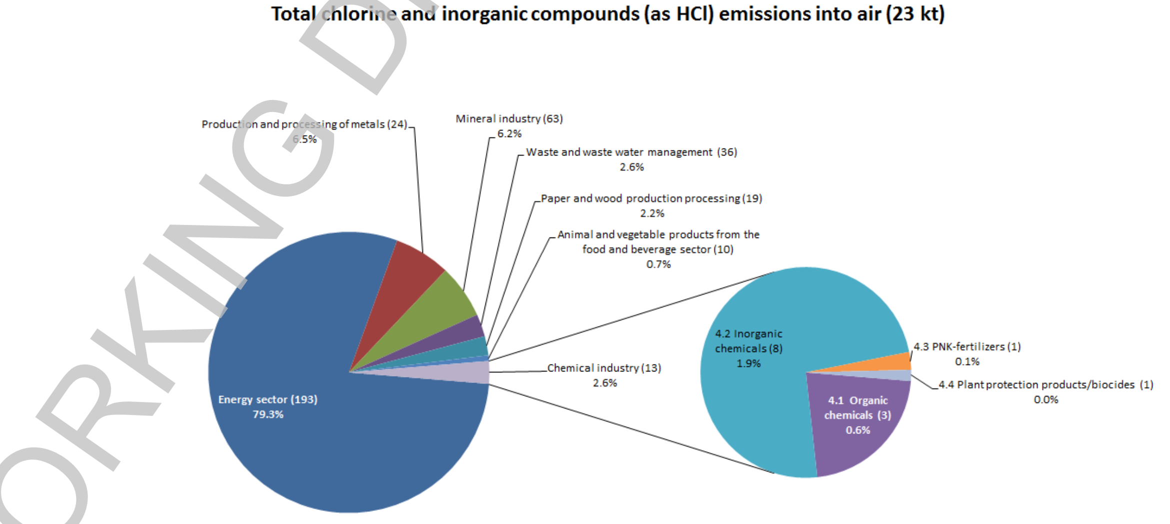


Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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

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.

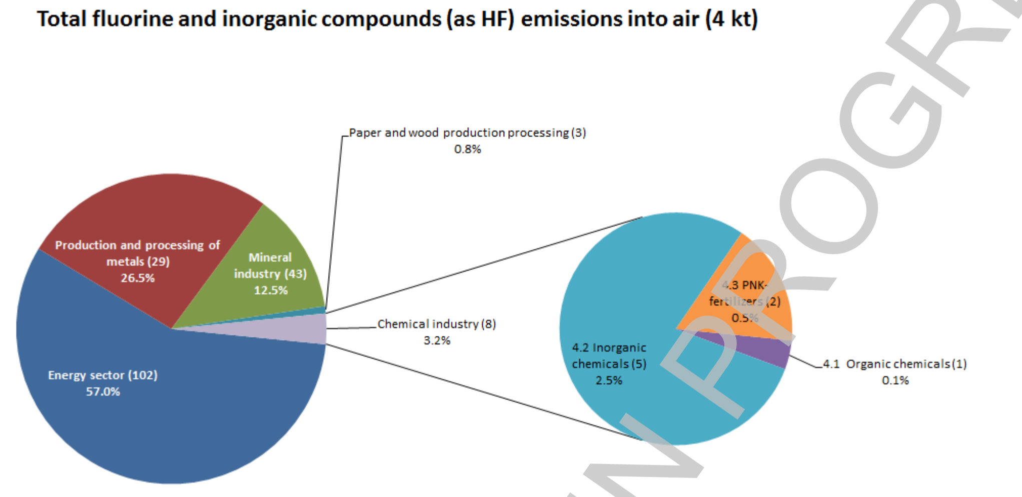


Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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.

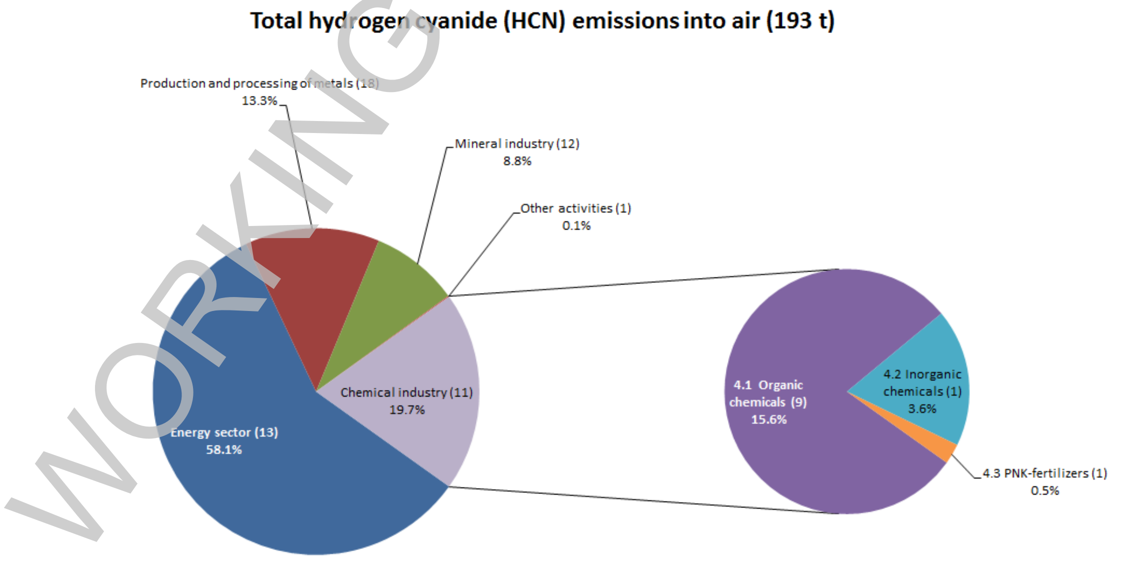


Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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.



Source: [45, EIPPCB 2018] based on data from [9, E-PRTR 2018]

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

1.3 Waste gas in the chemical industry

The character 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. Only channelled emissions can be treated. 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;
    - waste gases from purge vents or preheating equipment, which are used only in start-up or shutdown operations;
    - discharges from safety relief devices (e.g. safety vents, safety valves);
    - exhaust air from general ventilation systems;
    - 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, 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[2] in 2015 were diffuse emissions [31, FR 2017]. 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 [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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[2] 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 to decrease costs for additional treatment measures, as well as increase economic efficiency by increasing production yield and/or decreasing the input of raw material including water. 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.

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 tiny, 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 (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_3	HCl	HF	NO_x	SO_X	Other inorganic gaseous compounds	Volume flow rate (Nm^3/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 3.3.2.4
Dust scrubbing	X	+	X	+	+		+	+	720-170 000	See Section 3.3.2.1
Electrostatic precipitation	X								900-800 000	See Section 3.3.2.6
Filtration	X								2-5 000 000	See Sections 3.3.2.7, 3.3.2.8 and 3.3.2.9
Gravitational separation	X								5-300 000	See Section 3.3.2.5
Membrane Separation		X							< 3 000	See Section 3.5.1.2.1 in the CWW BREF
Reduction						X			1 500-50 000	See Sections 3.3.2.15 and 3.3.2.16
Catalytic or thermal oxidation	+	X		+				X	100-150 000	See Sections 3.3.2.13 and 3.3.2.14

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, EIPPCB 2019]

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 3.3.2.7, 3.3.2.8 and 3.3.2.9), waste water generated by scrubbers (see Section 3.3.2.1). Waste gas oxidation (see in particular Sections 3.3.2.13 and 3.3.2.14) 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.

It is difficult to give an indication of the break-even point where the positive effects outweigh the negative effects of a treatment measure, since this is strongly influenced by local conditions. Furthermore, it is generally considered preferable for pollutants to be in the most concentrated and controllable state. This offers the best opportunities for recycling, further treatment or controlled disposal. The ECM reference document describes methodologies that can help to determine the break-even point, where the positive effects outweigh the negative effects of a treatment measure [15, COM 2006].

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

Environmental medium	Potential effect/emission
Air	• In principle (and primarily), significant reduction of contaminant emissions. • 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.
Water	• Absorption (scrubbing) transfers contaminants from the air to the water medium. • However, some treatment techniques (e.g. scrubbing, water-run condensation) increase water consumption and waste water generation.
Waste	• Generation of sludge from secondary treatment of waste water, initially originating from waste gas treatment. • Generation of residues from waste gas treatment facilities (e.g. separated solids, condensed liquid not recycled, spent adsorbent, spent catalyst).
Other	• Waste gas treatment facilities normally consume energy. • Consumption of auxiliary chemicals (e.g. ammonia for selective non-catalytic reduction (SNCR), alkaline agents for scrubbing solutions).

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.

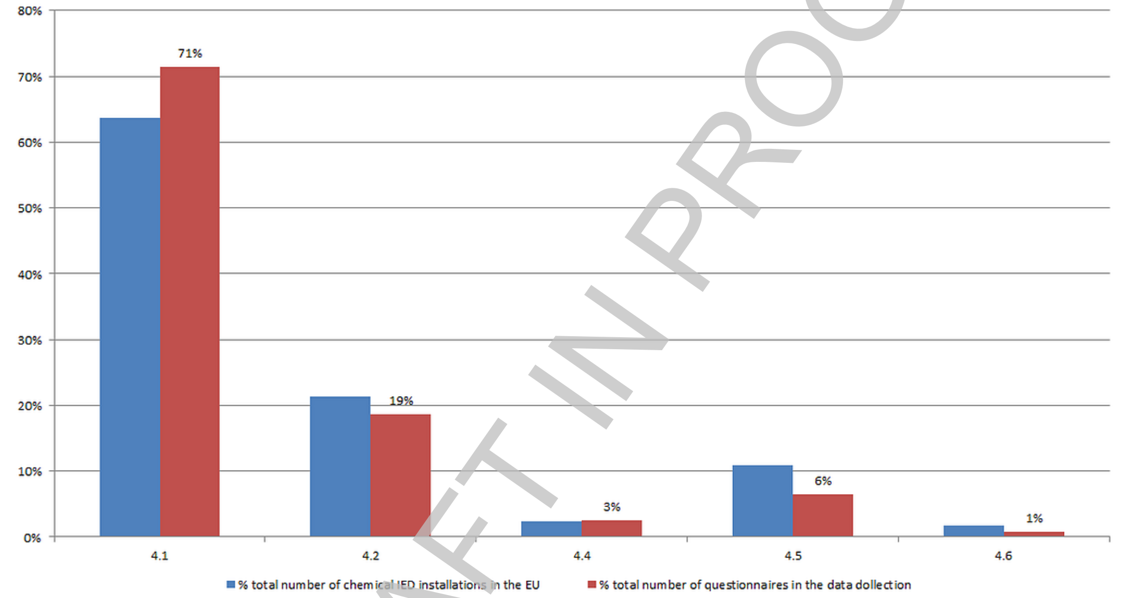
2 CURRENT EMISSION LEVELS

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 IED installations in the EU by chemical activity compared to the share of questionnaires in the data collection by chemical activity.



Source: [8, DG ENV 2015] and [43, EIPPCB 2019]

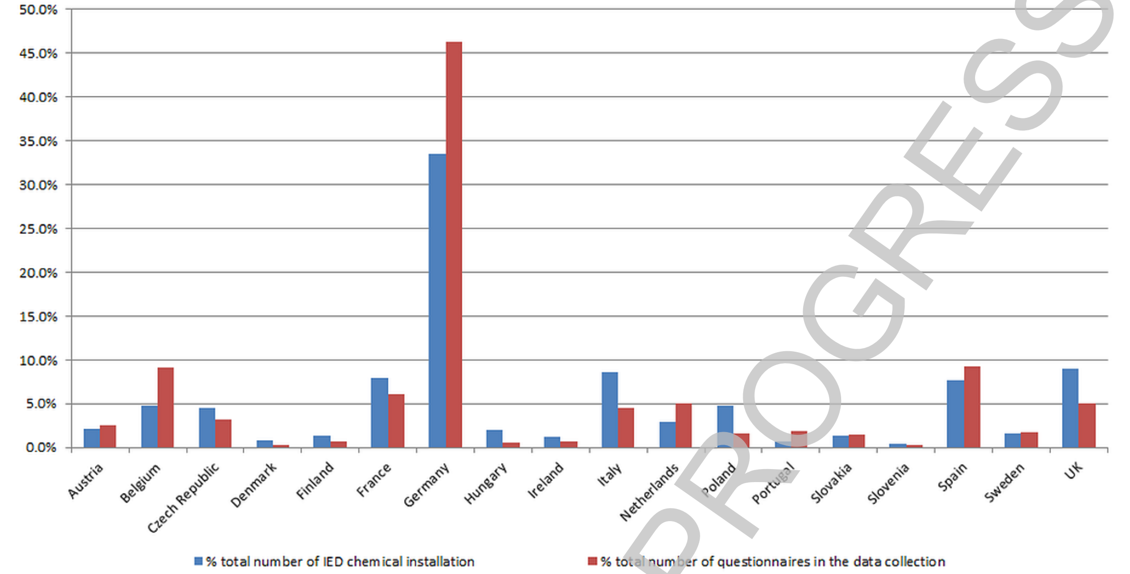
Figure 2.1: Share of IED installations in Europe by chemical IED activity versus share of questionnaires by chemical IED activity

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.

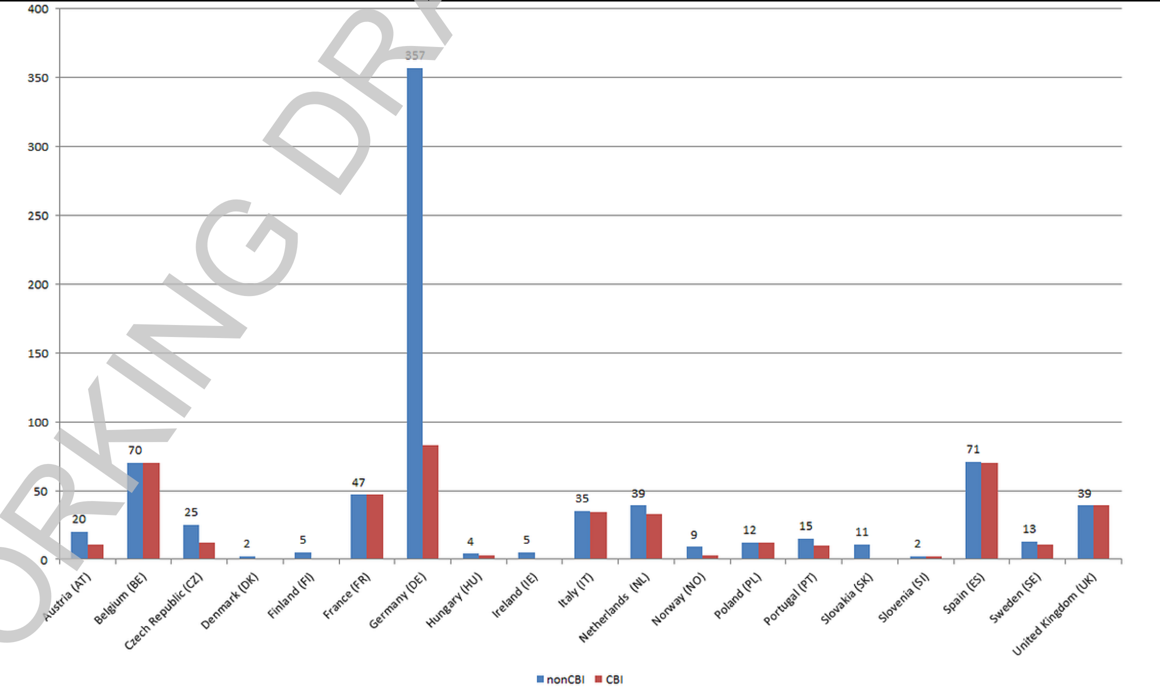
Figure 2.2 gives an overview of the number of questionnaires in the data collection compared to the number of chemical IED installations (for all chemical activities) per Member State.



Source: [8, DG ENV 2015] and [43, EIPPCB 2019]

Figure 2.2: Share of number of chemical IED installations in Europe versus share of questionnaires

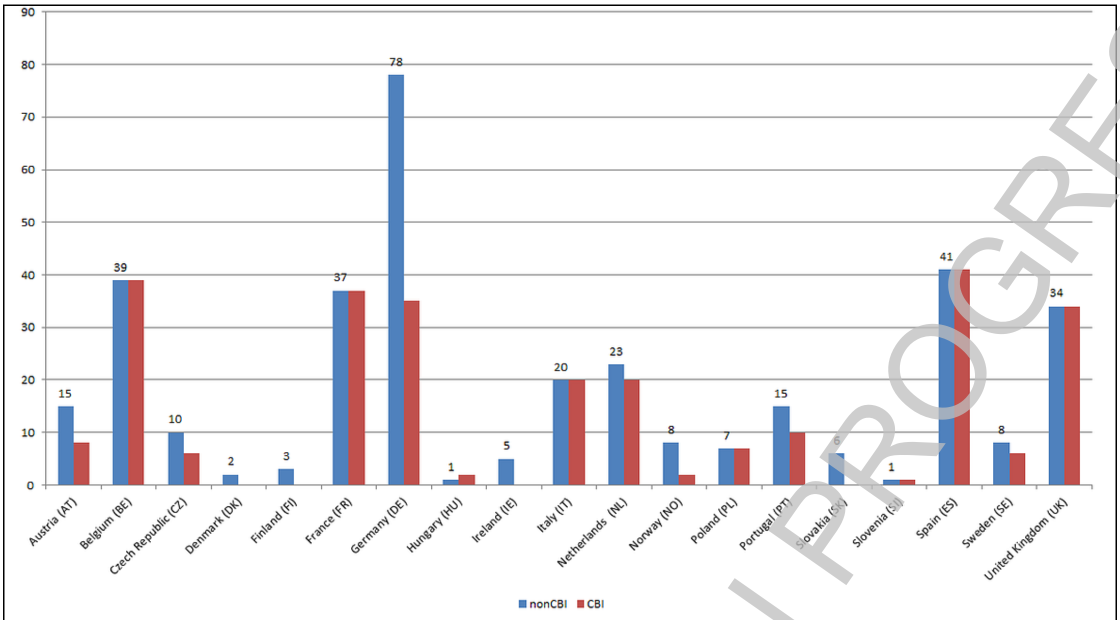
Figure 2.3 shows the number of questionnaires for the versions containing non-confidential business information (non-CBI versions), or submitted by email to the EIPPCB for the versions containing confidential business information (CBI versions). The total number of non-CBI versions is 781 and the total number of CBI versions is 440.



Source: [43, EIPPCB 2019]

Figure 2.3: Number of questionnaires submitted by Member State

Figure 2.4 gives an overview of the number of chemical IED companies by Member State. 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.



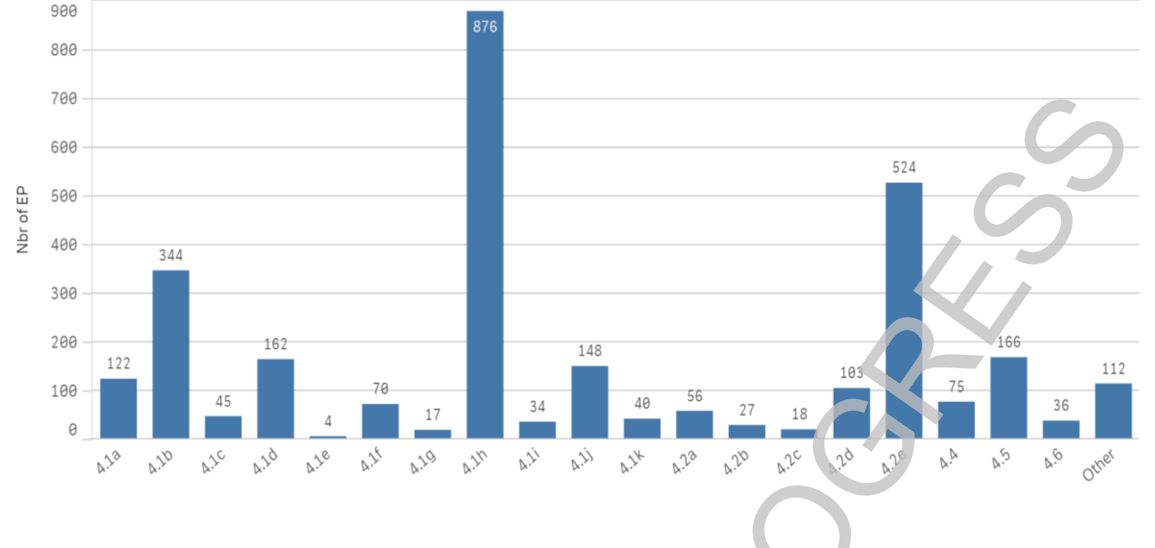
Source: [43, EIPPCB 2019]

Figure 2.4: Number of companies by Member State

2.1.2 Channelled 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.

Figure 2.5 gives an overview of the number of channelled emission points reported in the questionnaires per main chemical IED activity. The total number sums up to 3 248 channelled emission points. The data collection covers all chemical IED 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 chemical IED activity was not specified: those emission points do not appear on the graph.



Source: [43, EIPPCB 2019]

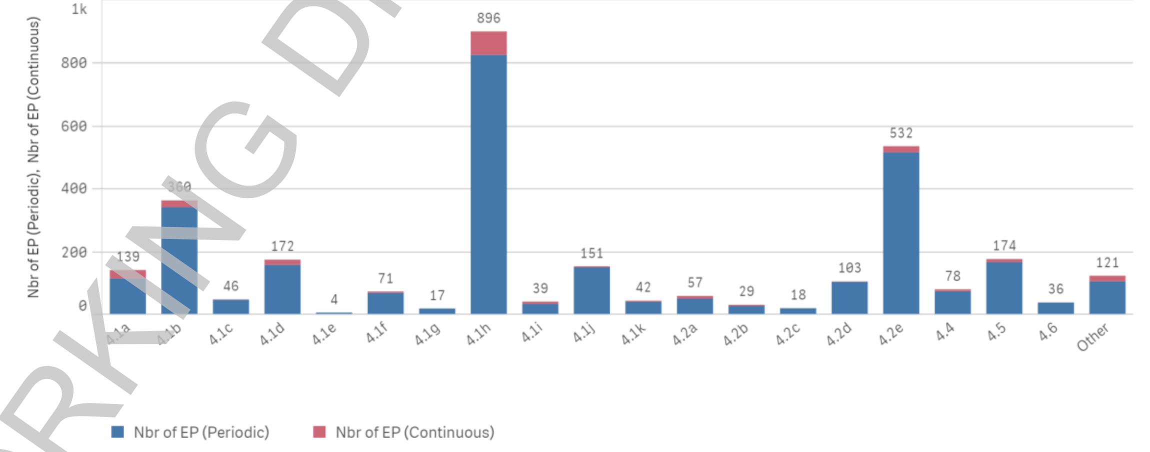
Figure 2.5: Number of channelled emission points reported by IED category

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

- total number of emission points where periodic monitoring is applied: 2 909;
- total number of emission points where continuous monitoring is applied: 219;

When several substances/parameters are monitored at the same emission point, both periodic and continuous monitoring are sometimes applied depending on the substance/parameter.

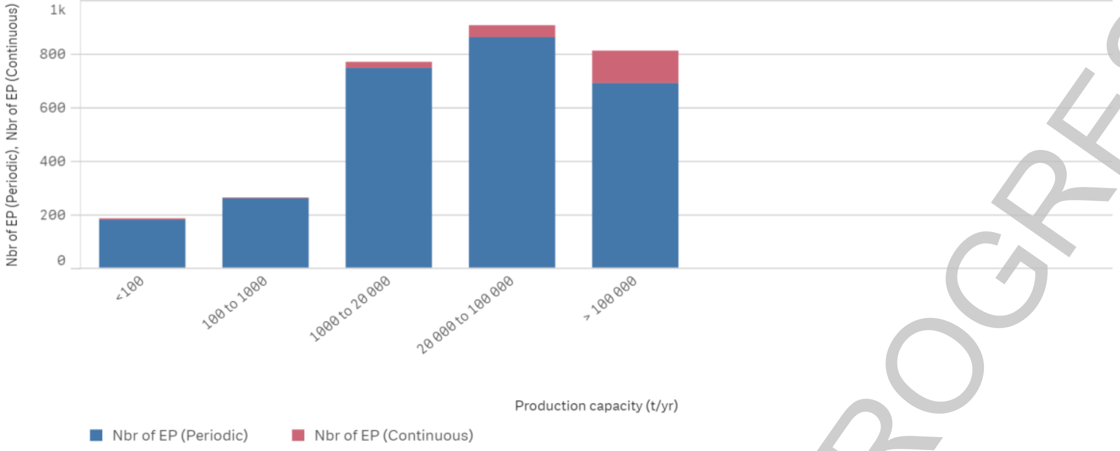
A total of 226 emission points reported monitoring substances/parameters that are not considered key environmental issues (KEIs) for this BREF. Those emission points do not appear in the graphs presented in this section.



Source: [43, EIPPCB 2019]

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).



Source: [43, EIPPCB 2019]

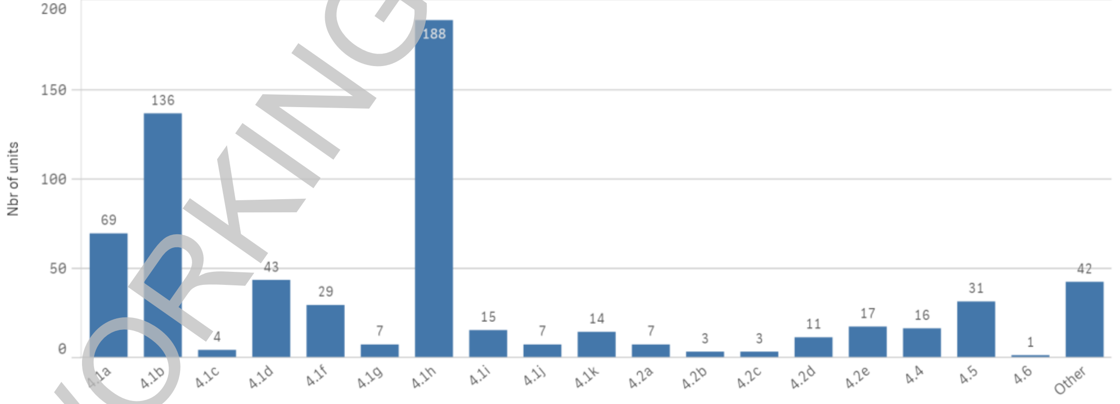
Figure 2.7: Production capacity ranges

2.1.3 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, 2.5, 2.6 and 2.7, the term ‘unit’ shall have the abovementioned meaning.

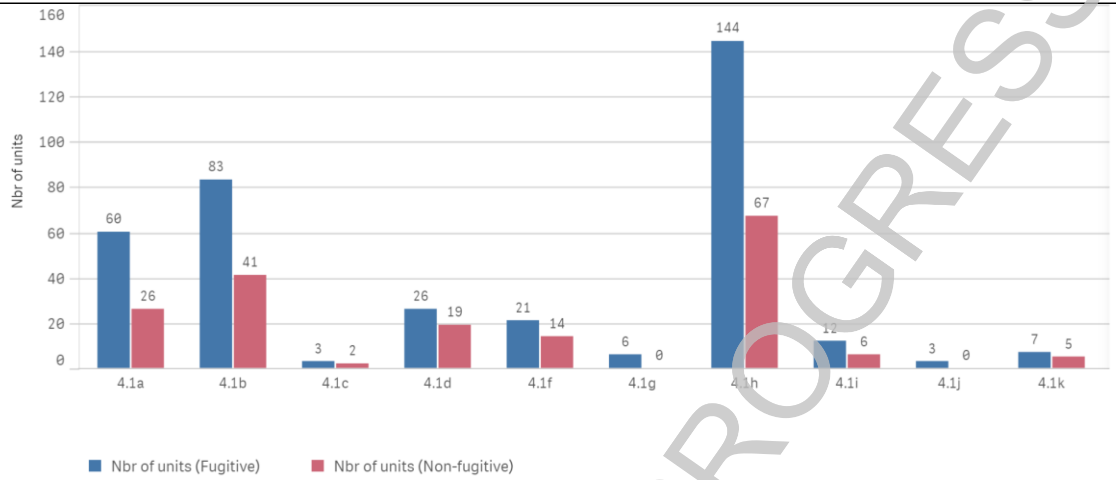
Figure 2.8 gives an overview of the number of units for which diffuse emissions were collected per main chemical IED activity (covered by Section 4 of Annex I to the IED). The total number sums up to 643 units.



Source: [43, EIPPCB 2019]

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 chemical IED activity. The total number sums up to 430 (fugitive) and 239 (non-fugitive).



Source: [43, EIPPCB 2019]

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 % (1)
Reduction	0.8 %
Thermal oxidation	9.8 %
No waste gas treatment	20.1 %

(1) The use of membrane separation was reported in one questionnaire for one emission point.

Source: [43, EIPPCB 2019]

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
Absorption (Packed-bed scrubber)	392
Absorption (Spray tower)	154
Adsorption (Fixed bed)	95
Condensation (Condenser)	129
Condensation (Cryogenic condensation)	34
Dust scrubbing (Wet dust scrubber)	66
Dust scrubbing (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 (RTO)	35
Regenerative thermal oxidiser	42
Straight thermal oxidiser	112

Source: [43, EIPPCB 2019]

The whole 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. NO_X, SO_X) and PCCD/F, additional techniques may be applied.

2.3 Channelled emission 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.

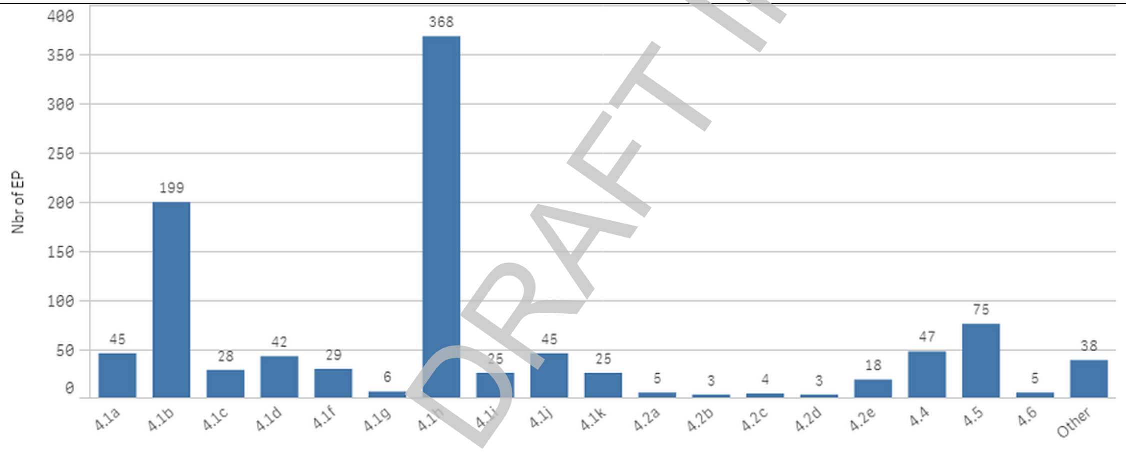
In general, the concentrations and the mass flows presented in the graphs from this section are given as average values, obtained as described in Annex 7.1.

2.3.2 Organic substances

2.3.2.1 Total volatile organic carbon (TVOC)

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.



NB: 192 operators reported 1 026 emission points.
Source: [43, EIPPCB 2019]

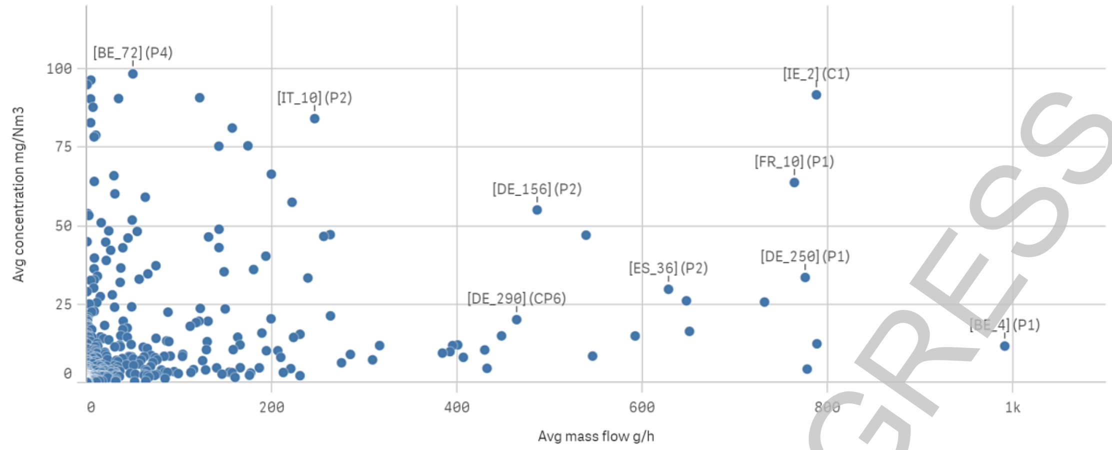
Figure 2.10: Number of emission points for TVOC emissions to air by IED category

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;
- condensation;
- thermal or catalytic oxidation.

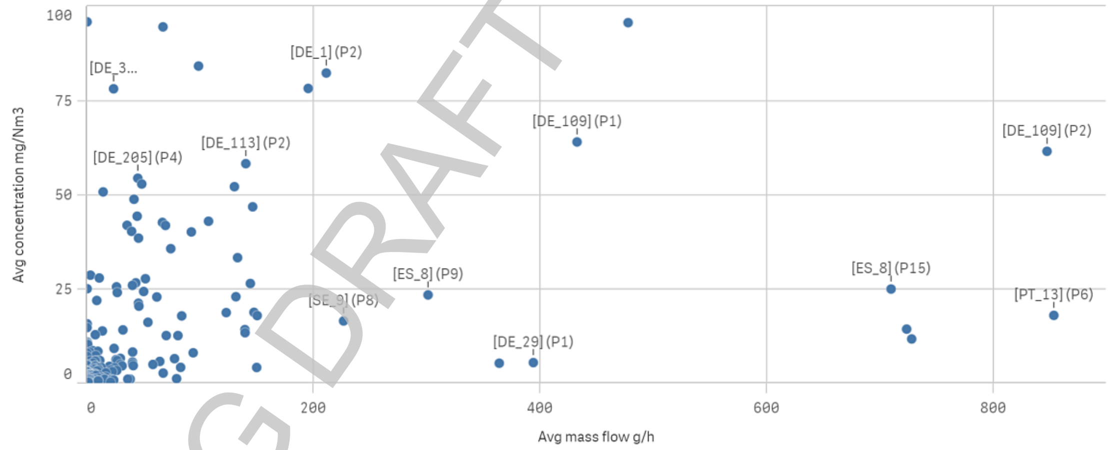


NB: 161 operators reported TVOC emissions from 599 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-100 mg TVOC/Nm^3 and mass flows in the range of 0-1 000 g TVOC/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.

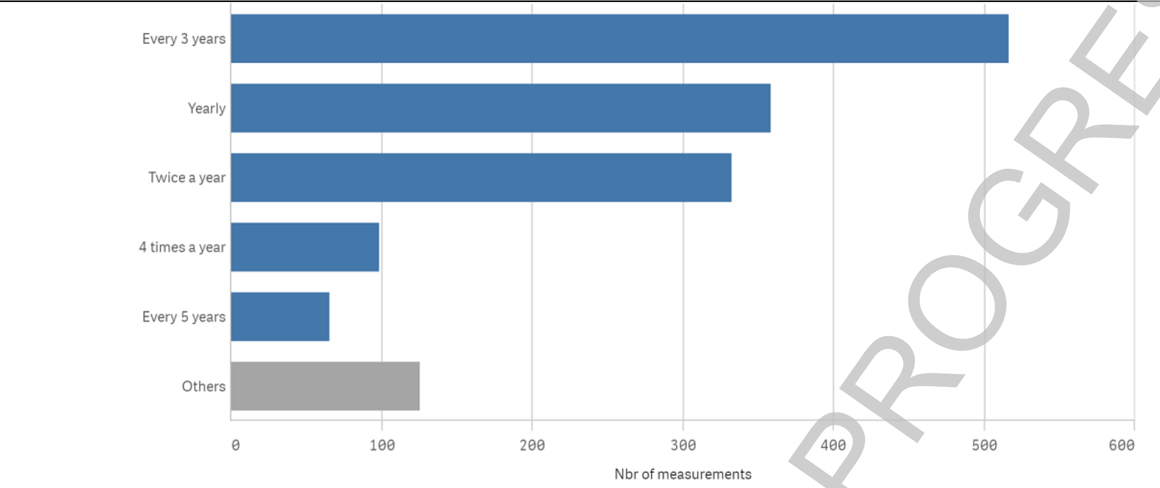


NB: 64 operators reported TVOC emissions from 255 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-100 mg TVOC/Nm^3 and mass flows in the range of 0-1 000 g TVOC/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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: 1 743 instances of periodic monitoring and 114 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.



Source: [43, EIPPCB 2019]

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

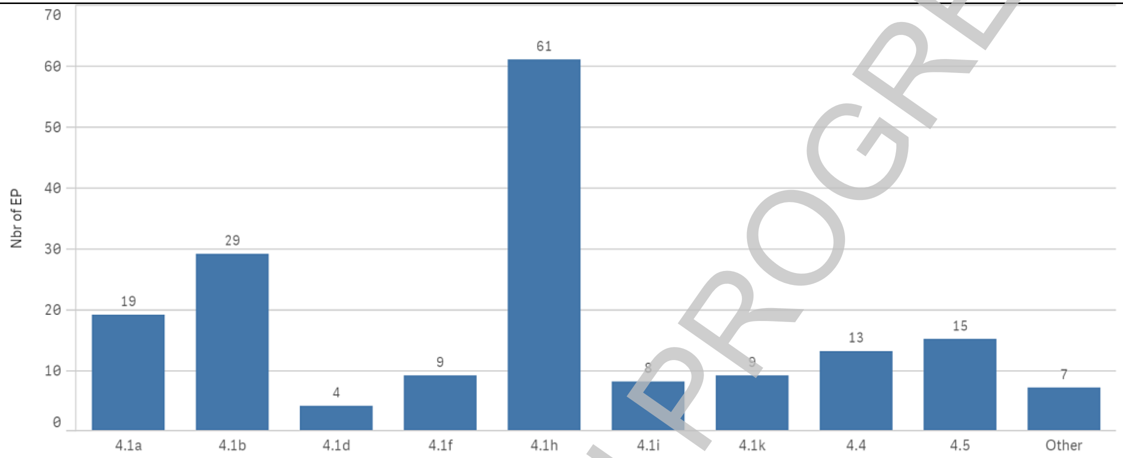
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.5	0.2
50th	1.0	0.5
80th	3.0	1.7

NB: The numbers of instances reported for the limits of quantification and detection are 483 and 510, respectively.
Source: [43, EIPPCB 2019]

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 is typically emitted by chemical sectors as shown in the bar chart of Figure 2.14.



NB: 70 operators reported TVOC emissions (containing substances classified as CMR 1A or 1B) from 184 emission points in the data collection.
Source: [43, EIPPCB 2019]

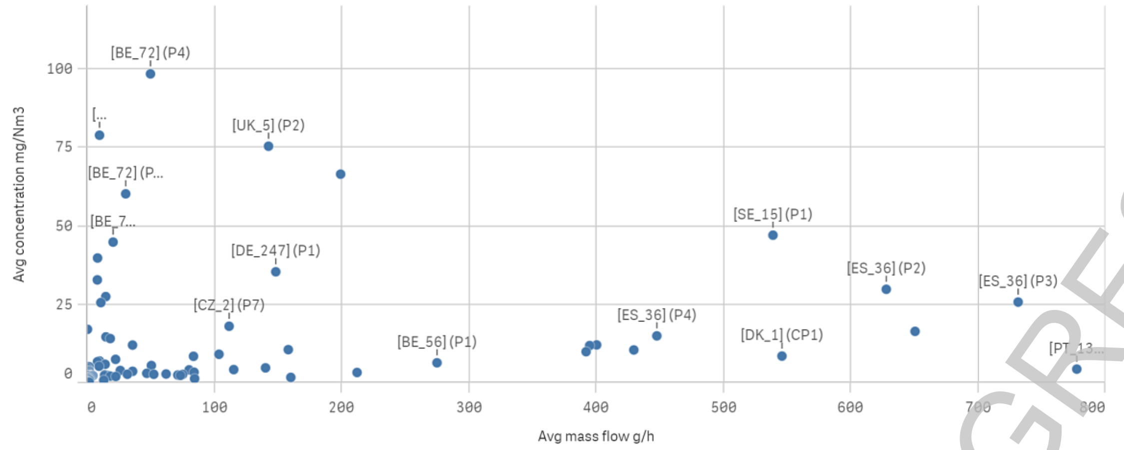
Figure 2.14: Number of emission points for TVOC emissions containing substances classified as CMR 1A or 1B by IED category

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;
- condensation;
- thermal or catalytic oxidation.

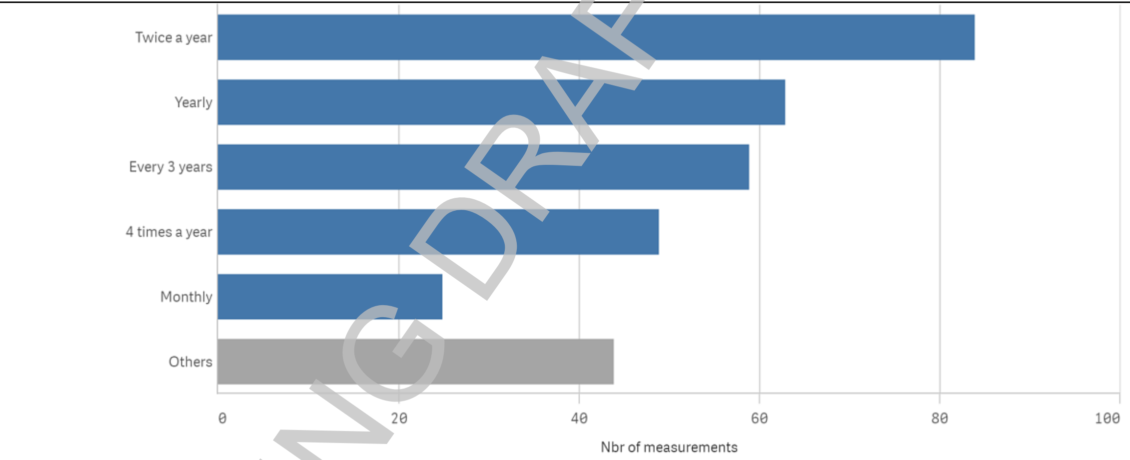


NB: 50 operators reported TVOC emissions from 121 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-100 mg TVOC/Nm^3 and mass flows in the range of 0-1 000 g TVOC/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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: 380 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.



Source: [43, EIPPCB 2019]

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

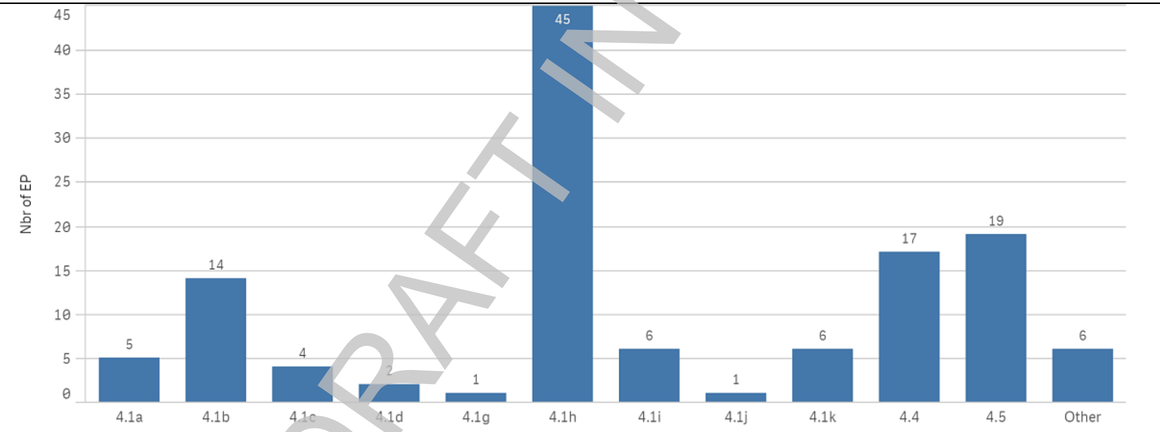
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	1.0	0.2
50th	1.6	1.0
80th	4.0	3.0

NB: The numbers of instances reported for the limits of quantification and detection are 125 and 146, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 53 operators reported emissions of TVOC containing substances classified as CMR 2 from 126 emission points in the data collection.
Source: [43, EIPPCB 2019]

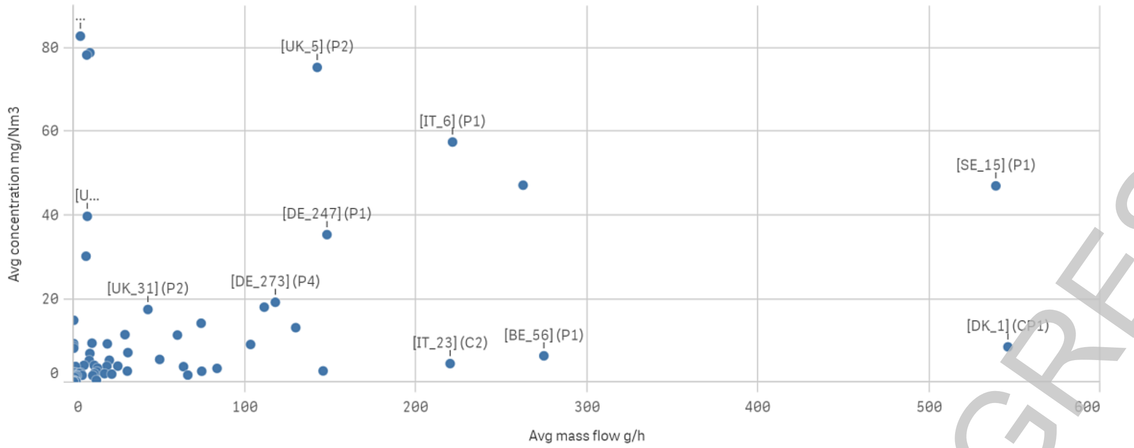
Figure 2.17: Number of emission points for TVOC containing substances classified as CMR 2 by IED category

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;
- condensation;
- thermal or catalytic oxidation.

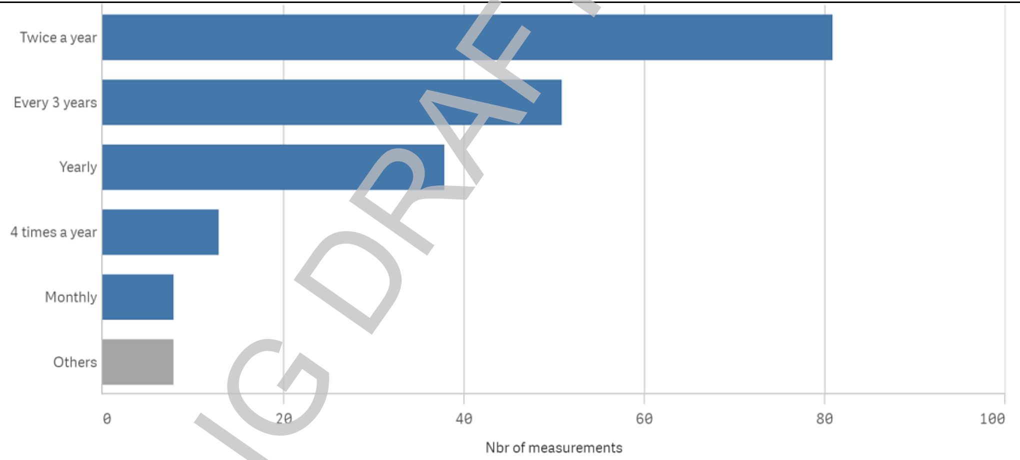


NB: 47 operators reported TVOC emissions from 97 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-100 mg TVOC/Nm^3 and mass flows in the range of 0-1 000 g TVOC/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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: 188 instances of periodic monitoring and 21 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.



Source: [43, EIPPCB 2019]

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

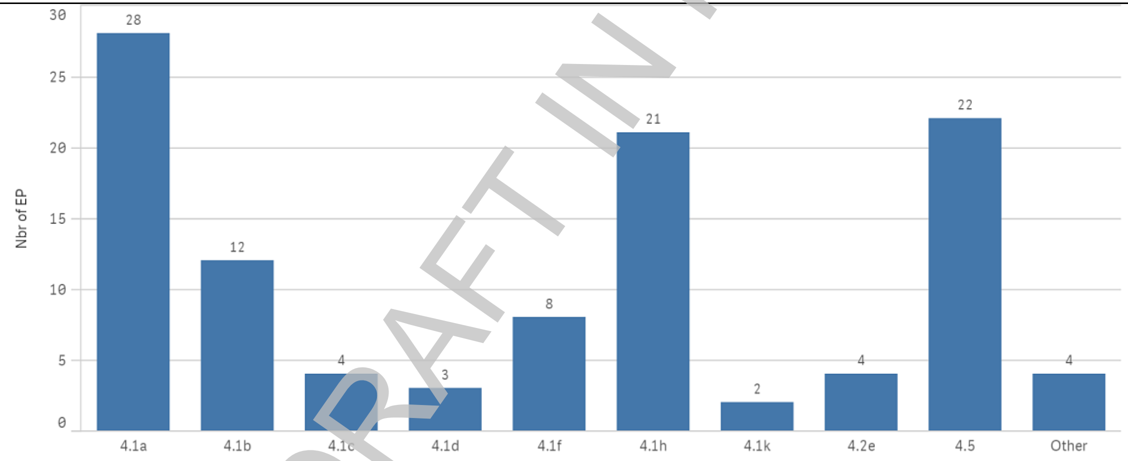
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.3	0.2
50th	1.0	0.3
80th	1.0	1.0

NB: The numbers of instances reported for the limits of quantification and detection are 70 and 93, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 37 operators reported 110 emission points in the data collection.
Source: [43, EIPPCB 2019]

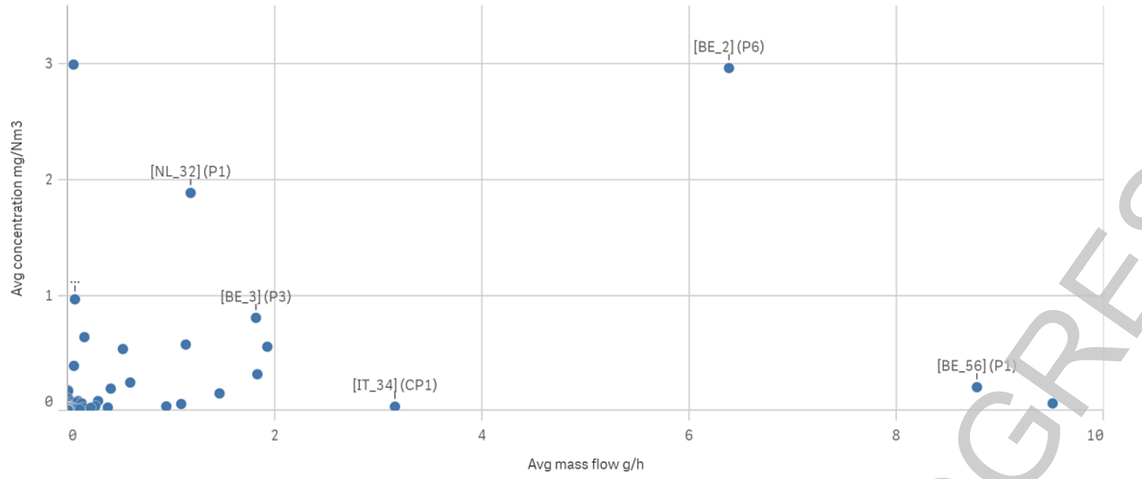
Figure 2.20: Number of emission points for benzene by IED category

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;
- condensation;
- thermal or catalytic oxidation.

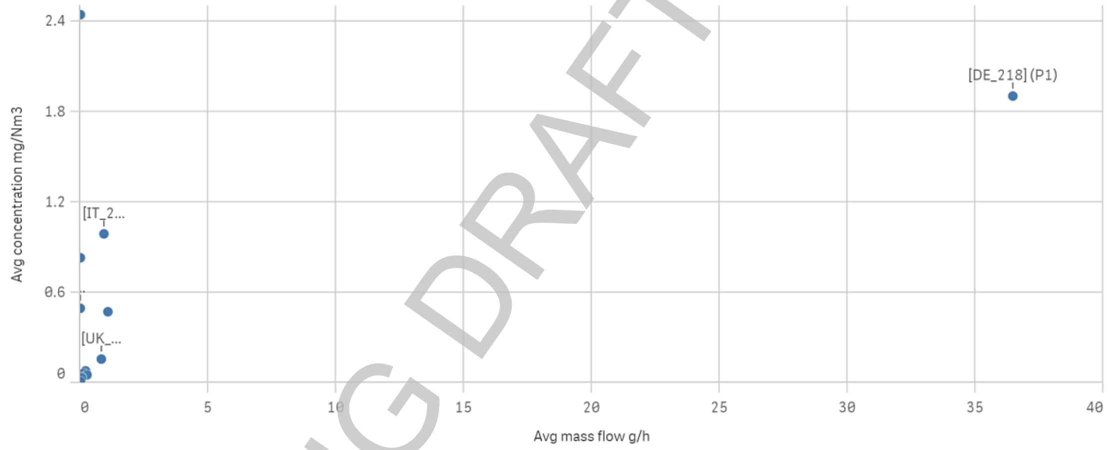


NB: 30 operators reported benzene emissions from 83 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-5 mg C_6H_6/Nm^3 and mass flows in the range of 0-12.5 g C_6H_6/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.

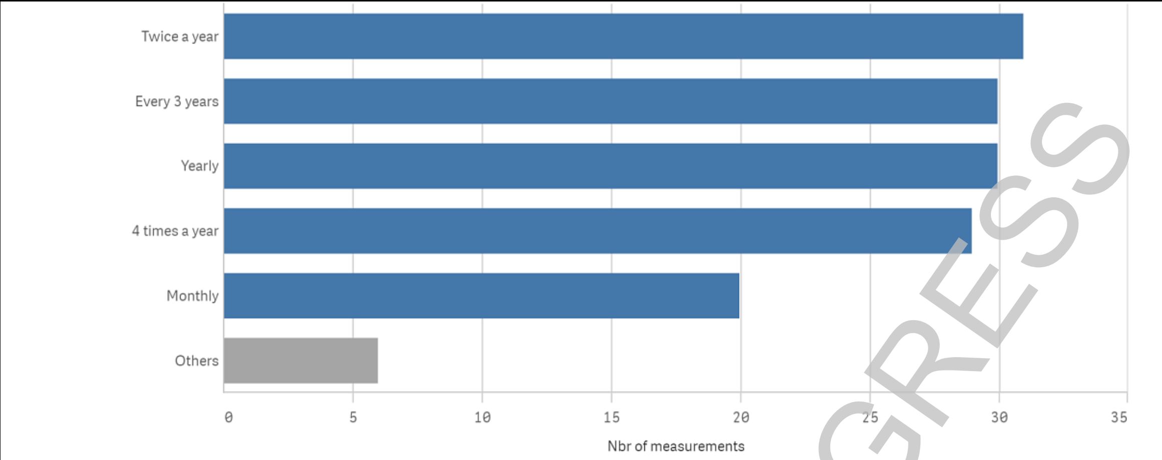


NB: 8 operators reported benzene emissions from 16 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-5 mg C_6H_6/Nm^3 and mass flows in the range of 0-12.5 g C_6H_6/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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: 167 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.



Source: [43, EIPPCB 2019]

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

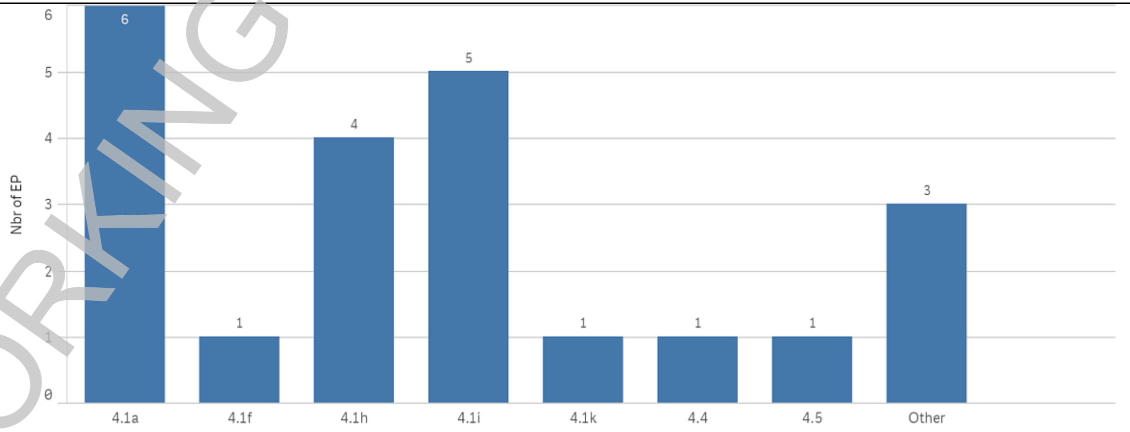
Percentile	Limit of quantification (mg/Nm³)	Limit of detection (mg/Nm³)
20th	0.01	0.03
50th	0.05	0.05
80th	0.50	0.16

NB: The numbers of instances reported for the limits of quantification and detection are 92 and 73, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 13 operators reported 22 emission points in the data collection.
Source: [43, EIPPCB 2019]

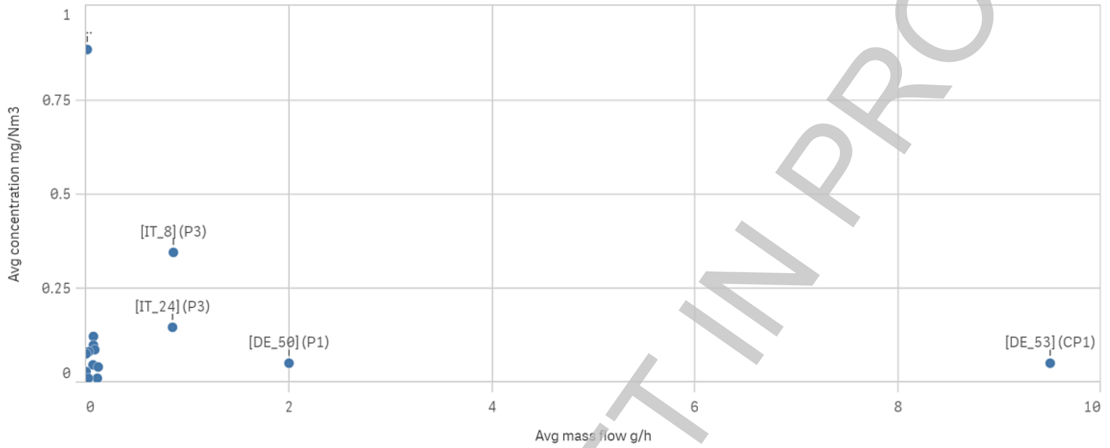
Figure 2.24: Number emission of points for 1,3-butadiene by IED category

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;
- condensation;
- thermal or catalytic oxidation.



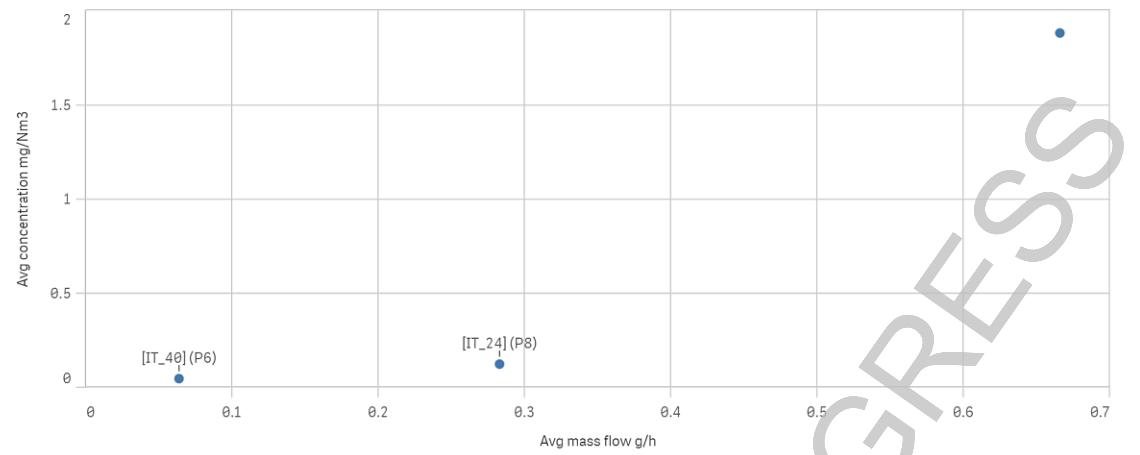
NB: 10 operators reported 1,3-butadiene emissions from 16 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-5 mg C_4H_6/Nm^3 and mass flows in the range of 0-12.5 g C_4H_6/h are represented in the scatter plot.

Source: [43, EIPPCB 2019]

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.

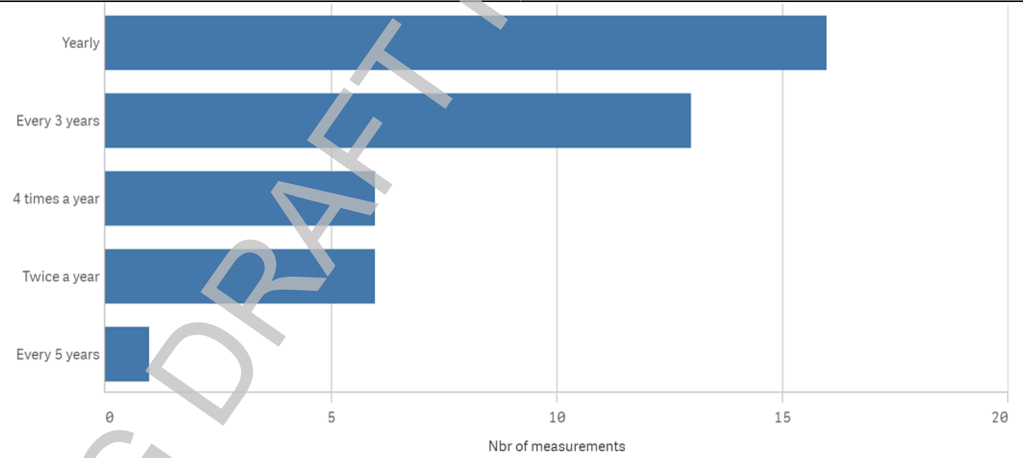


NB: 5 operators reported 1,3-butadiene emissions from 5 emission points in the data collection, without any prior waste gas treatment. For 2 emission points, no information on the mass flow was available.
Source: [43, EIPPCB 2019]

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.



Source: [43, EIPPCB 2019]

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

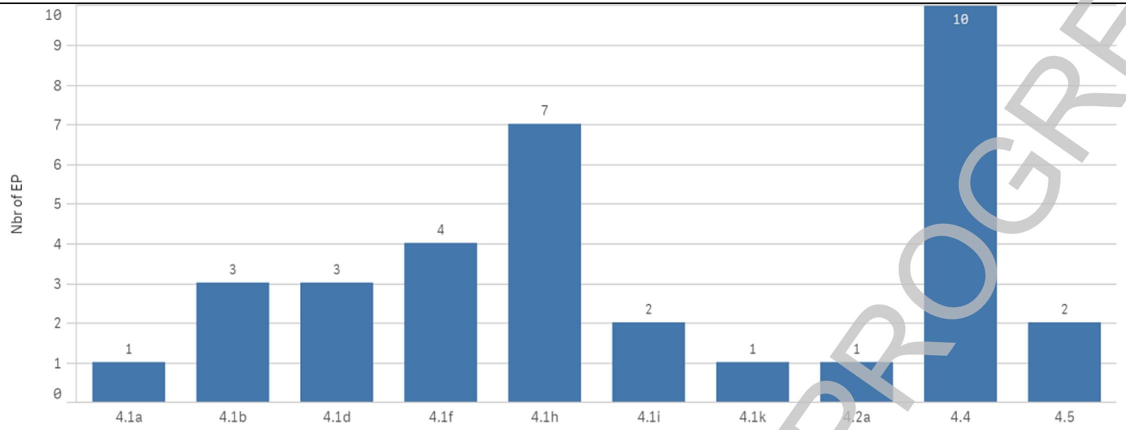
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.05	0.05
50th	0.07	0.06
80th	0.50	0.10

NB: The numbers of instances reported for the limits of quantification and detection are 19 and 26, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 18 operators reported 34 emission points in the data collection.
Source: [43, EIPPCB 2019]

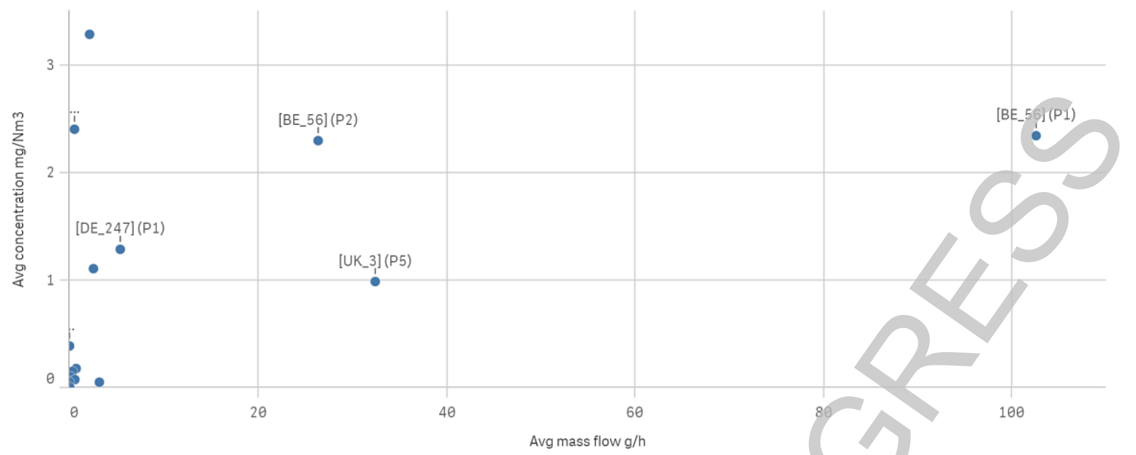
Figure 2.28: Number of emission points for chloromethane by IED category

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;
- condensation;
- thermal or catalytic oxidation.



NB: 15 operators reported chloromethane emissions from 27 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-5 mg CH_3Cl/Nm^3 and mass flows in the range of 0-500 g CH_3Cl/h are represented in the scatter plot.

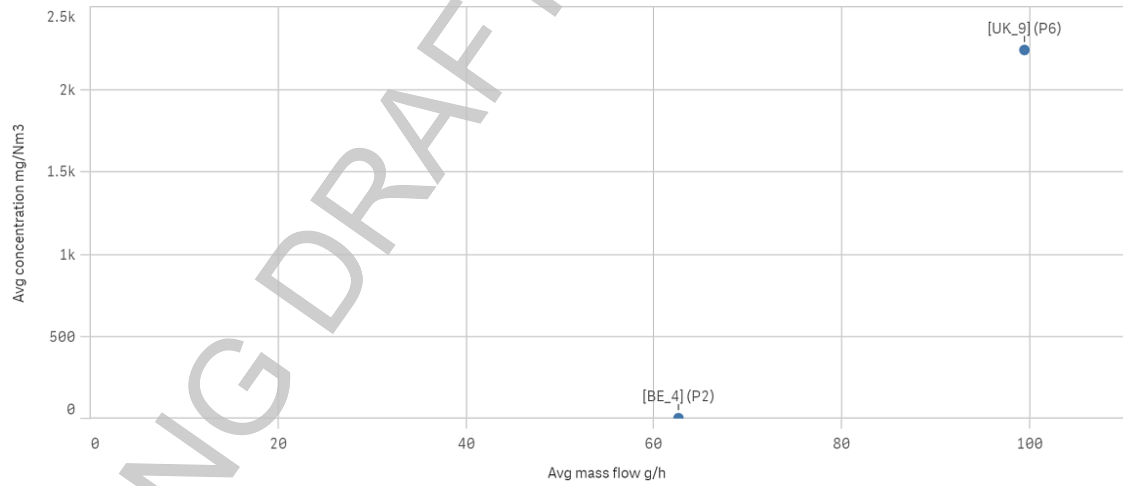
Data not shown for 4 emission points applying waste gas treatment techniques other than the ones listed above.

Source: [43, EIPPCB 2019]

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.



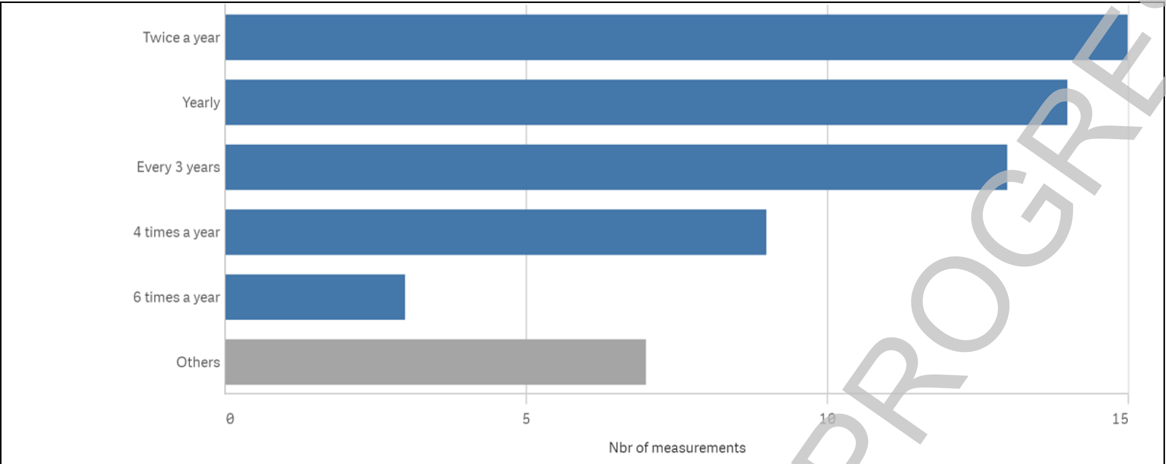
NB: 3 operators reported chloromethane emissions from 3 emission points in the data collection, without any prior waste gas treatment. For one emission point, no information on the mass flow was available.

Source: [43, EIPPCB 2019]

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.



Source: [43, EIPPCB 2019]

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

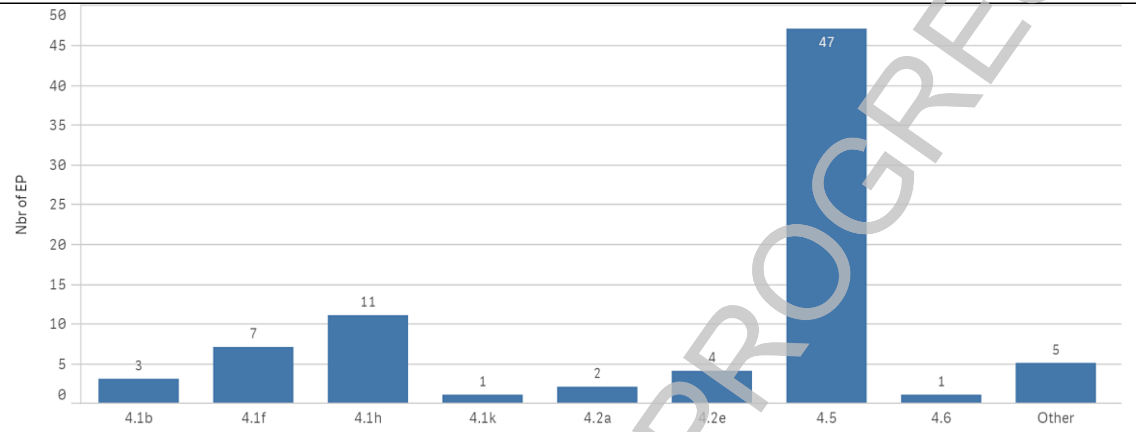
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.1	0.04
50th	10.0	2.2
80th	45.0	15.0

NB: The numbers of instances reported for the limits of quantification and detection are 29 and 28, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 30 operators reported 83 emission points in the data collection.
Source: [43, EIPPCB 2019]

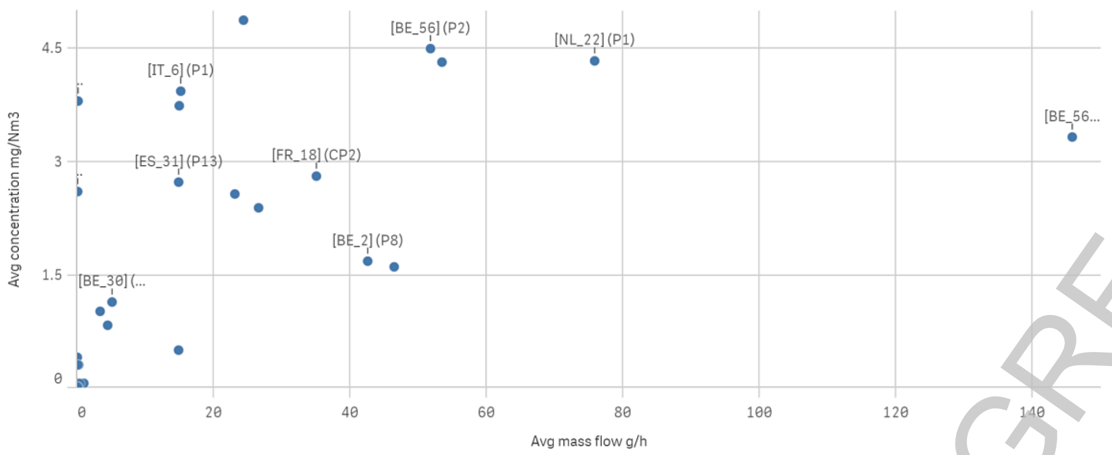
Figure 2.32: Number of emission points for dichloromethane by IED category

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.

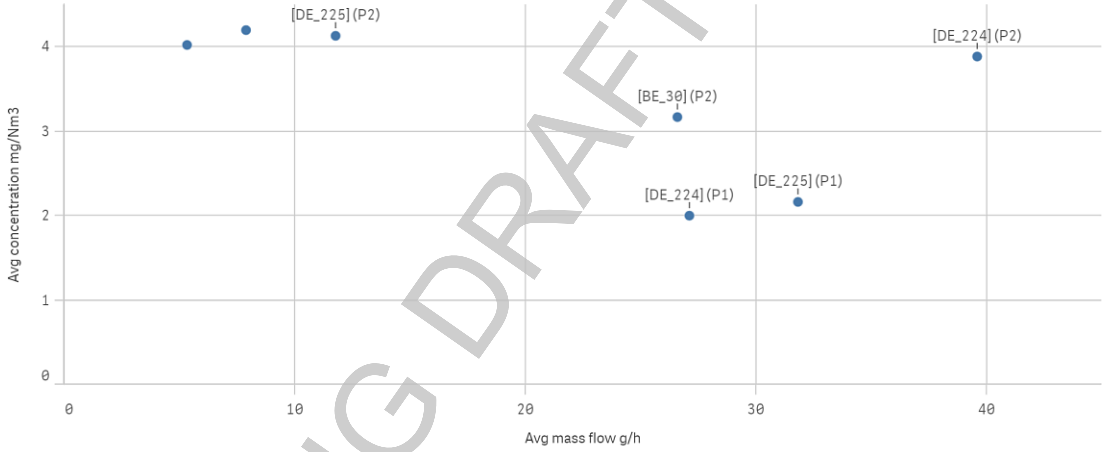


NB: 27 operators reported dichloromethane emissions from 65 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-5 mg CH_2Cl_2/Nm^3 and mass flows in the range of 0-500 g CH_2Cl_2/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.

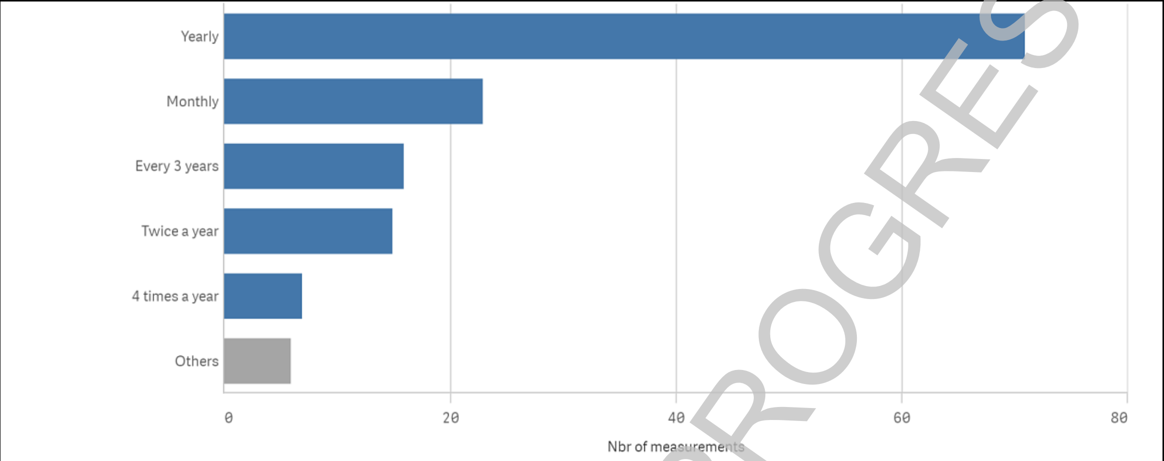


NB: 4 operators reported dichloromethane emissions from 10 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-5 mg CH_2Cl_2/Nm^3 and mass flows in the range of 0-500 g CH_2Cl_2/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.



Source: [43, EIPPCB 2019]

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.

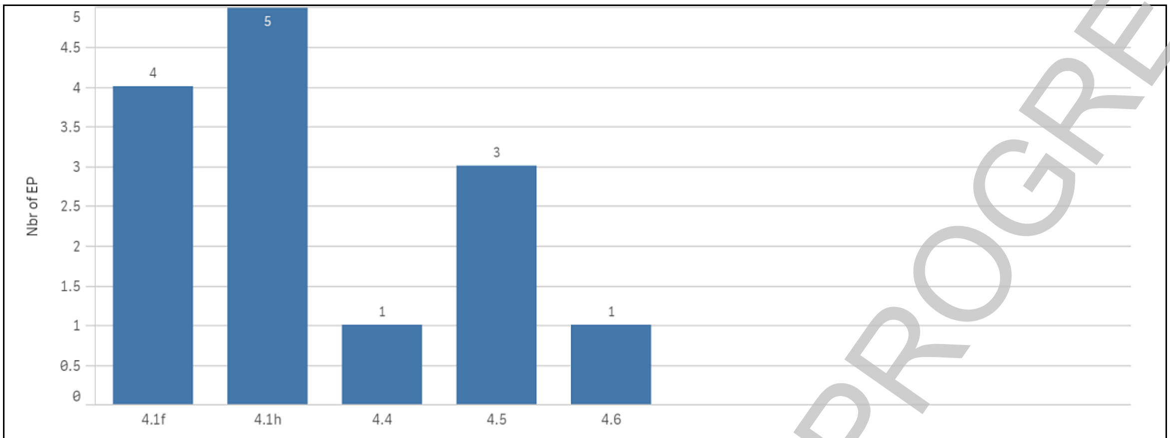
Table 2.9: Reported limits of quantification and detection for dichloromethane

Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.05	0.02
50th	1.0	0.1
80th	2.0	0.2
NB: The numbers of instances reported for the limits of quantification and detection are 50 and 26, respectively. *Source*: [43, EIPPCB 2019]		

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.



NB: 11 operators reported 14 emission points in the data collection.
Source: [43, EIPPCB 2019]

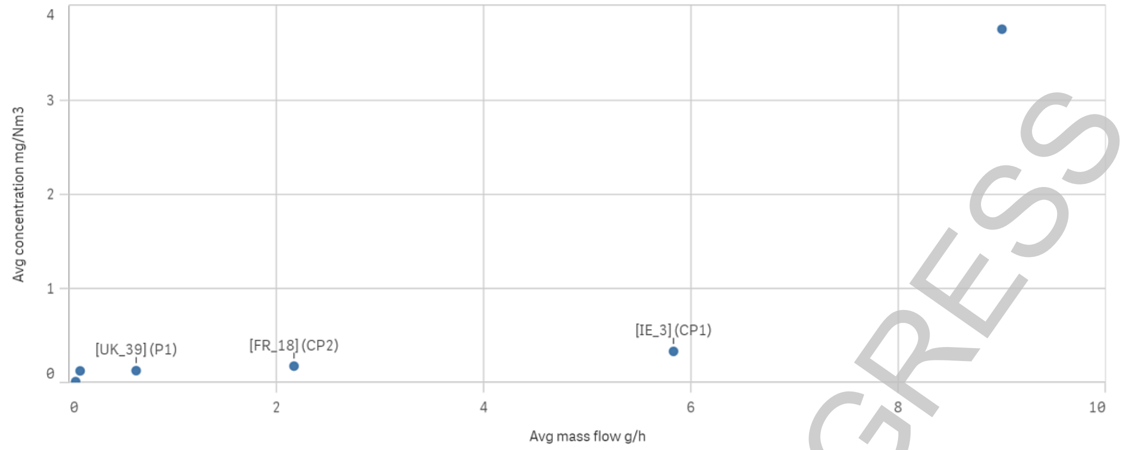
Figure 2.36: Number of emission points for ethylene dichloride by IED category

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:

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

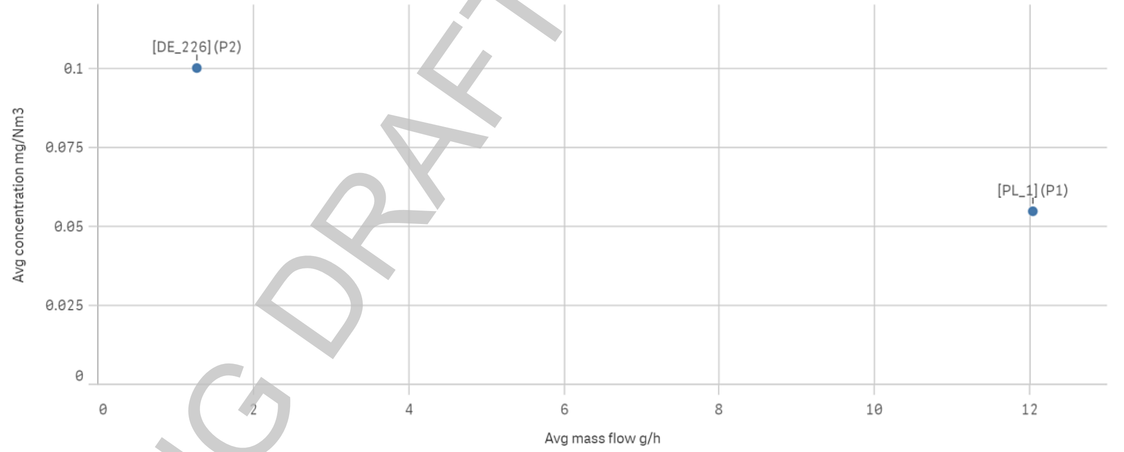


NB: 7 operators reported ethylene dichloride emissions from 9 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-5 mg $C_2H_4Cl_2/Nm^3$ and mass flows in the range of 0-12.5 g $C_2H_4Cl_2/h$ are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.

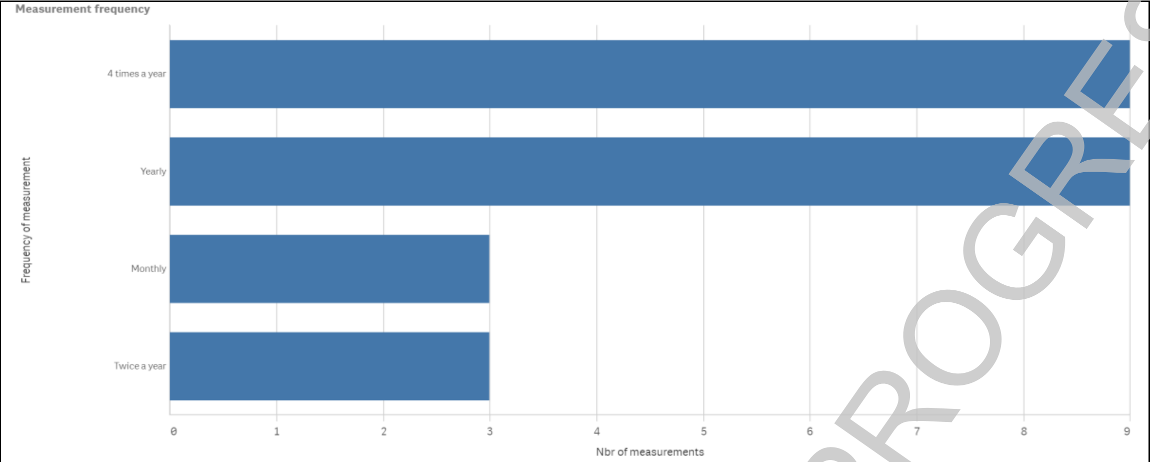


NB: 4 operators reported ethylene dichloride emissions from 4 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-5 mg $C_2H_4Cl_2/Nm^3$ and mass flows in the range of 0-12.5 g $C_2H_4Cl_2/h$ are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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

2.3.2.8.4 Monitoring

Only periodic monitoring was reported (25 instances). Typical frequencies for the monitoring of channelled ethylene dichloride emissions are shown in the bar chart of Figure 2.39.



Source: [43, EIPPCB 2019]

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.

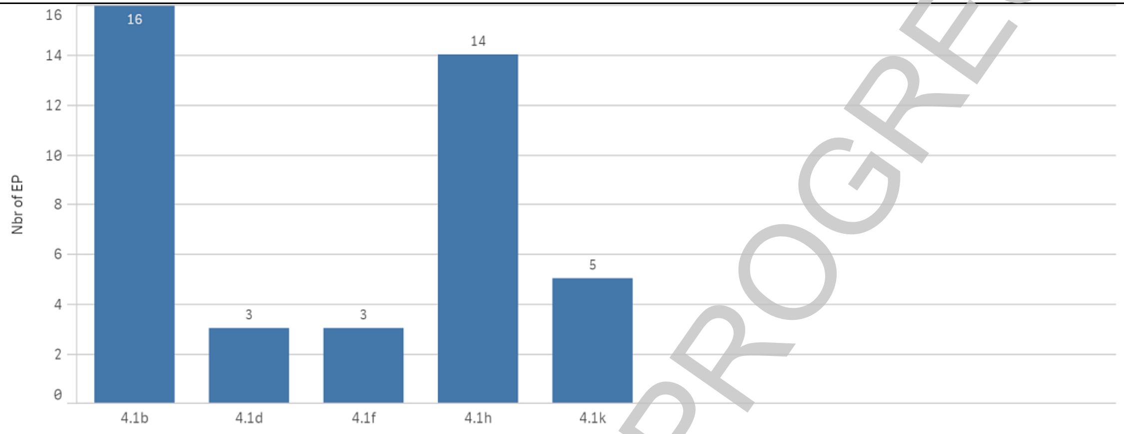
Table 2.10: Reported limits of quantification and detection for ethylene dichloride

Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.07	0.02
50th	0.10	0.07
80th	0.83	0.23
NB: The numbers of instances reported for the limits of quantification and detection are 11 and 8, respectively. *Source*: [43, EIPPCB 2019]		

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.



NB: 21 operators reported 41 emission points in the data collection.
Source: [43, EIPPCB 2019]

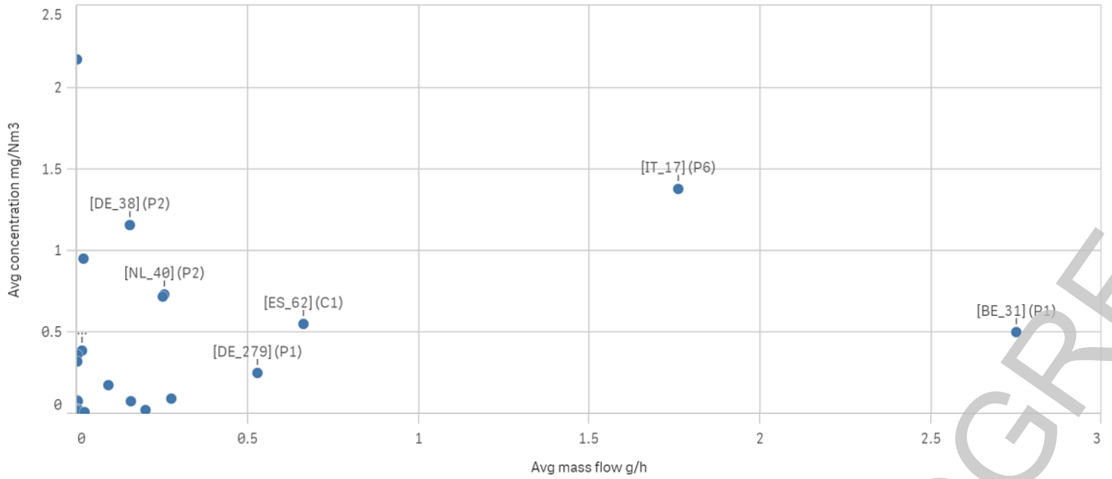
Figure 2.40: Number of emission points for ethylene oxide by IED category

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

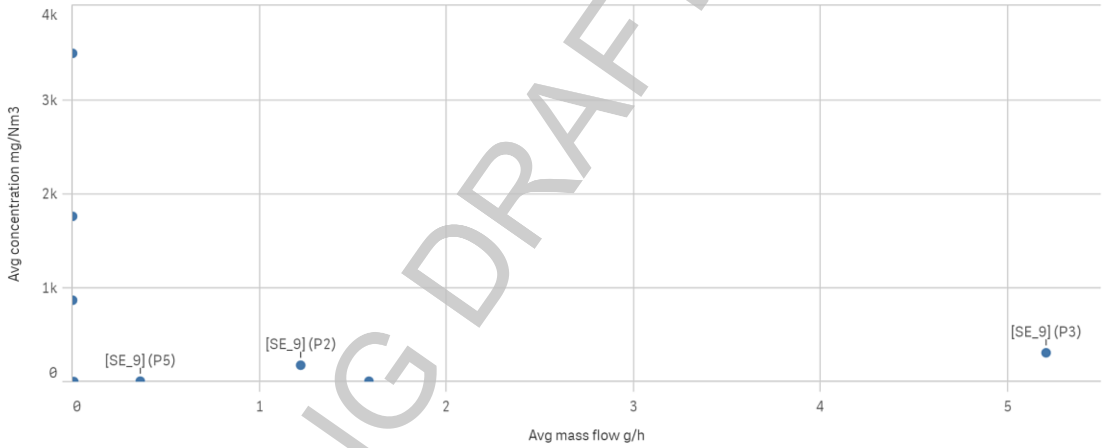


NB: 19 operators reported ethylene oxide emissions from 30 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-5 mg C_2H_4O/Nm^3 and mass flows in the range of 0-12.5 g C_2H_4O/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.

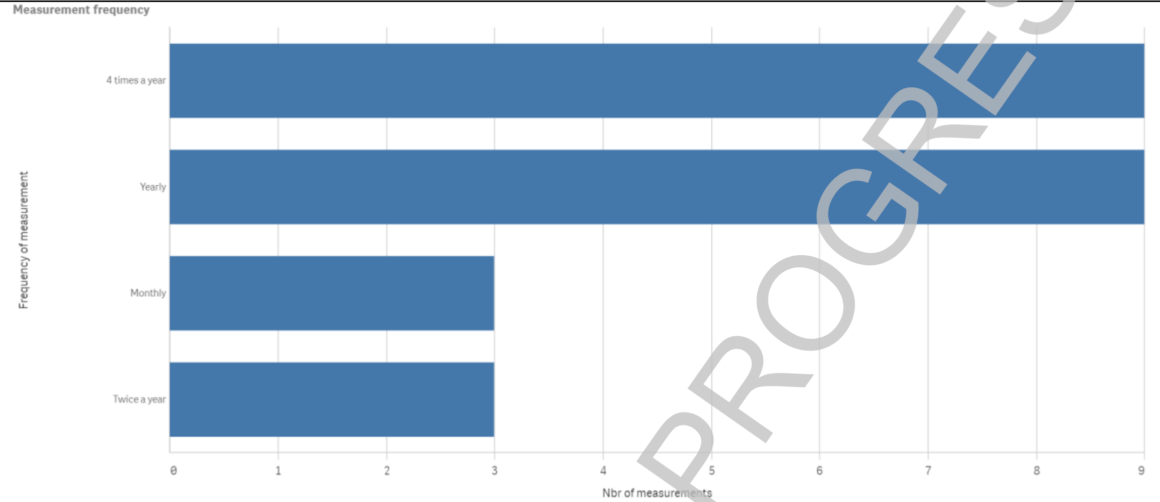


NB: 2 operators reported ethylene oxide emissions from 11 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-5 mg C_2H_4O/Nm^3 and mass flows in the range of 0-12.5 g C_2H_4O/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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: 78 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.



Source: [43, EIPPCB 2019]

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

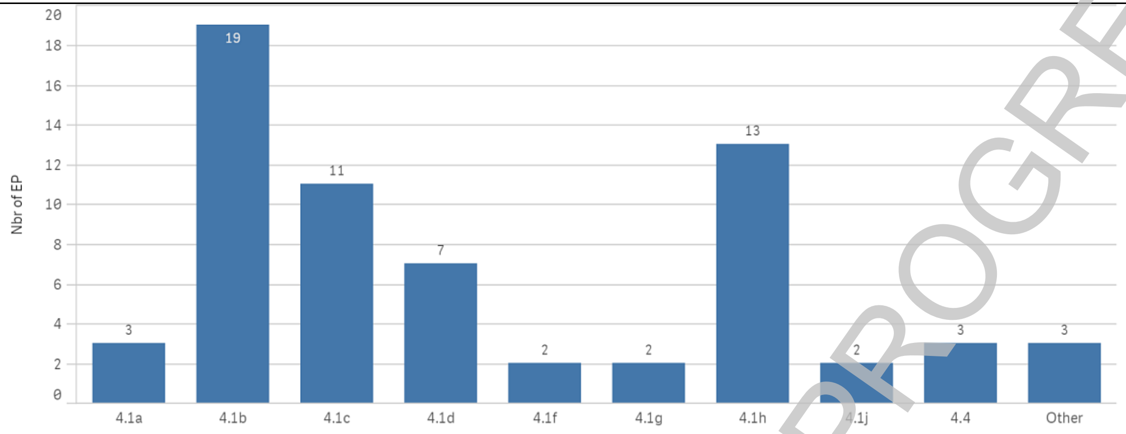
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.02	0.02
50th	0.08	0.10
80th	0.50	0.35

NB: The numbers of instances reported for the limits of quantification and detection are 10 and 19, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 26 operators reported 65 emission points in the data collection.
Source: [43, EIPPCB 2019]

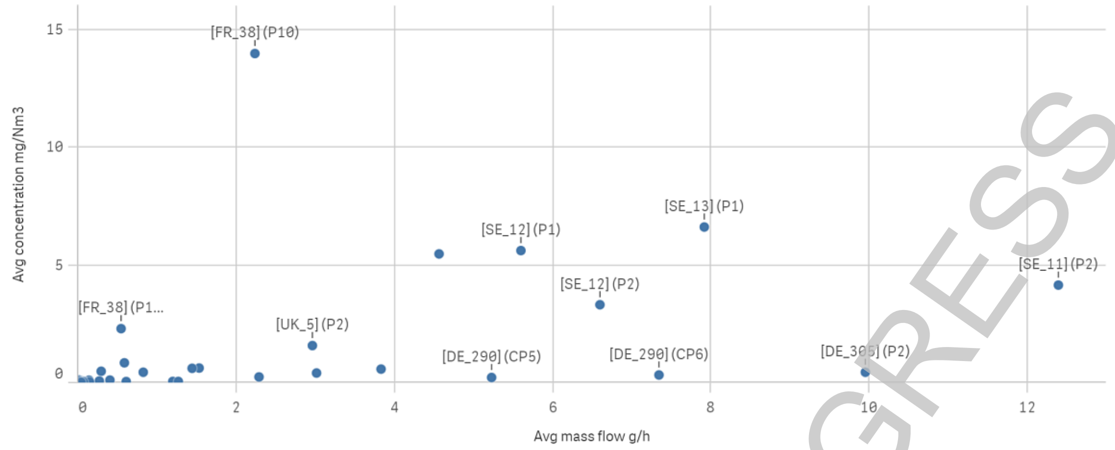
Figure 2.44: Number of emission points for formaldehyde by IED category

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;
- condensation;
- thermal or catalytic oxidation.

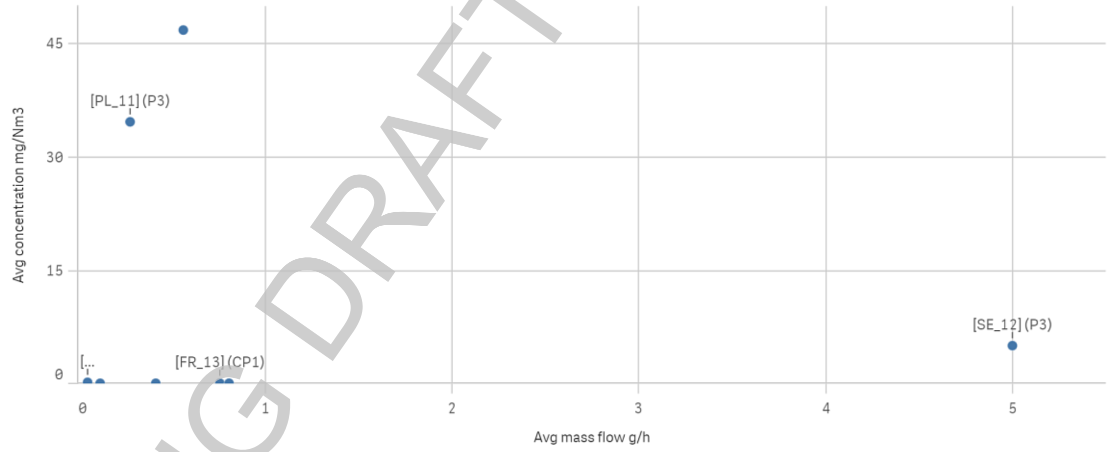


NB: 21 operators reported formaldehyde emissions from 47 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-25 mg CH_2O/Nm^3 and mass flows in the range of 0-12.5 g CH_2O/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.

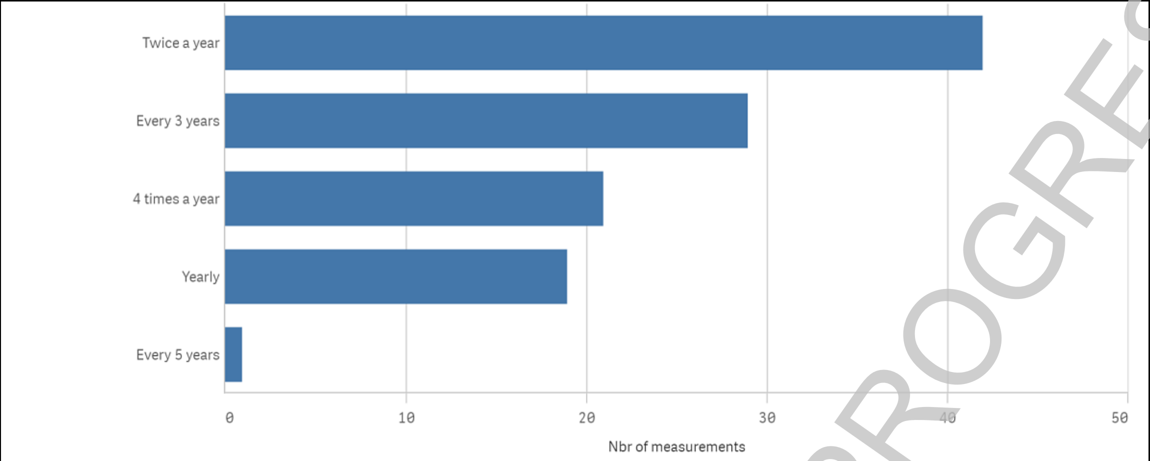


NB: 5 operators reported formaldehyde emissions from 10 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-25 mg CH_2O/Nm^3 and mass flows in the range of 0-12.5 g CH_2O/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.



Source: [43, EIPPCB 2019]

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

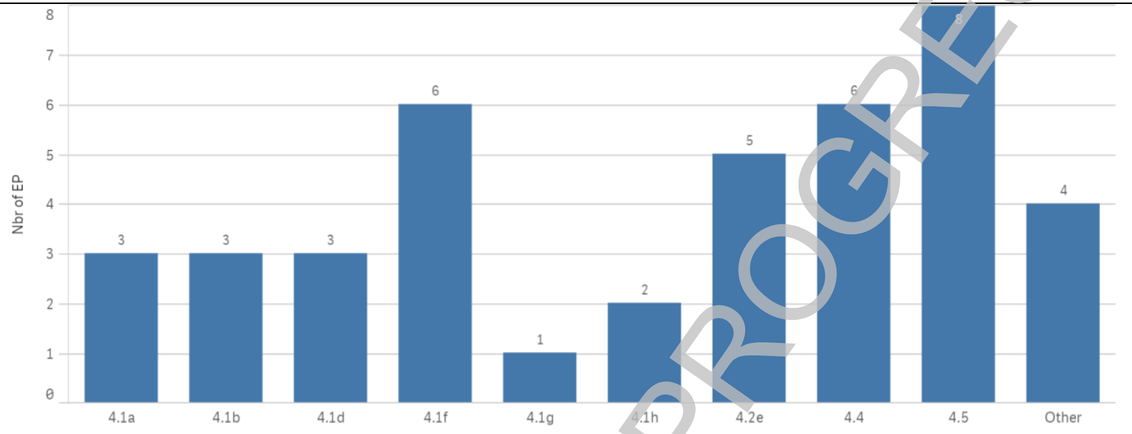
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.03	0.004
50th	0.06	0.06
80th	0.40	1.50

NB: The numbers of instances reported for the limits of quantification and detection are 36 and 20, respectively.
Source: [43, EIPPCB 2019]

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.

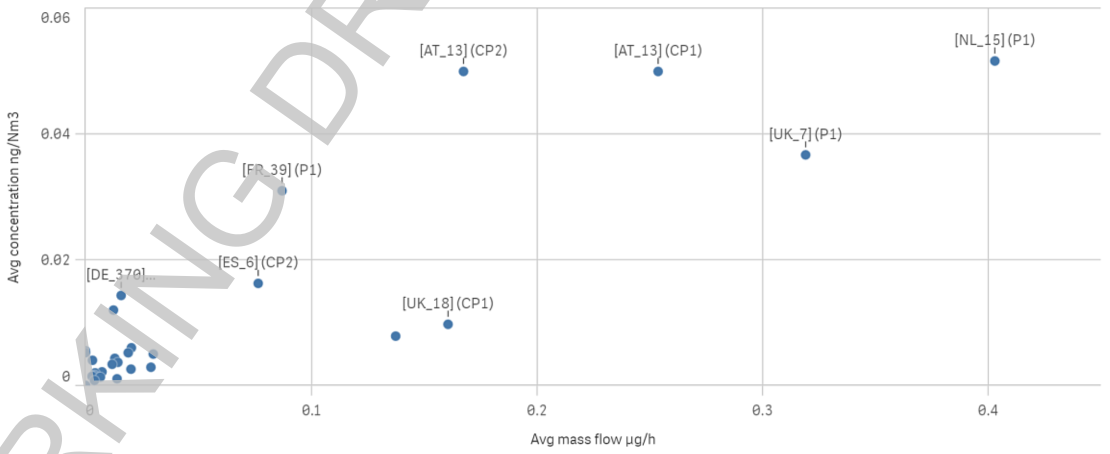


NB: 37 operators reported 43 emission points in the data collection.
Source: [43, EIPPCB 2019]

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.

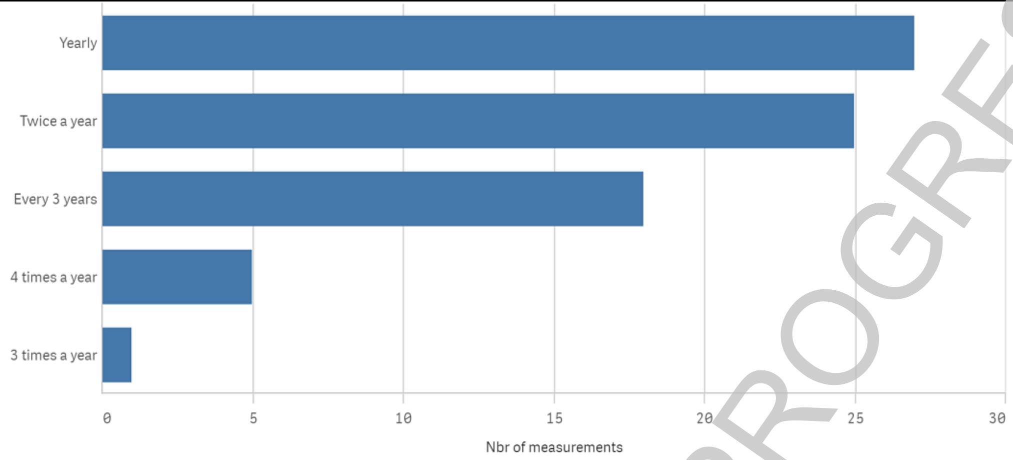


NB: 29 operators reported PCDD/F emissions from 34 emission points in the data collection, applying thermal or catalytic oxidation. For better visualisation, only emission points with concentrations in the range of 0-0.25 ng I-TEQ/Nm^3 and mass flows in the range of 0-1.25 µg I-TEQ/h are represented in the scatter plot.
Data not shown for 7 emission points applying waste gas treatment techniques other than catalytic or thermal oxidation.
Source: [43, EIPPCB 2019]

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.



Source: [43, EIPPCB 2019]

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

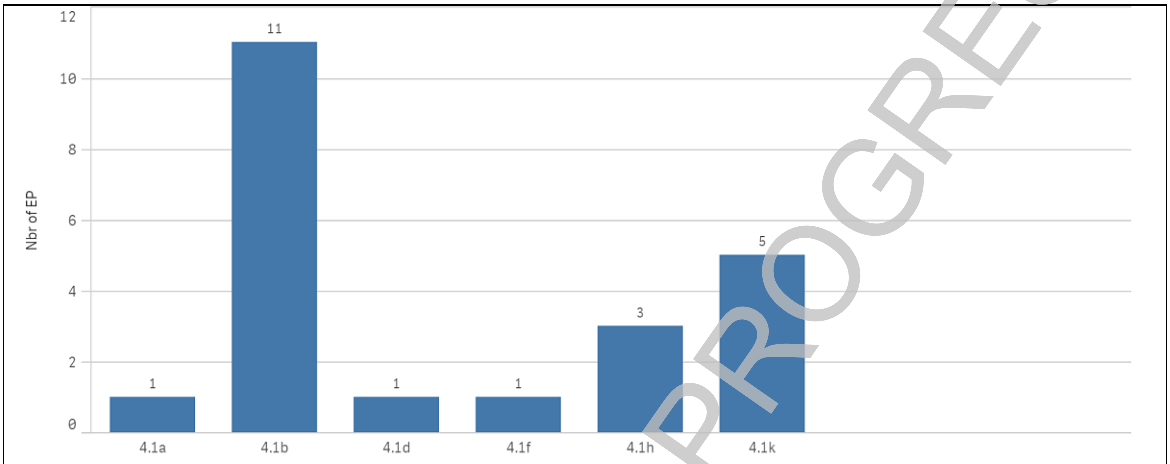
Percentile	Limit of quantification (µg/Nm^3)	Limit of detection (µg/Nm^3)
20th	0.00010	1.6 x 10^{-5}
50th	0.00062	0.00056
80th	0.0030	0.0054

NB: The numbers of instances reported for the limits of quantification and detection are 25 and 24, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 15 operators reported 22 emission points in the data collection.
Source: [43, EIPPCB 2019]

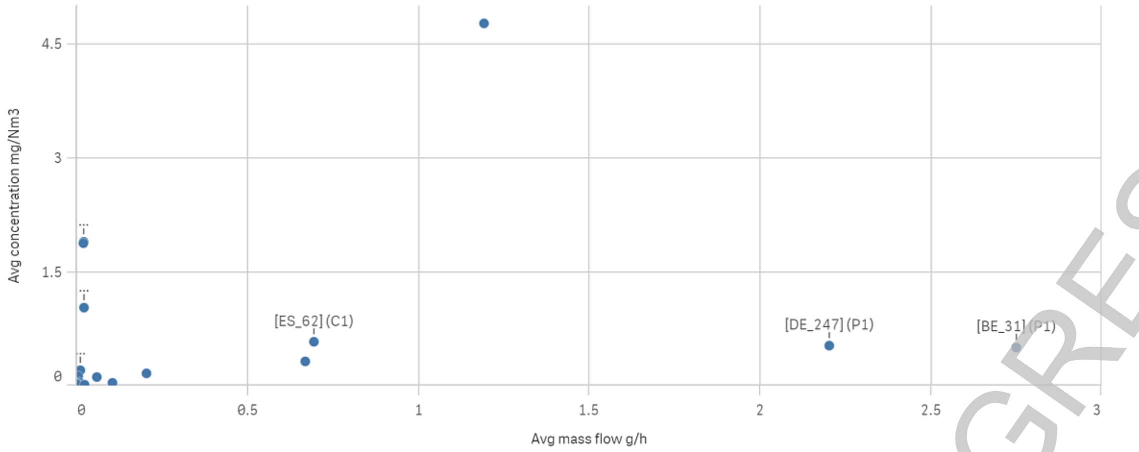
Figure 2.51: Number of emission points for propylene oxide by IED category

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



NB: 15 operators reported propylene oxide emissions from 22 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-5 mg C_3H_6O/Nm^3 and mass flows in the range of 0-12.5 g C_3H_6O/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

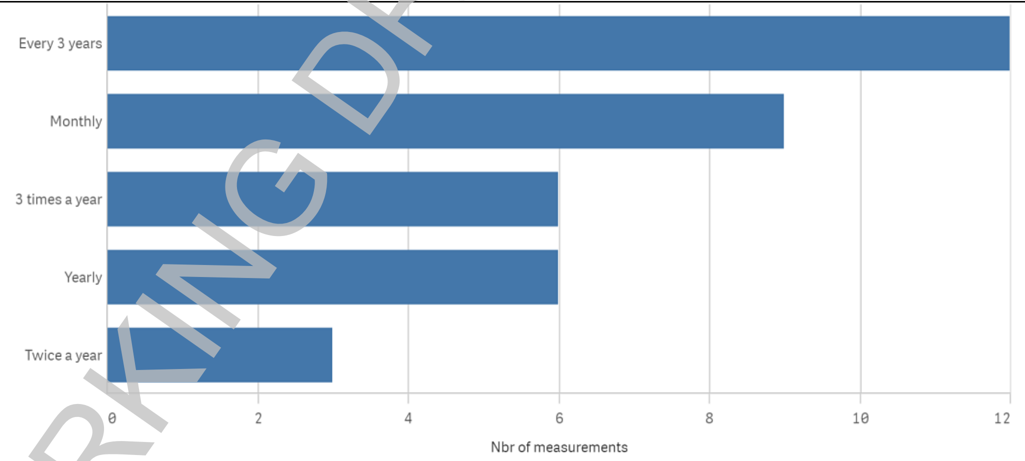
Figure 2.52: Propylene oxide emissions after waste gas treatment

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: 37 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.



Source: [43, EIPPCB 2019]

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

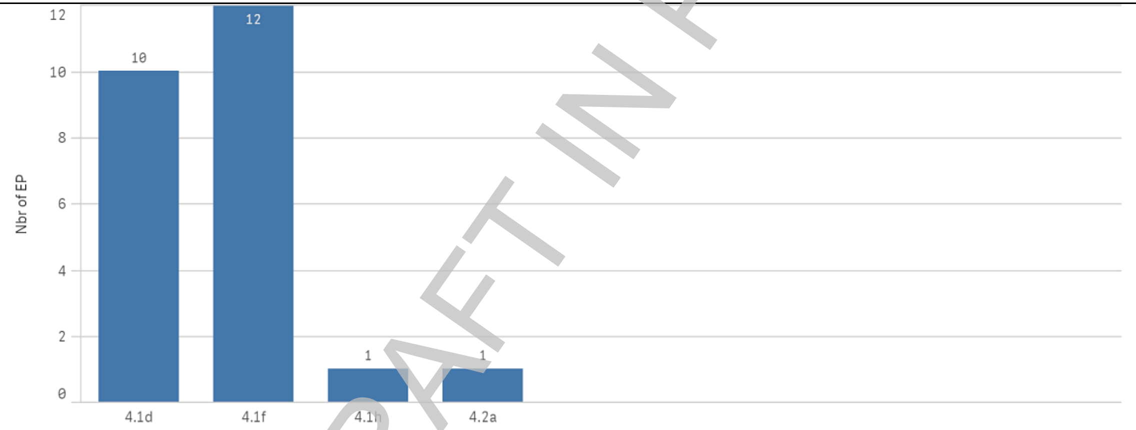
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.07	0.06
50th	0.40	0.06
80th	0.50	0.20

NB: The numbers of instances reported for the limits of quantification and detection are 9 and 7, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 9 operators reported 24 emission points in the data collection.
Source: [43, EIPPCB 2019]

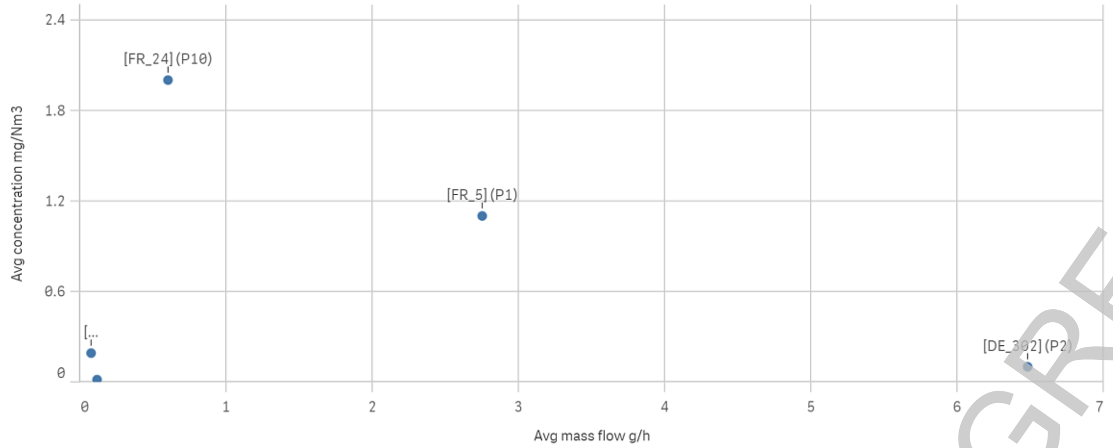
Figure 2.54: Number of emission points for tetrachloromethane by IED category

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:

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

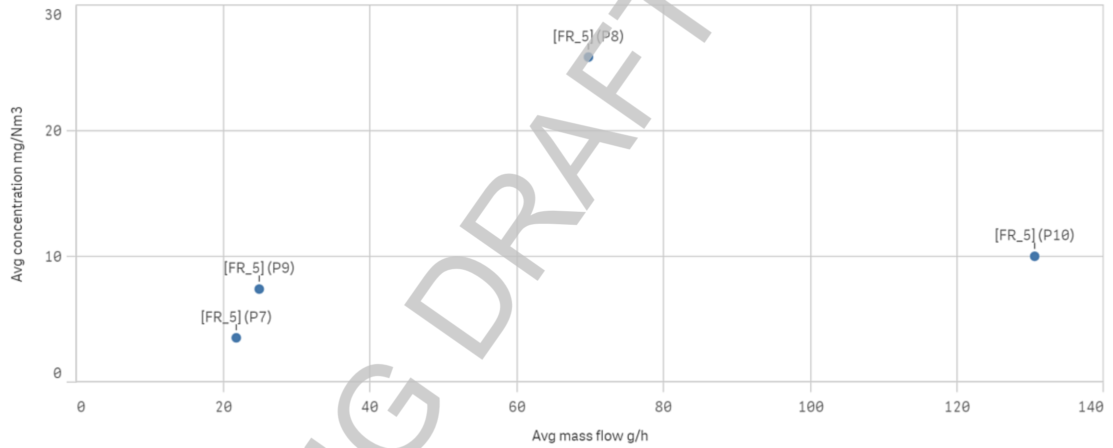


NB: 9 operators reported tetrachloromethane emissions from 16 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-5 mg CCl_4/Nm^3 and mass flows in the range of 0-500 g CCl_4/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.

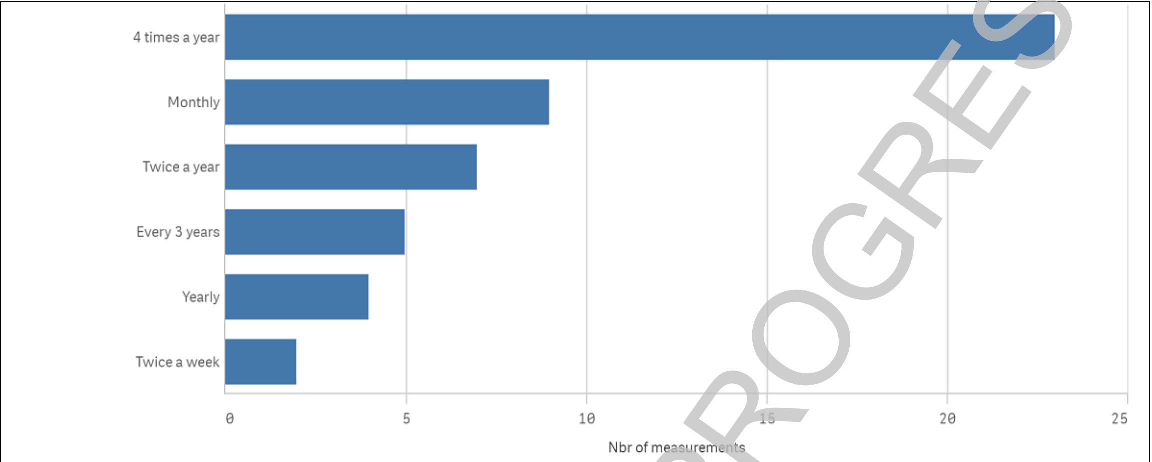


NB: 2 operators reported tetrachloromethane emissions from 7 emission points in the data collection, without any prior waste gas treatment.
Source: [43, EIPPCB 2019]

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.



Source: [43, EIPPCB 2019]

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

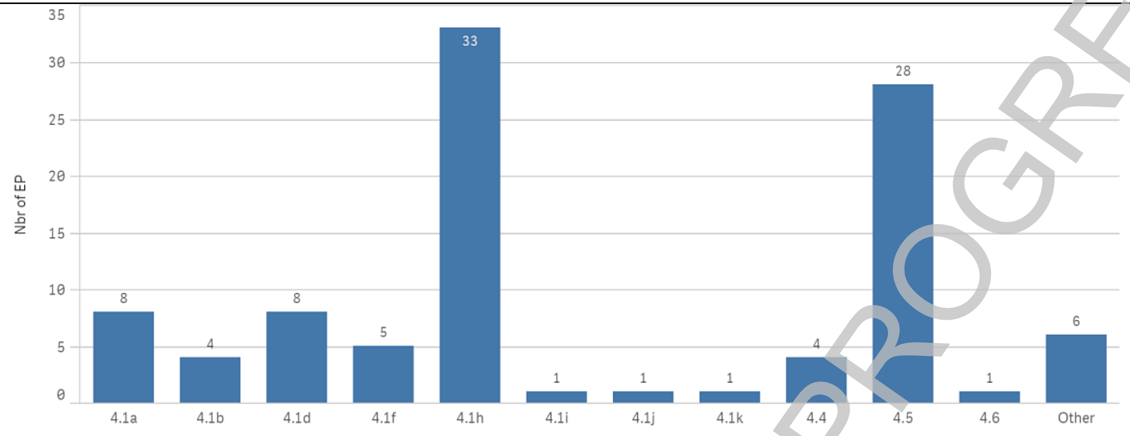
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.10	0.01
50th	5.0	0.22
80th	100.0	0.22

NB: The numbers of instances reported for the limits of quantification and detection are 36 and 21, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 32 operators reported 100 emission points in the data collection.
Source: [43, EIPPCB 2019]

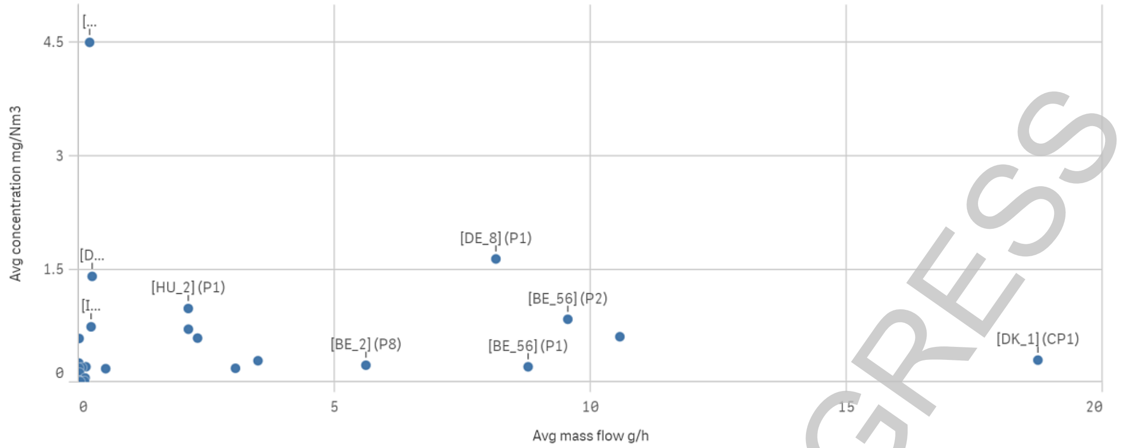
Figure 2.58: Number of emission points for toluene by IED category

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.

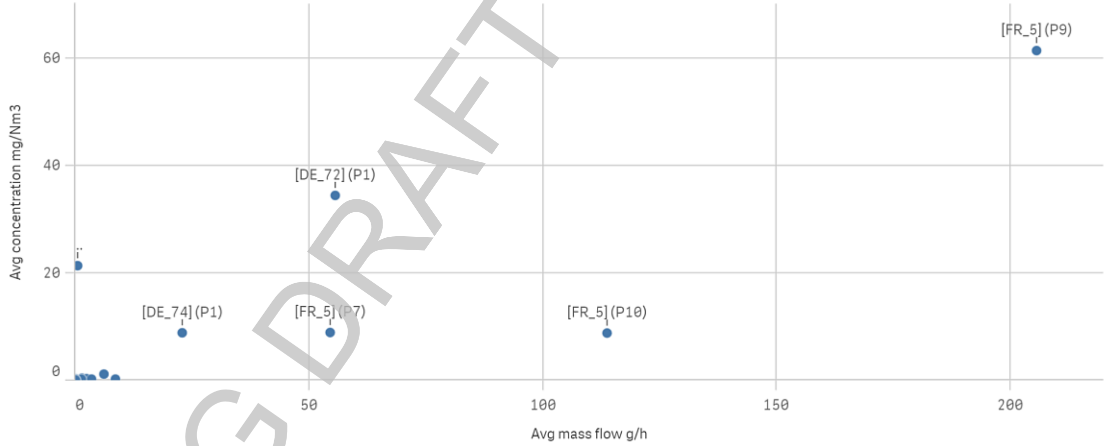


NB: 28 operators reported toluene emissions from 70 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-5 mg C_7H_8/Nm^3 and mass flows in the range of 0-500 g C_7H_8/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.

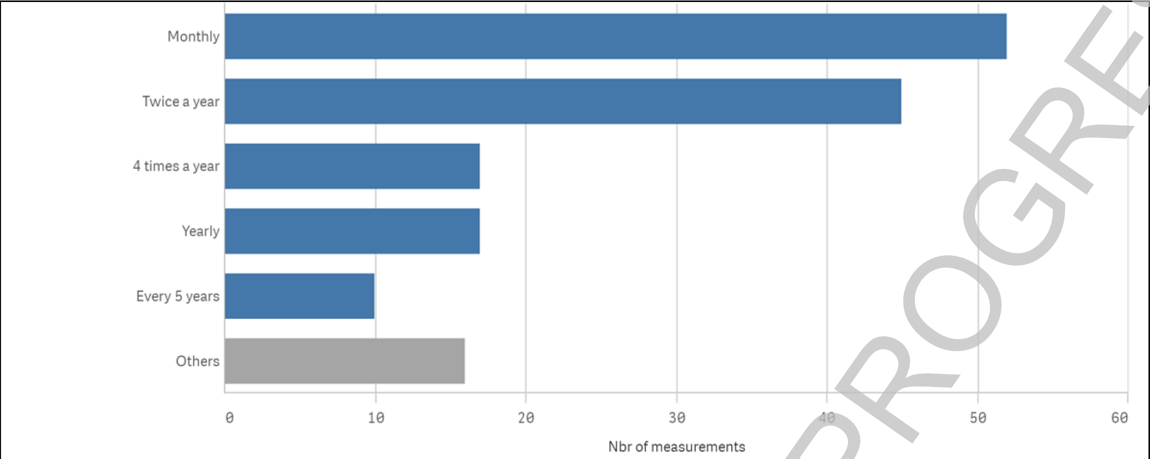


NB: 6 operators reported toluene emissions from 21 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-5 mg C_7H_8/Nm^3 and mass flows in the range of 0-500 g C_7H_8/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.



Source: [43, EIPPCB 2019]

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

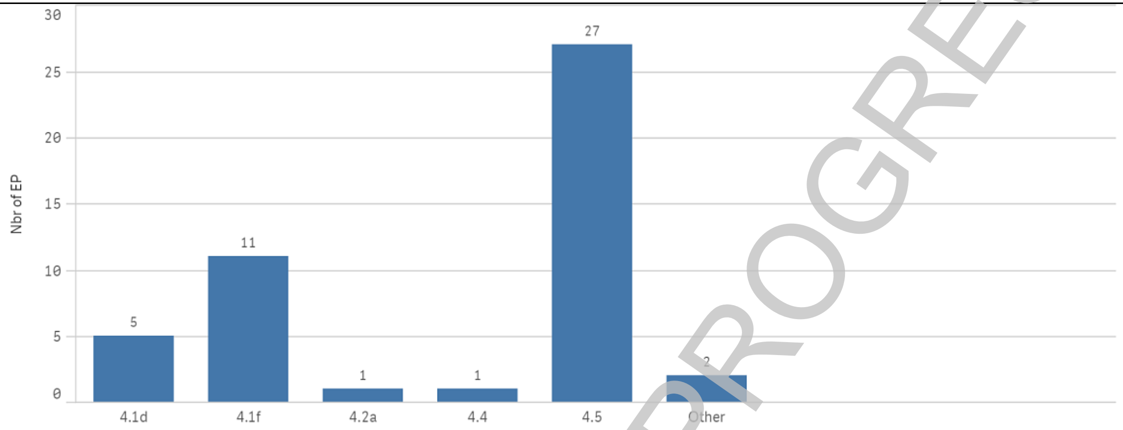
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.05	0.05
50th	0.13	0.20
80th	0.50	0.43

NB: The numbers of instances reported for the limits of quantification and detection are 66 and 74, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 14 operators reported 47 emission points in the data collection.
Source: [43, EIPPCB 2019]

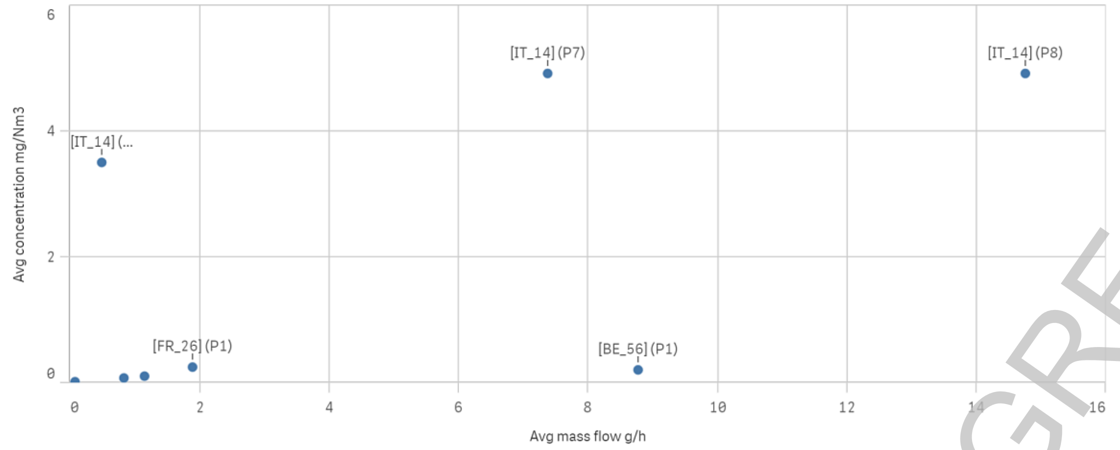
Figure 2.62: Number of emission points for trichloromethane by IED category

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.

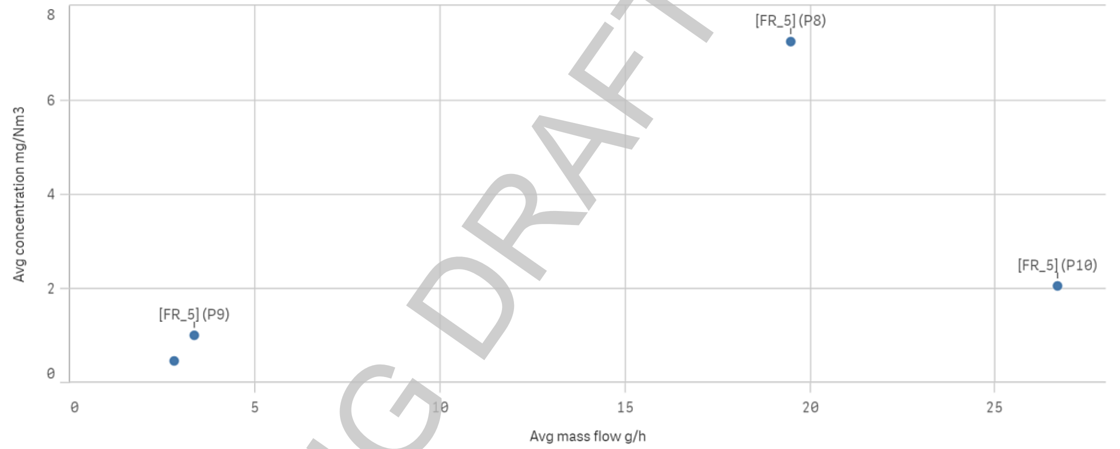


NB: 14 operators reported trichloromethane emissions from 40 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-5 mg $CHCl_3/Nm^3$ and mass flows in the range of 0-500 g $CHCl_3$/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.

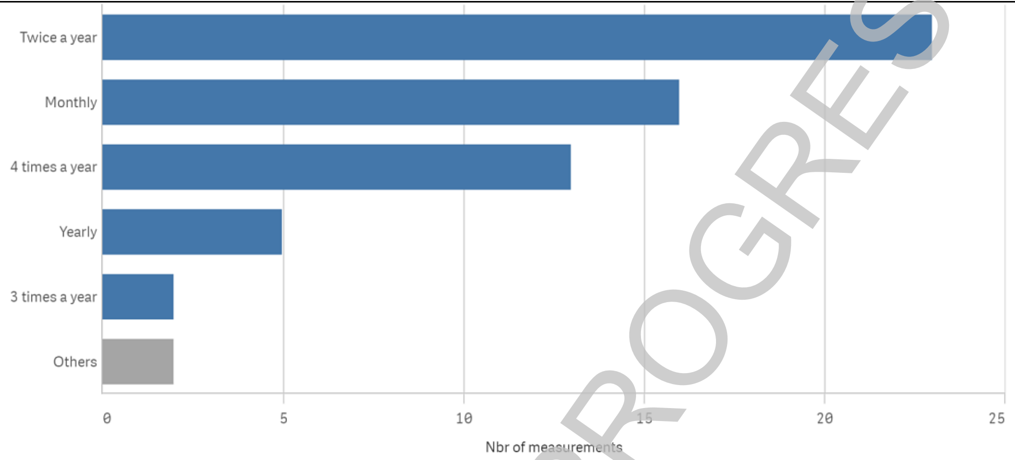


NB: 2 operators reported trichloromethane emissions from 7 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-5 mg $CHCl_3/Nm^3$ and mass flows in the range of 0-500 g $CHCl_3$/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.



Source: [43, EIPPCB 2019]

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^3)	Limit of detection (mg/Nm^3)
20th	0.1	0.13
50th	1.0	0.13
80th	5.0	0.3

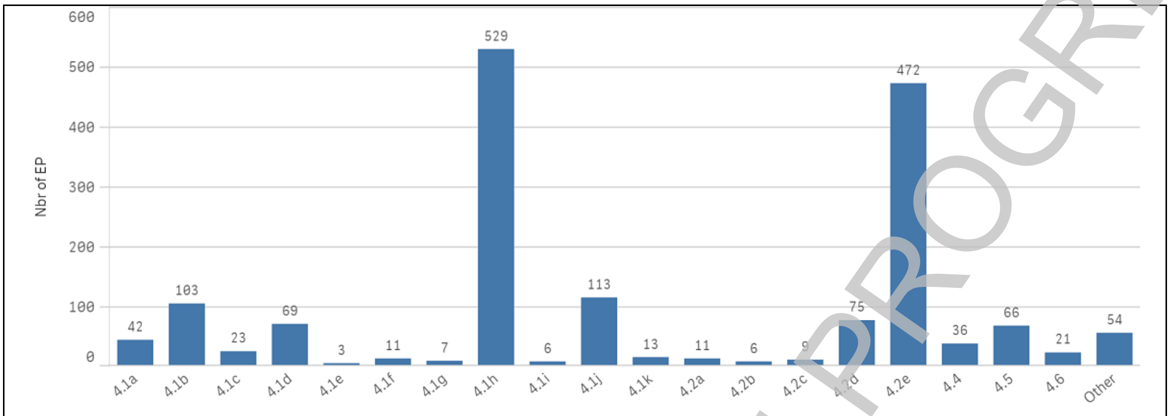
NB: The numbers of instances reported for the limits of quantification and detection are 49 and 33, respectively.
Source: [43, EIPPCB 2019]

2.3.3 Dust (including PM_{10}, and $PM_{2.5}$) 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.



NB: 211 operators reported dust emissions from 1 697 emission points in the data collection.
Source: [43, EIPPCB 2019]

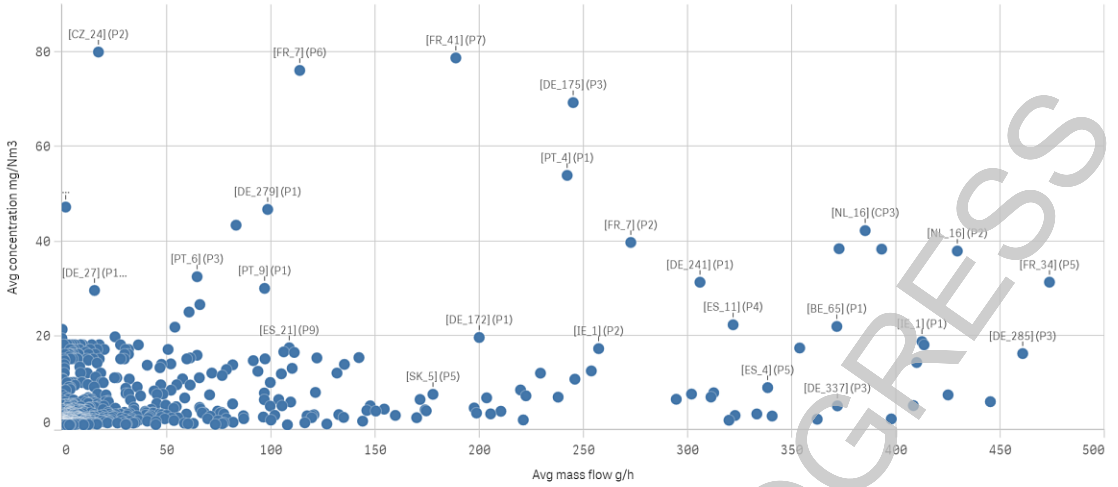
Figure 2.66: Number of emission points for dust by IED category

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.

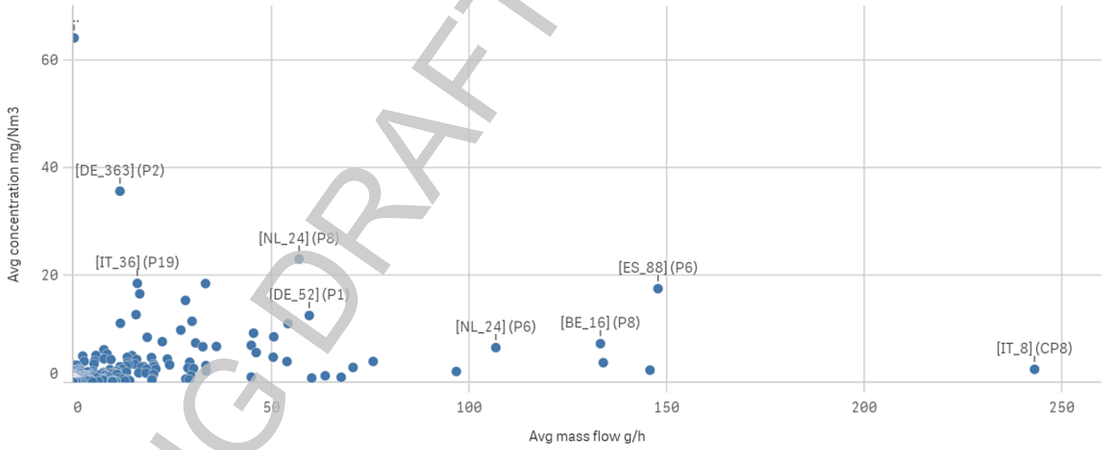


NB: 177 operators reported dust emissions from 1 371 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-100 mg dust/Nm^3 and mass flows in the range of 0-500 g dust/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.

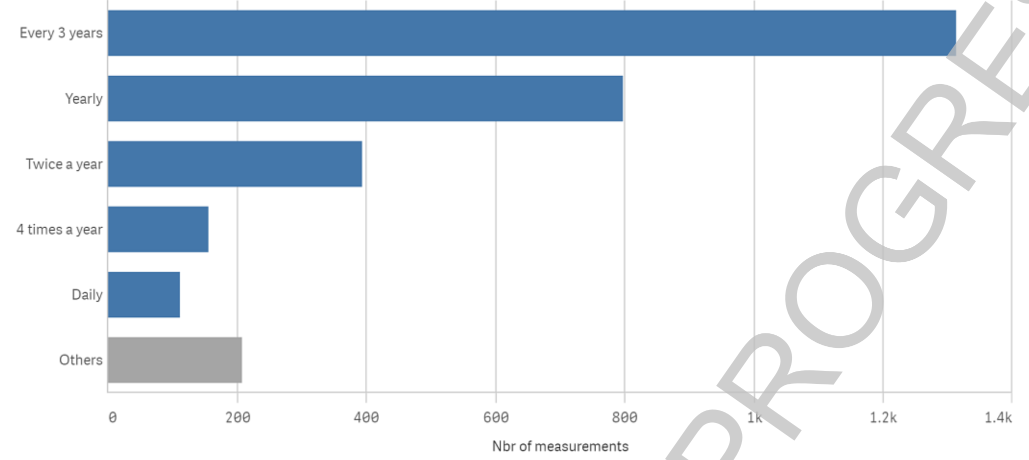


NB: 62 operators reported dust emissions from 244 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-100 mg dust/Nm^3 and mass flows in the range of 0-500 g dust/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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: 3 230 instances of periodic monitoring and 65 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled dust emissions are shown in the bar chart of Figure 2.69.



Source: [43, EIPPCB 2019]

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

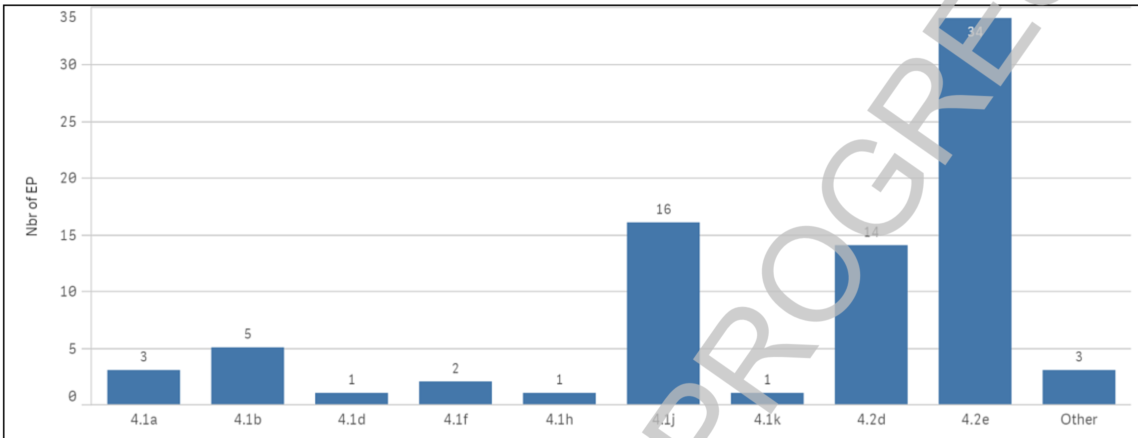
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.2	0.1
50th	0.3	0.3
80th	1.0	0.5

NB: The numbers of instances reported for the limits of quantification and detection are 1141 and 1239, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 18 operators reported emissions of dust containing substances classified as CMR 1A or 1B from 80 emission points in the data collection.
Source: [43, EIPPCB 2019]

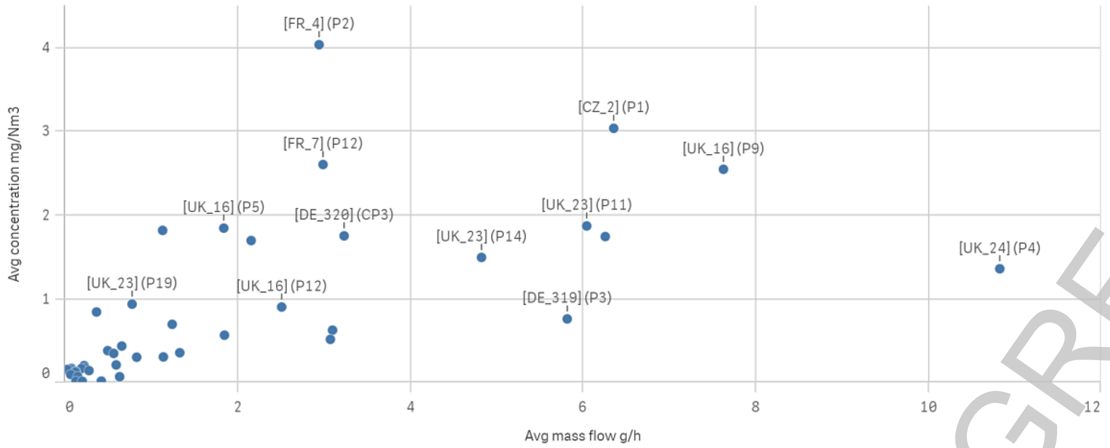
Figure 2.70: Number of emission points for dust containing substances classified as CMR 1A or 1B by IED category

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.

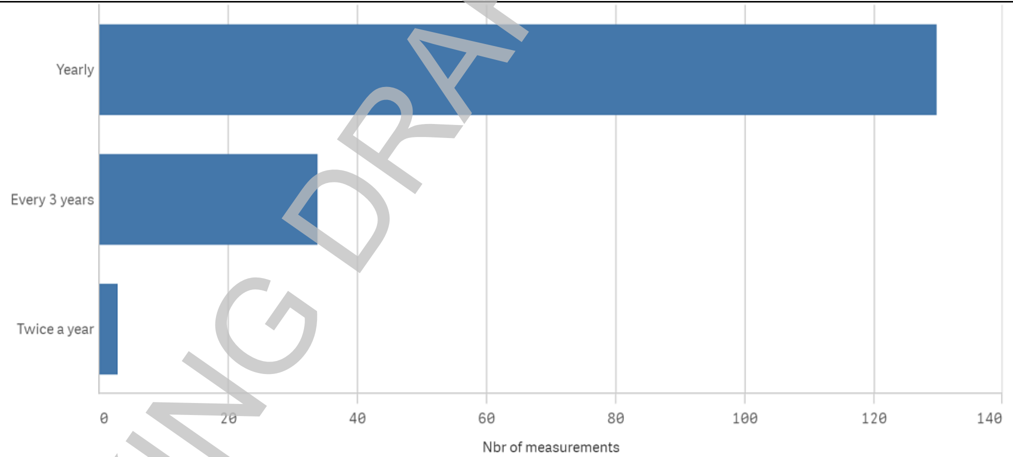


NB: 16 operators reported dust emissions from 72 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-12.5 mg dust/Nm^3 and mass flows in the range of 0-12.5 g dust/h are represented in the scatter plot.
Data not shown for 6 emission points applying waste gas treatment techniques other than the ones listed above.
Source: [43, EIPPCB 2019]

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: 168 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.



Source: [43, EIPPCB 2019]

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.

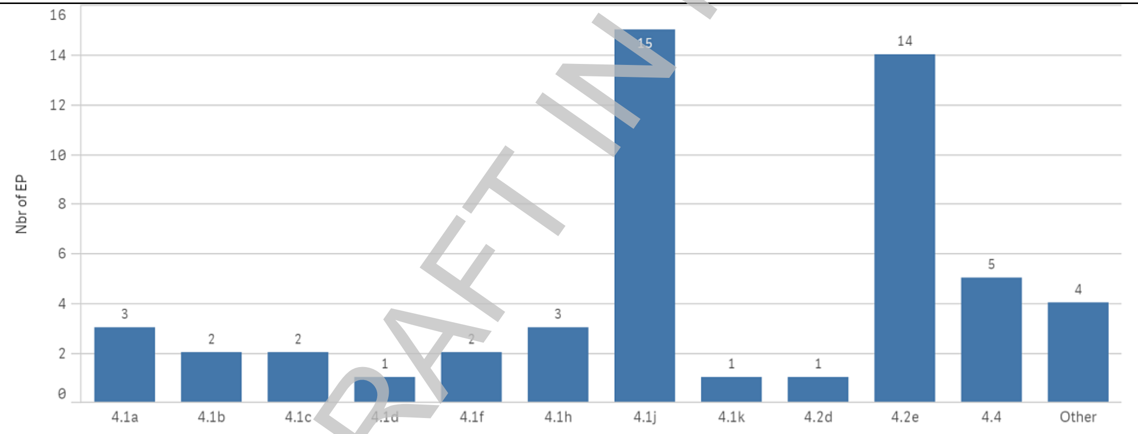
Table 2.19: Reported limits of quantification and detection for dust containing substances classified as CMR 1A or 1B

Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.30	0.28
50th	0.30	0.30
80th	0.30	0.30
NB: The numbers of instances reported for the limits of quantification and detection are 58 and 57, respectively. *Source*: [43, EIPPCB 2019]		

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.



NB: 15 operators reported emissions of dust containing substances classified as CMR 2 from 53 emission points in the data collection.
Source: [43, EIPPCB 2019]

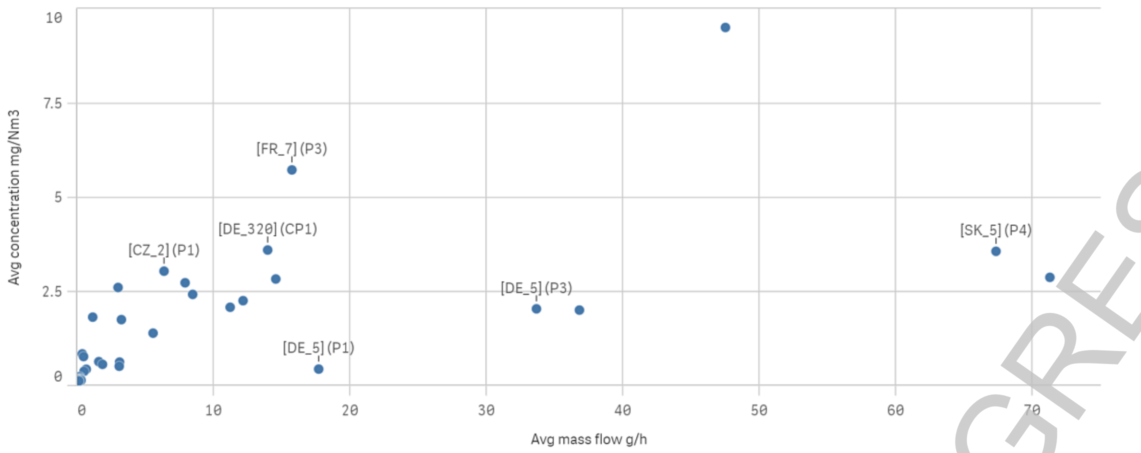
Figure 2.73: Number of emission points for dust containing substances classified as CMR 2 by IED category

2.3.3.3.2 Emissions

Emissions of dust containing substances classified as CMR 2 is 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.

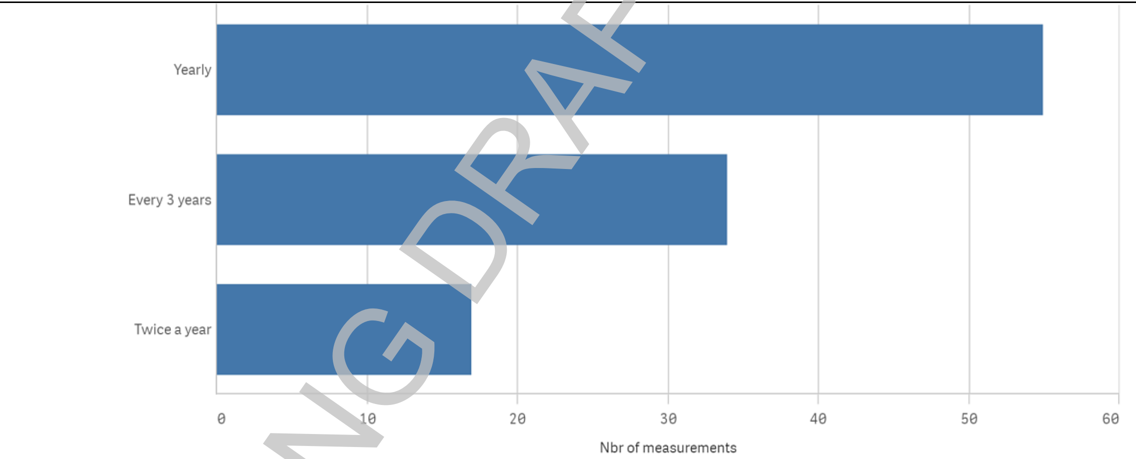


NB: 13 operators reported dust emissions from 48 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-12.5 mg dust/Nm^3 and mass flows in the range of 0-75 g dust/h are represented in the scatter plot.
Data not shown for 4 emission points applying waste gas treatment techniques other than the ones listed above.
Source: [43, EIPPCB 2019]

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: 109 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.



Source: [43, EIPPCB 2019]

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)

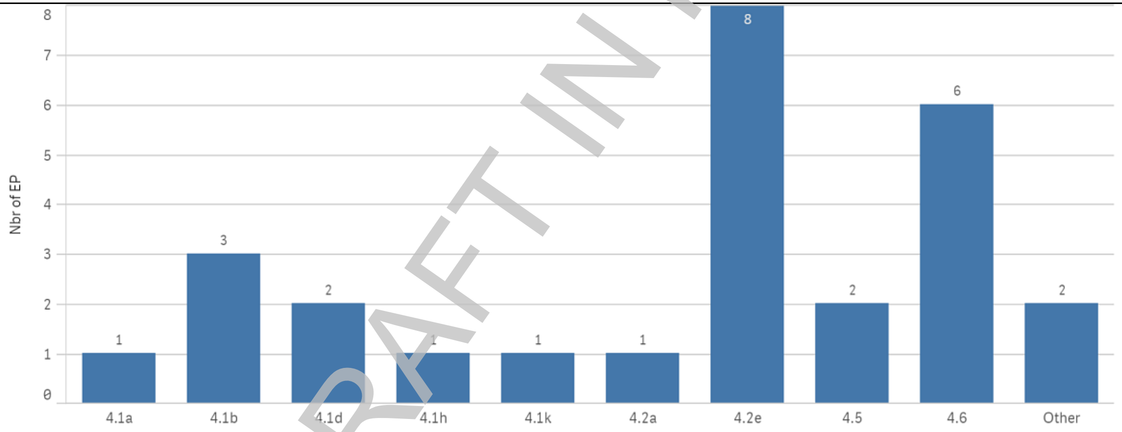
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.20	0.20
50th	0.30	0.30
80th	0.31	0.30

NB: The numbers of instances reported for the limits of quantification and detection are 71 and 53, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 18 operators reported lead emissions from 27 emission points in the data collection.
Source: [43, EIPPCB 2019]

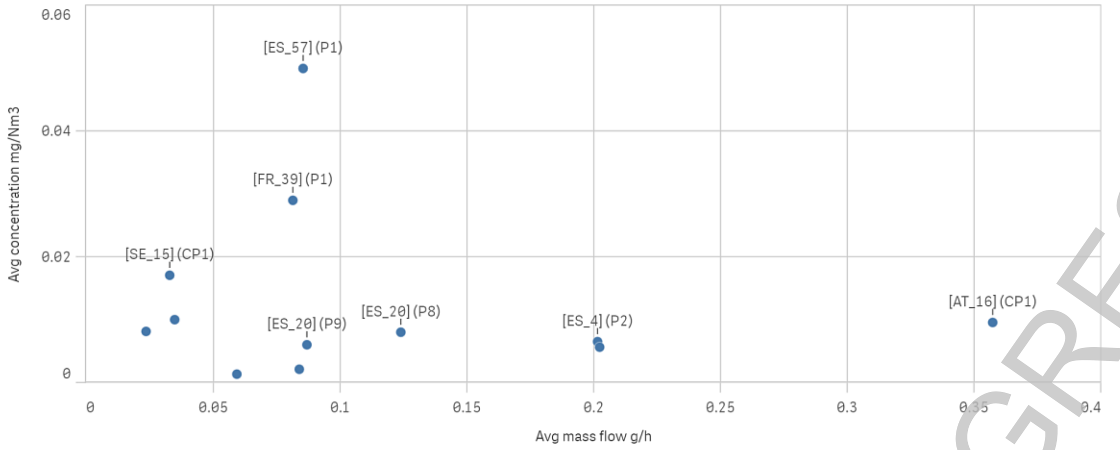
Figure 2.76: Number of emission points for lead by IED category

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:

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

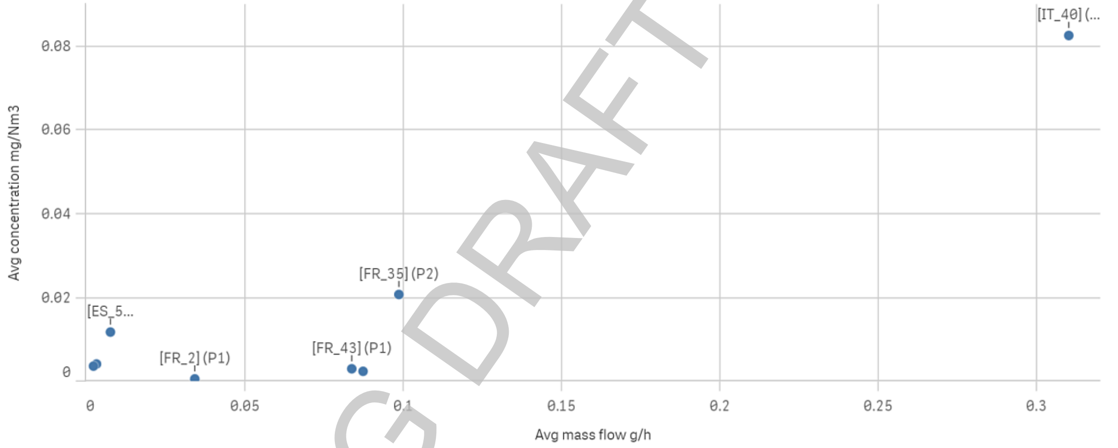


NB: 8 operators reported lead emissions from 15 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-2.5 mg PbNm^3 and mass flows in the range of 0-0.75 g Pb/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.77: Lead emissions after waste gas treatment

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.

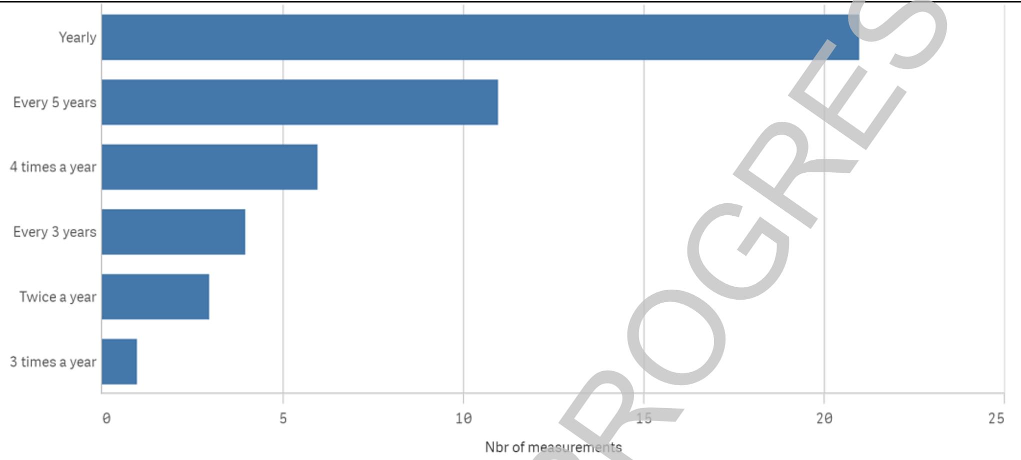


NB: 6 operators reported lead emissions from 8 emission points in the data collection, without any prior waste gas treatment.
Source: [43, EIPPCB 2019]

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

2.3.3.4.4 Monitoring

Only periodic monitoring was reported (50 instances). Typical frequencies for the monitoring of channelled lead emissions are shown in the bar chart of Figure 2.79.



Source: [43, EIPPCB 2019]

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.

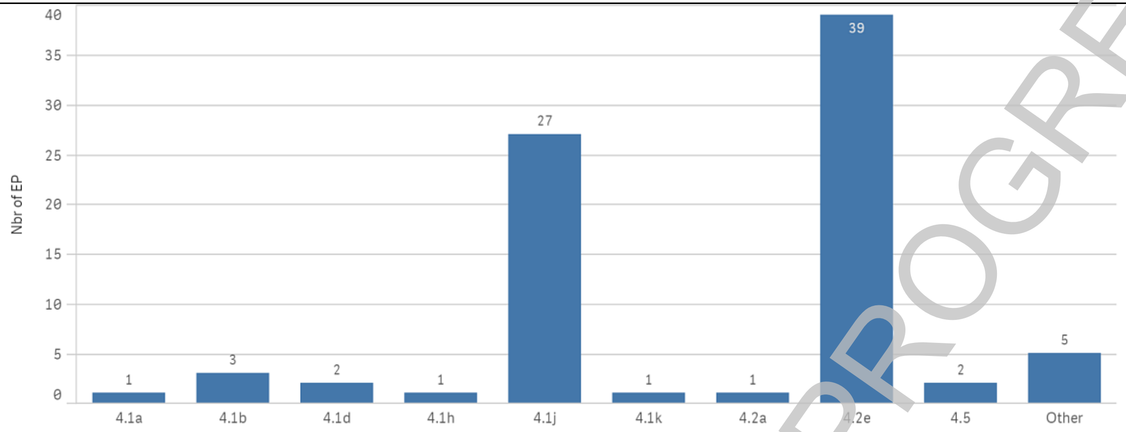
Table 2.21: Reported limits of quantification and detection for lead and its compounds

Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.0001	0.0004
50th	0.0001	0.0035
80th	0.005	0.005
NB: The numbers of instances reported for the limits of quantification and detection are 9 and 8, respectively. *Source*: [43, EIPPCB 2019]		

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.



NB: 24 operators reported nickel emissions from 82 emission points in the data collection.
Source: [43, EIPPCB 2019]

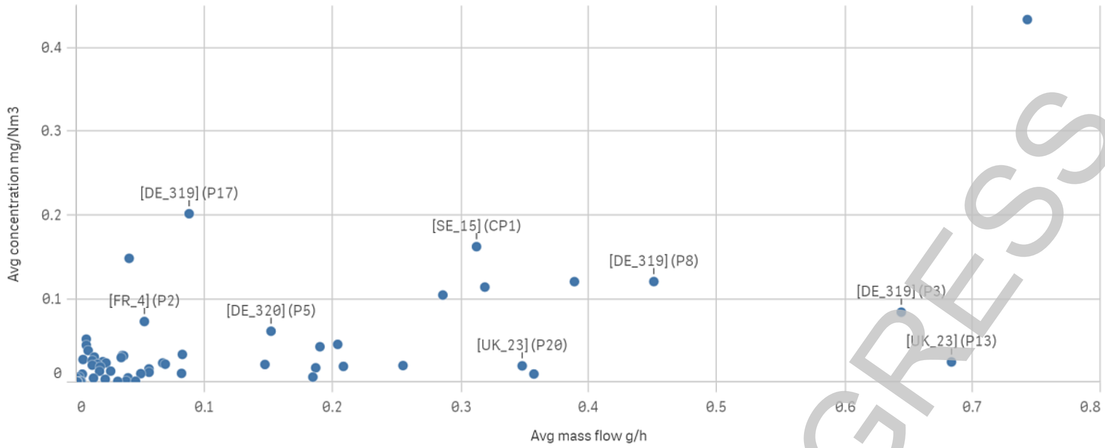
Figure 2.80: Number of emission points for nickel by IED category

2.3.3.5.2 Treated emissions

Emissions of nickel and its compounds is 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.

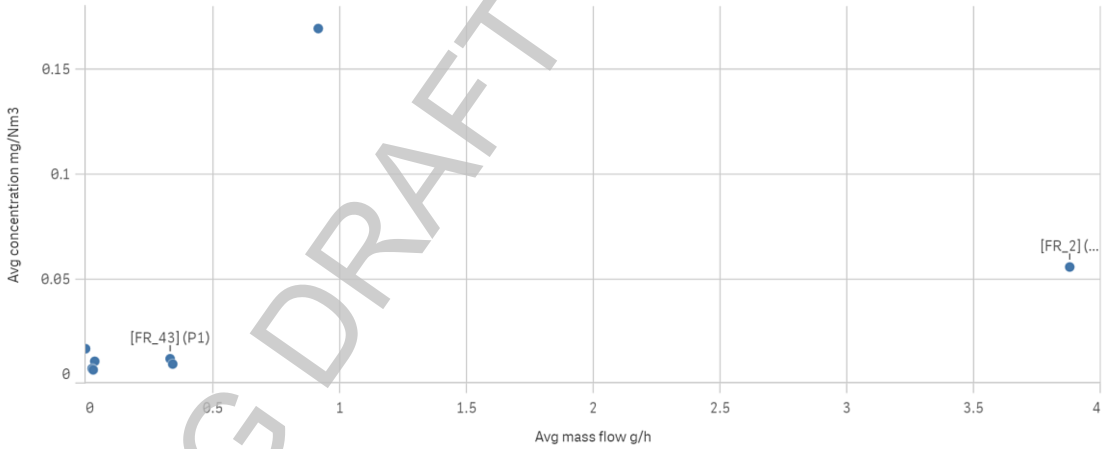


NB: 15 operators reported nickel emissions from 70 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-2.5 mg Ni/Nm^3 and mass flows in the range of 0-0.75 g Ni/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.

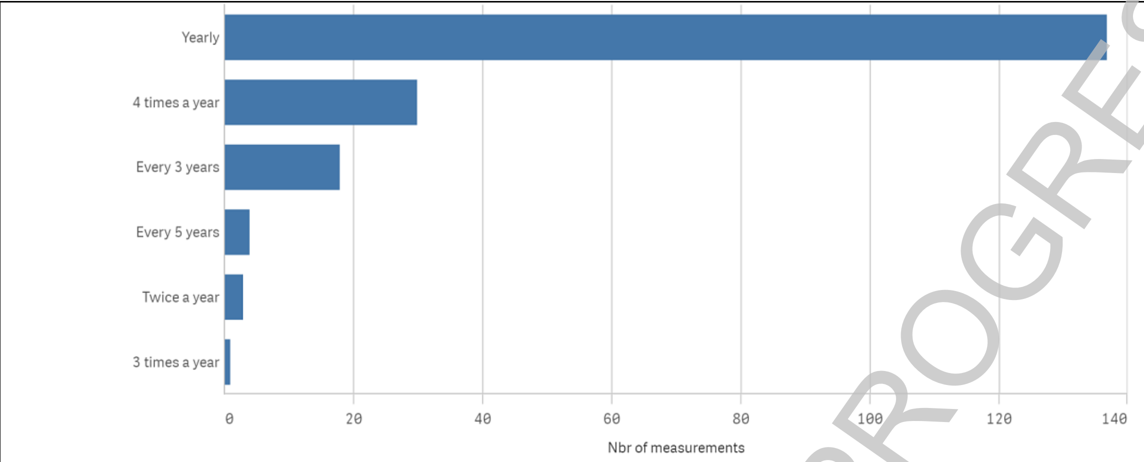


NB: 7 operators reported nickel emissions from 8 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-2.5 mg nickel/Nm^3 and mass flows in the range of 0-0.75 g nickel/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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

2.3.3.5.4 Monitoring

Only periodic monitoring was reported (175 instances). Typical frequencies for the monitoring of channelled nickel emissions are shown in the bar chart of Figure 2.83.



Source: [43, EIPPCB 2019]

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

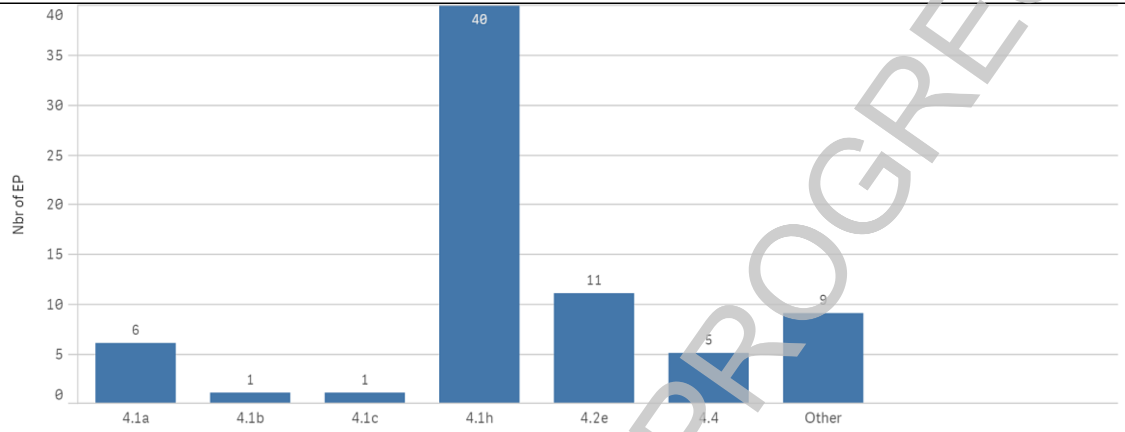
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.005	0.001
50th	0.005	0.05
80th	0.005	0.05

NB: The numbers of instances reported for the limits of quantification and detection are 71 and 74, respectively.
Source: [43, EIPPCB 2019]

2.3.3.6 PM_{10}

2.3.3.6.1 Sectors

PM_{10} is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.84.



NB: 15 operators reported PM_{10} emissions from 73 emission points in the data collection.
Source: [43, EIPPCB 2019]

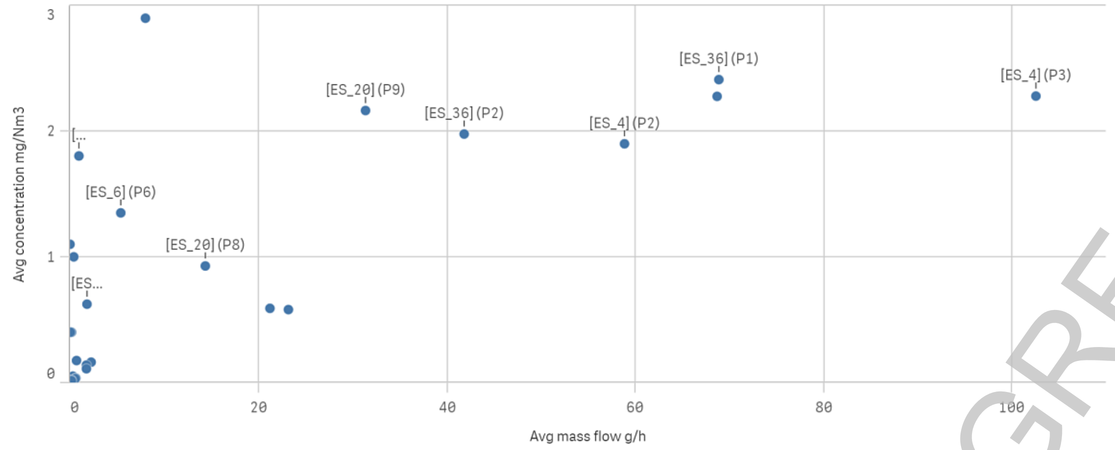
Figure 2.84: Number of emission points for PM_{10} by IED category

2.3.3.6.2 Treated emissions

Emissions of PM_{10} may occur with at least one prior waste gas treatment technique applied. The typical emission levels of PM_{10} 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:

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

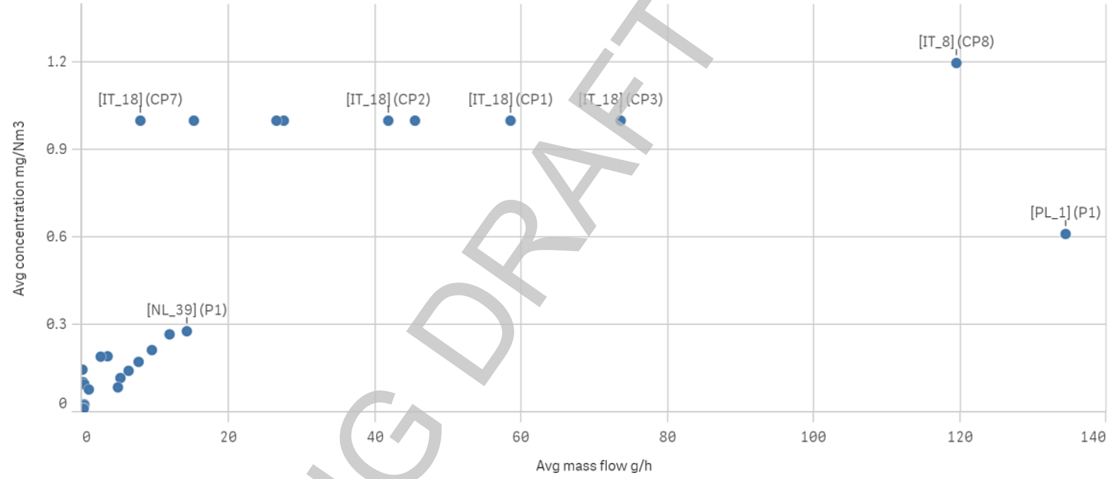


NB: 9 operators reported PM_{10} emissions from 32 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-5 mg PM_{10}/Nm^3 and mass flows in the range of 0-200 g PM_{10}/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.85: PM_{10} emissions after waste gas treatment

2.3.3.6.3 Untreated emissions

The typical emission levels of PM_{10} when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.86.

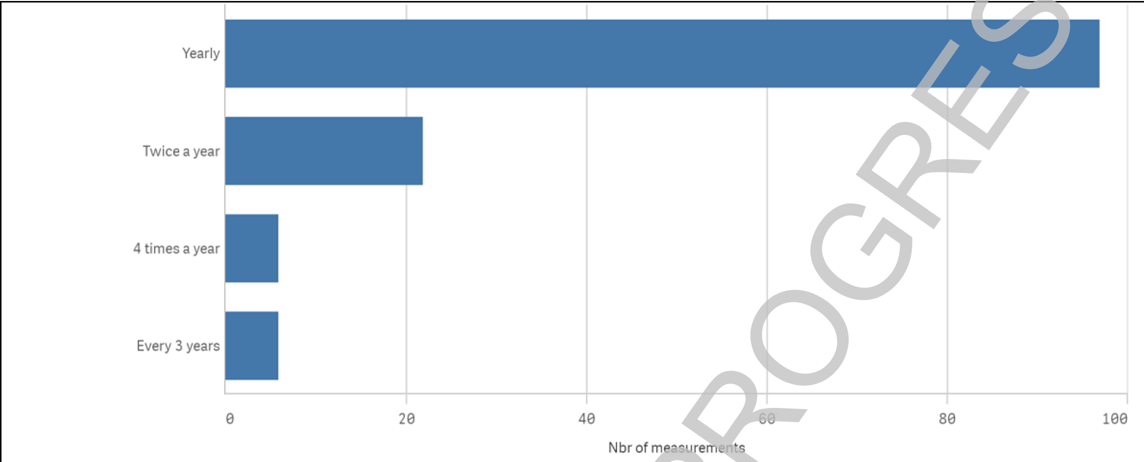


NB: 7 operators reported PM_{10} emissions from 38 emission points in the data collection, without any prior waste gas treatment.
Source: [43, EIPPCB 2019]

Figure 2.86: PM_{10} 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_{10} emissions are shown in the bar chart of Figure 2.87.



Source: [43, EIPPCB 2019]

Figure 2.87: Reported measurement frequencies for periodic PM_{10} monitoring

Percentiles for reported limits of quantification and limits of detection for PM_{10} measurements are shown in Table 2.23.

Table 2.23: Reported limits of quantification and detection for PM_{10}

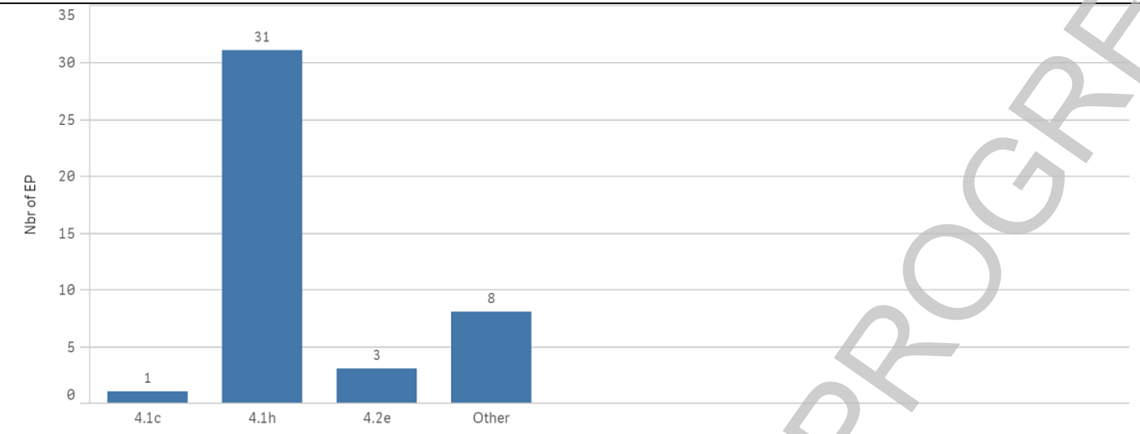
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.2	0.06
50th	0.2	0.06
80th	0.2	1.0

NB: The numbers of instances reported for the limits of quantification and detection are 78 and 106, respectively.
Source: [43, EIPPCB 2019]

2.3.3.7 $PM_{2.5}$

2.3.3.7.1 Sectors

$PM_{2.5}$ is typically emitted by a range of different chemical sectors as shown in the bar chart of Figure 2.88.



NB: 7 operators reported $PM_{2.5}$ emissions from 43 emission points in the data collection.
Source: [43, EIPPCB 2019]

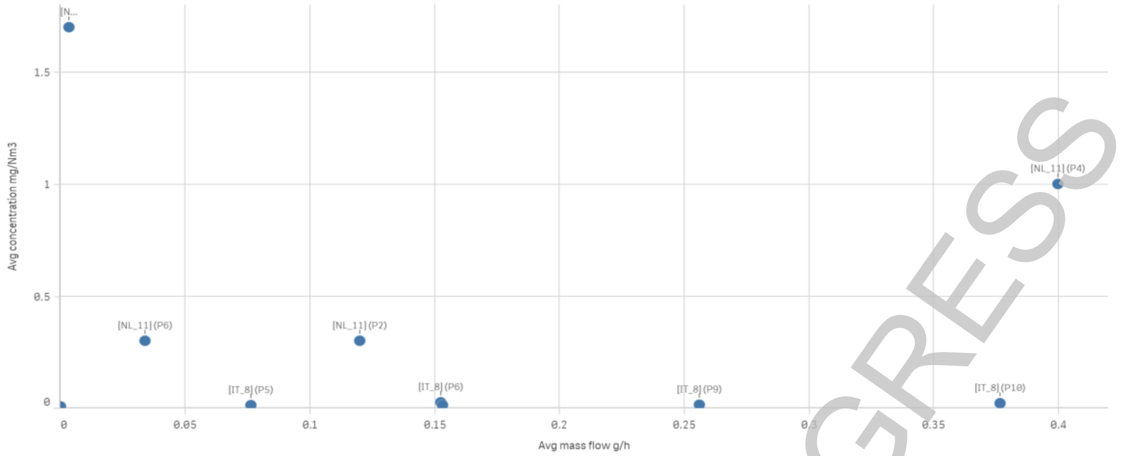
Figure 2.88: Number of emission points for $PM_{2.5}$ by IED category

2.3.3.7.2 Treated emissions

Emissions of $PM_{2.5}$ are generally treated with at least one waste gas treatment technique. The typical emission levels of $PM_{2.5}$ after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.89.

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.

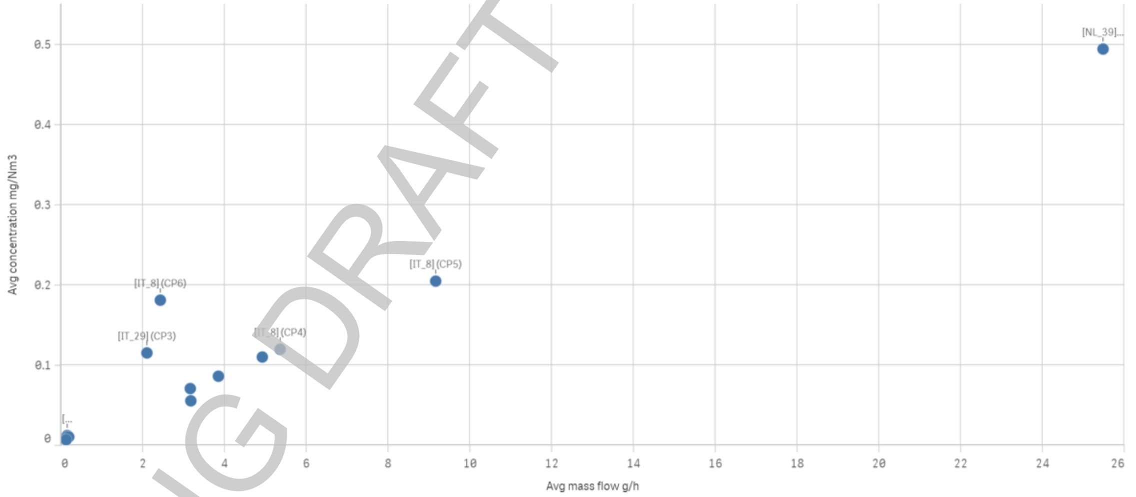


NB: 4 operators reported $PM_{2.5}$ emissions from 16 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-2 mg $PM_{2.5}/Nm^3$ and mass flows in the range of 0-1 g $PM_{2.5}$/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.89: $PM_{2.5}$ emissions after waste gas treatment

2.3.3.7.3 Untreated emissions

The typical emission levels of $PM_{2.5}$ when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.90.

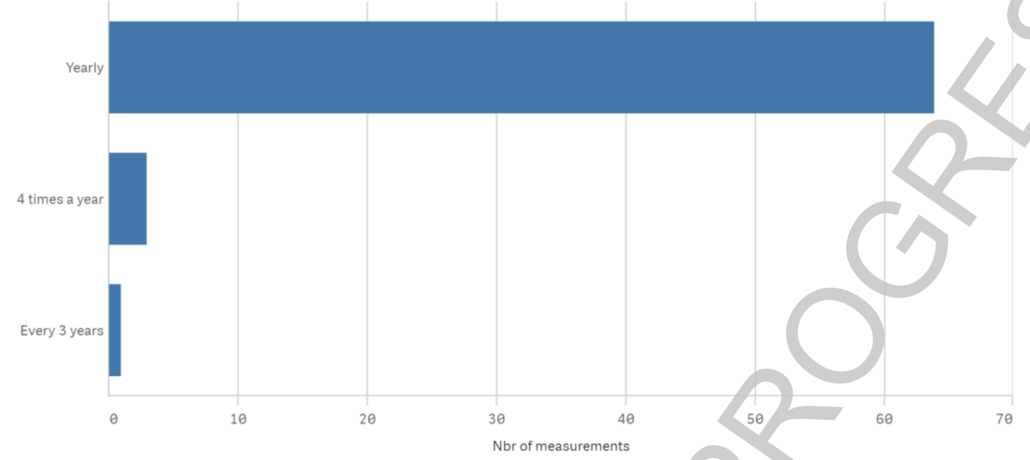


NB: 4 operators reported $PM_{2.5}$ emissions from 25 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-0.5 mg $PM_{2.5}/Nm^3$ and mass flows in the range of 0-50 g $PM_{2.5}$/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.90: $PM_{2.5}$ 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 $PM_{2.5}$ emissions are shown in the bar chart of Figure 2.91.



Source: [43, EIPPCB 2019]

Figure 2.91: Reported measurement frequencies for periodic $PM_{2.5}$ monitoring

Percentiles for reported limits of quantification and limits of detection for $PM_{2.5}$ measurements are shown in Table 2.24.

Table 2.24: Reported limits of quantification and detection for $PM_{2.5}$

Percentile	Limit of quantification (mg/Nm³)	Limit of detection (mg/Nm³)
20th	0.2	0.06
50th	0.2	0.06
80th	0.2	0.06

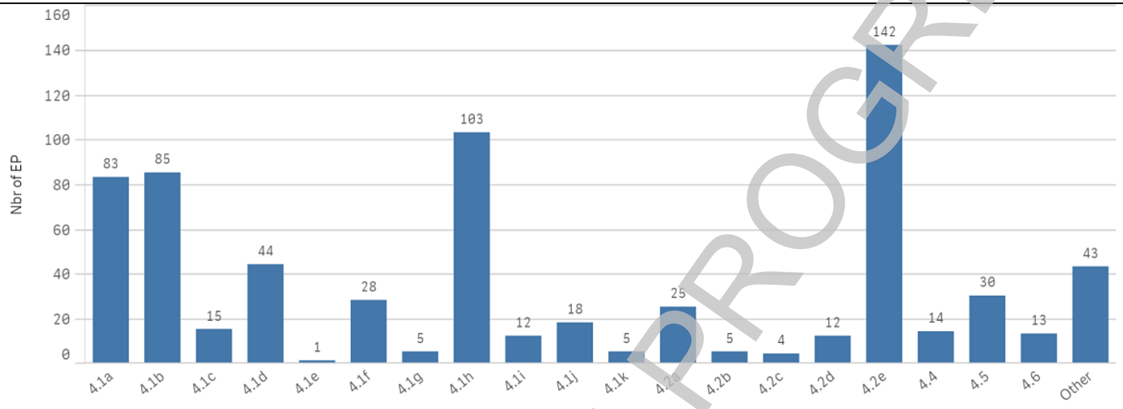
NB: The numbers of instances reported for the limits of quantification and detection are 66 and 67, respectively.
Source: [43, EIPPCB 2019]

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.



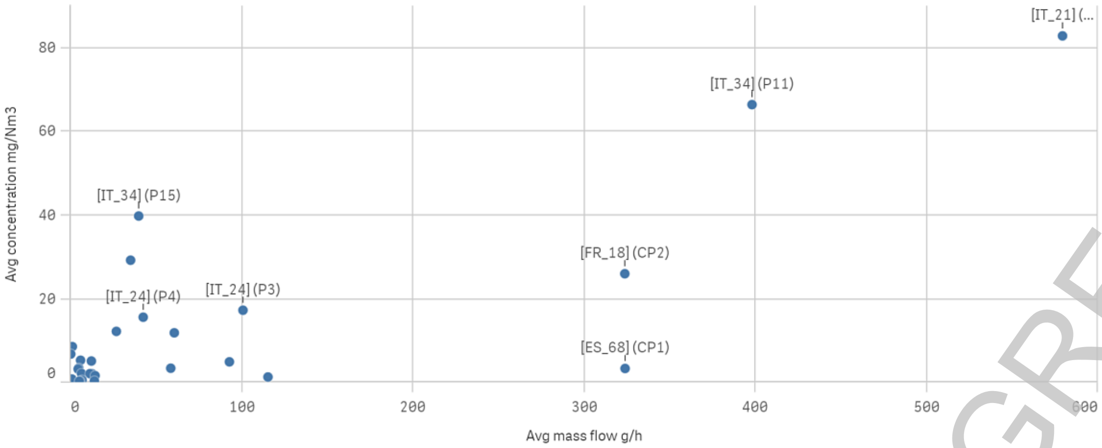
NB: 203 operators reported NO_X emissions from 691 emission points in the data collection.
Source: [43, EIPPCB 2019]

Figure 2.92: Number of emission points for NO_X by IED category

2.3.4.1.2 Emissions

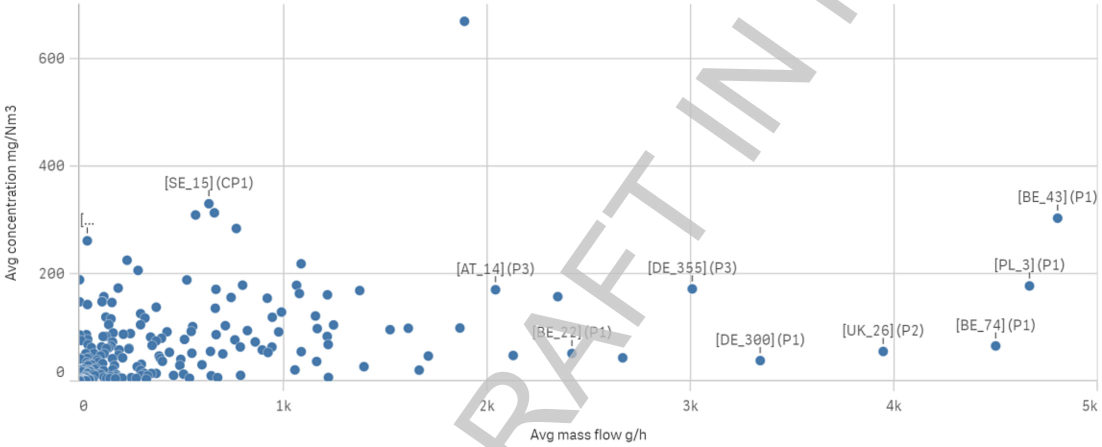
Emissions of nitrogen oxides may originate from different sources, e.g. from the use of catalytic or thermal oxidation of waste gases, or from chemical processes. Emissions of nitrogen oxides from process furnaces/heaters are described in Section 2.9.2.1.

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



NB: 20 operators reported nitrogen oxide emissions from 33 emission points in the data collection, applying catalytic oxidation either alone or in combination with another waste gas treatment technique. For better visualisation, only emission points with concentrations in the range of 0-250 mg NO_X/Nm^3 and mass flows in the range of 0-1 000 g NO_X/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

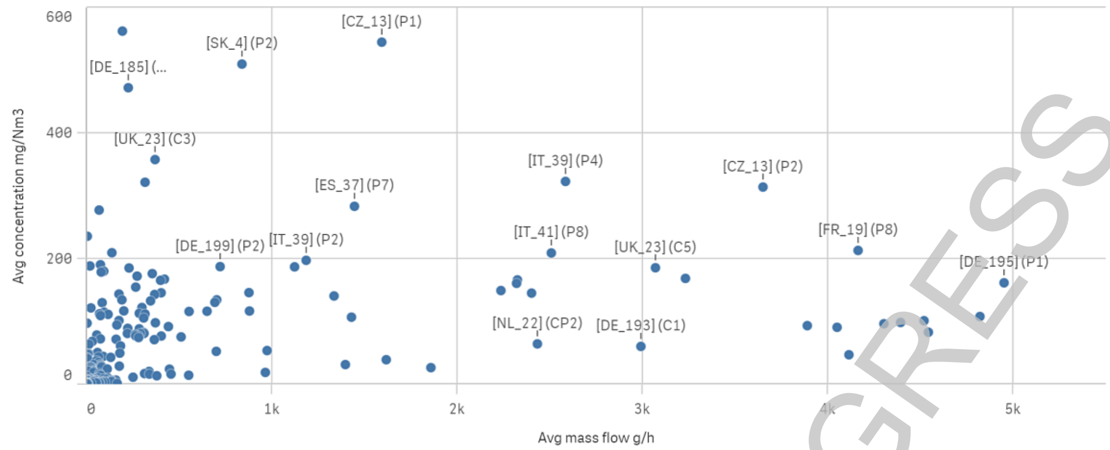
Figure 2.93: NO_X emissions from catalytic oxidation



NB: 105 operators reported nitrogen oxide emissions from 224 emission points in the data collection. For better visualisation, only emission points with concentrations in the range of 0-750 mg NO_X/Nm^3 and mass flows in the range of 0-5 000 g NO_X/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.94: NO_X emissions from thermal oxidation

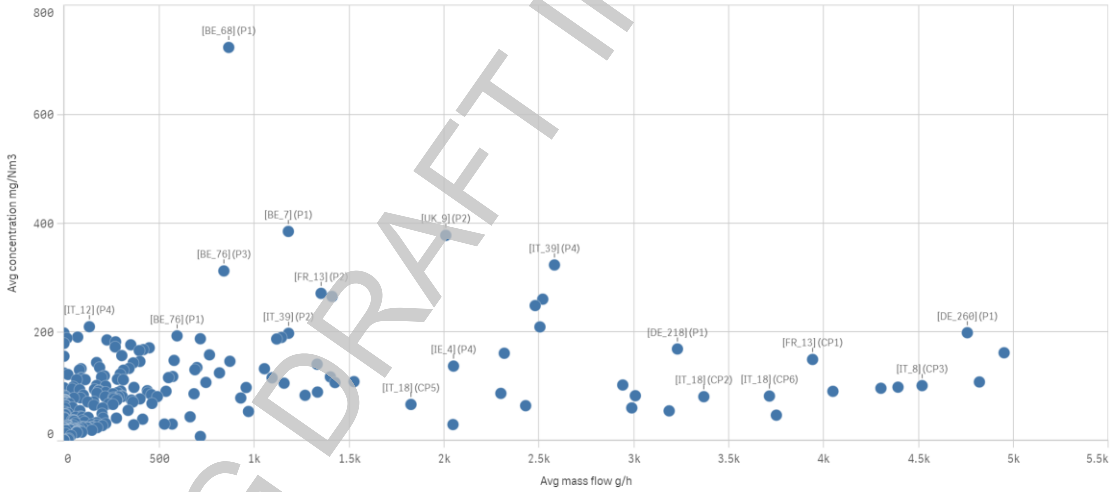
In addition, emissions of nitrogen oxides may occur from chemical processes. The typical emission levels of nitrogen oxides in this case are shown as concentration and mass flow in the scatter plot of Figure 2.95.



NB: 63 operators reported nitrogen oxide emissions from 196 emission points in the data collection. For better visualisation, only emission points with concentrations in the range of 0-750 mg NO_X/Nm^3 and mass flows in the range of 0-5 000 g NO_X/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.95: NO_X 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.

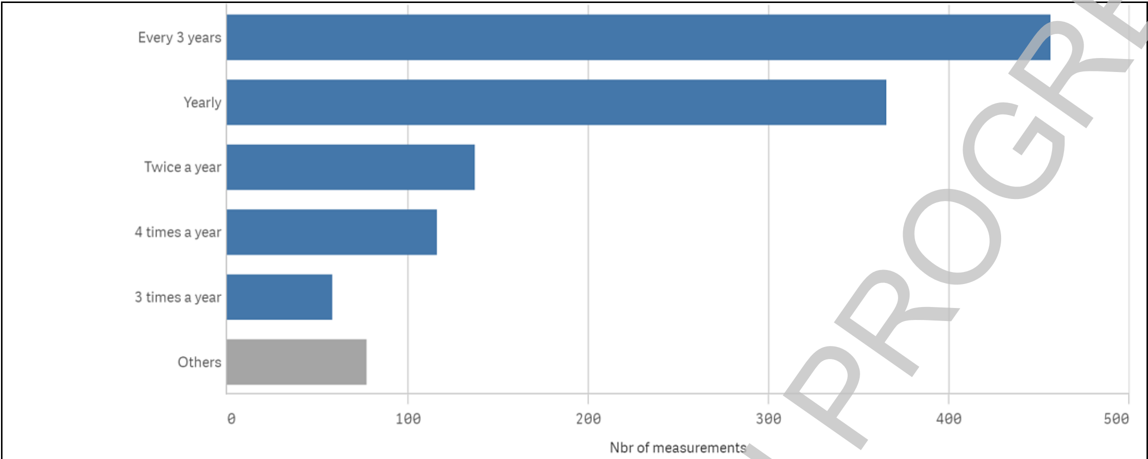


NB: 76 operators reported nitrogen oxide emissions from 249 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-750 mg NO_X/Nm^3 and mass flows in the range of 0-5 000 g NO_X/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.96: NO_X emission points with no waste gas treatment technique

2.3.4.1.3 Monitoring

Periodic monitoring is more common than continuous monitoring: 1 278 instances of periodic monitoring and 213 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.



Source: [43, EIPPCB 2019]

Figure 2.97: Reported measurement frequencies for periodic NO_X 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_X

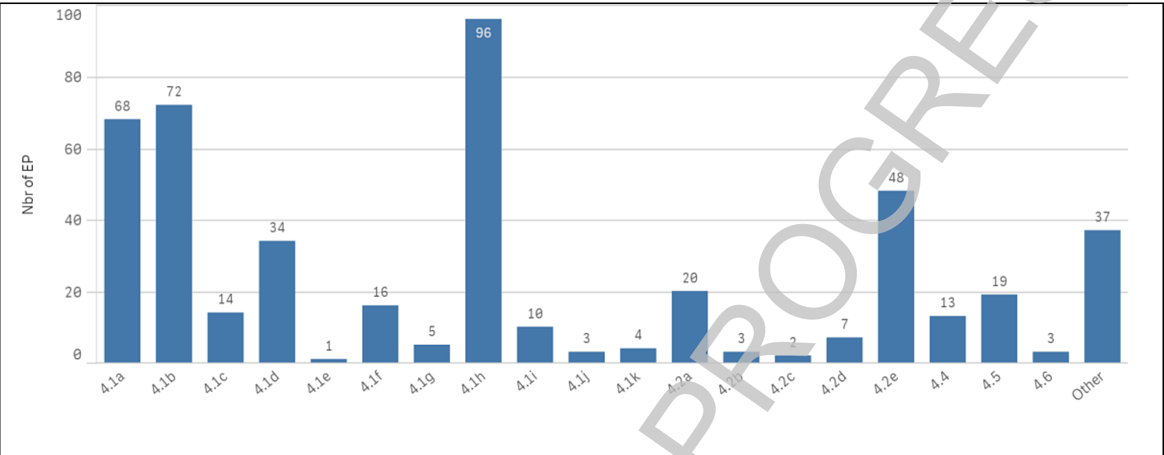
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	1.0	0.4
50th	4.1	1.8
80th	8.0	5.0

NB: The numbers of instances reported for the limits of quantification and detection are 427 and 373, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 151 operators reported CO emissions from 479 emission points in the data collection.
Source: [43, EIPPCB 2019]

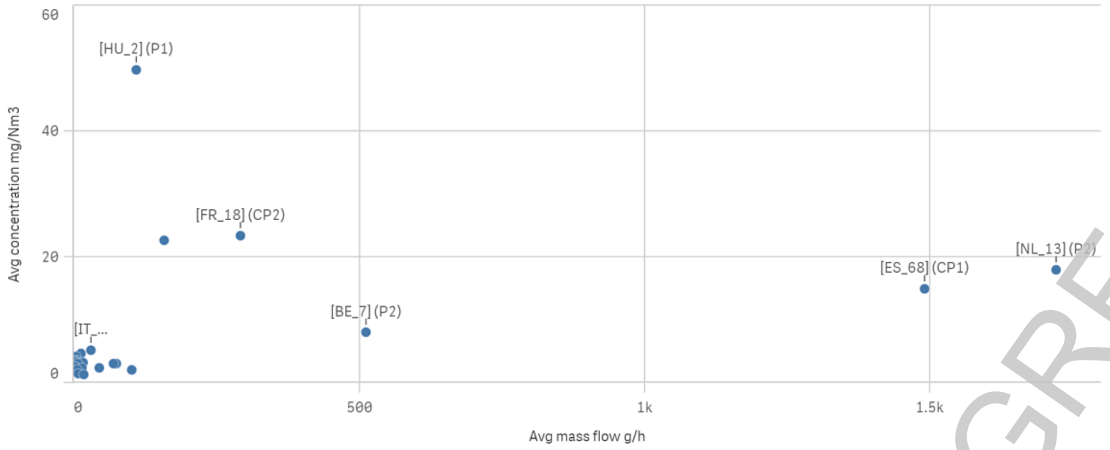
Figure 2.98: Number of emission points for carbon monoxide by IED category

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.

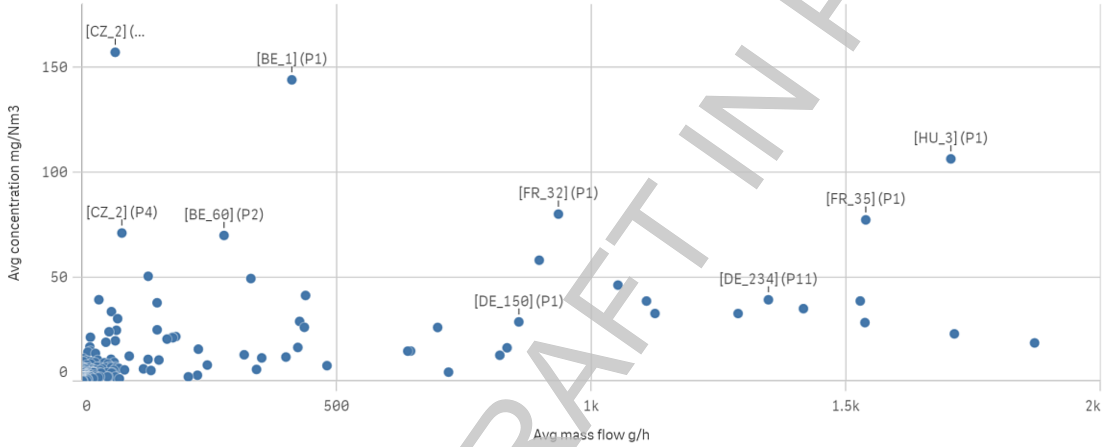
For process furnaces/heaters, the typical emission levels of carbon monoxide are shown as concentration and mass flow in the scatter plot of Figure 2.191.

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.



NB: 17 operators reported carbon monoxide emissions from 27 emission points in the data collection. For better visualisation, only emission points with concentrations in the range of 0-500 mg CO/Nm^3 and mass flows in the range of 0-2 000 g CO/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

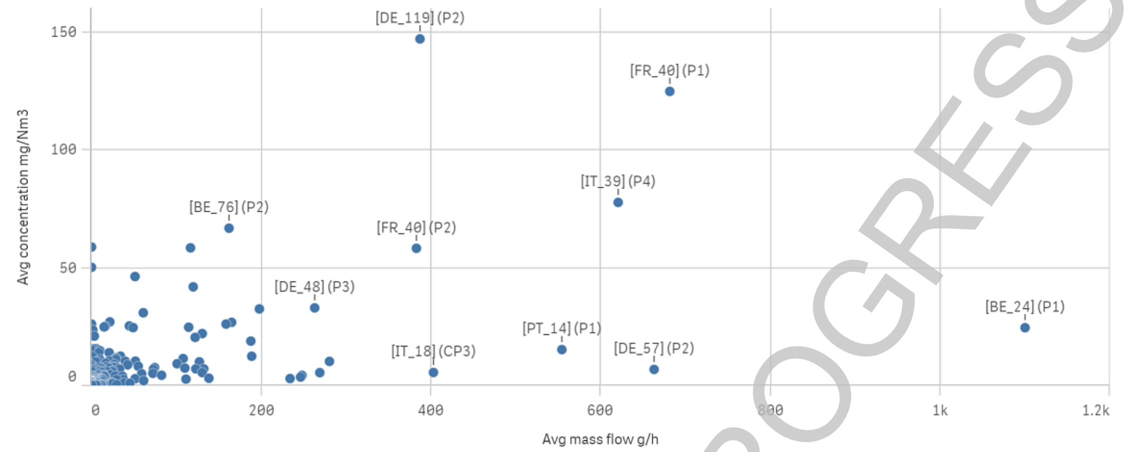
Figure 2.99: CO emissions from catalytic oxidation



NB: 78 operators reported carbon monoxide emissions from 166 emission points in the data collection. For better visualisation, only emission points with concentrations in the range of 0-500 mg CO/Nm^3 and mass flows in the range of 0-2 000 g CO/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.

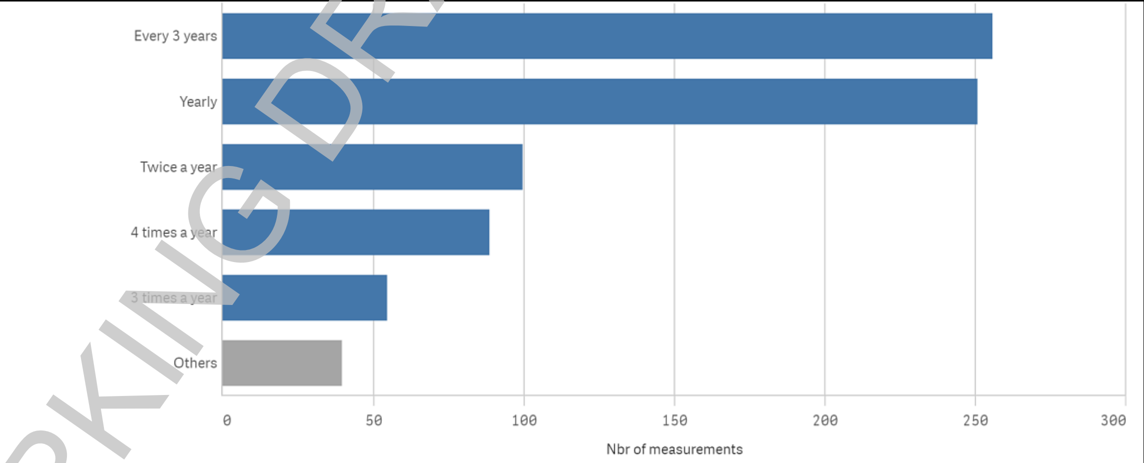


NB: 53 operators reported carbon monoxide emissions from 173 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-500 mg CO/Nm^3 and mass flows in the range of 0-2 000 g CO/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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: 797 instances of periodic monitoring and 163 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.



Source: [43, EIPPCB 2019]

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

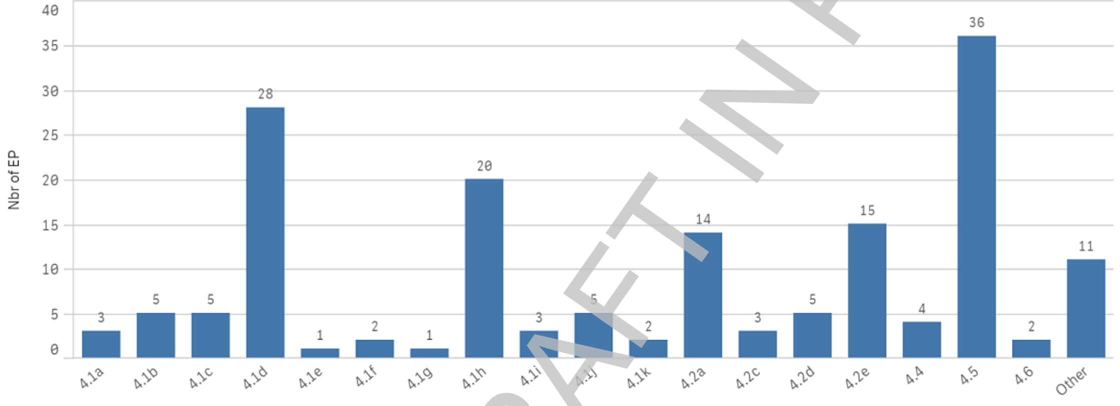
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	1.0	0.3
50th	3.8	1.3
80th	6.3	3.0

NB: The numbers of instances reported for the limits of quantification and detection are 345 and 331, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 69 operators reported NH_3 emissions from 167 emission points in the data collection.
Source: [43, EIPPCB 2019]

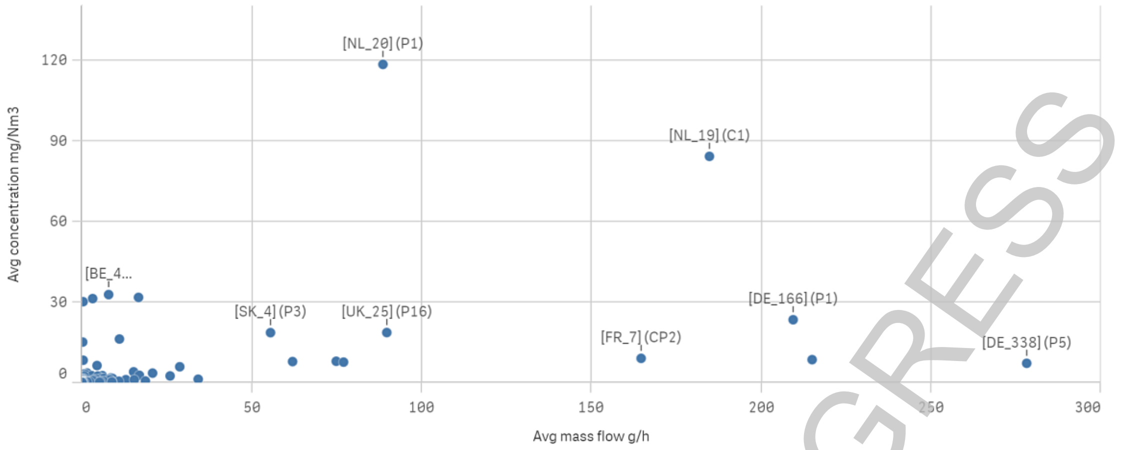
Figure 2.103:Number of emission points for NH_3 by IED category

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:

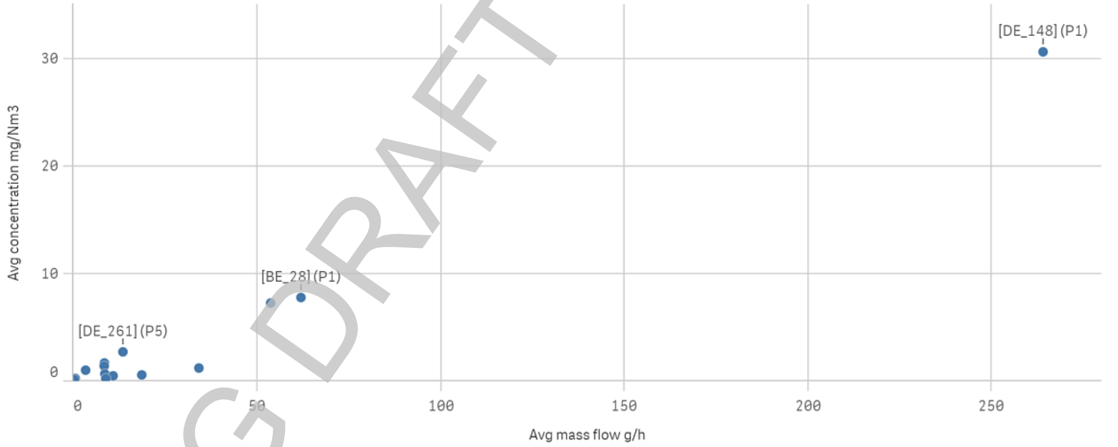
- absorption;
- adsorption.



NB: 44 operators reported ammonia emissions from 98 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-150 mg NH_3/Nm^3 and mass flows in the range of 0-500 g NH_3/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.104:NH_3 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_X 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.

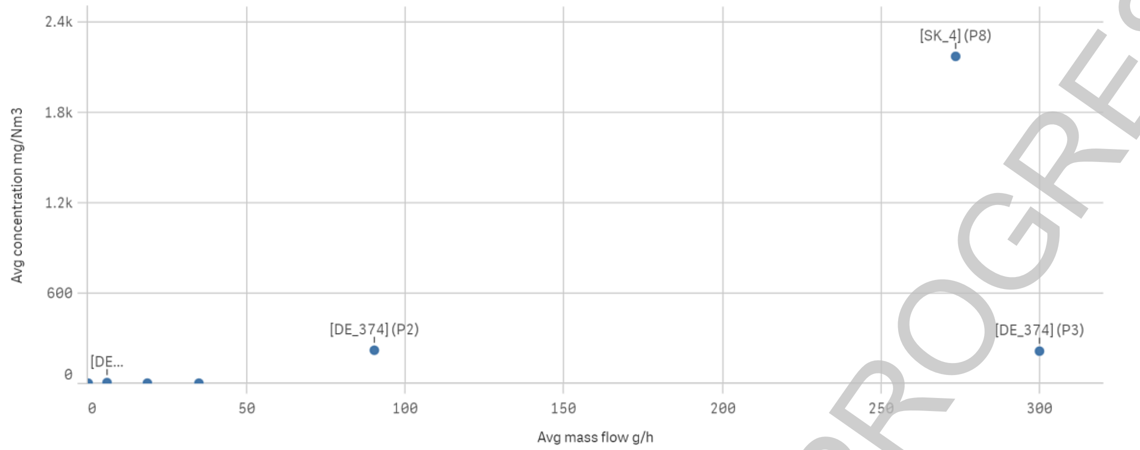


NB: 8 operators reported ammonia emissions from 16 emission points in the data collection, applying SCR or SNCR. For better visualisation, only emission points with concentrations in the range of 0-40 mg NH_3/Nm^3 and mass flows in the range of 0-500 g NH_3/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.105:NH_3 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.

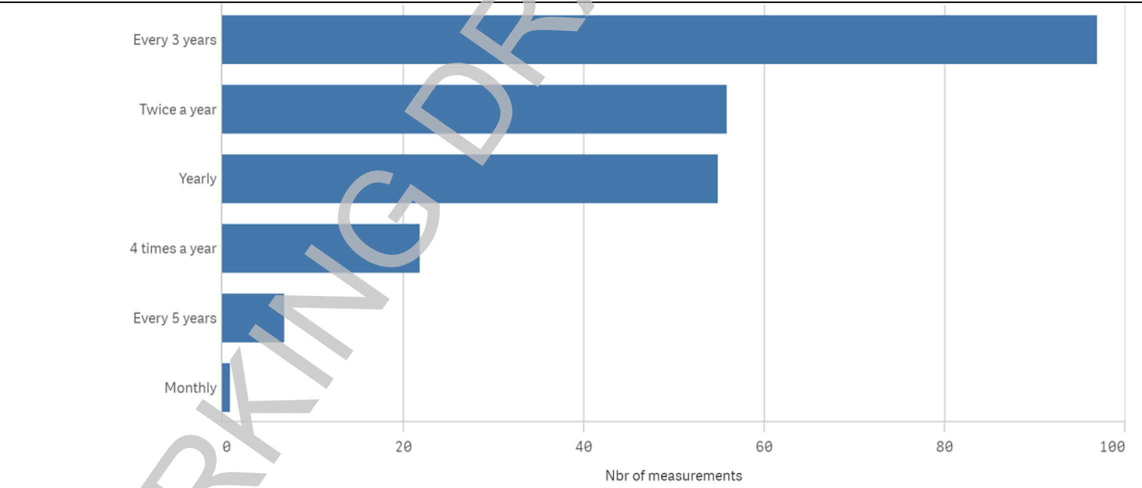


NB: 6 operators reported ammonia emissions from 9 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-150 mg NH_3/Nm^3 and mass flows in the range of 0-500 g NH_3/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.106:NH_3 emission points with no waste gas treatment technique

2.3.4.3.4 Monitoring

Periodic monitoring is more common than continuous monitoring: 247 instances of periodic monitoring and 23 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled ammonia emissions are shown in the bar chart of Figure 2.107.



Source: [43, EIPPCB 2019]

Figure 2.107:Reported measurement frequencies for periodic NH_3 monitoring

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

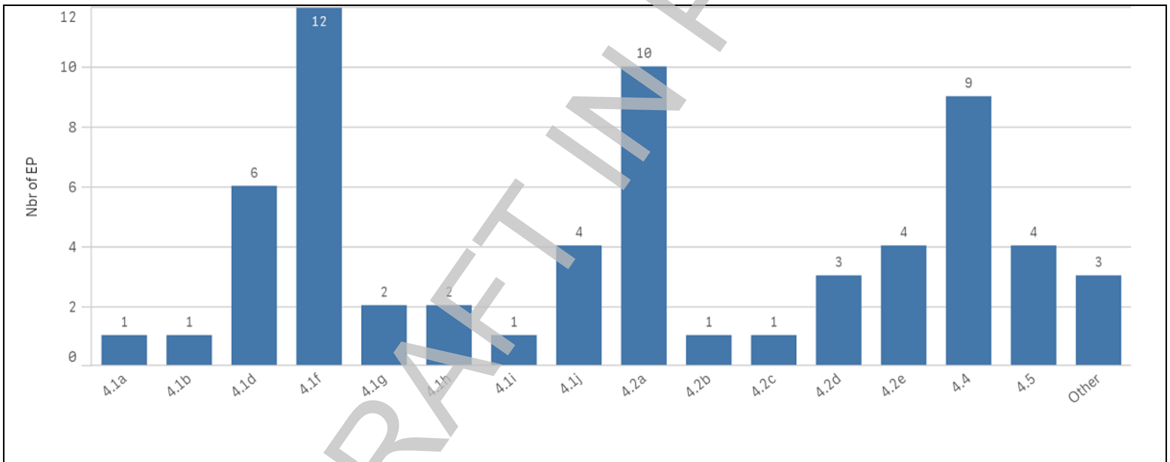
Table 2.27: Reported limits of quantification and detection for NH_3

Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.05	0.05
50th	0.40	0.22
80th	1.08	0.40
NB: The numbers of instances reported for the limits of quantification and detection are 132 and 96, respectively. *Source*: [43, EIPPCB 2019]		

2.3.4.4 Elementary chlorine

2.3.4.4.1 Sectors

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

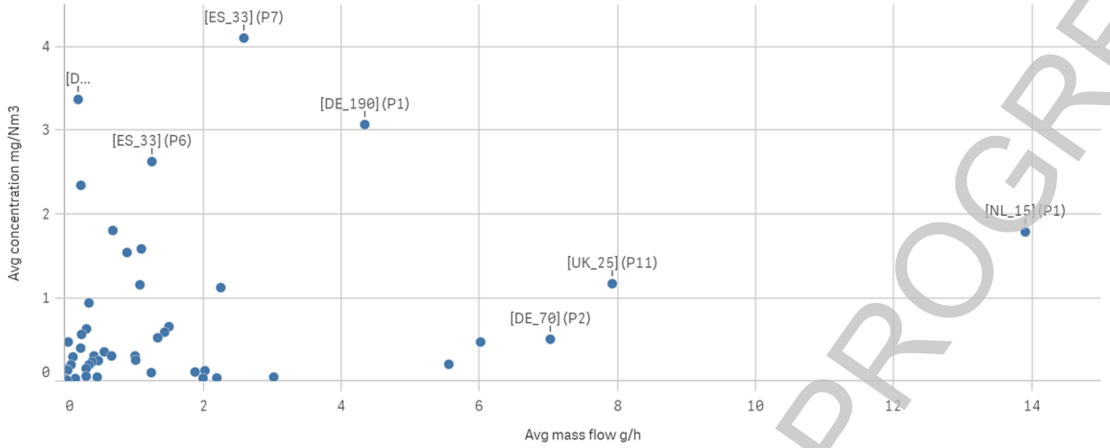


NB: 30 operators reported Cl_2 emissions from 65 emission points in the data collection.
Source: [43, EIPPCB 2019]

Figure 2.108:Number of emission points for Cl_2 by IED category

2.3.4.4.2 Treated missions

Emissions of elementary chlorine are generally treated with at least one waste gas treatment technique applied. The typical emission levels of elementary 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.



NB: 24 operators reported elementary chlorine emissions from 59 emission points in the data collection, applying absorption. For better visualisation, only emission points with concentrations in the range of 0-10 mg Cl_2/Nm^3 and mass flows in the range of 0-25 g Cl_2/h are represented in the scatter plot.
Data not shown for 6 emission points applying waste gas treatment techniques other than absorption.
Source: [43, EIPPCB 2019]

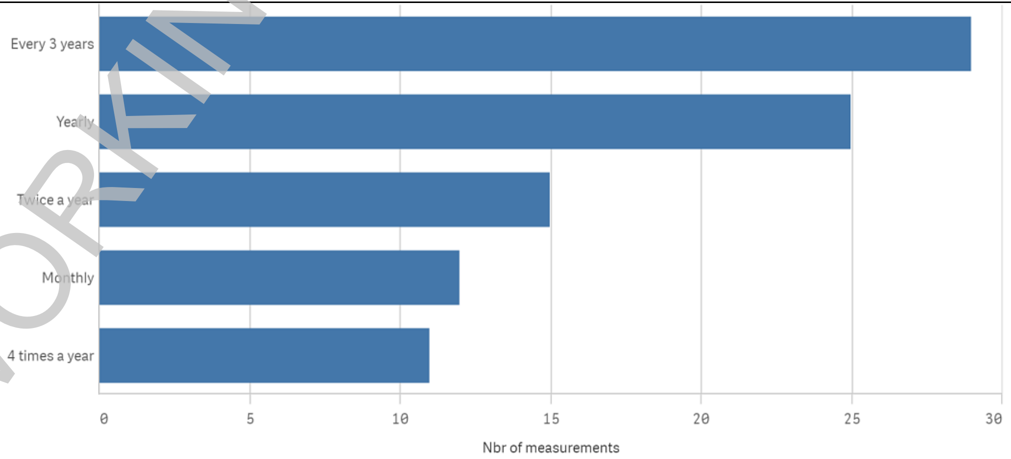
Figure 2.109:Cl_2 emissions after waste gas treatment

2.3.4.4.3 Untreated emissions

All operators reported at least one waste gas treatment technique for their emissions of elementary 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 elementary chlorine emissions are shown in the bar chart of Figure 2.110.



Source: [43, EIPPCB 2019]

Figure 2.110:Reported measurement frequencies for periodic Cl_2 monitoring

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

Table 2.28: Reported limits of quantification and detection for Cl_2

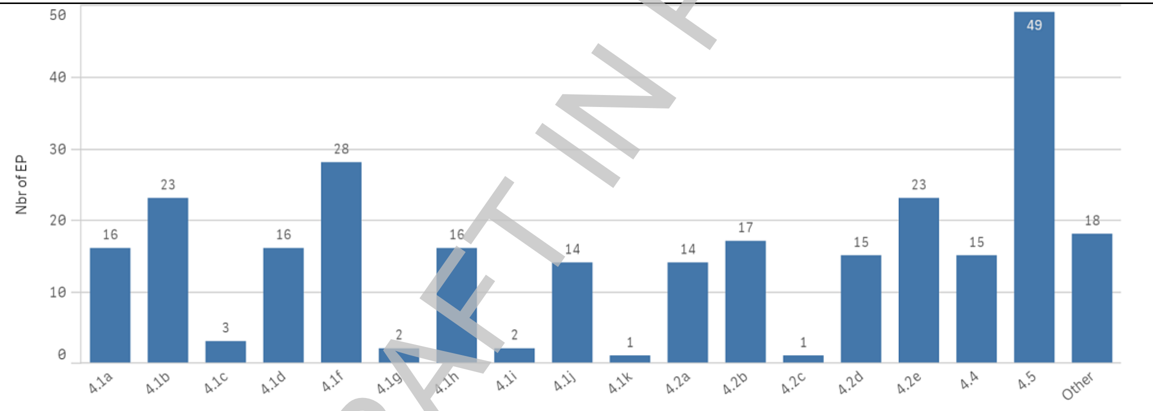
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.13	0.02
50th	0.25	0.16
80th	0.50	0.25

NB: The numbers of instances reported for the limits of quantification and detection are 67 and 64, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 110 operators reported HCl emissions from 279 emission points in the data collection.
Source: [43, EIPPCB 2019]

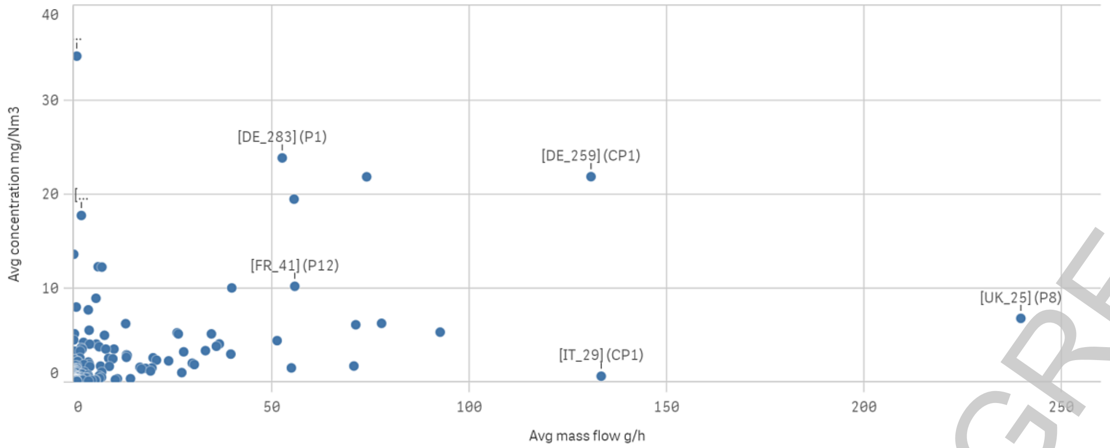
Figure 2.111:Number of emission points for HCl by IED category

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.



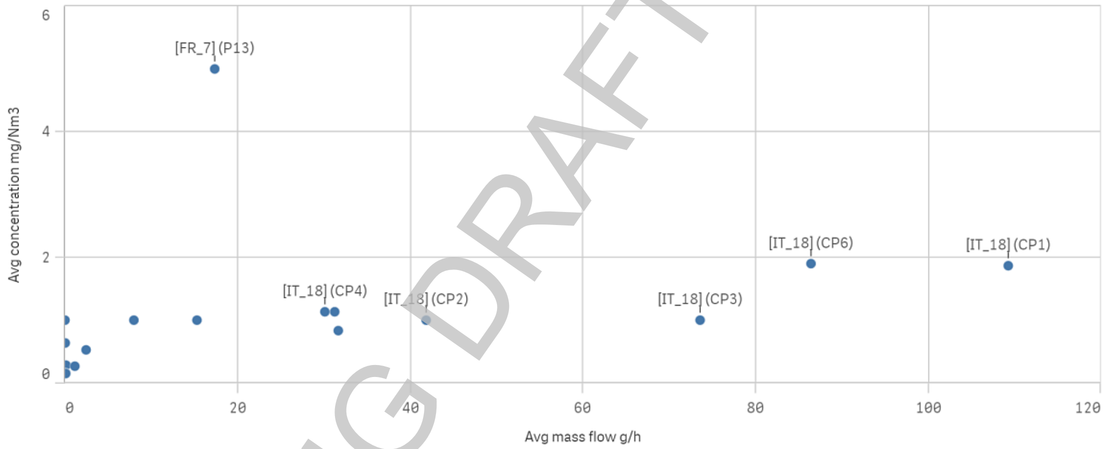
NB: 82 operators reported gaseous chloride emissions from 217 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-50 mg HCl/Nm^3 and mass flows in the range of 0-250 g HCl/h are represented in the scatter plot.

Source: [43, EIPPCB 2019]

Figure 2.112:HCl emissions after waste gas treatment

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.



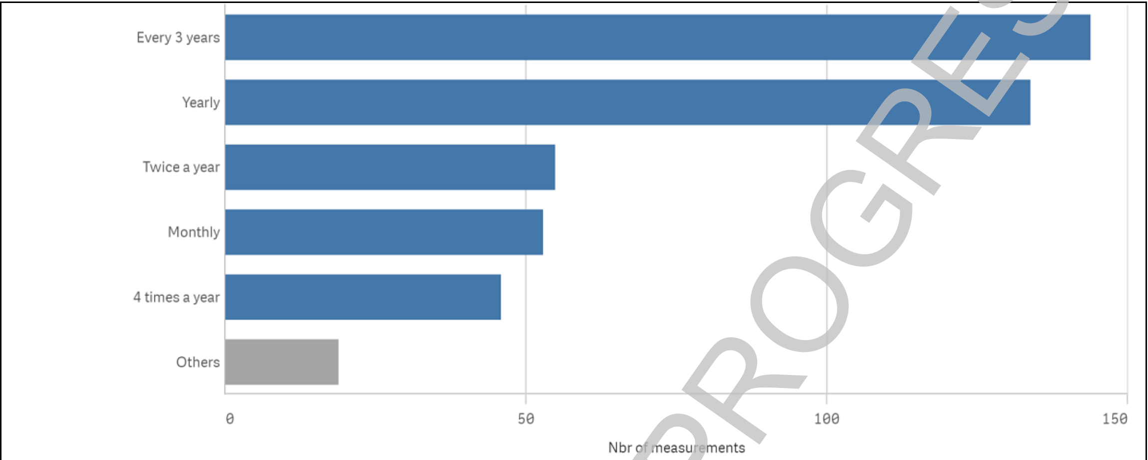
NB: 10 operators reported gaseous chloride emissions from 20 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-50 mg HCl/Nm^3 and mass flows in the range of 0-250 g HCl/h are represented in the scatter plot.

Source: [43, EIPPCB 2019]

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: 478 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.



Source: [43, EIPPCB 2019]

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

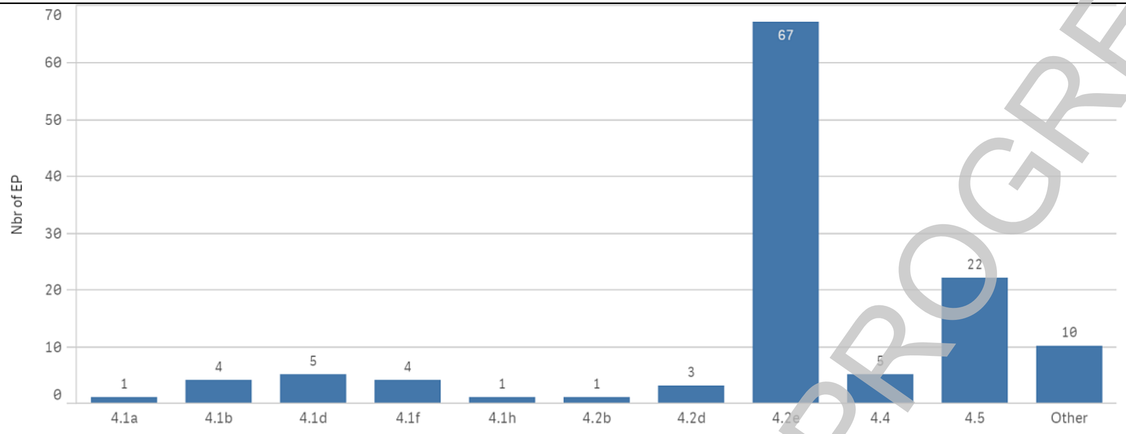
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.13	0.03
50th	0.5	0.22
80th	1.0	1.0

NB: The numbers of instances reported for the limits of quantification and detection are 194 and 178, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 37 operators reported HF emissions from 123 emission points in the data collection.
Source: [43, EIPPCB 2019]

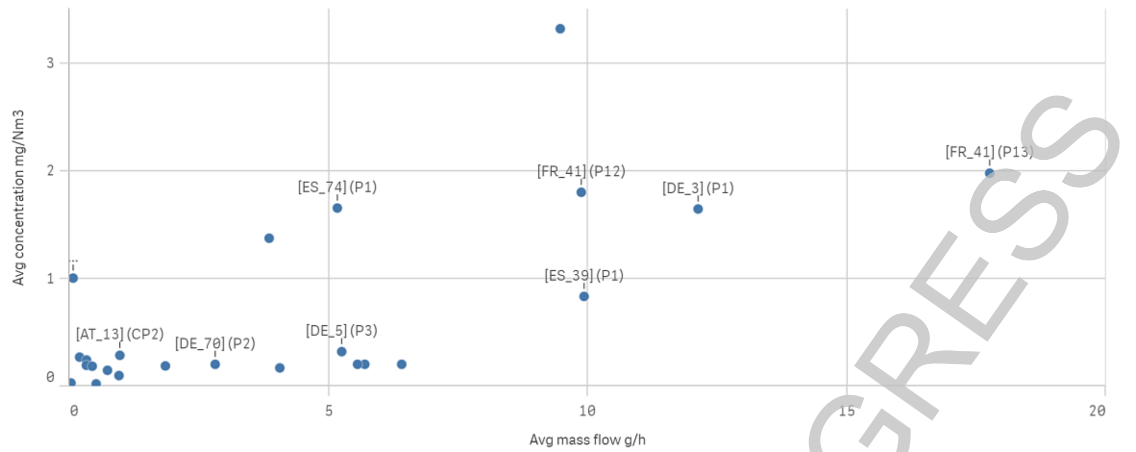
Figure 2.115:Number of emission points for HF by IED category

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.

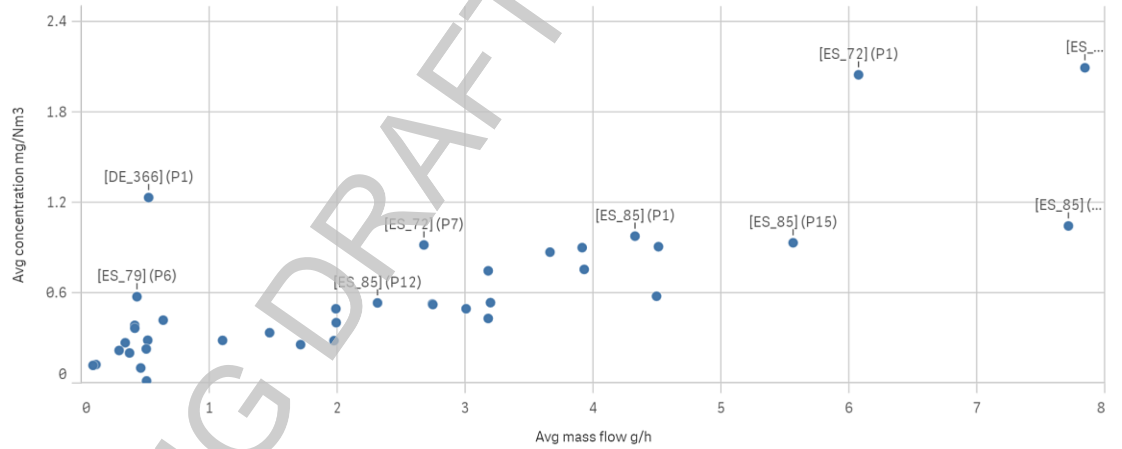


NB: 17 operators reported gaseous fluoride emissions from 50 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-10 mg HF/Nm^3 and mass flows in the range of 0-25 g HF/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

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.

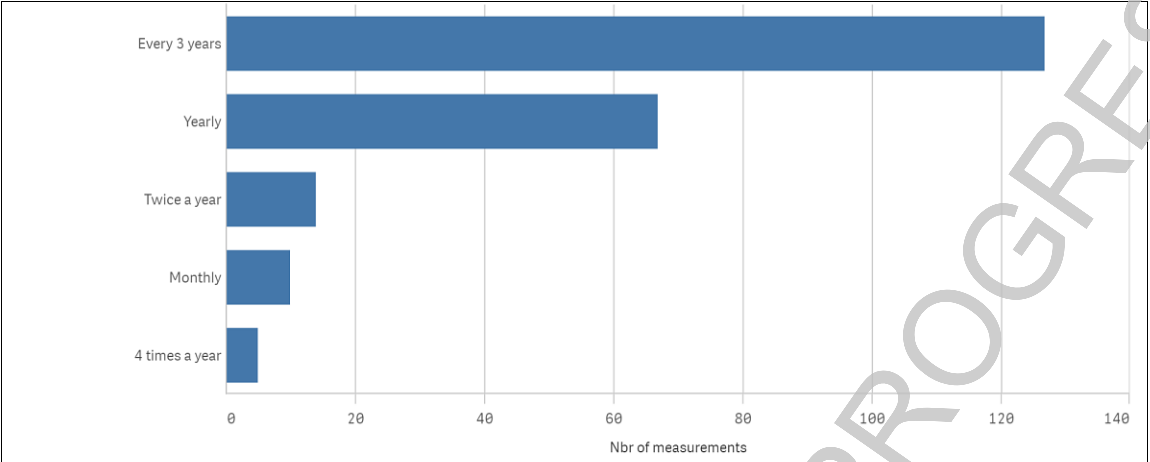


NB: 8 operators reported gaseous fluoride emissions from 38 emission points in the data collection, without any prior waste gas treatment.
Source: [43, EIPPCB 2019]

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

2.3.4.6.4 Monitoring

Only periodic monitoring was reported (239 instances). Typical frequencies for the monitoring of channelled gaseous fluoride emissions are shown in the bar chart of Figure 2.118.



Source: [43, EIPPCB 2019]

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

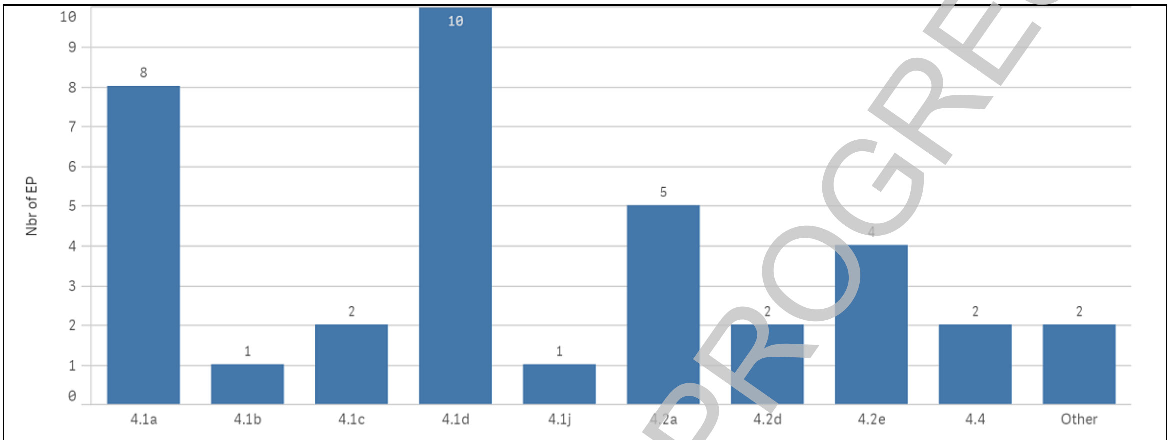
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.14	0.01
50th	0.2	0.06
80th	1.0	0.14

NB: The numbers of instances reported for the limits of quantification and detection are 34 and 22, respectively.
Source: [43, EIPPCB 2019]

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.

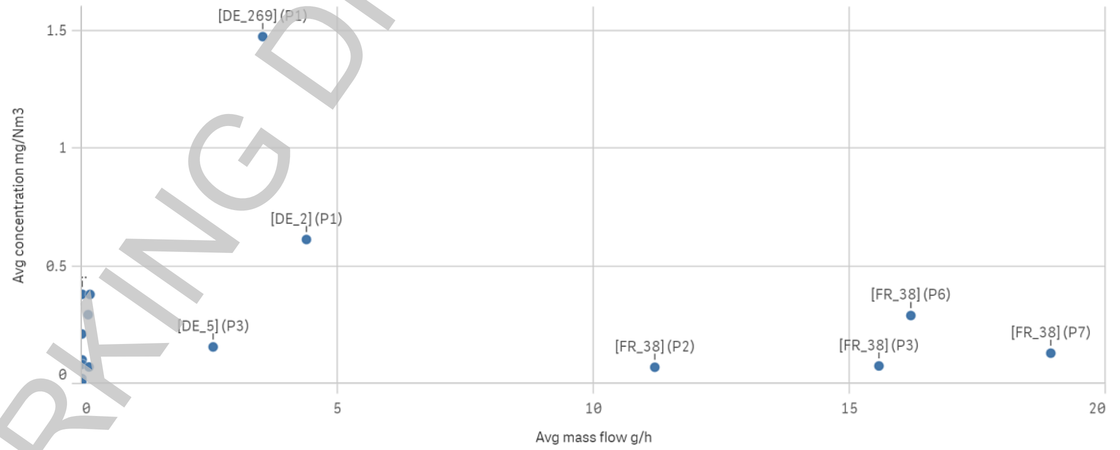


NB: 14 operators reported dust emissions from 37 emission points in the data collection.
Source: [43, EIPPCB 2019]

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 technique is absorption.



NB: 10 operators reported hydrogen cyanide emissions from 23 emission points in the data collection, applying absorption. For better visualisation, only emission points with concentrations in the range of 0-5 mg HCN/Nm^3 and mass flows in the range of 0-25 g HCN/h are represented in the scatter plot.
Data not shown for 13 emission points applying waste gas treatment techniques other than absorption.
Source: [43, EIPPCB 2019]

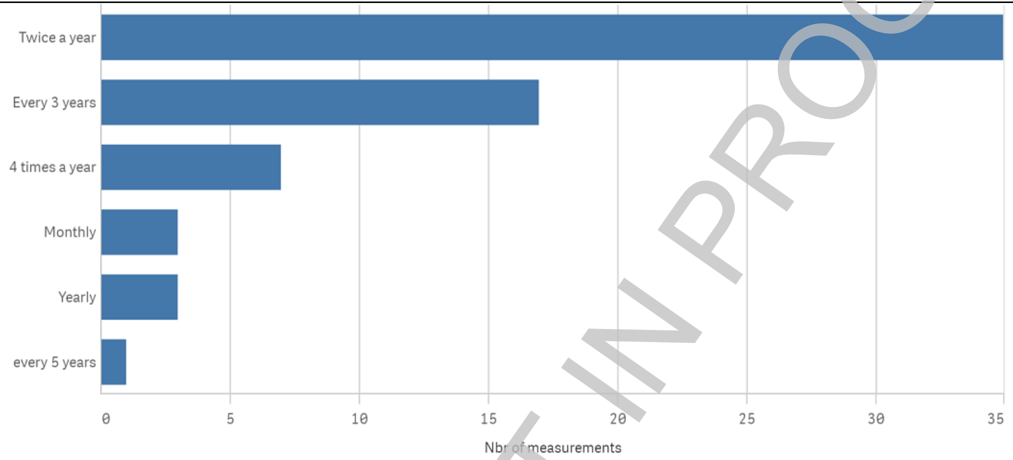
Figure 2.120:HCN emissions after waste gas treatment

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.



Source: [43, EIPPCB 2019]

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

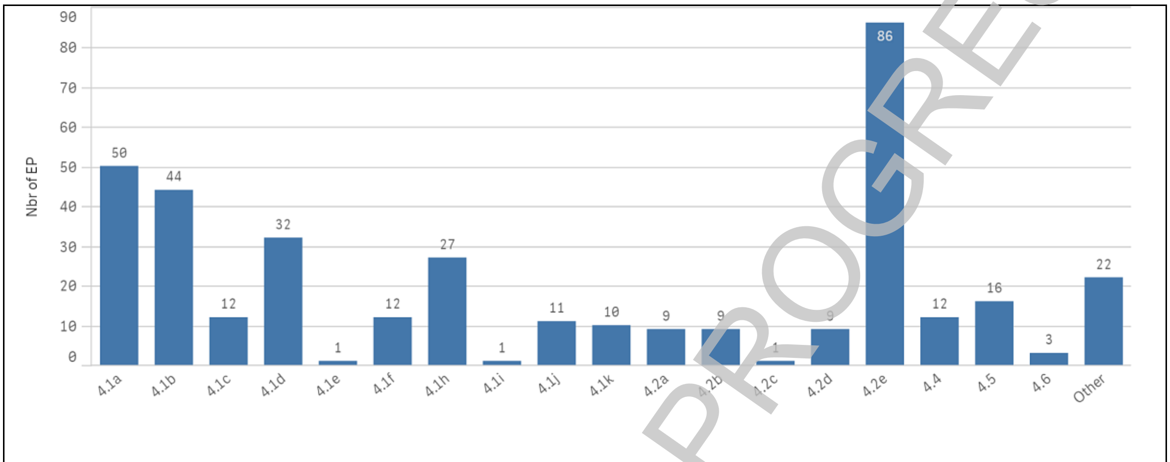
Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.02	0.01
50th	0.11	0.14
80th	0.6	0.2

NB: The numbers of instances reported for the limits of quantification and detection are 19 and 6, respectively.
Source: [43, EIPPCB 2019]

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.



NB: 137 operators reported SO_X emissions from 370 emission points in the data collection.
Source: [43, EIPPCB 2019]

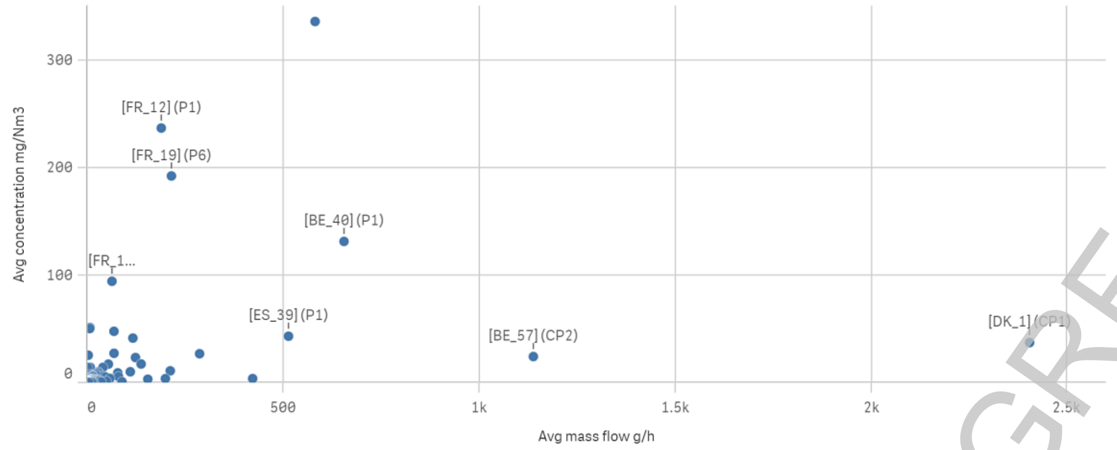
Figure 2.122:Number of emission points for SO_X by IED category

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.

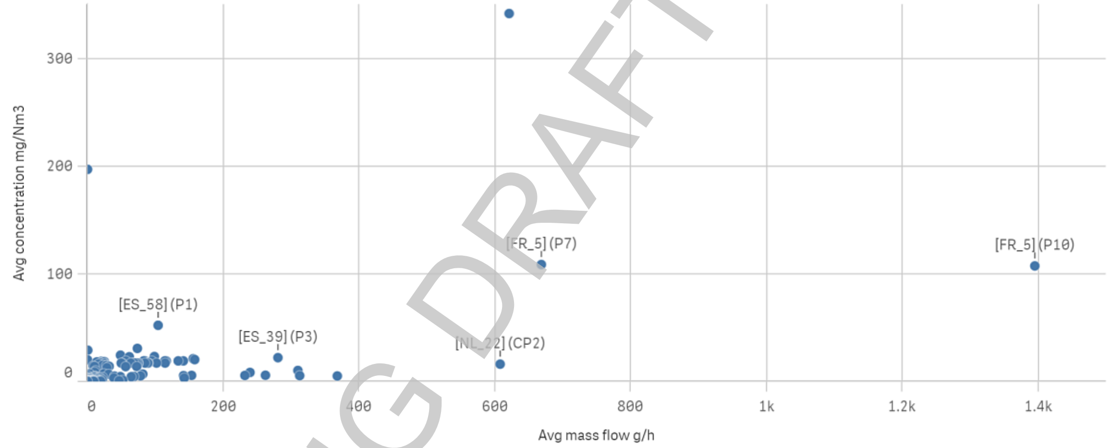


NB: 65 operators reported sulphur oxide emissions from 120 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-750 mg SO_X/Nm^3 and mass flows in the range of 0-5 000 g SO_X/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.123: SO_X **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.

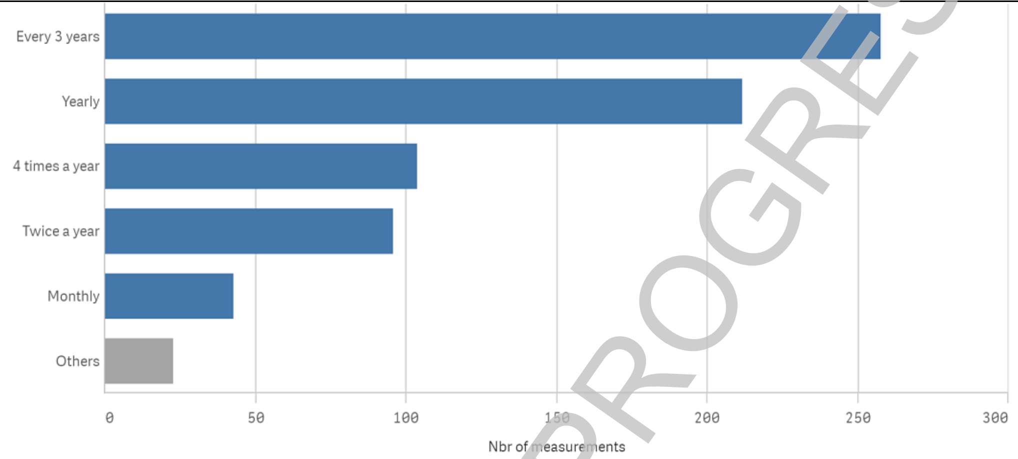


NB: 48 operators reported sulphur oxide emissions from 135 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-750 mg SO_X/Nm^3 and mass flows in the range of 0-5 000 g SO_X/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.124: SO_X **emission points with no waste gas treatment technique**

2.3.4.8.4 Monitoring

Periodic monitoring is more common than continuous monitoring: 750 instances of periodic monitoring and 66 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.



Source: [43, EIPPCB 2019]

Figure 2.125:Reported measurement frequencies for periodic SO_X 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_X

Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.1	0.03
50th	1.0	2.8
80th	11.0	14.0

NB: The numbers of instances reported for the limits of quantification and detection are 288 and 227, respectively.
Source: [43, EIPPCB 2019]

2.4 Diffuse VOC emissions

2.4.1 Fugitive VOC emissions

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

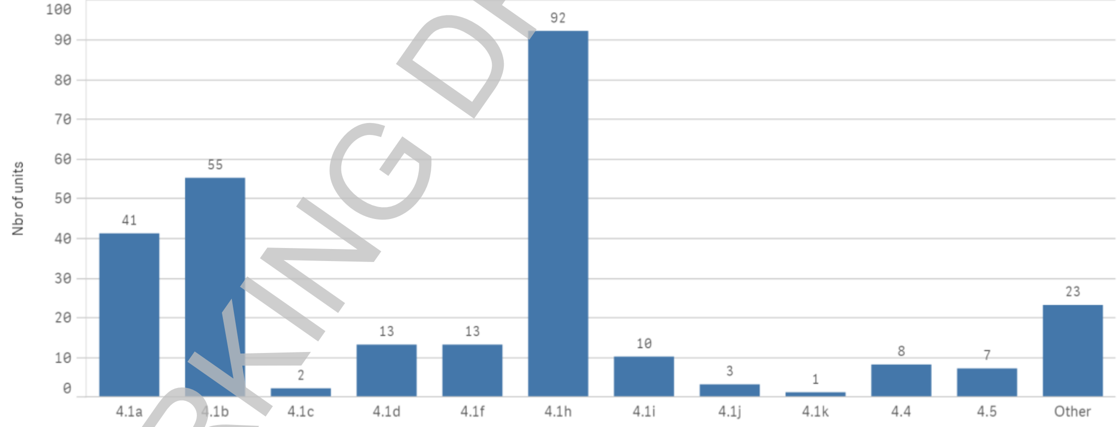
Table 2.33: Substances/Parameters reported as fugitive VOC emissions

Substance/Parameter	No of units
TVOC	361
TVOC containing substances classified as CMR 1A or 1B	108
TVOC containing substances classified as CMR 2	63
Benzene	35
1,3-Butadiene	30
Toluene	25
Vinyl chloride	23
Ethylene oxide	12
Others	44
Source: [43, EIPPCB 2019]	

2.4.1.1 Emissions

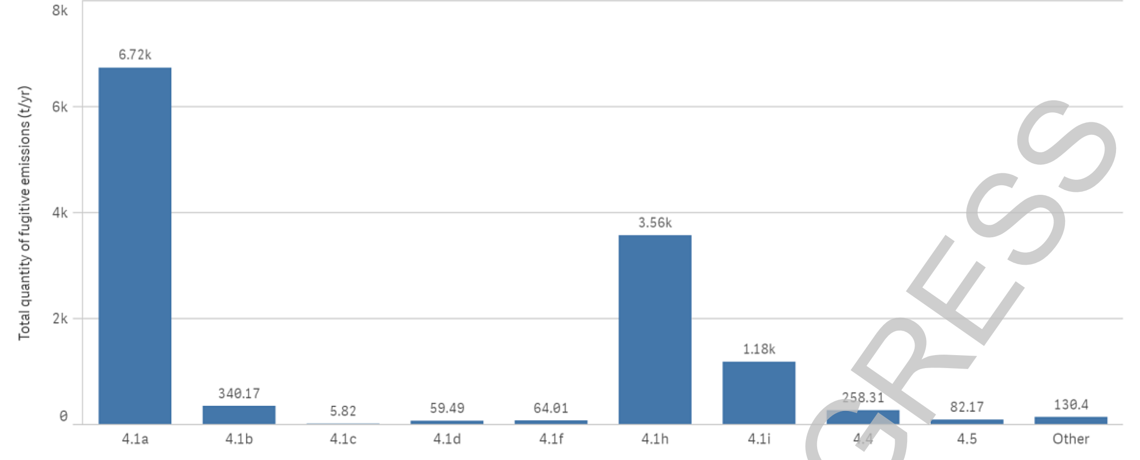
2.4.1.1.1 TVOC

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



Source: [43, EIPPCB 2019]

Figure 2.126:Fugitive TVOC emissions reported by chemical activity



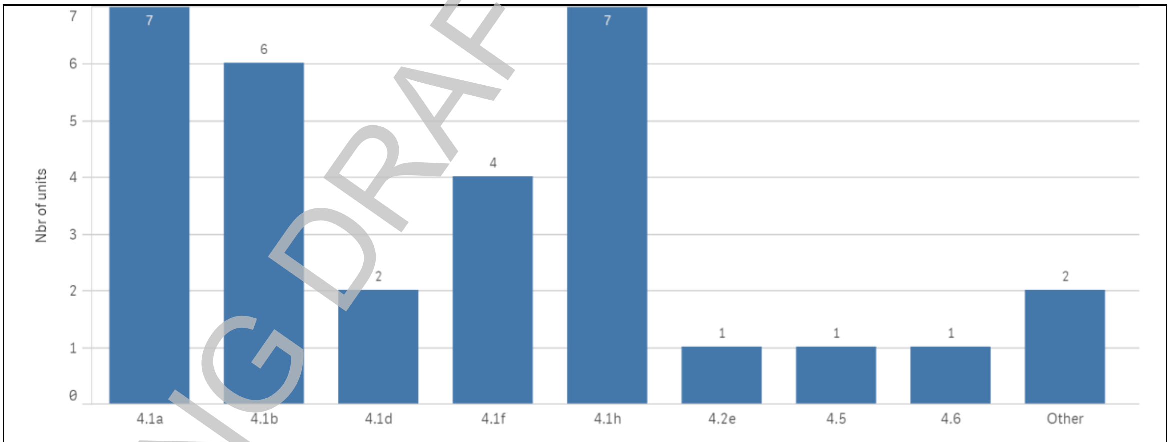
Source: [43, EIPPCB 2019]

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.

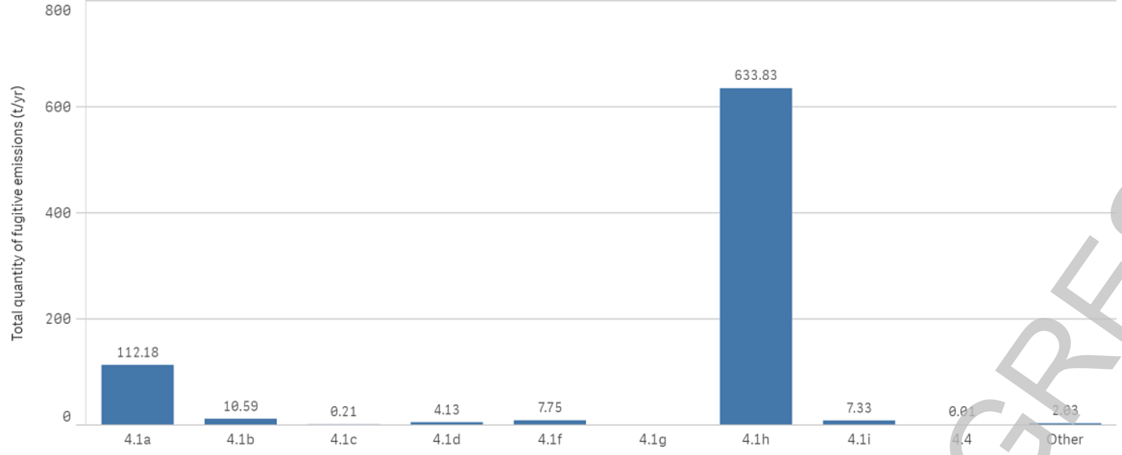
2.4.1.1.2 TVOC containing substances classified as CMR 1A or 1B

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.



Source: [43, EIPPCB 2019]

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



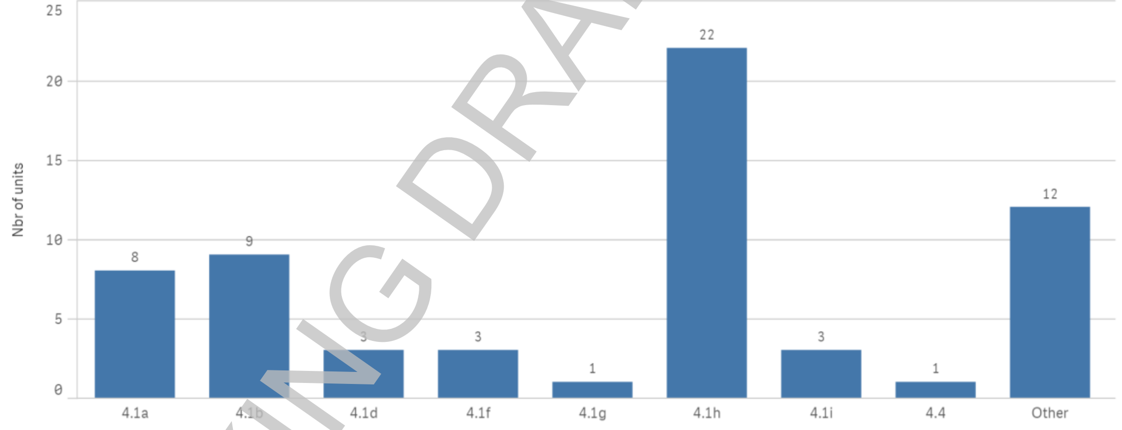
Source: [43, EIPPCB 2019]

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 to 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.

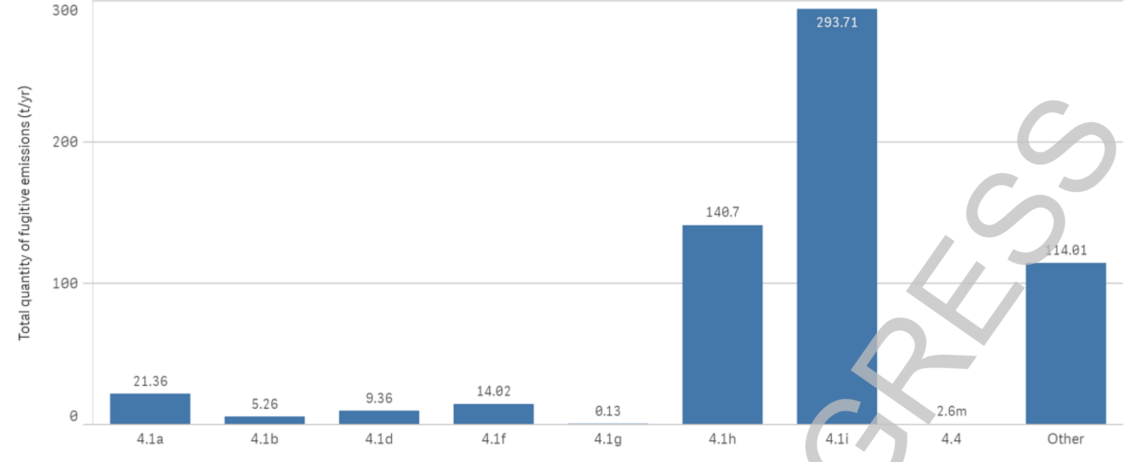
2.4.1.1.3 TVOC containing substances classified as CMR 2

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.



Source: [43, EIPPCB 2019]

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



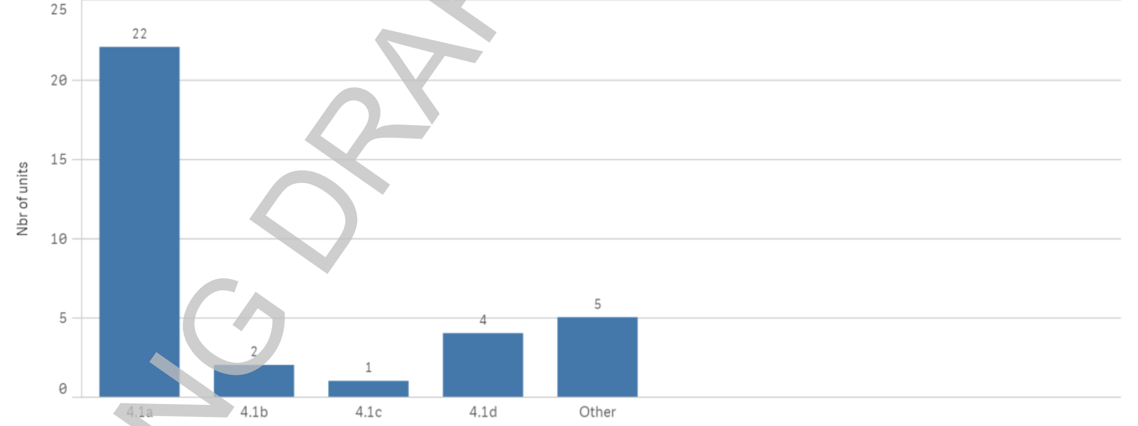
Source: [43, EIPPCB 2019]

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.

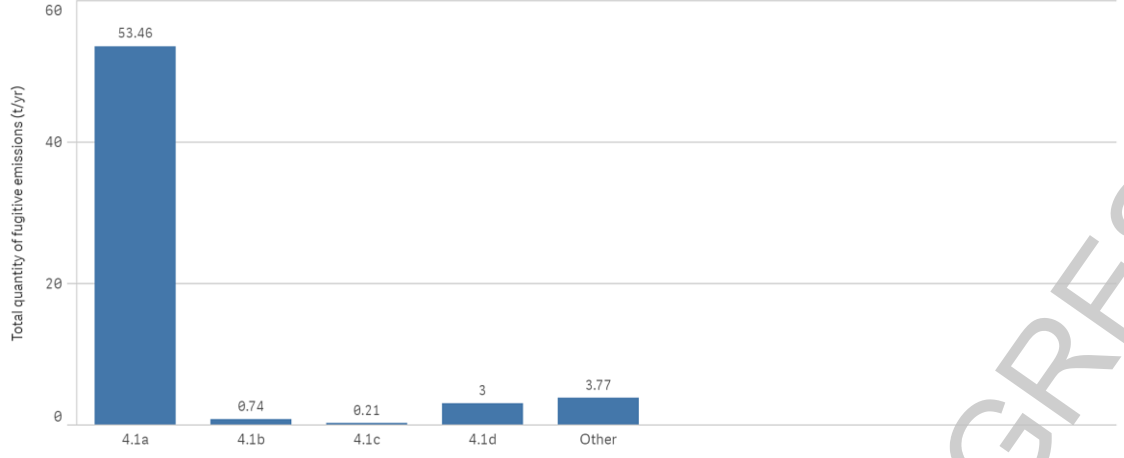
2.4.1.1.4 Benzene

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.



Source: [43, EIPPCB 2019]

Figure 2.132:Fugitive benzene emissions reported by chemical activity



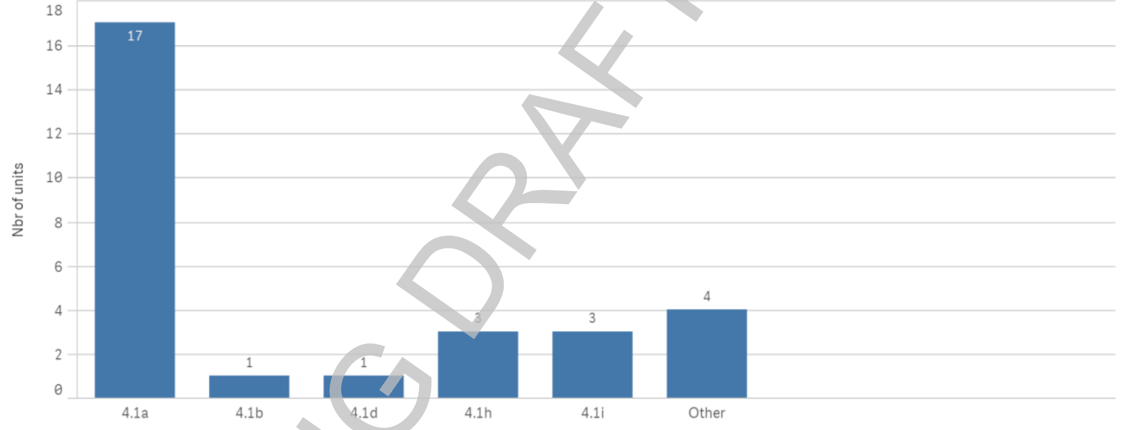
Source: [43, EIPPCB 2019]

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

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

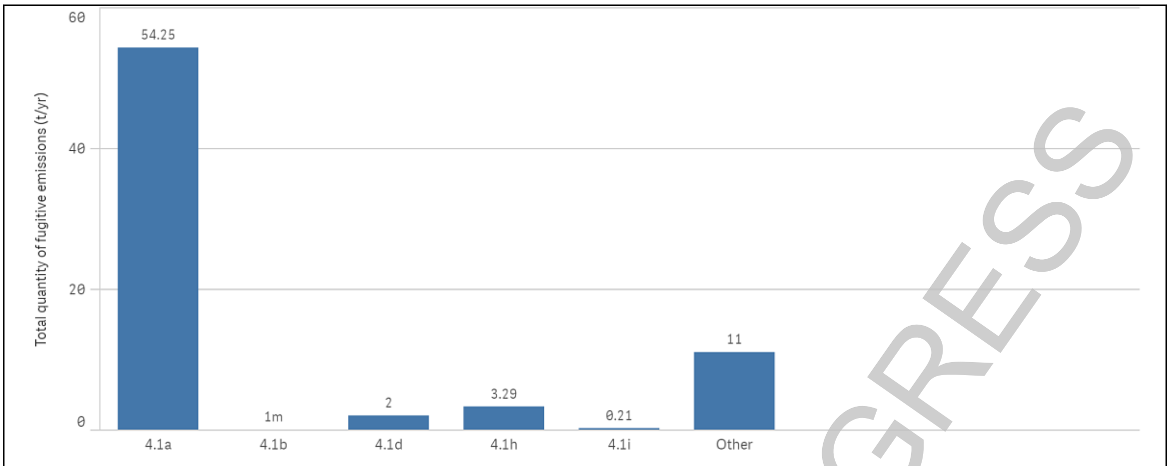
2.4.1.1.5 1,3-Butadiene

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.



Source: [43, EIPPCB 2019]

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



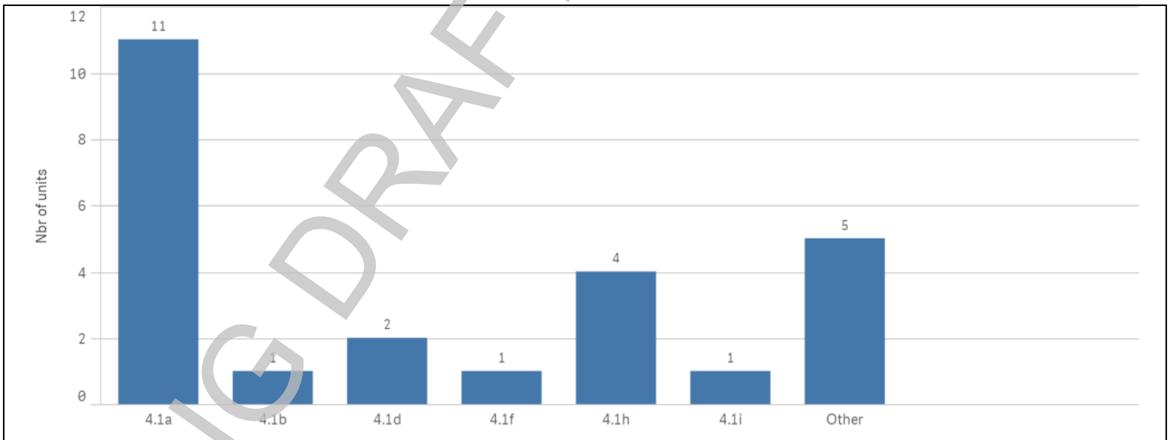
NB: 16 operators reported fugitive 1,3-butadiene emissions for 30 units.
Source: [43, EIPPCB 2019]

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

A wide range of quantities was reported from to 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.

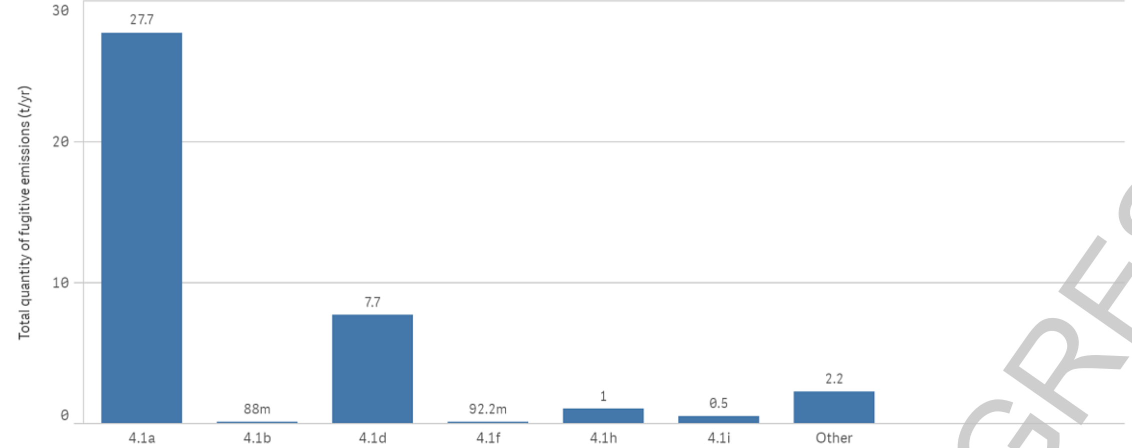
2.4.1.1.6 Toluene

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.



Source: [43, EIPPCB 2019]

Figure 2.136:Fugitive toluene emissions reported by chemical activity



NB: 18 operators reported fugitive toluene emissions for 25 units.
Source: [43, EIPPCB 2019]

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

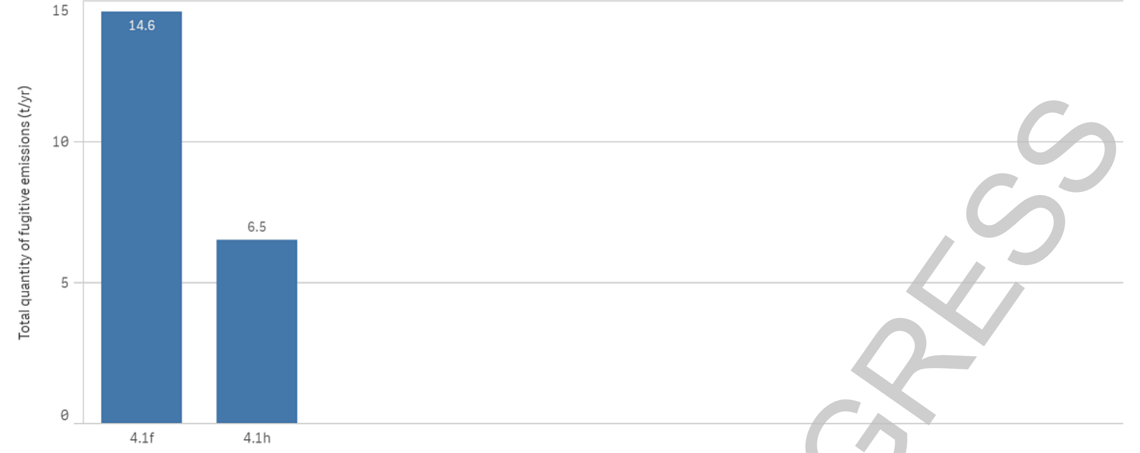
A wide range of quantities was reported from to 20 kg to 22 tonnes of toluene per year. The total quantity of fugitive emissions of toluene sums up to 39 tonnes per year.

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.

Source: [43, EIPPCB 2019]

Figure 2.138:Fugitive vinyl chloride emissions reported by chemical activity



Source: [43, EIPPCB 2019]

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

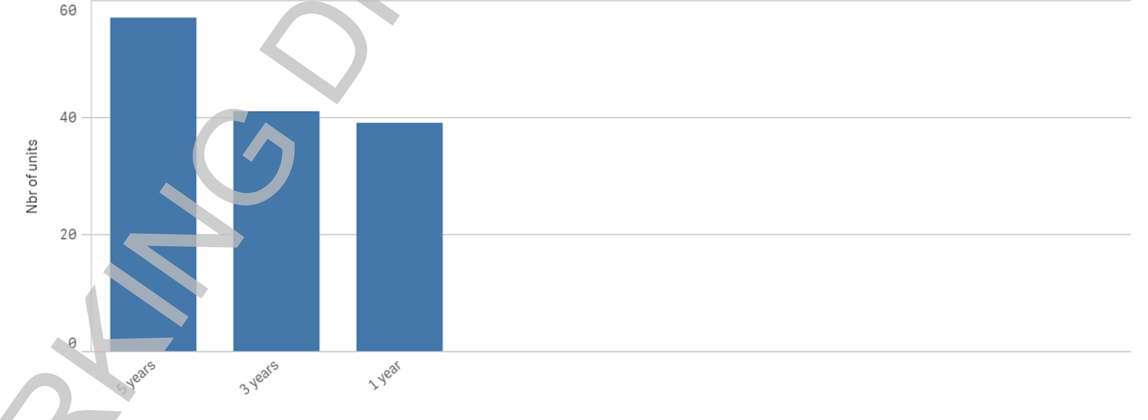
A wide range of quantities was reported from to 30 kg to 3 tonnes of vinyl chloride per year. The total quantity of fugitive emissions of vinyl chloride sums up to 21 tonnes per year.

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

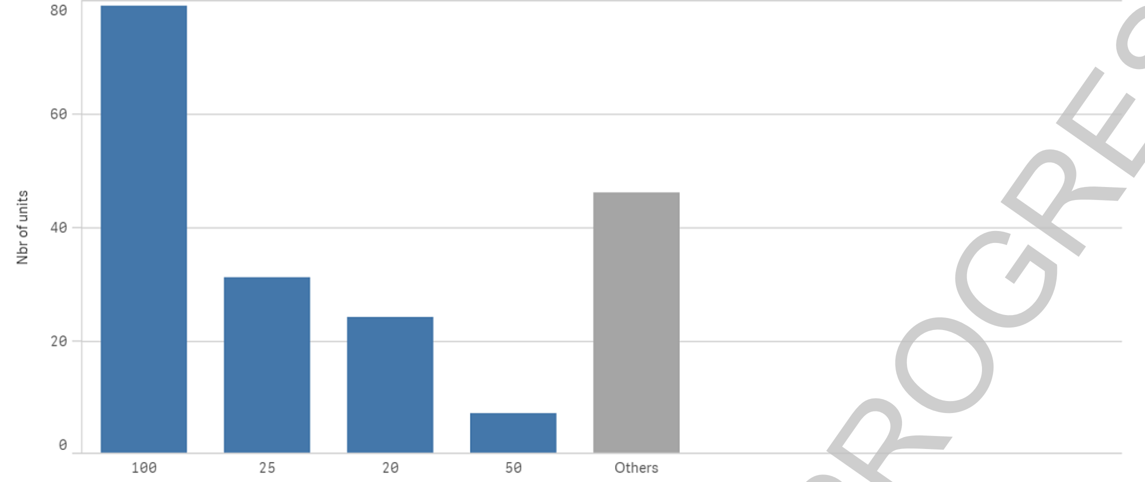
Figure 2.140 shows the period of time for monitoring campaigns of fugitive VOC emissions. In most cases, a campaign is carried out in 5 years.



Source: [43, EIPPCB 2019]

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

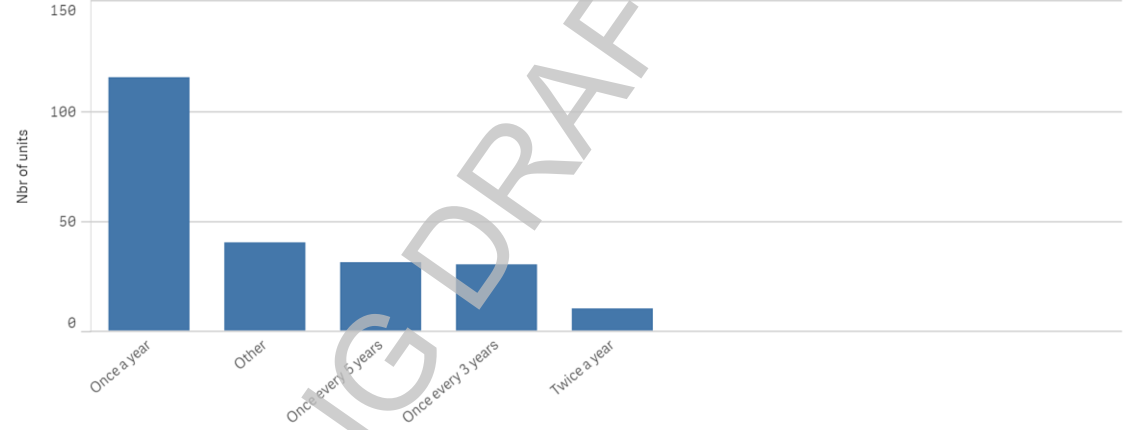
Figure 2.141 shows the percentage of equipment included in the monitoring of fugitive VOC emissions over a campaign. In most cases, 100 % of the equipment is monitored during a campaign.



Source: [43, EIPPCB 2019]

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.



Source: [43, EIPPCB 2019]

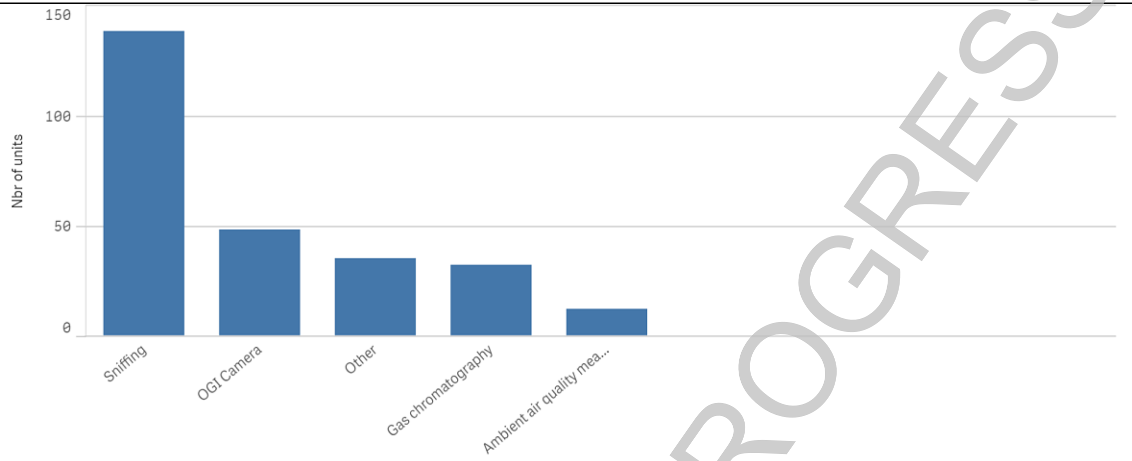
Figure 2.142:Monitoring frequency of fugitive VOC emissions from equipment

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 (52 units).

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



Source: [43, EIPPCB 2019]

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

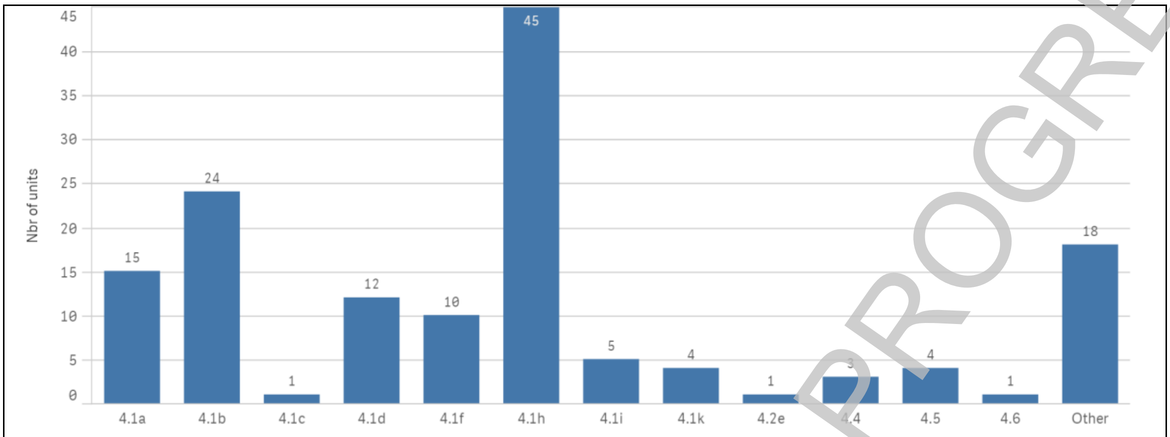
Substance/Parameter	No of units
TVOC	196
TVOC containing substances classified as CMR 1A or 1B	31
TVOC containing substances classified as CMR 2	20
Benzene (C6H6)	13
1,3-Butadiene (C4H6)	30
Toluene	12
Vinyl chloride	12
Others	26

Source: [43, EIPPCB 2019]

2.4.2.1 Emissions

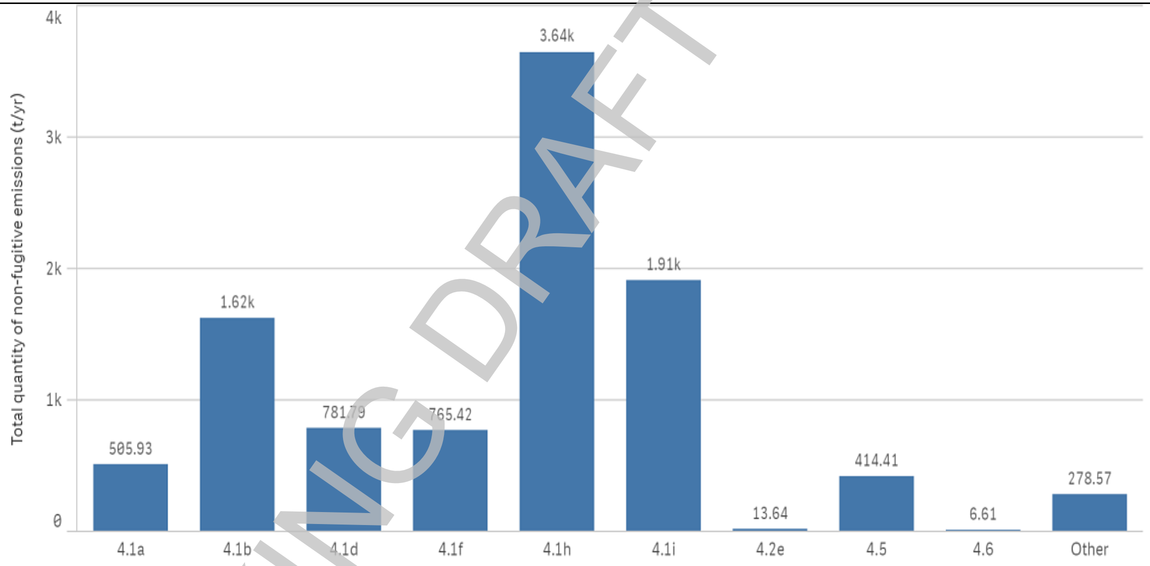
2.4.2.1.1 TVOC

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.



Source: [43, EIPPCB 2019]

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



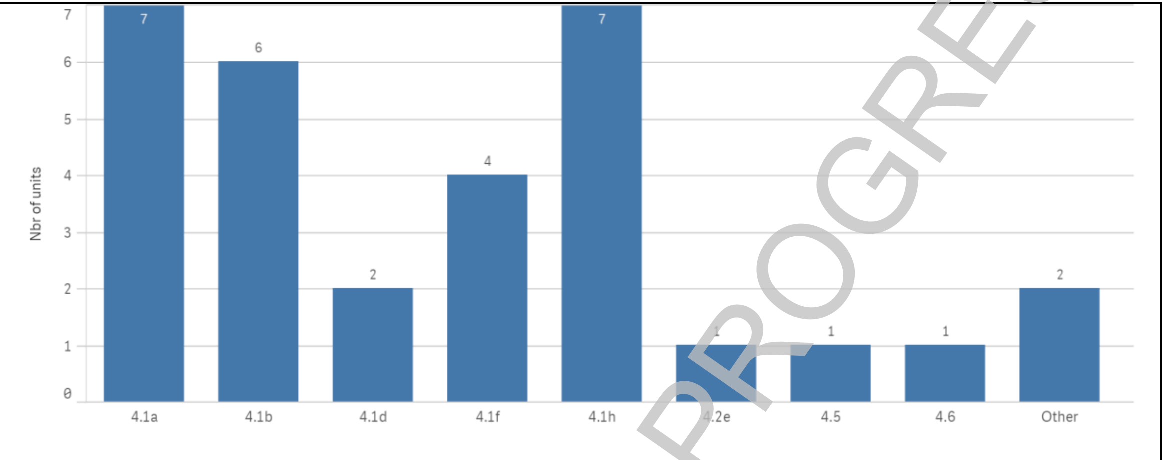
Source: [43, EIPPCB 2019]

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

A wide range of quantities was reported from 30 kg to 180 000 tonnes of TVOC per year. The total quantity of non-fugitive emissions of TVOC sums up to 730 000 tonnes per year.

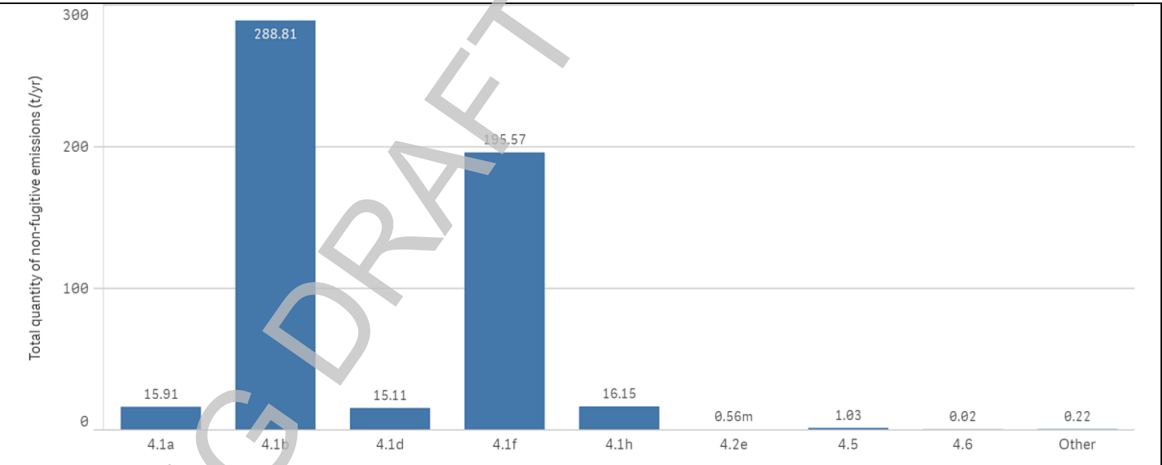
2.4.2.1.2 TVOC containing substances classified as CMR 1A or 1B

Figure 2.146 shows the number of units reporting non-fugitive emissions of TVOC containing substances classified as CMR 1A or 1B and Figure 2.147 shows the chemical IED activities that most contribute to non-fugitive emissions of TVOC containing substances classified as CMR 1A or 1B.



Source: [43, EIPPCB 2019]

Figure 2.146:Non-fugitive emissions of TVOC containing substances classified as CMR 1A or 1B reported by chemical activity



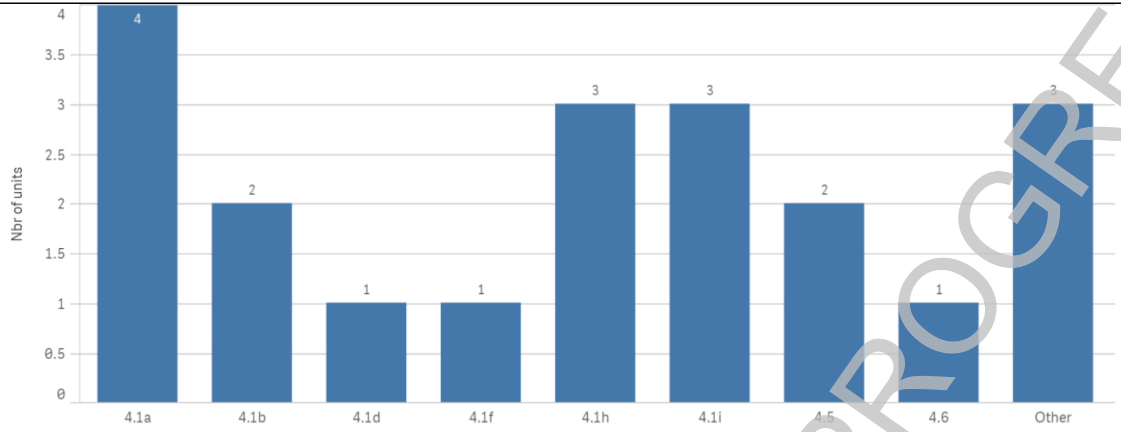
Source: [43, EIPPCB 2019]

Figure 2.147:Quantity of total VOC containing substances classified as CMR 1A or 1B non-fugitive emissions reported by chemical activity

A wide range of quantities was reported from 560 g to 282 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.

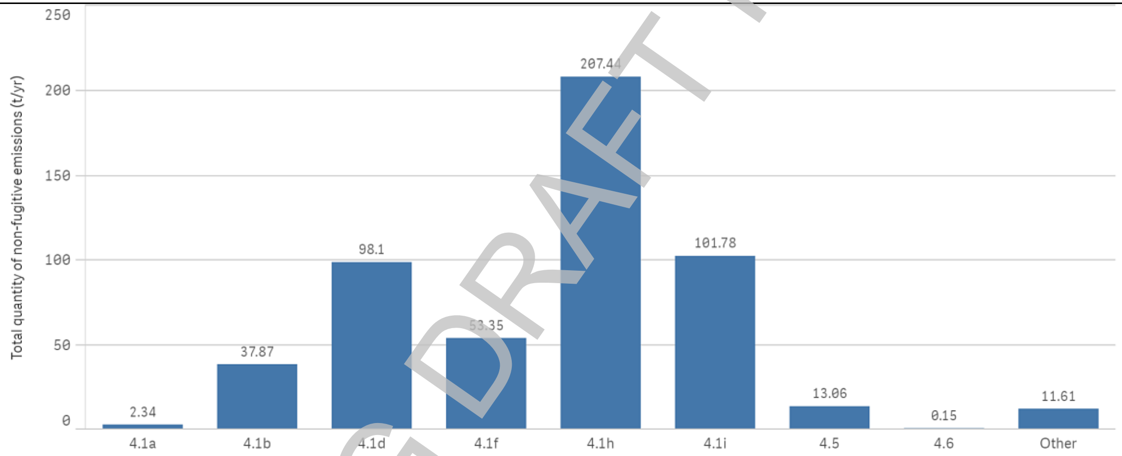
2.4.2.1.3 TVOC containing substances classified as CMR 2

Figure 2.148 shows the number of units reporting non-fugitive TVOC containing substances classified as CMR 2 emissions and Figure 2.149 shows the chemical IED activities that most contribute to non-fugitive emissions of TVOC containing substances classified as CMR 2.



Source: [43, EIPPCB 2019]

Figure 2.148:Non-fugitive emissions of TVOC containing substances classified as CMR 2 reported by chemical activity



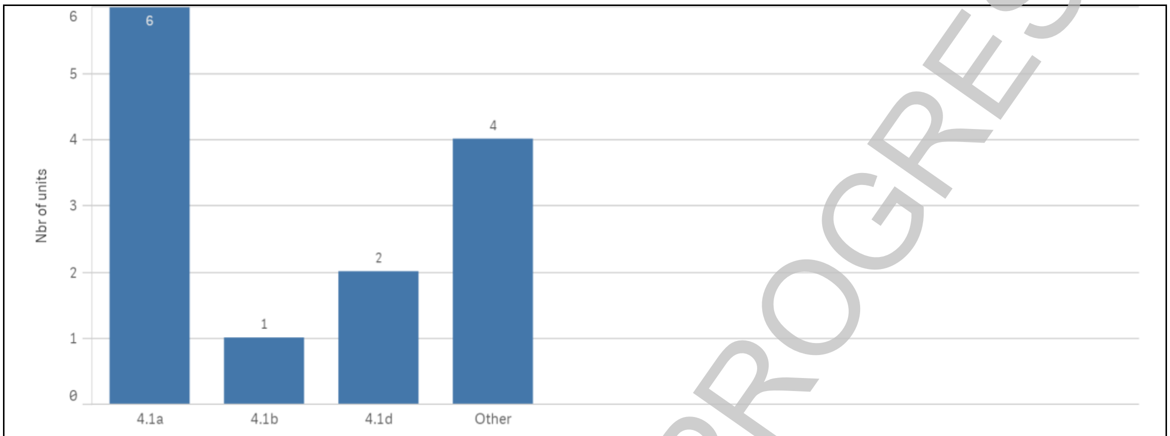
NB: 16 operators reported fugitive emissions of TVOC containing substances classified as CMR 1A or 1B for 20 units.
Source: [43, EIPPCB 2019]

Figure 2.149:Quantity of total VOC containing substances classified as CMR 2 non-fugitive emissions reported by chemical activity

A wide range of quantities was reported 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 526 tonnes per year.

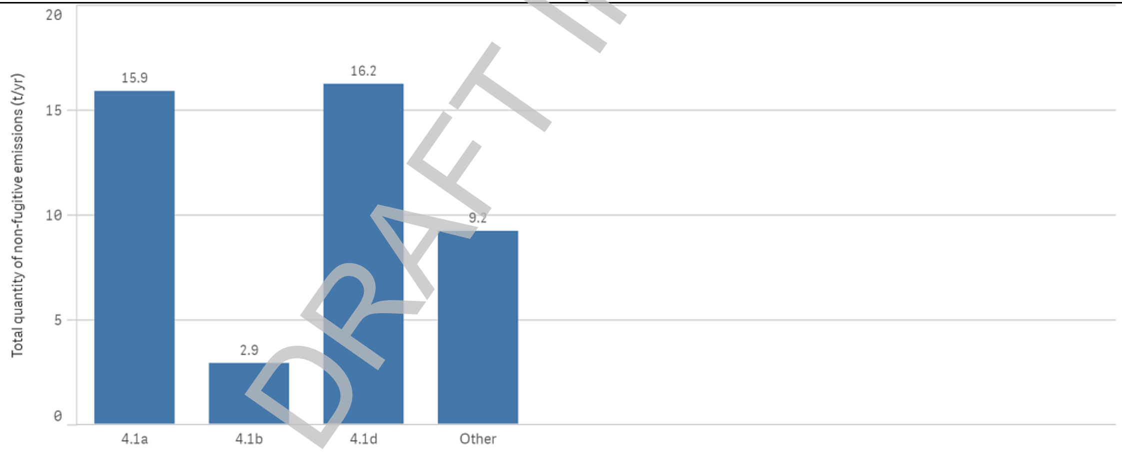
2.4.2.1.4 Benzene

Figure 2.150 shows the number of units reporting non-fugitive benzene emissions and Figure 2.151 shows the chemical activities that most contribute to non-fugitive benzene emissions.



Source: [43, EIPPCB 2019]

Figure 2.150:Non-fugitive benzene emissions reported by chemical activity



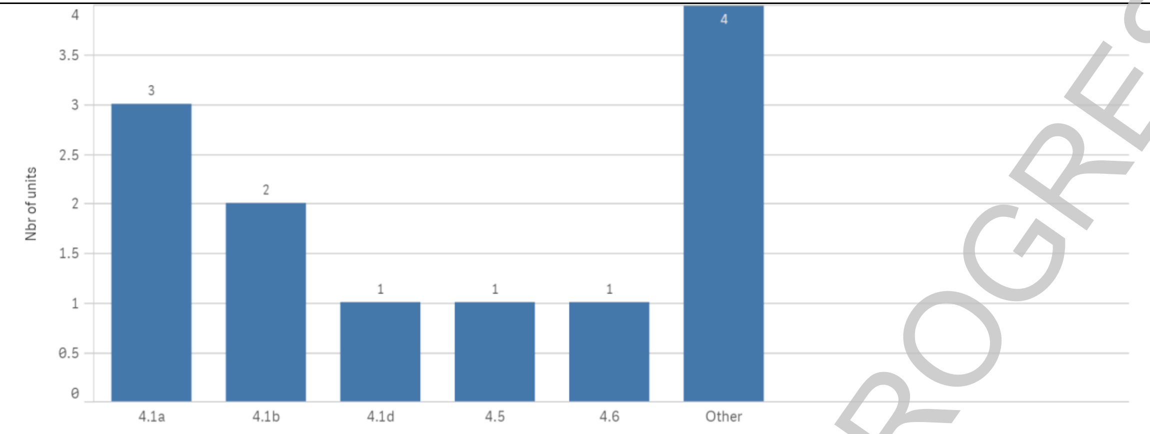
Source: [43, EIPPCB 2019]

Figure 2.151:Quantity of non-fugitive benzene emissions reported by chemical activity

A wide range of quantities was reported 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.

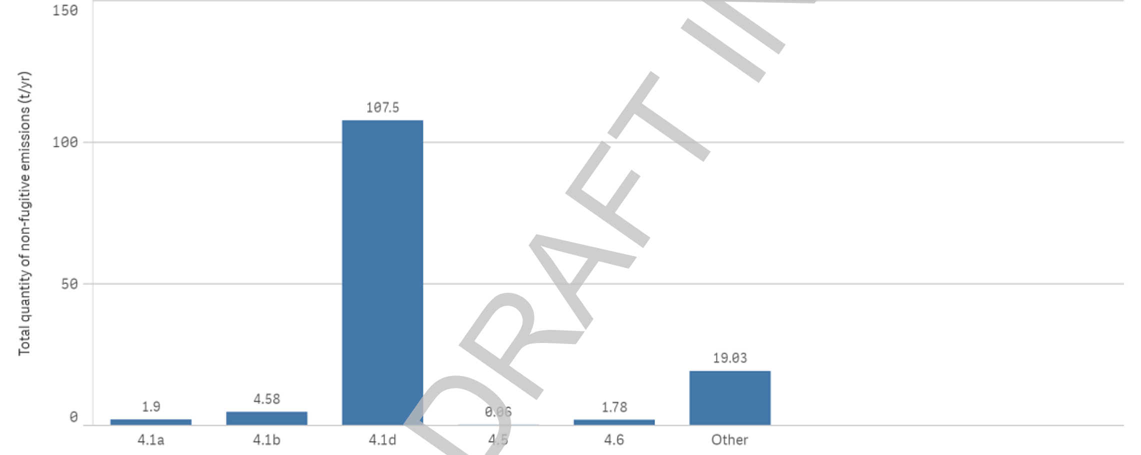
2.4.2.1.5 Toluene

Figure 2.152 shows the number of units reporting non-fugitive toluene emissions and Figure 2.153 shows the chemical activities contributing to non-fugitive emissions of toluene.



Source: [43, EIPPCB 2019]

Figure 2.152:Non-fugitive toluene emissions reported by chemical activity



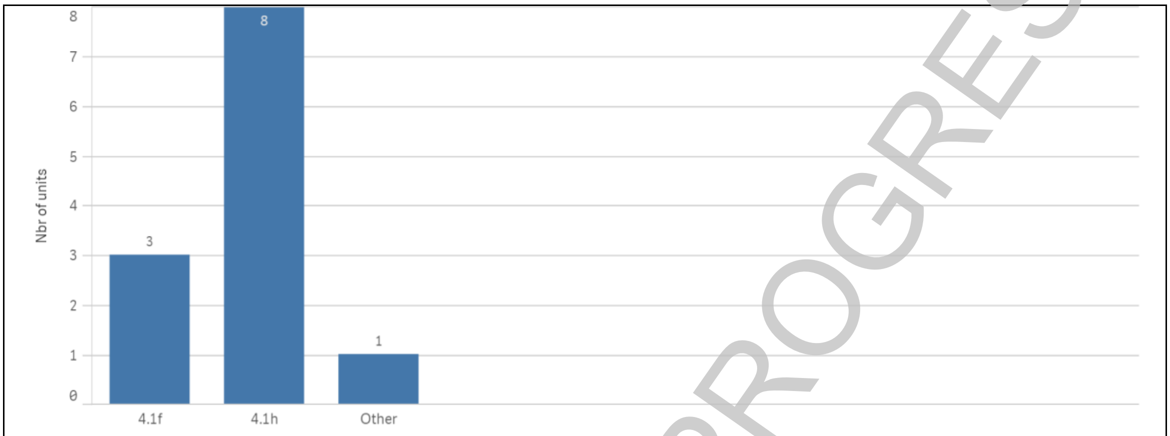
Source: [43, EIPPCB 2019]

Figure 2.153:Quantity of non-fugitive toluene emissions reported by chemical activity

A wide range of quantities was reported 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 2.154 shows the number of units reporting non-fugitive vinyl chloride emissions and Figure 2.155 shows the chemical activities contributing to non-fugitive emissions of vinyl chloride.



Source: [43, EIPPCB 2019]

Figure 2.154:Non-fugitive vinyl chloride emissions reported by chemical activity

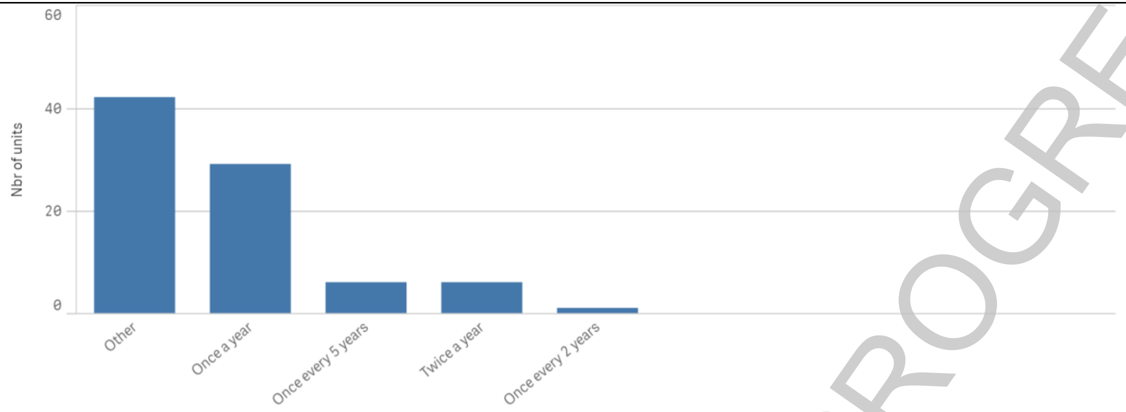
Source: [43, EIPPCB 2019]

Figure 2.155:Quantity of non-fugitive vinyl chloride emissions reported by chemical activity

A wide range of quantities was reported from 10 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 2.156 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.



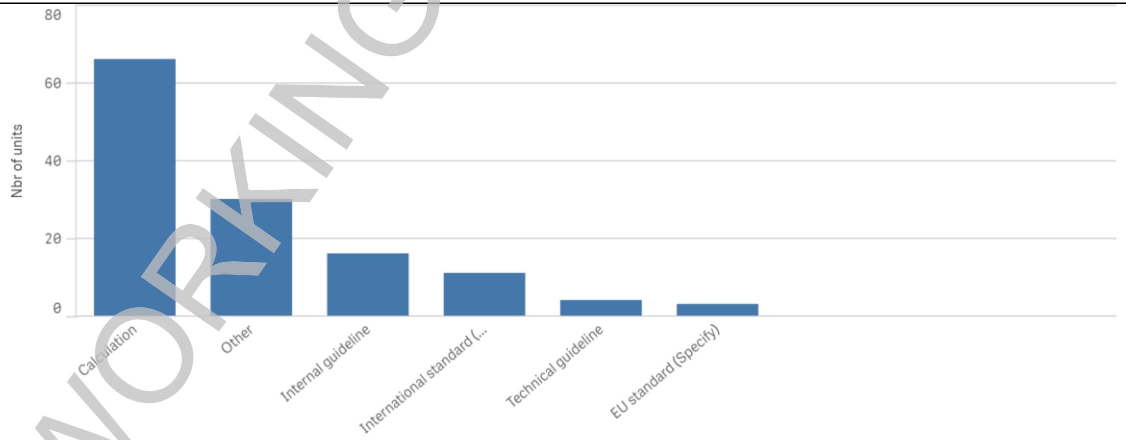
Source: [43, EIPPCB 2019]

Figure 2.156:Monitoring frequency for non-fugitive VOC emissions

The following sources are included in the monitoring:

- atmospheric vents (reported by 32 units);
- bulk storage (reported by 6 units);
- loading/unloading operations (reported by 15 units);
- open gutters (reported by 2 units);
- opening of vessel and tanks (reported by 10 units);
- sampling systems (reported by 8 units);
- sewers (reported by 2 units).

Figure 2.157 shows the monitoring methods for non-fugitive VOC emissions. In most cases, calculation methods are applied.



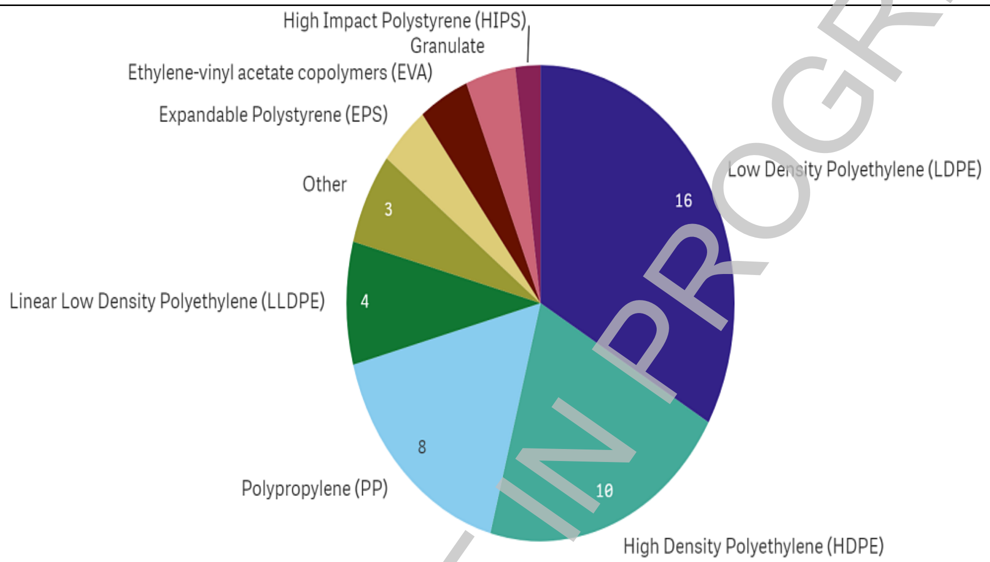
Source: [43, EIPPCB 2019]

Figure 2.157:Monitoring methods for non-fugitive VOC emissions

2.5 Production of polyolefins

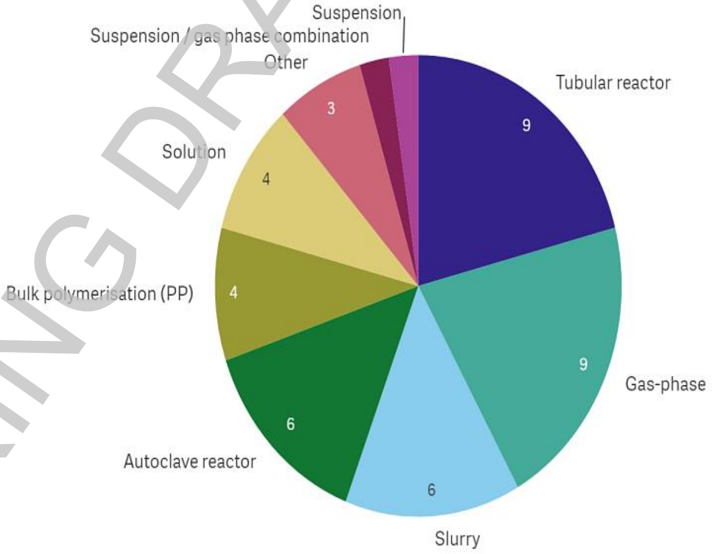
2.5.1 Overview

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 2.158 and Figure 2.159 show the types of products and the types of processes reported in the data collection.



Source: [43, EIPPCB 2019]

Figure 2.158:Types of polyolefin products



Source: [43, EIPPCB 2019]

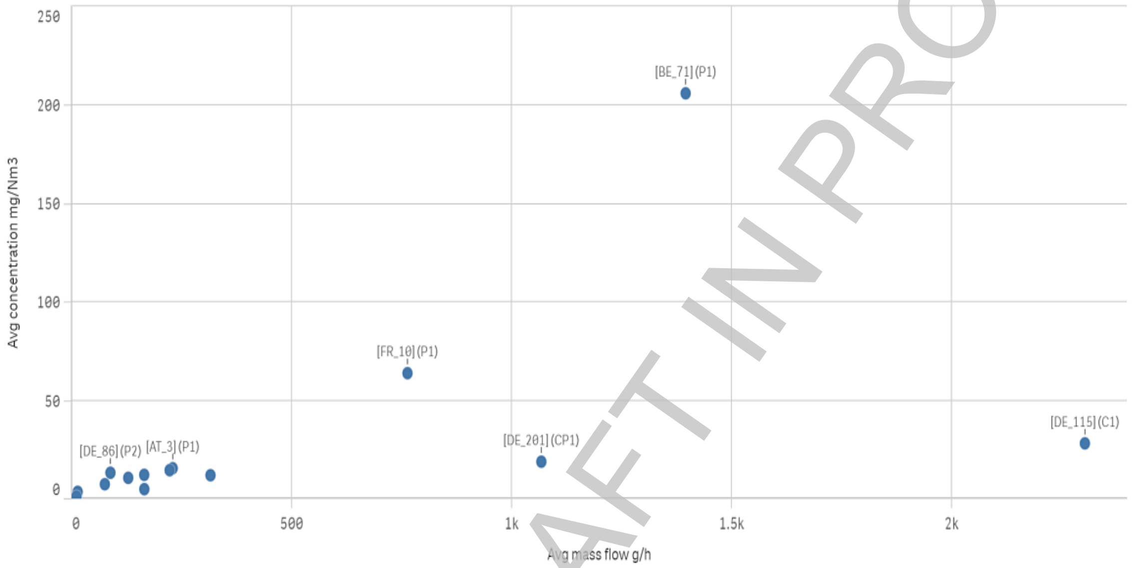
Figure 2.159:Types of production processes for polyolefins

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 2.160.

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.

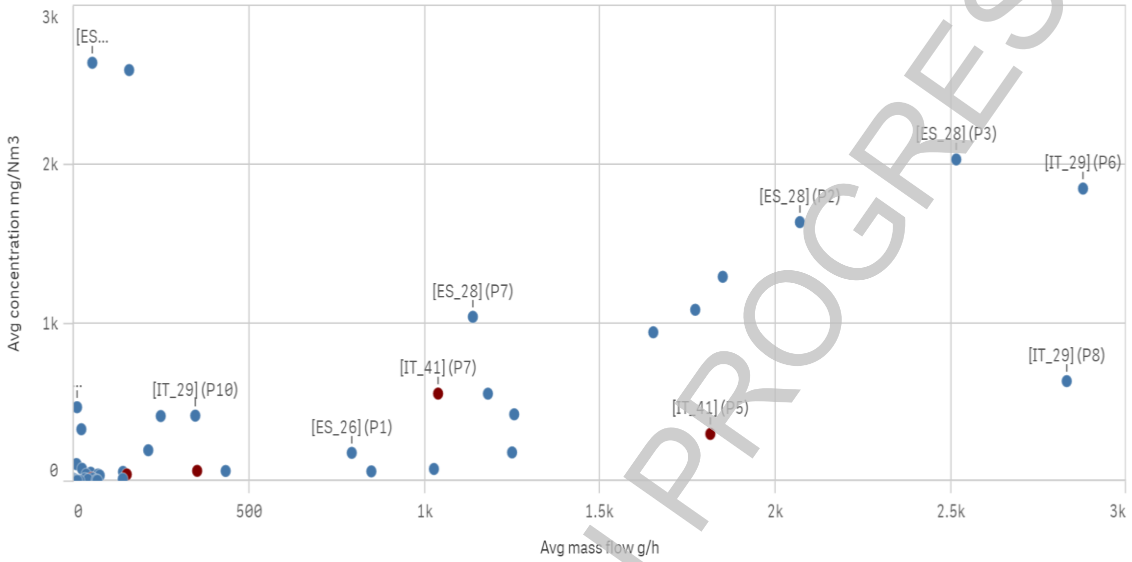


NB: 10 operators reported TVOC emissions from 15 emission points in the data collection, applying the common waste gas treatment techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-2 500 mg TVOC/Nm^3 are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.160: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 2.161.

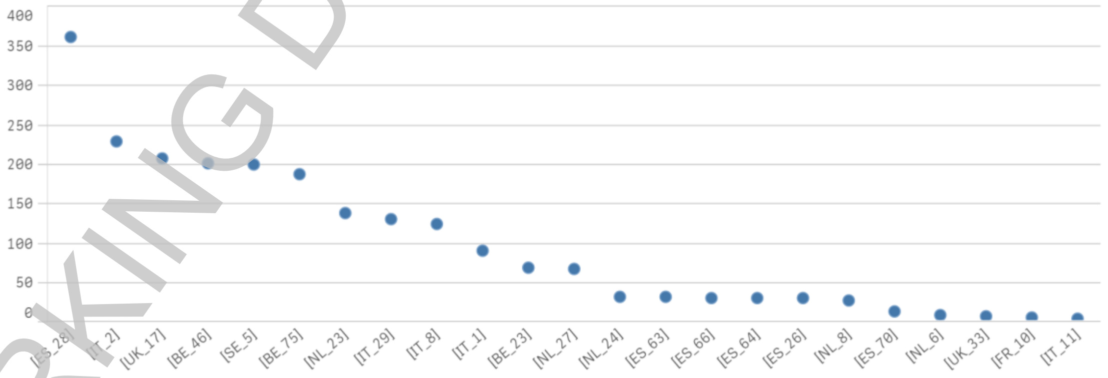


NB: 14 operators reported TVOC (or NMVOC shown as red dots) emissions from 85 emission points in the data collection. For better visualisation, emission points with concentrations in the range of 0-3 000 mg TVOC/Nm^3 are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.161:TVOC emission points with no waste gas treatment

2.5.4 Fugitive emissions

Fugitive TVOC emissions are shown in Figure 2.162.

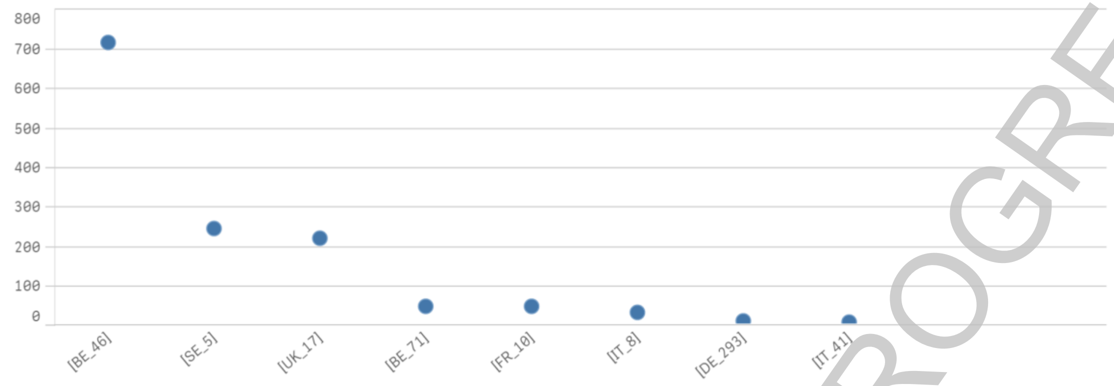


Source: [43, EIPPCB 2019]

Figure 2.162:Fugitive TVOC emissions

2.5.5 Non-fugitive emissions

Seven questionnaires reported non-fugitive TVOC emissions. Non-fugitive emissions are shown in Figure 2.163.

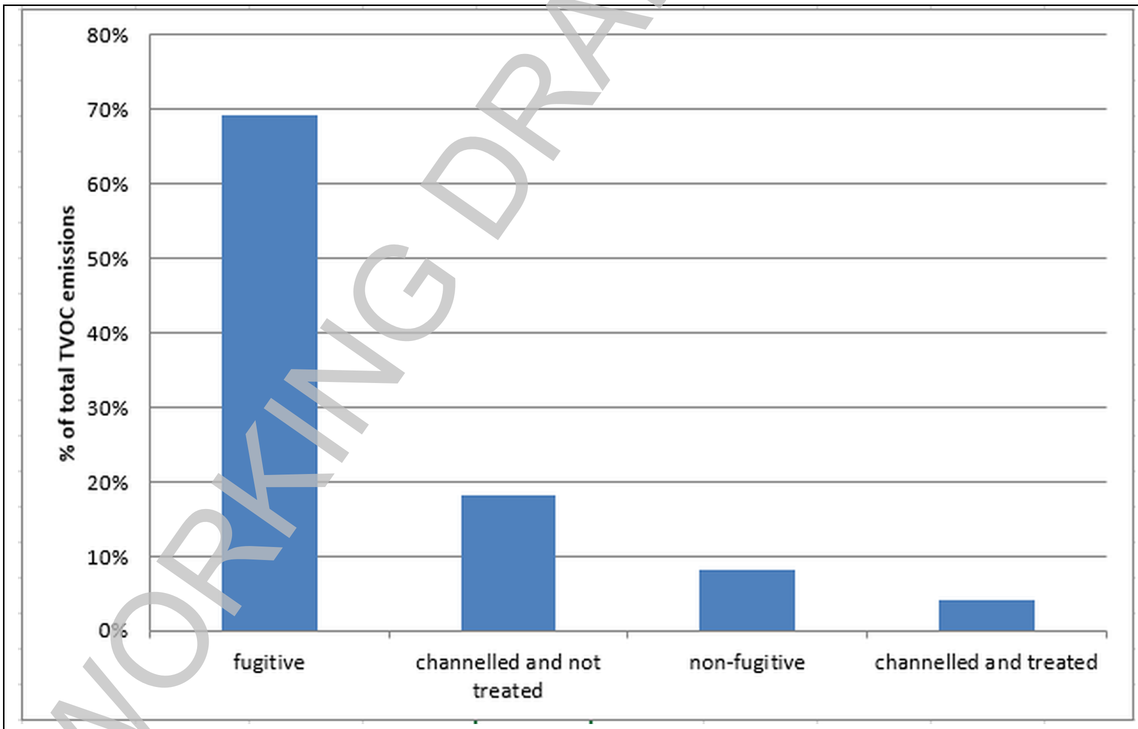


Source: [43, EIPPCB 2019]

Figure 2.163:Non-fugitive TVOC emissions

2.5.6 Total TVOC emissions

Total TVOC emissions reported for the polyolefins sector are shown as percentages in Figure 2.164. Data reported for fugitive and non-fugitive emissions provided in tonnes per year were converted into grams per hour.



NB: Aggregated data on TVOC emissions reported by the polyolefin sector.
Source: [43, EIPPCB 2019]

Figure 2.164:Total TVOC emissions

2.5.7 Specific loads

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

Table 2.35 shows specific loads for common types of polyolefins, see Section 2.5.1.

Table 2.35: Specific loads for types of polyolefins (kg TVOC/t of product)

No of companies	No of emission points / units	Type	Specific loads		
			Min.	Average	Max.
12	49	All	0.03	0.8	20.4
8	14	LDPE	0.03	0.8	1.9
4	7	HDPE	Data not shown		
3	13	PP			

Source: [43, EIPPCB 2019]

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 2.36 shows monomer concentrations after treatment (see Section 3.5.1.2).

Table 2.36: 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	9.9
4	18	LDPE	Data not shown		
1	3	HDPE			
1	4	PP			

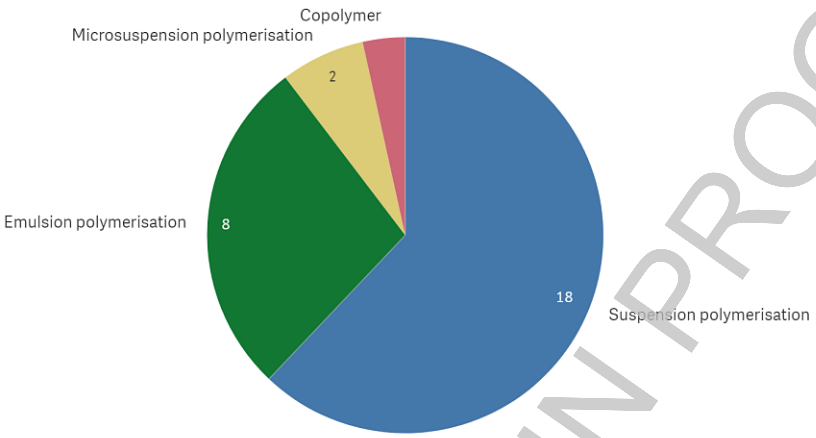
Source: [43, EIPPCB 2019]

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 2.165 shows the types of PVC reported in the data collection.



Source: [43, EIPPCB 2019]

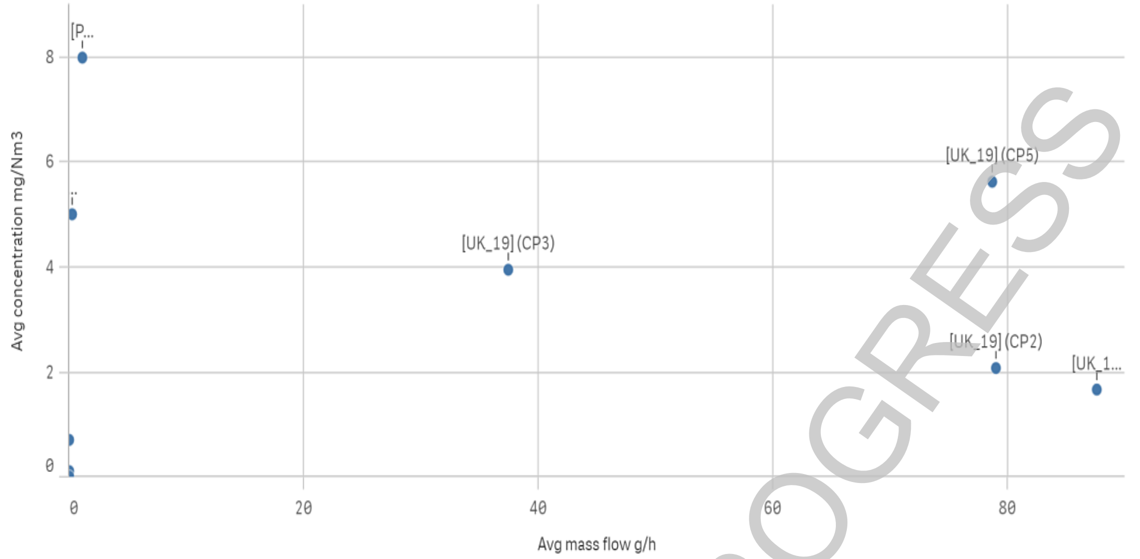
Figure 2.165:Types of PVC

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 2.166.

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

- absorption;
- adsorption;
- condensation.

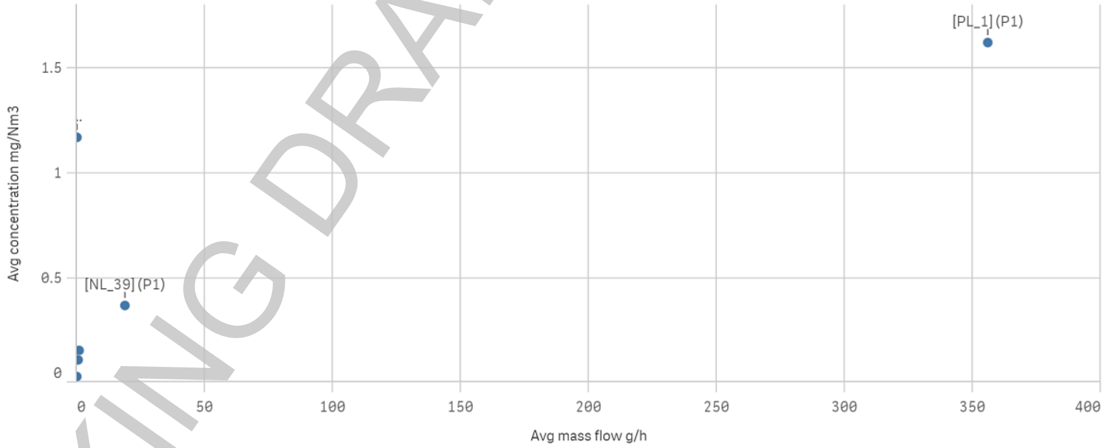


NB: 8 operators reported VCM emissions from 15 emission points in the data collection, applying the common waste gas treatment techniques listed above. For 5 emission points, no information on the mass flow was available.
For better visualisation, only emission points with concentrations in the range of 0-20 mg VCM/Nm^3 and mass flows in the range of 0-100 g VCM/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.166:VCM emissions after waste gas treatment

2.6.3 Untreated channelled emissions

The typical emission levels of VCM when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.167.

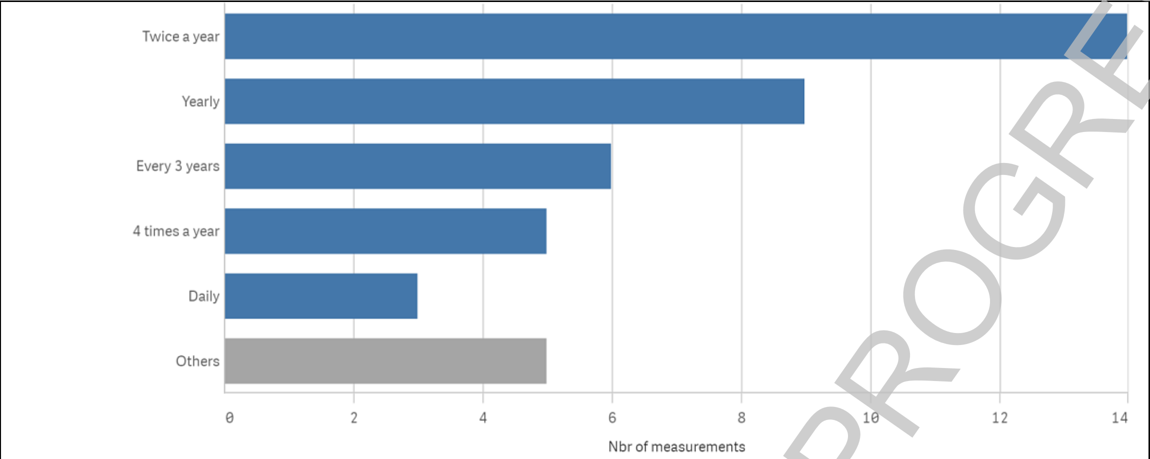


NB: 5 operators reported VCM emissions from 5 emission points in the data collection.
Source: [43, EIPPCB 2019]

Figure 2.167:VCM emission points with no waste gas treatment technique

2.6.4 Monitoring

Periodic monitoring and continuous monitoring are both commonly used: 39 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 2.168.



Source: [43, EIPPCB 2019]

Figure 2.168:Reported measurement frequencies for periodic VCM monitoring

Percentiles for reported limits of quantification and limits of detection for VCM measurements are shown in Table 2.37.

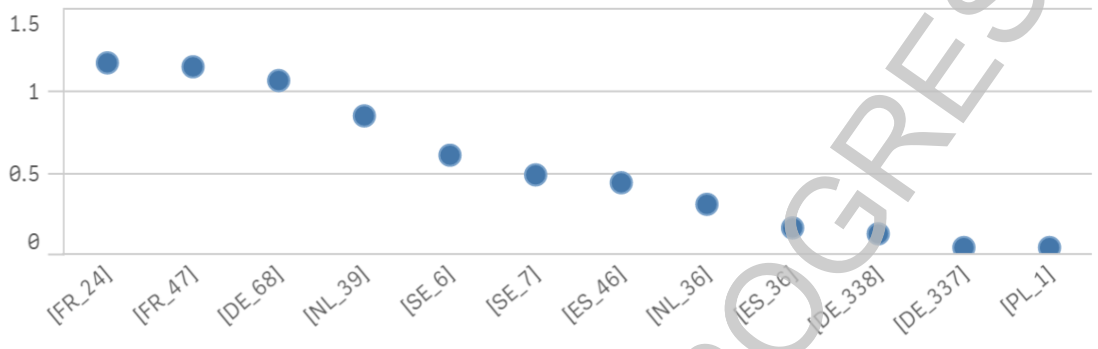
Table 2.37: Reported limits of quantification and detection for VCM

Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.04	0.03
50th	0.06	0.06
80th	0.10	0.10

NB: The numbers of instances reported for the limits of quantification and detection are 22 and 18, respectively.
Source: [43, EIPPCB 2019]

2.6.5 Fugitive emissions

Figure 2.169 shows fugitive emissions of vinyl chloride.

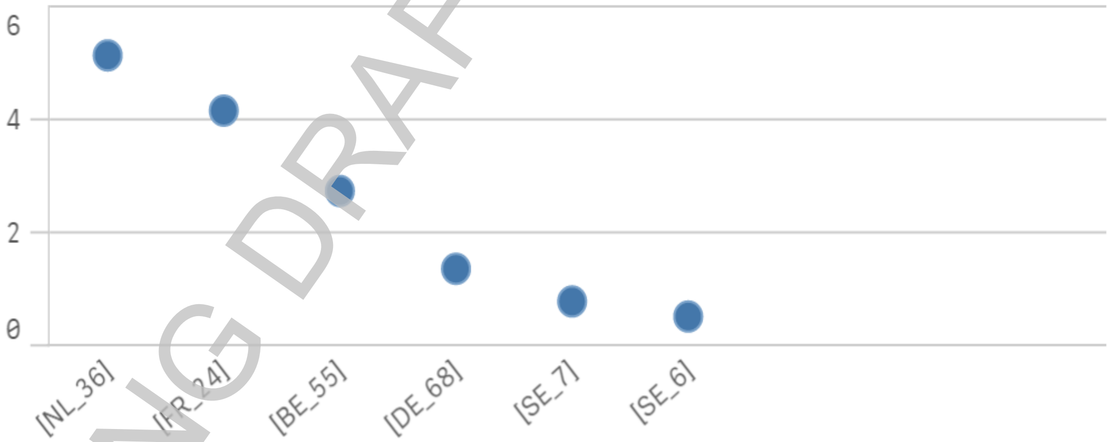


Source: [43, EIPPCB 2019]

Figure 2.169:Fugitive vinyl chloride emissions

2.6.6 Non-fugitive emissions

Non-fugitive vinyl chloride emissions are shown in Figure 2.170.

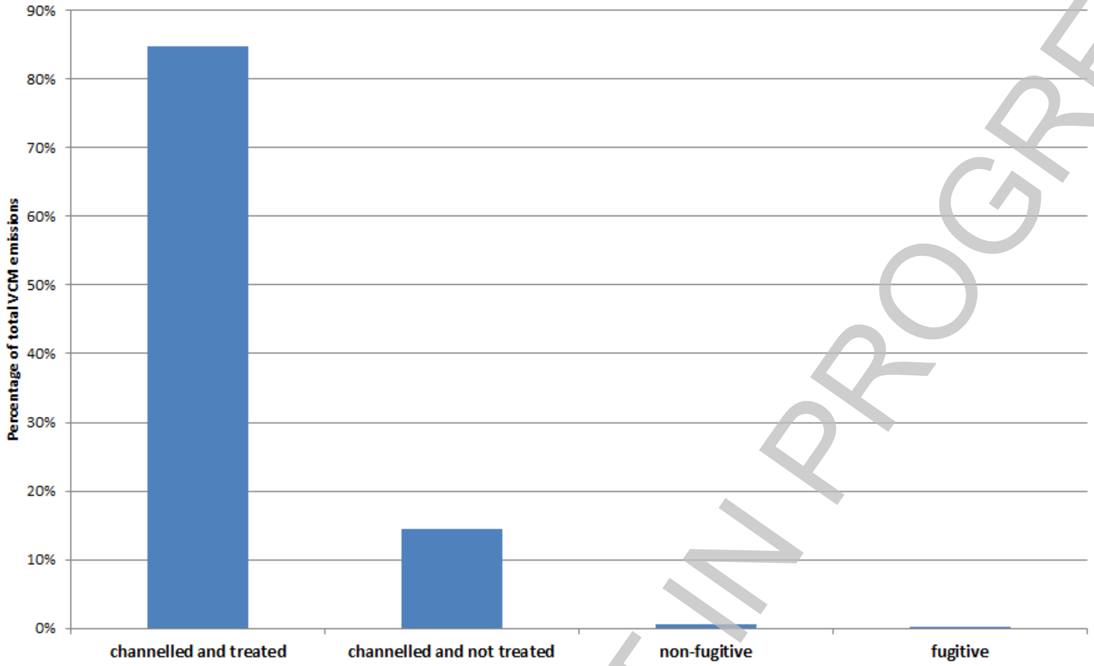


Source: [43, EIPPCB 2019]

Figure 2.170:Non-fugitive vinyl chloride emissions

2.6.7 Total vinyl chloride emissions

Total vinyl chloride emissions reported for the PVC sector are shown as percentages in Figure 2.171. Data reported for fugitive and non-fugitive emissions provided in tonnes per year were converted into grams per hour.



NB: Aggregated data on vinyl chloride emissions reported by the PVC sector via 20 questionnaires representing 34 emission points.
Source: [43, EIPPCB 2019]

Figure 2.171:Total vinyl chloride emissions

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.

Table 2.38 shows specific loads for common types of PVC (see Section 2.6.1).

Table 2.38: Specific loads for types of PVC (kg vinyl chloride/t of PVC)

No of companies	No of emission points / units	Type	Specific load		
			Min.	Average	Max.
15	18	Suspension	0.01	0.03	0.05
6	6	Emulsion	0.1	0.3	0.5
1	2	Emulsion microsuspension	Data not shown		

Source: [43, EIPPCB 2019]

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.

Table 2.39 shows monomer concentrations after treatment (see Section 3.5.1.2).

Table 2.39: Monomer concentrations after treatment for common PVC types (g vinyl chloride/kg of PVC)

No of companies	No of emission points / units	Type	Monomer concentrations		
			Min.	**Average**	**Max.**
9	25	Suspension	0.001	0.025	0.3
2	3	Emulsion	Data not shown		
1	1	Emulsion - microsuspension			

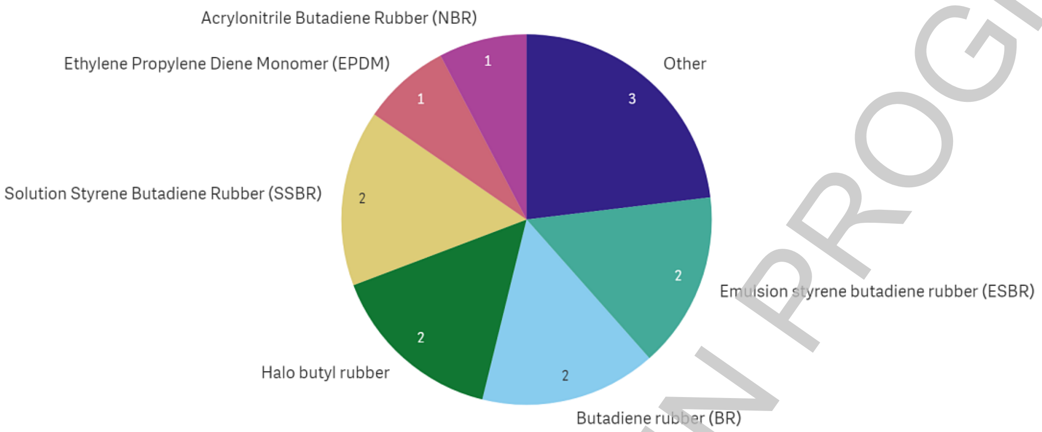
Source: [43, EIPPCB 2019]

2.7 Production of solution-polymerised rubbers

2.7.1 Overview

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

Figure 2.172 shows the types of solution-polymerised rubbers reported in the data collection.



Source: [43, EIPPCB 2019]

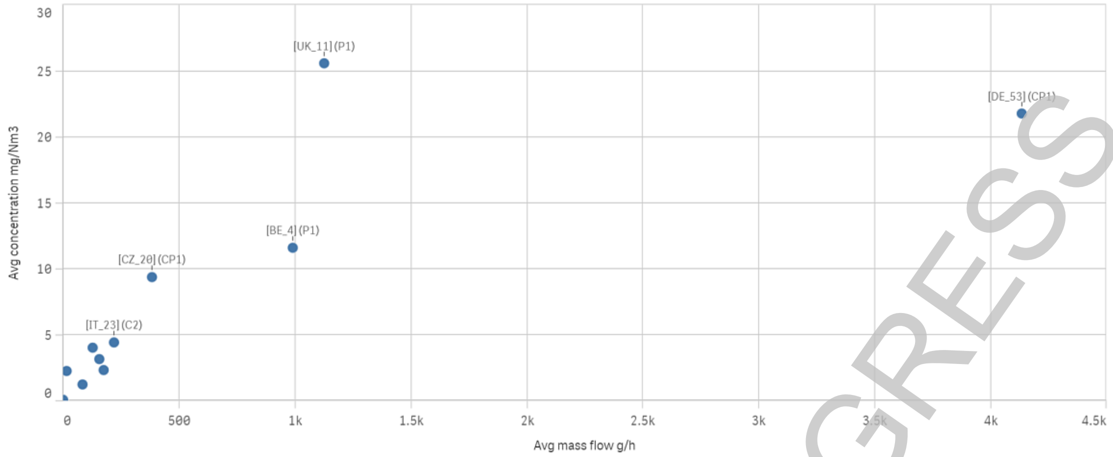
Figure 2.172:Types of solution-polymerised rubber

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 2.173 and Figure 2.174.

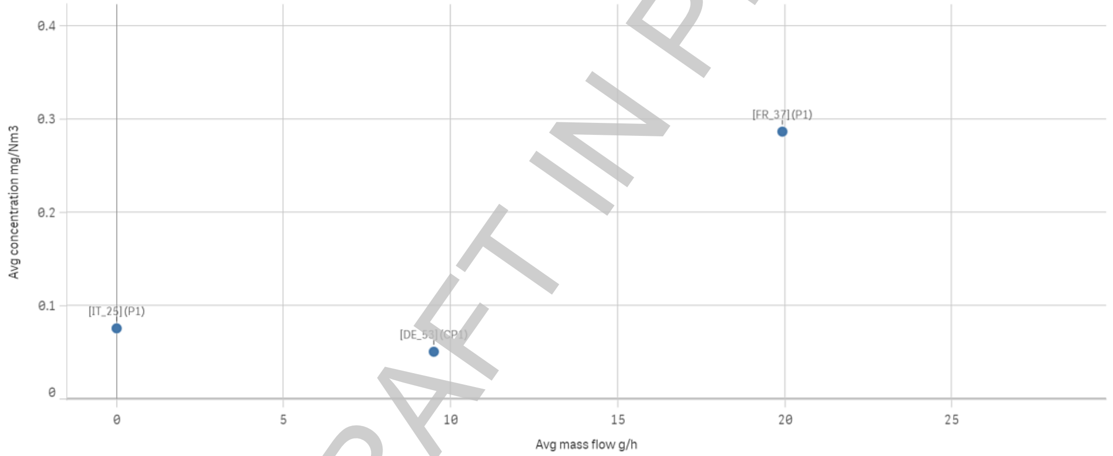
The techniques most commonly applied, alone or in combination, in waste gas treatment systems of chemical plants are the following:

- adsorption;
- condensation;
- thermal oxidation.



NB: 9 operators reported TVOC emissions from 16 emission points in the data collection, applying the common waste gas treatment techniques listed above.
Source: [43, EIPPCB 2019]

Figure 2.173:TVOC emissions after waste gas treatment

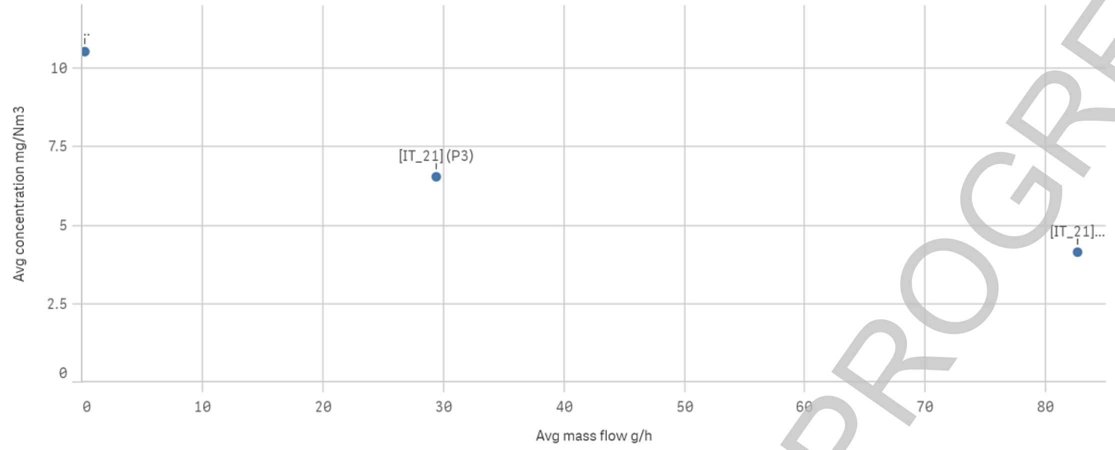


NB: 3 operators reported 1,3-butadiene emissions from 3 emission points in the data collection, applying the common waste gas treatment techniques listed above.
Source: [43, EIPPCB 2019]

Figure 2.174:1,3-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 2.175. No data for 1,3-butadiene were reported in the data collection.



NB: 1 operator reported TVOC emissions from 3 emission points in the data collection.
Source: [43, EIPPCB 2019]

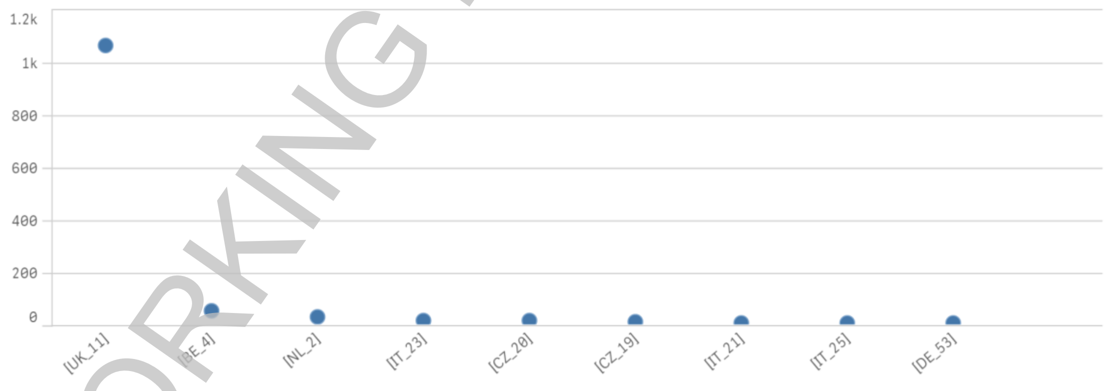
Figure 2.175:TVOC emission points with no waste gas treatment technique

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

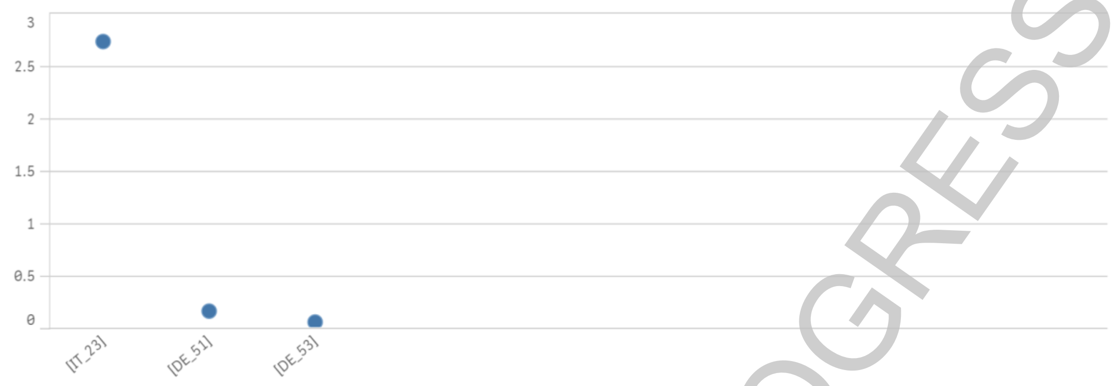
Figure 2.176 shows reported data for fugitive TVOC emissions.



Source: [43, EIPPCB 2019]

Figure 2.176:Fugitive TVOC emissions

Figure 2.177 shows reported data for fugitive 1,3-butadiene emissions.

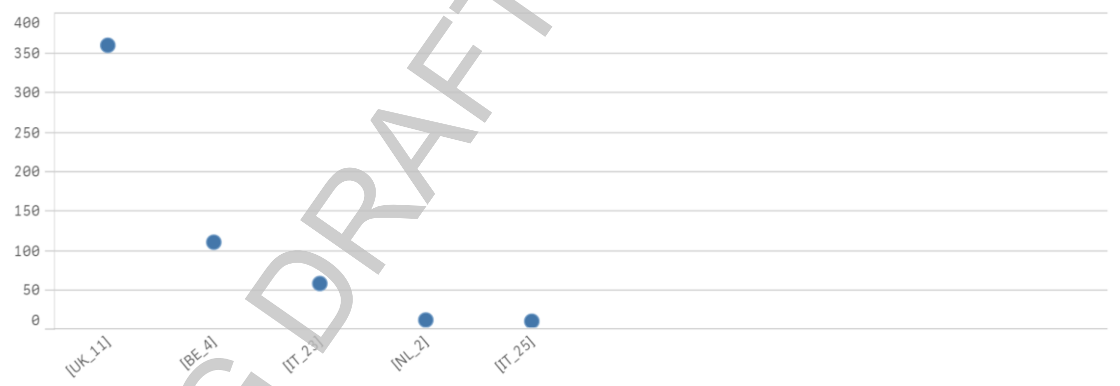


NB: 2 operators reported fugitive 1,3-butadiene emissions.
Source: [43, EIPPCB 2019]

Figure 2.177:Fugitive 1,3-butadiene emissions

2.7.6 Non-fugitive emissions

Figure 2.178 shows reported data for the non-fugitive TVOC emissions.



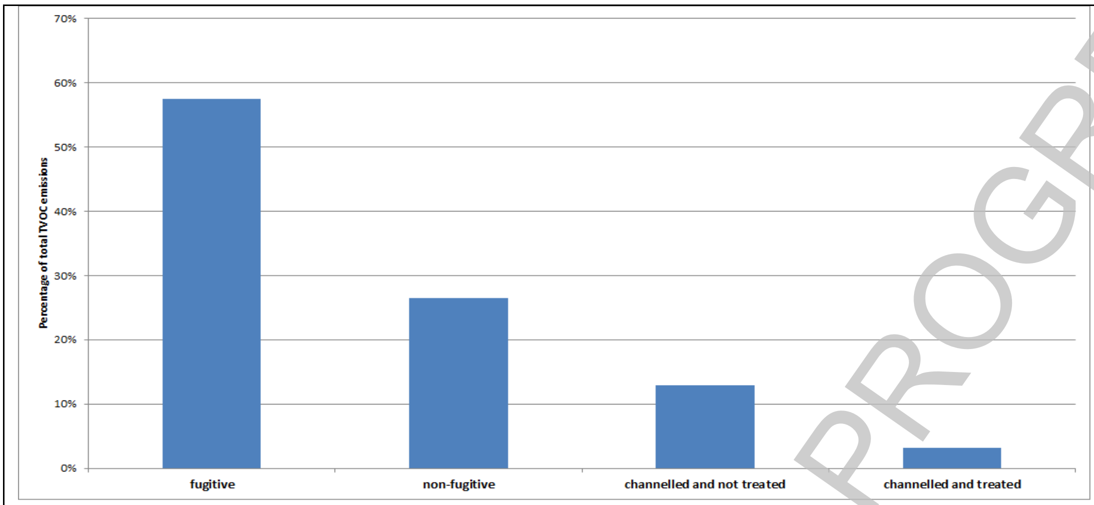
Source: [43, EIPPCB 2019]

Figure 2.178:Non-fugitive TVOC emissions

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

2.7.7 Total TVOC emissions

Total TVOC emissions reported for the solution-polymerised rubber sector are shown as percentages in Figure 2.179. Data reported for fugitive and non-fugitive emissions provided in tonnes per year were converted into grams per hour.



NB: Aggregated TVOC emissions reported by the solution-polymerised rubber sector via 10 questionnaires representing 25 emission points.
Source: [43, EIPPCB 2019]

Figure 2.179: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.

Table 2.40 shows specific loads for common types of solution-polymerised rubbers (see Section 2.7.1).

Table 2.40: Specific loads for types of solution-polymerised rubbers (kg TVOC/t of product)

No of companies	**No of emission points / units**	**Type**	**Specific loads**		
			Min.	**Average**	**Max.**
6	8	All	0.1	3.9	10.9
1	2	EDPM	Data not shown		
1	1	NBR			
Source: [43, EIPPCB 2019]					

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_2)

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 2.41 shows the types of products reported in the data collection.

Table 2.41: Types of viscose

Product	Plant
Cellophane	UK_12 (1)
Filament fibre	CZ_6, DE_376, DE_377
Food casings	BE_73, DE_378, FI_4
Sponge cloth	DE_378
Staple fibre	AT_8, DE_341
(1) No data on concentration available.	

2.8.2 Channelled emissions of carbon disulphide (CS_2) to air

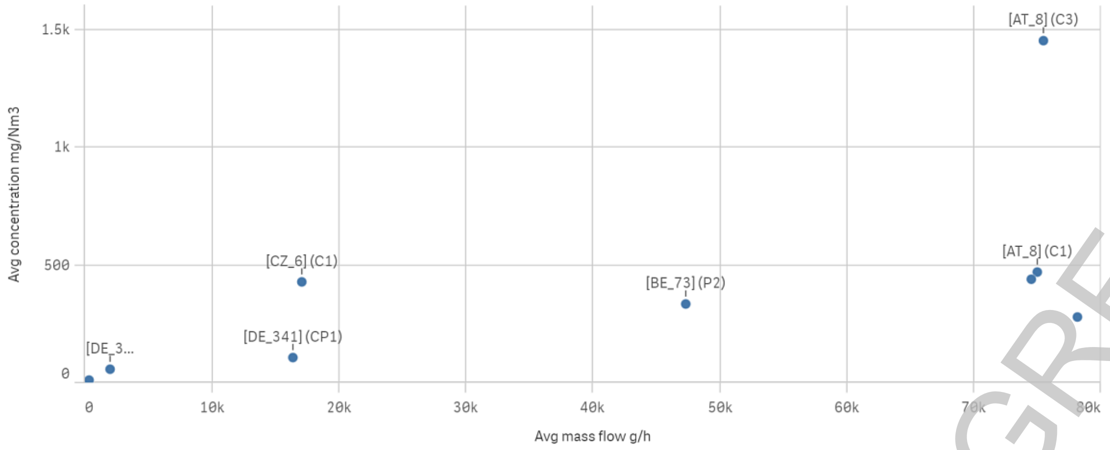
CS_2 is typically emitted from the production of viscose and it was reported by nine operators for 23 emission points in the data collection.

2.8.2.1 Treated emissions

CS_2 is generally treated with at least one waste gas treatment technique. The typical emission levels of CS_2 after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.180.

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.

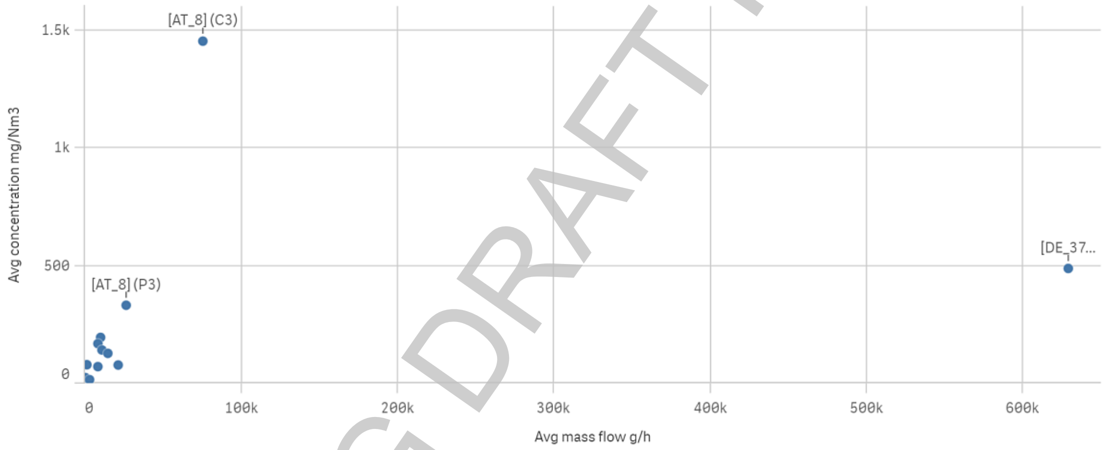


NB: 7 operators reported CS_2 emissions from 10 emission points in the data collection, applying the common waste gas treatment techniques listed above.
Source: [43, EIPPCB 2019]

Figure 2.180:CS_2 emissions after waste gas treatment

2.8.2.2 Untreated emissions

The typical emission levels of CS_2 when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.181.

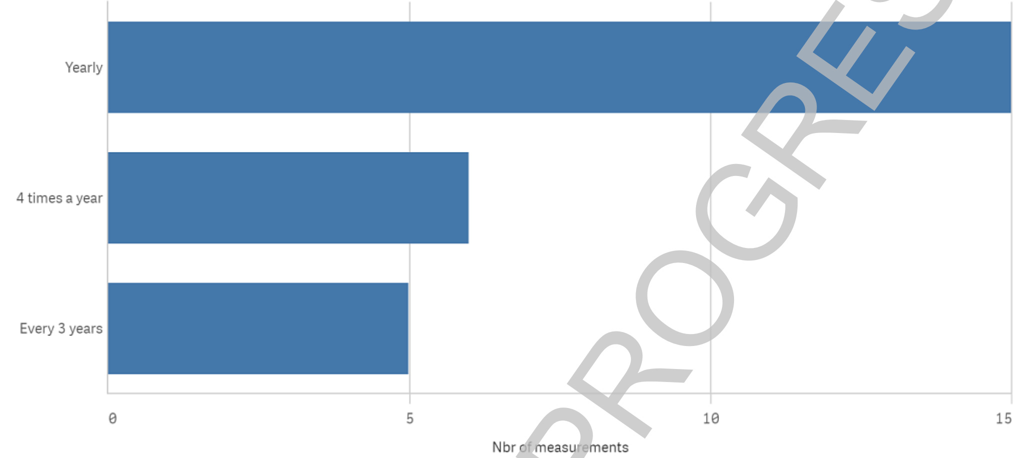


NB: 5 operators reported CS_2 emissions from 12 emission points in the data collection, without any prior waste gas treatment. For better visualisation, only emission points with concentrations in the range of 0-500 mg CS_2/Nm^3 are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.181:CS_2 emission points with no waste gas treatment technique

2.8.2.3 Monitoring

Periodic monitoring and continuous monitoring are both commonly used: 25 instances of periodic monitoring and 29 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled CS_2 emissions are shown in the bar chart of Figure 2.182.



Source: [43, EIPPCB 2019]

Figure 2.182:Reported measurement frequencies for periodic CS_2 monitoring

Percentiles for reported limits of quantification and limits of detection for CS_2 measurements are shown in Table 2.42.

Table 2.42: Reported limits of quantification and detection for CS_2

Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	12.0	0.1
50th	56.0	0.2
80th	100.0	4.1

NB: The numbers of instances reported for the limits of quantification and detection are 21 and 14, respectively.
Source: [43, EIPPCB 2019]

2.8.3 Channelled emissions of hydrogen sulphide (H_2S) to air

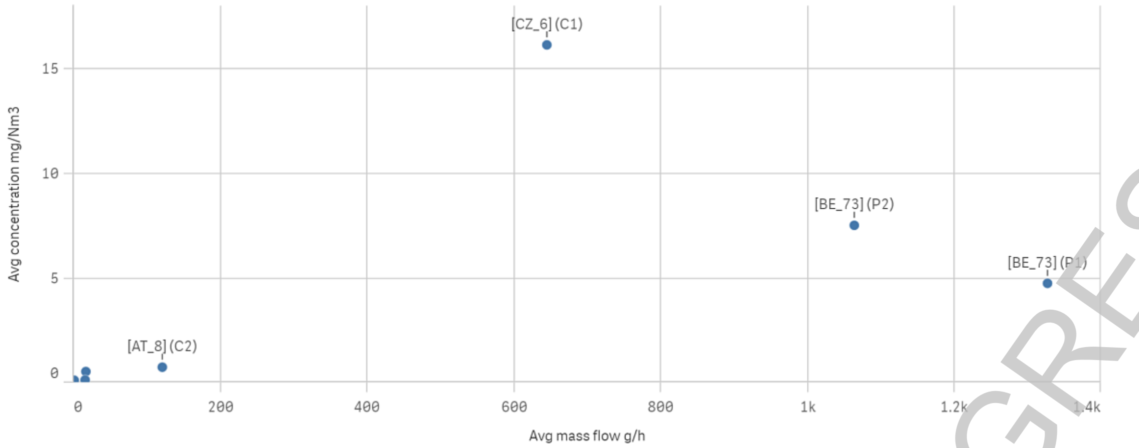
H_2S is typically emitted from the production of viscose and it was reported by eight operators representing 19 emission points in the data collection.

2.8.3.1 Treated emissions

H_2S is generally treated with at least one waste gas treatment technique. The typical emission levels of H_2S after waste gas treatment are shown as concentration and mass flow in the scatter plot of Figure 2.183.

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

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

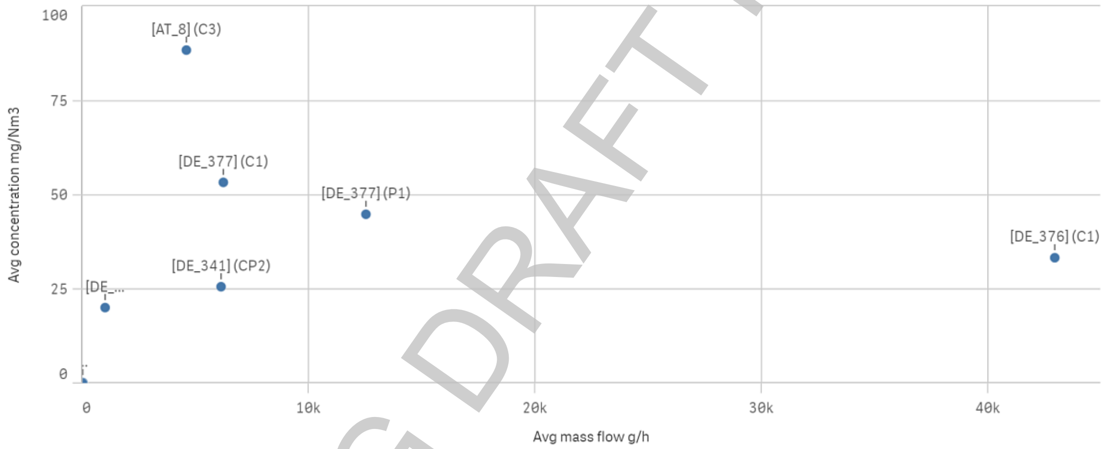


NB: 5 operators reported H_2S emissions from 6 emission points in the data collection, applying the common waste gas treatment techniques listed above.
Source: [43, EIPPCB 2019]

Figure 2.183:H_2S emissions after waste gas treatment

2.8.3.2 Untreated emissions

The typical emission levels of H_2S when no waste gas treatment is applied are shown as concentration and mass flow in the scatter plot of Figure 2.184.

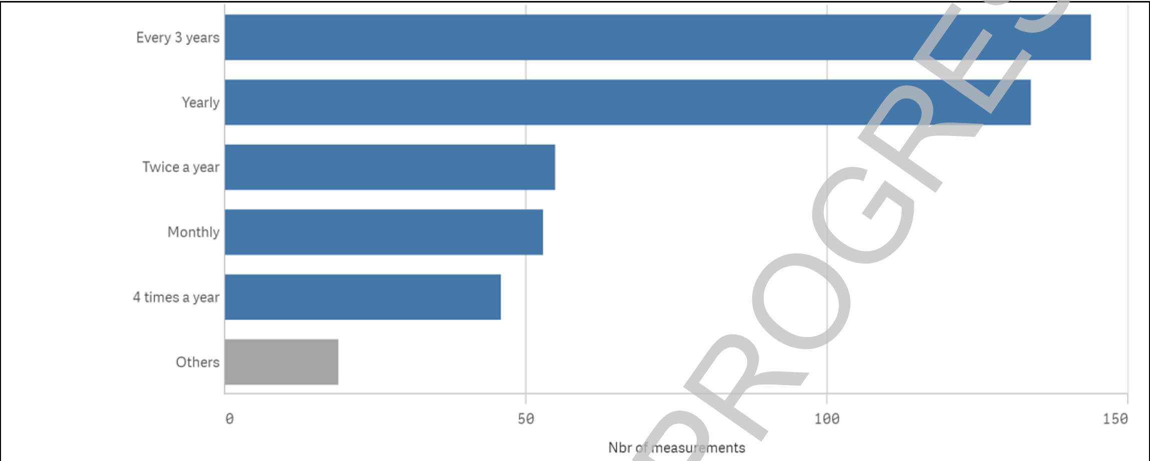


NB: 6 operators reported H_2S emissions from 9 emission points in the data collection, without any prior waste gas treatment.
Source: [43, EIPPCB 2019]

Figure 2.184:H_2S 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_2S emissions are shown in the bar chart of Figure 2.185.



Source: [43, EIPPCB 2019]

Figure 2.185: Reported measurement frequencies for periodic H_2S monitoring

Percentiles for reported limits of quantification and limits of detection for H_2S measurements are shown in Table 2.43.

Table 2.43: Reported limits of quantification and detection for H_2S

Percentile	Limit of quantification (mg/Nm^3)	Limit of detection (mg/Nm^3)
20th	0.45	0.1
50th	5.23	0.1
80th	10.0	1.5

NB: The numbers of instances reported for the limits of quantification and detection are 13 and 23, respectively.
Source: [43, EIPPCB 2019]

2.8.4 Specific loads of carbon disulphide (CS_2) to air

Information on specific loads of CS_2 was provided by six operators via six questionnaires. The range of specific loads is between 3 kg and 250 kg CS_2 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_2S) to air

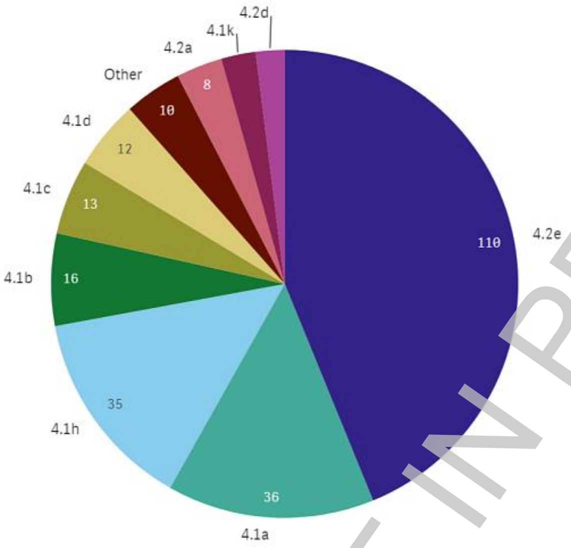
Information on specific loads of H_2S was provided by five operators via five questionnaires. The range of specific loads is between 0.1 kg and 23 kg H_2S per tonne of product. Specific loads are considered confidential business information. Data on types of products are not shown as the number of companies is less than five.

2.9 Process furnaces/heaters

2.9.1 Overview

Information on process furnaces/heaters was provided by 79 operators via 102 questionnaires representing 282 emission points.

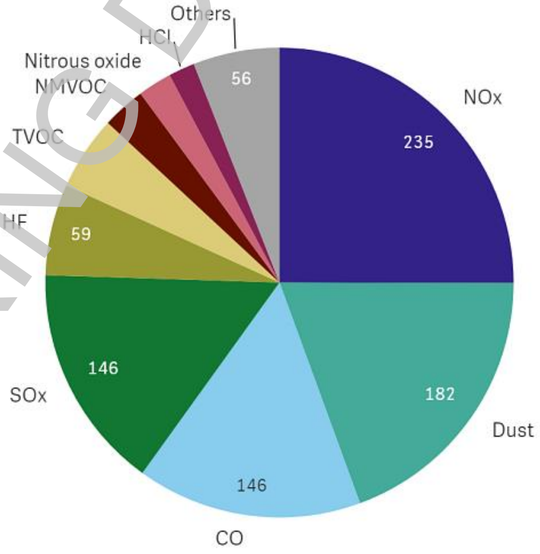
Figure 2.186 shows the use of process furnaces/heaters across the chemical industry.



NB: only the 10 top reported IED activities are shown on the diagram.
Source: [43, EIPPCB 2019]

Figure 2.186:Process furnace/heaters reported by main IED activity

Figure 2.187 shows the main substances/parameters emitted by process furnaces/heaters.



Source: [43, EIPPCB 2019]

Figure 2.187:Main substances/parameters emitted by process furnaces/heaters

Table 2.44 shows thermal input of individual process furnaces/heaters reported by emission point in the data collection.

Table 2.44: Thermal input per emission point (MW)

Thermal input (MW)	No of emission points
< 1	74
1-10	122
10-50	35
> 50	4
Source: [43, EIPPCB 2019]	

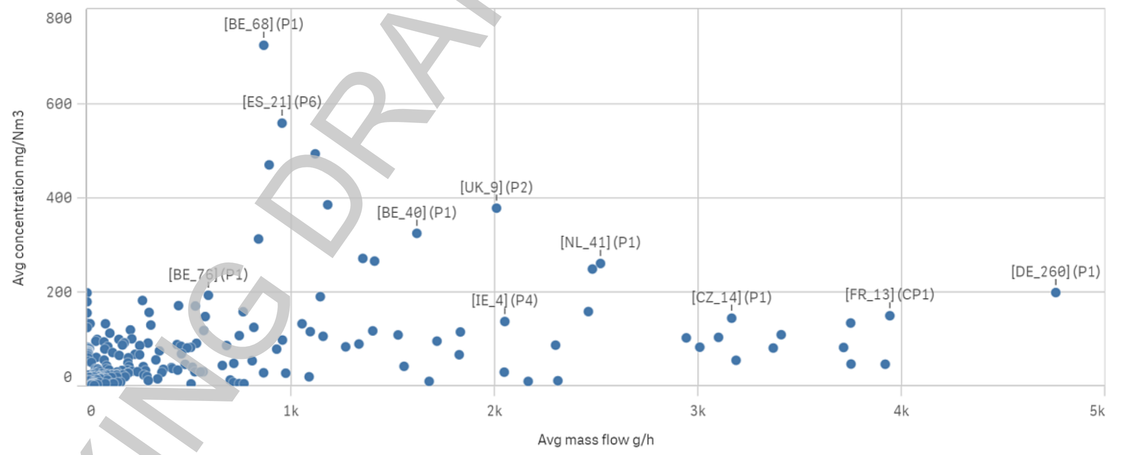
In most cases, natural gas is used as the fuel. Sometimes, process gases such as hydrogen are used as fuel in addition to natural gas.

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. Two companies reported emission levels of nitrogen oxides above 400 mg/Nm^3.

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 2.188.

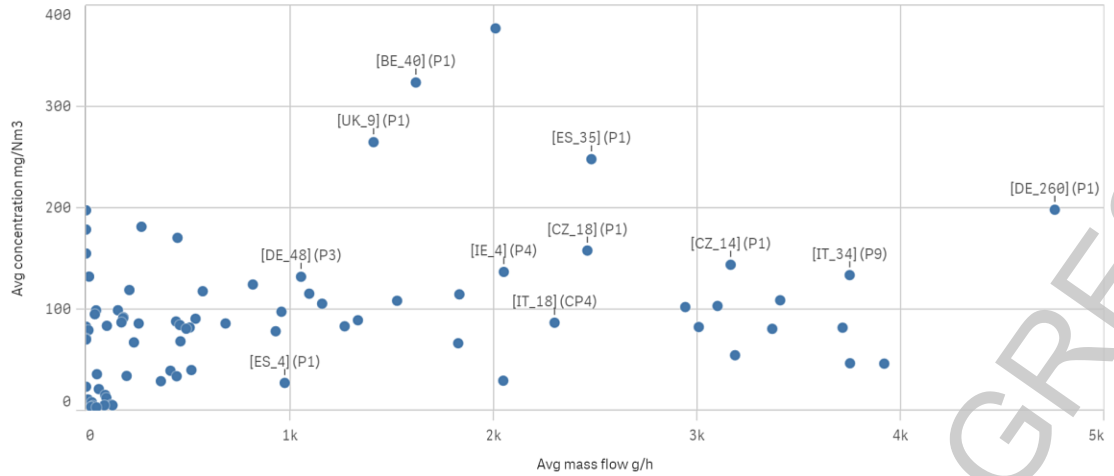


NB: 68 operators reported nitrogen oxide emissions from 233 emission points in the data collection. For better visualisation, only emission points with concentrations in the range of 0-750 mg NO_X/Nm^3 and mass flows in the range of 0-5 000 g NO_X/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.188:NO_X 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_X burners;
- reduction (SCR or SNCR).

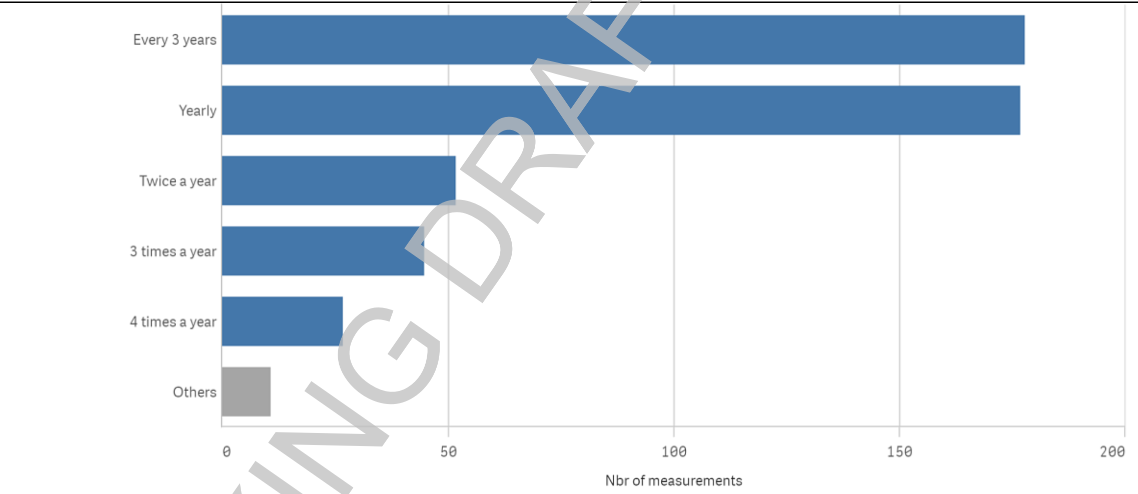


NB: 37 operators reported nitrogen oxide emissions from 85 emission points in the data collection, applying the common techniques listed above. For better visualisation, only emission points with concentrations in the range of 0-750 mg NO$_X$/Nm^3 and mass flows in the range of 0-5 000 g NO$_X$/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.189:NO$_X$ emissions from process furnaces/heaters applying common techniques for NO$_X$ reduction

2.9.2.2 Monitoring

Periodic monitoring is more common than continuous monitoring: 526 instances of periodic monitoring and 52 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled nitrogen oxide emissions are shown in the bar chart of Figure 2.190.



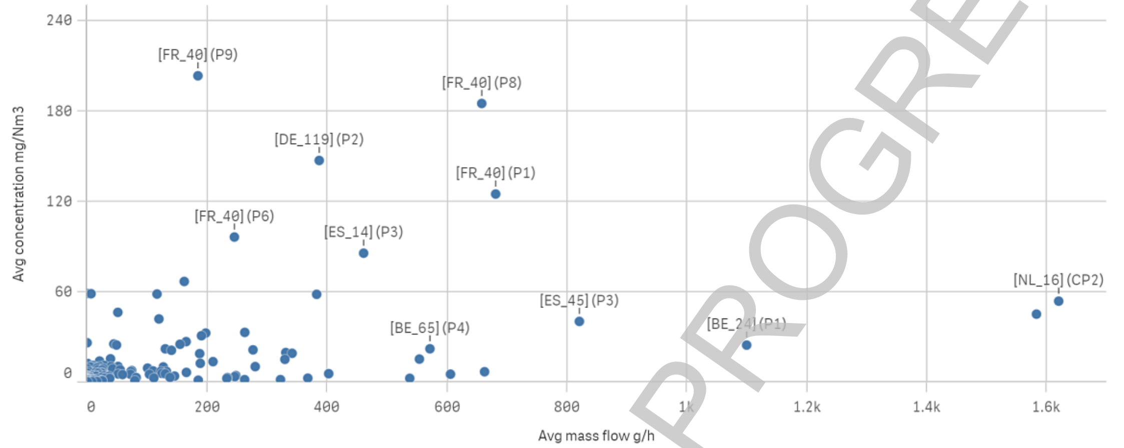
Source: [43, EIPPCB 2019]

Figure 2.190:Reported measurement frequencies for periodic monitoring of NO$_X$ from process furnaces/heaters

2.9.3 Carbon monoxide

2.9.3.1 Emissions

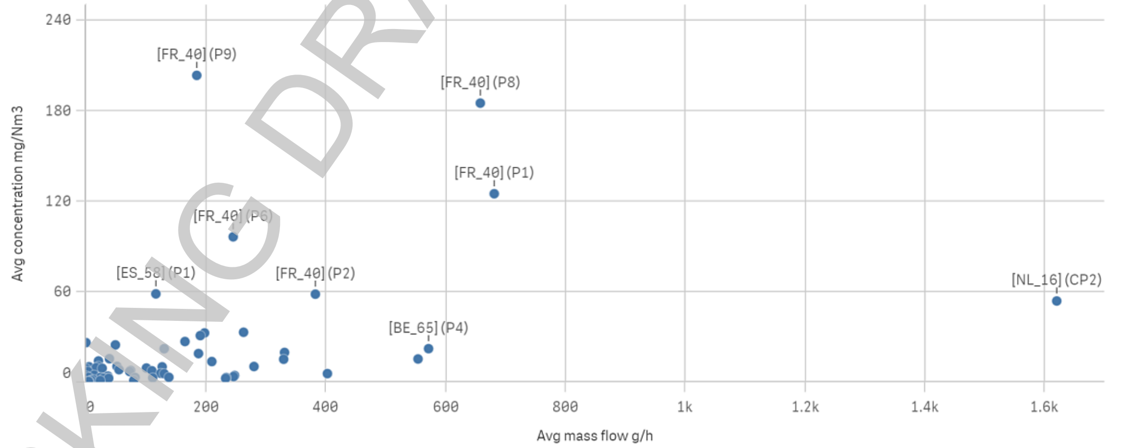
For process furnaces/heaters, the typical emission levels of carbon monoxide are shown as concentration and mass flow in the scatter plot of Figure 2.191.



NB: 49 operators reported carbon monoxide emissions from 145 emission points in the data collection. For better visualisation, only emission points with concentrations in the range of 0-500 mg CO/Nm^3 and mass flows in the range of 0-2 000 g CO/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.191: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.

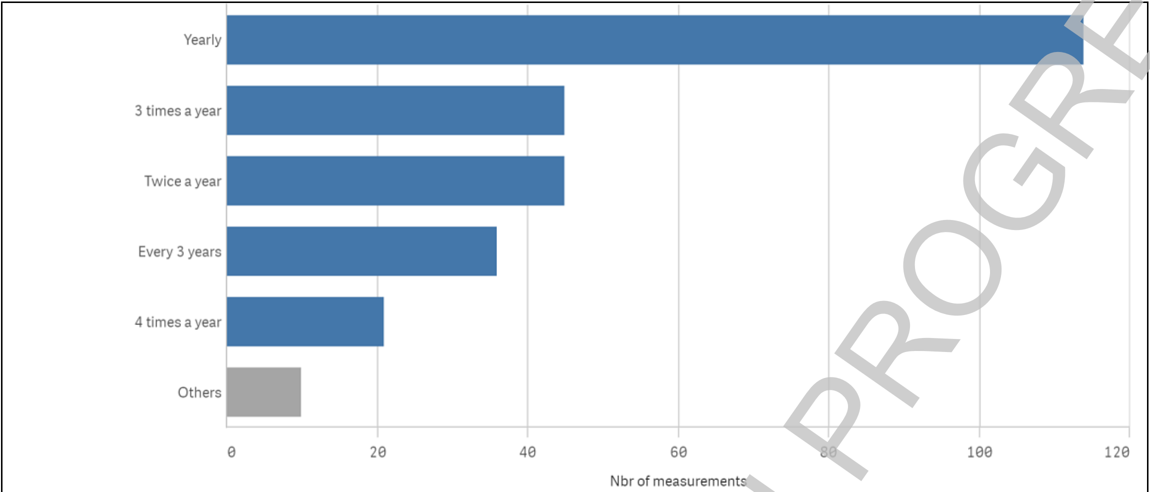


NB: 27 operators reported carbon monoxide emissions from 70 emission points in the data collection, applying optimised combustion. For better visualisation, only emission points with concentrations in the range of 0-500 mg CO/Nm^3 and mass flows in the range of 0-2 000 g CO/h are represented in the scatter plot.
Source: [43, EIPPCB 2019]

Figure 2.192:CO emissions from process furnaces/heaters applying optimised combustion

2.9.3.2 Monitoring

Periodic monitoring is more common than continuous monitoring: 288 instances of periodic monitoring and 47 of continuous monitoring were reported. Typical frequencies for the monitoring of channelled carbon monoxide emissions are shown in the bar chart of Figure 2.193.



Source: [43, EIPPCB 2019]

Figure 2.193: 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

Heading within the sections	Type of information included
Description	A brief description of the technique with a view to being used in the BAT conclusions.
Technical description	A more detailed and yet concise technical description using, as appropriate, chemical or other equations, pictures, diagrams and flow charts.
Achieved environmental benefits	The **main** potential environmental benefits to be gained through implementing the technique (including reduced consumption of energy; reduced emissions to water, air and land; raw material savings; as well as production yield increases, reduced waste, etc.).
Environmental performance and operational data	Actual and **plant-specific** performance data (including emission levels, consumption levels – of raw materials, water, energy – and amounts of residues/wastes generated) from well-performing installations/plants (with respect to the environment taken as a whole) applying the technique accompanied by the relevant contextual information. Any other useful information on the following items: • how to design, operate, maintain, control and decommission the technique; • emission monitoring issues related to the use of the technique; • sensitivity and durability of the technique; • issues regarding accident prevention. Links between inputs (e.g. nature and quantity of raw material and fuel, energy, water) and outputs (emissions, residues/wastes, products) are highlighted, in particular where relevant to enhancing an understanding of different environmental impacts and their interaction, for example where trade-offs have been made between different outputs such that certain environmental performance levels cannot be achieved at the same time.

	Emission and consumption data are qualified as far as possible with details of relevant operating conditions (e.g. percentage of full capacity, fuel composition, bypassing of the (abatement) technique, inclusion or exclusion of other than normal operating conditions, reference conditions), sampling and analytical methods, and statistical presentation (e.g. short- and long-term averages, maxima, ranges and distributions). Information is included on conditions/circumstances hampering the use of the (abatement) technique at full capacity and/or necessitating full or partial bypassing of the (abatement) technique and measures taken to restore full (abatement) capacity.
Cross-media effects	Relevant negative effects on the environment due to implementing the technique, allowing a comparison between techniques in order to assess the impact on the environment as a whole. This may include issues such as: • consumption and nature of raw materials and water; • energy consumption and contribution to climate change; • stratospheric ozone depletion potential; • photochemical ozone creation potential; • acidification resulting from emissions to air; • presence of particulate matter in ambient air (including microparticles and metals); • eutrophication of land and waters resulting from emissions to air or water; • oxygen depletion potential in water; • persistent/toxic/bioaccumulable components (including metals); • generation of residues/waste; • limitation of the ability to reuse or recycle residues/waste; • generation of noise and/or odour; • increased risk of accidents. The Reference Document on Economics and Cross-media Effects (ECM) should be taken into account.
Technical considerations relevant to applicability	It is indicated whether the technique can be applied throughout the sector. Otherwise, the main general technical restrictions on the use of the technique within the sector are indicated. These may be: • an indication of the type of plants or processes within the sector to which the technique cannot be applied; • constraints to implementation in certain generic cases, considering, e.g.: o whether it concerns a new or an existing plant, taking into account factors involved in retrofitting (e.g. space availability) and interactions with techniques already installed; o plant size, capacity or load factor; o quantity, type or quality of product manufactured; o type of fuel or raw material used; o animal welfare; o climatic conditions. These restrictions are indicated together with the reasons for them. These restrictions are not meant to be a list of the possible local conditions that could affect the applicability of the technique for an individual plant.
Economics	Information on the costs (capital/investment, operating and maintenance costs including details on how they have been calculated/estimated) and any possible savings (e.g. reduced raw material or energy consumption, waste charges, reduced payback time compared to other techniques), or revenues or other benefits including details on how these have been calculated/estimated. Cost data are preferably given in euros (EUR). If a conversion is made from another currency, the data in the original currency and the year when the data were collected are indicated. The price/cost of the equipment or service is accompanied by the year it was purchased.

	Information on the market for the sector is given in order to put costs of techniques into context. Information relevant to both newly built, retrofitted and existing plants is included. This should allow assessment, where possible, of the economic viability of the technique for the sector concerned. Information on the cost-effectiveness of the technique (e.g. in EUR per mass of pollutant abated) and related assumptions for its calculation can be reported. The Reference Document on Economics and Cross-media Effects (ECM) and the Reference Report on Monitoring of Emissions to Air and Water from IED Installations (ROM) are taken into account with regard to economic aspects and monitoring costs, respectively.
Driving force for implementation	Where applicable, specific local conditions, requirements (e.g. legislation, safety measures) or non-environmental triggers (e.g. increased yield, improved product quality, economic incentives – e.g. subsidies, tax breaks) which have driven or stimulated the implementation of the technique to date are provided. This subsection should be very short and use a list of bullet points.
Example plants	Reference to a plant(s) where the technique has been implemented and from which information has been collected and used in writing the section. An indication of the degree to which the technique is in use in the EU or worldwide.
Reference literature	Literature or other reference material (e.g. books, reports, studies) that was used in writing the section and that contains more detailed information on the technique. When the reference material consists of many pages, reference will be made to the relevant page(s) or section(s).

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).

Source: [13, COM 2016]

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).

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 forces for implementation
The driving forces for the implementation of an EMS include:

- improved environmental performance;
- improved insight into the environmental aspects of the company which can be used to fulfil the environmental requirements of customers, regulatory authorities, banks, insurance companies or other stakeholders (e.g. people living or working in the vicinity of the installation);
- improved basis for decision-making;
- improved motivation of personnel (e.g. managers can have confidence that environmental impacts are controlled and employees can feel that they are working for an environmentally responsible company);
- additional opportunities for operational cost reduction and product quality improvement;
- improved company image;
- reduced liability, insurance and non-compliance costs.

Example plants
EMSs are applied in a number of installations throughout the EU.

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 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 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, NOX, SOX, Cl2, 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;

iii. information 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), including CMR properties.

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 diffuse 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 more than 10 % organic compounds with a vapour pressure greater than 0.3 kPa at 20 °C.

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 to activities producing large volumes of organic chemicals or using large amounts of solvents (e.g. for the production of pharmaceuticals).

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 the recovery of materials as well as the consumption of energy and materials for the waste gas treatment.

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 is usually ensured by monitoring operational parameters such as the waste gas flow, the temperature or the pressure.

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.

For some substances/parameters, EN standards are not available. In this case, ISO, national or other international standards are used.

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, EIPPCB 2019]

3.3.2 Techniques to reduce channelled emissions to air

3.3.2.1 Absorption

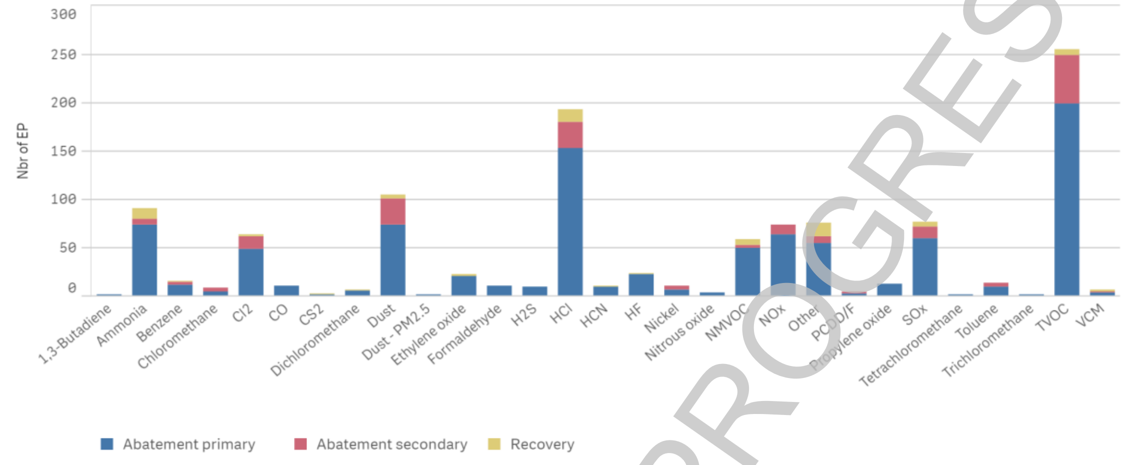
Description

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, EIPPCB 2019]

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

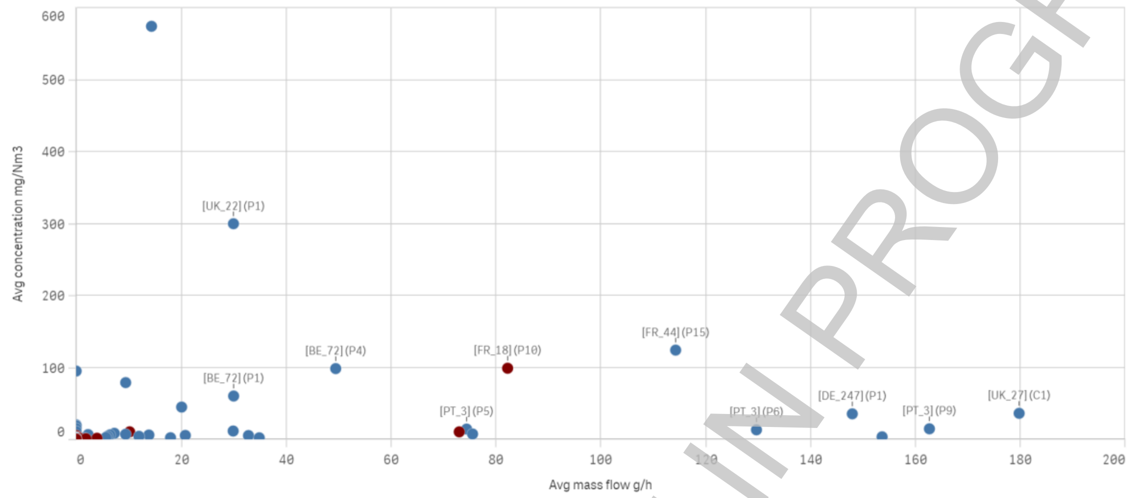
Type	Waste gas flows (Nm^3/h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	1	30	2 000	30 000	360 000	793

Source: [43, EIPPCB 2019]

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, EIPPCB 2019].

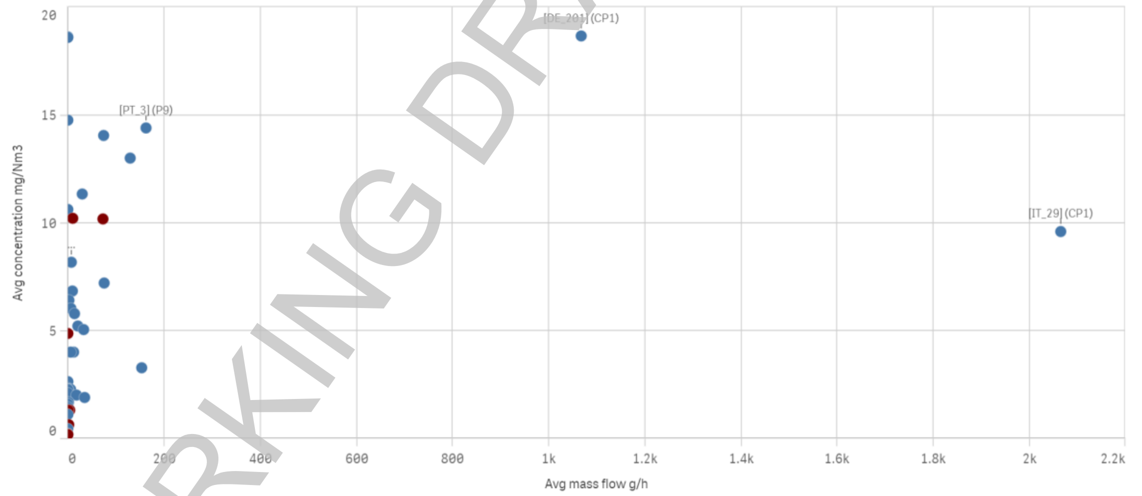
Figure 3.3 and Figure 3.4 show TVOC concentration versus mass flow when absorption is used as the final waste gas treatment technique and thermal oxidation is not used. Figure 3.3 shows data from emission points with a mass flow of less than 200 g/h and Figure 3.4 shows data from emission points with a concentration of less than 20 mg/Nm^3.



NB: Some of the emissions were reported as NMVOC (red dots).

Source: [43, EIPPCB 2019]

Figure 3.3: **TVOC concentration versus mass flow, for mass flows < 200 g/h when absorption is used as the final waste gas treatment**



NB: Some of the data were reported as NMVOC (red dots).

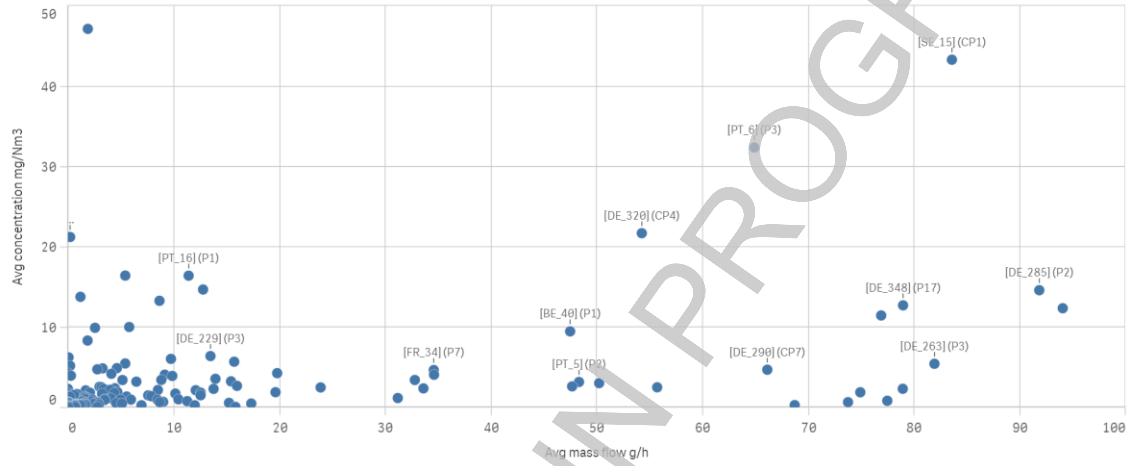
Source: [43, EIPPCB 2019]

Figure 3.4: **TVOC concentration versus mass flow, for concentrations < 20 mg/Nm^3 when absorption is used as the final waste gas treatment**

Dust

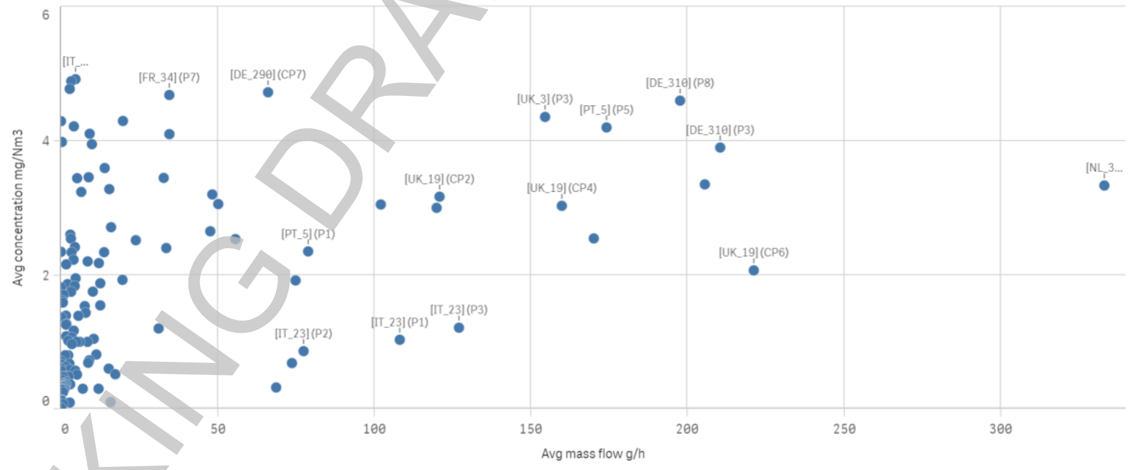
In the case of dust, absorption (also referred to as dust scrubbing) may be combined with a post-treatment by filtration (i.e. absolute filters or fabric filters) or electrostatic precipitation. Removal efficiencies for dust typically range from 90 % to more than 99 % [43, EIPPCB 2019].

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 100 g/h and Figure 3.6 shows data from emission points with a concentration of less than 5 mg/Nm^3.



Source: [43, EIPPCB 2019]

Figure 3.5: Dust concentration versus mass flow, for mass flows < 100 g/h when absorption is used as the final waste gas treatment

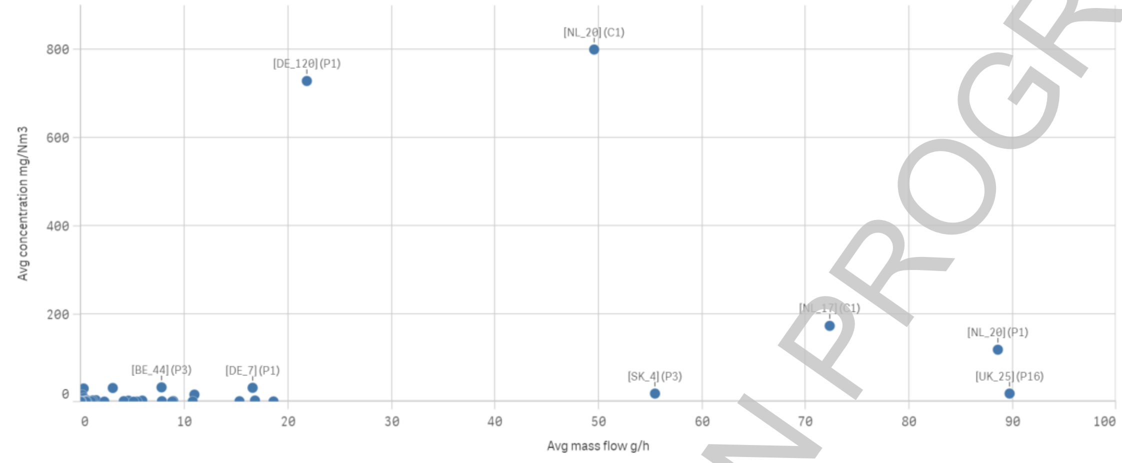


Source: [43, EIPPCB 2019]

Figure 3.6: Dust concentration versus mass flow, for concentrations < 5 mg/Nm^3 when absorption is used as the final waste gas treatment

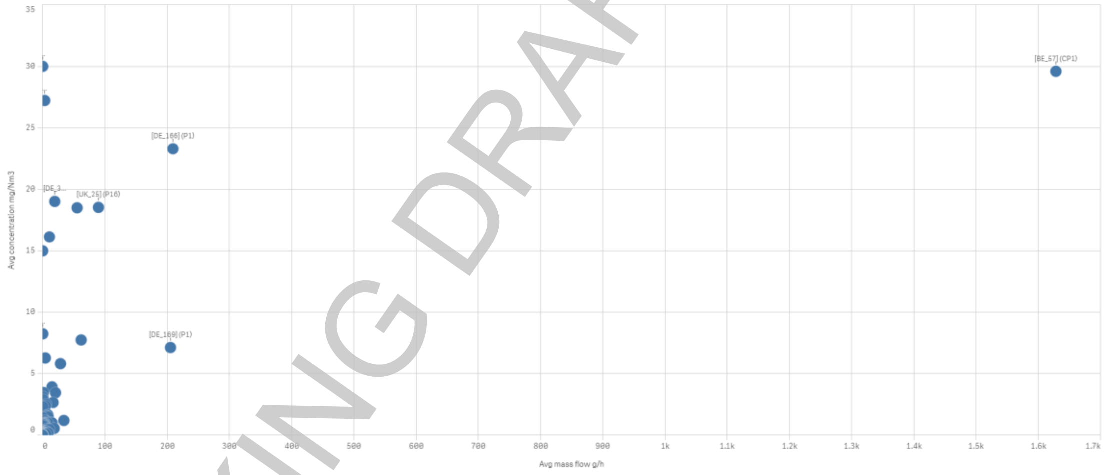
Ammonia
Absorption is often reported as the main technique to remove ammonia. Removal efficiencies for ammonia typically range from 95 % to more than 99 % [43, EIPPCB 2019].

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 100 g/h and Figure 3.8 shows data from emission points with a concentration of less than 30 mg/Nm^3.



Source: [43, EIPPCB 2019]

Figure 3.7: Ammonia concentration versus mass flow, for mass flows < 100 g/h when absorption is used as the final waste gas treatment



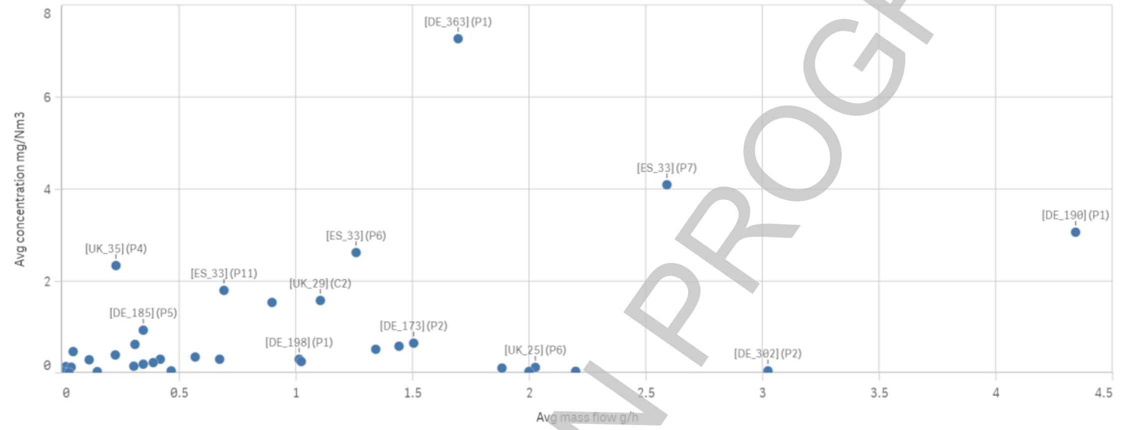
Source: [43, EIPPCB 2019]

Figure 3.8: Ammonia concentration versus mass flow, for concentrations < 30 mg/Nm^3 when absorption is used as the final waste gas treatment

Elementary chlorine

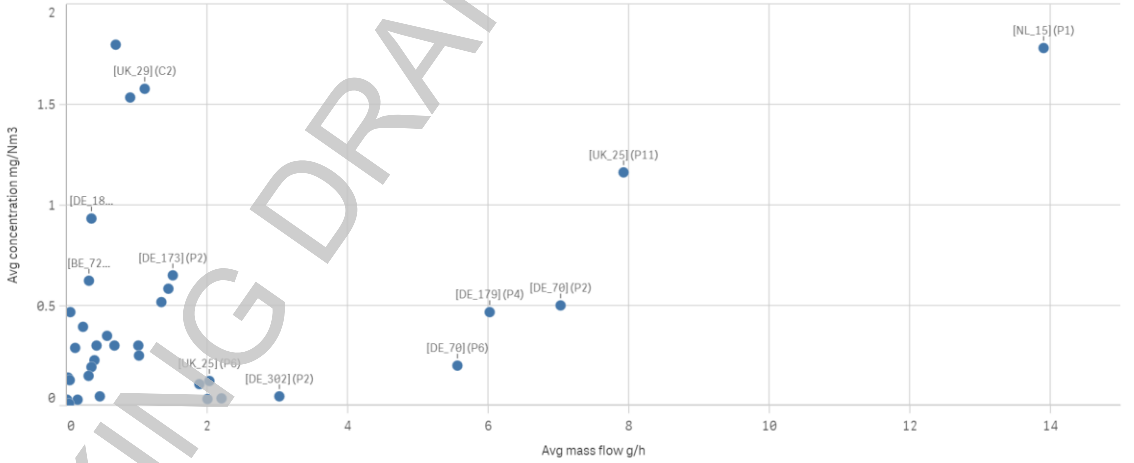
Absorption is often reported as the main technique to remove elementary chlorine. Removal efficiencies for elementary chlorine typically range from 95 % to more than 99 % [43, EIPPCB 2019].

Figure 3.9 and Figure 3.10 show elementary 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^3.



Source: [43, EIPPCB 2019]

Figure 3.9: Elementary chlorine concentration versus mass flow, for mass flows < 5 g/h when absorption is used as the final waste gas treatment



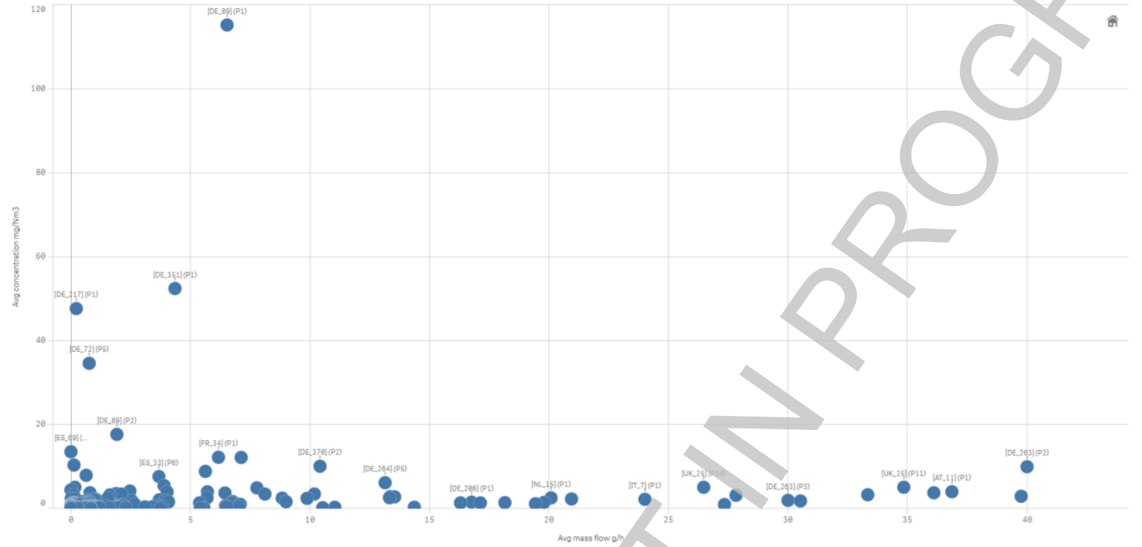
Source: [43, EIPPCB 2019]

Figure 3.10: Elementary chlorine concentration versus mass flow, for concentrations < 2 mg/Nm^3 when absorption is used as the final waste gas treatment

Gaseous chlorides

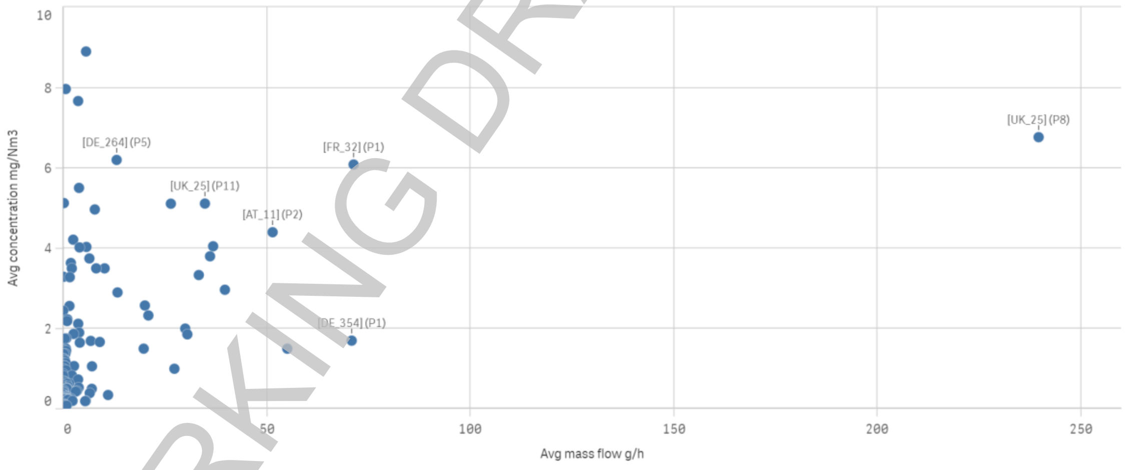
Absorption is often reported as the main technique to remove gaseous chlorides. Removal efficiencies for gaseous chlorides typically range from 80 % to more than 99 % [43, EIPPCB 2019].

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 50 g/h and Figure 3.12 shows data from emission points with a concentration of less than 10 mg/Nm^3.



Source: [43, EIPPCB 2019]

Figure 3.11: Gaseous chloride concentration versus mass flow, for mass flows < 50 g/h when absorption is used as the final waste gas treatment



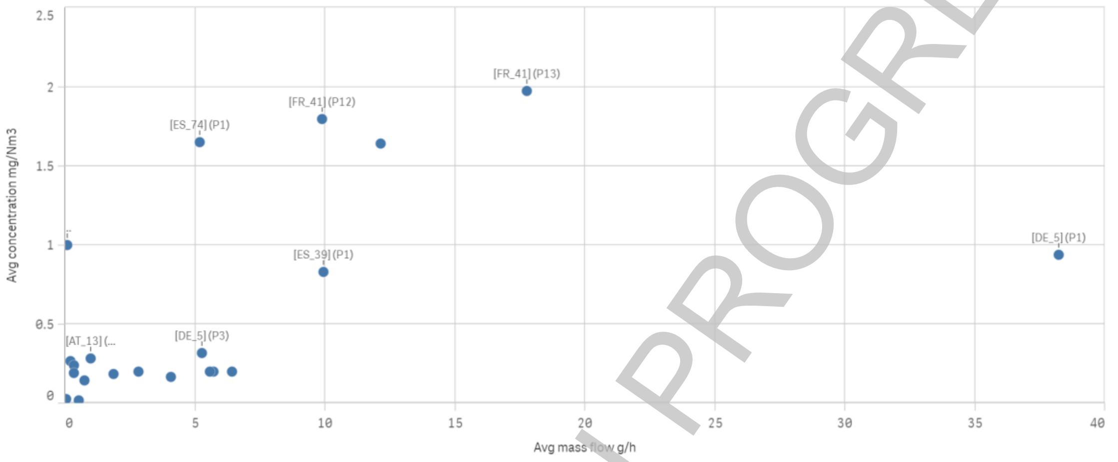
Source: [43, EIPPCB 2019]

Figure 3.12: Gaseous chloride concentration versus mass flow, for concentrations < 10 mg/Nm^3 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, EIPPCB 2019].

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 2 mg/Nm^3 are shown.



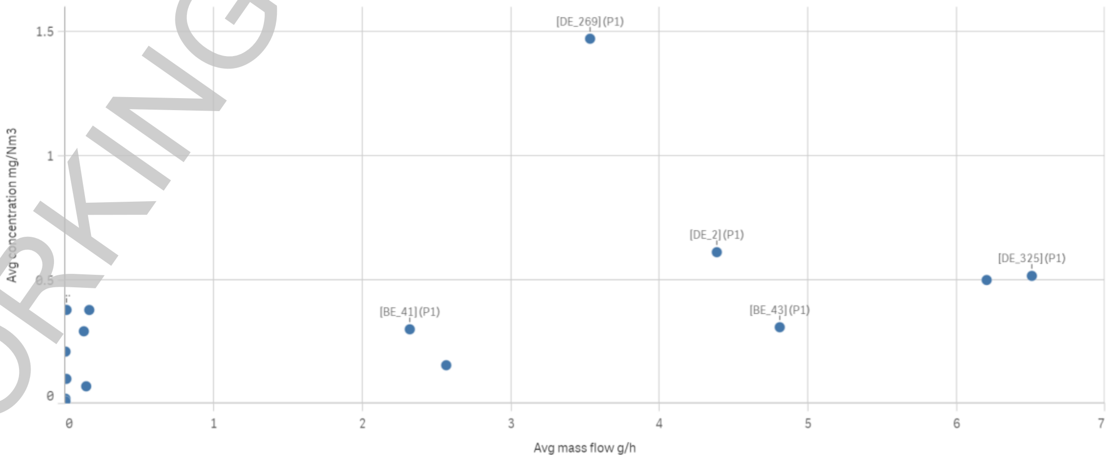
Source: [43, EIPPCB 2019]

Figure 3.13: Gaseous fluoride concentration versus mass flow, for concentrations < 2 mg/Nm^3 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, EIPPCB 2019].

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 2 mg/Nm^3 are shown.



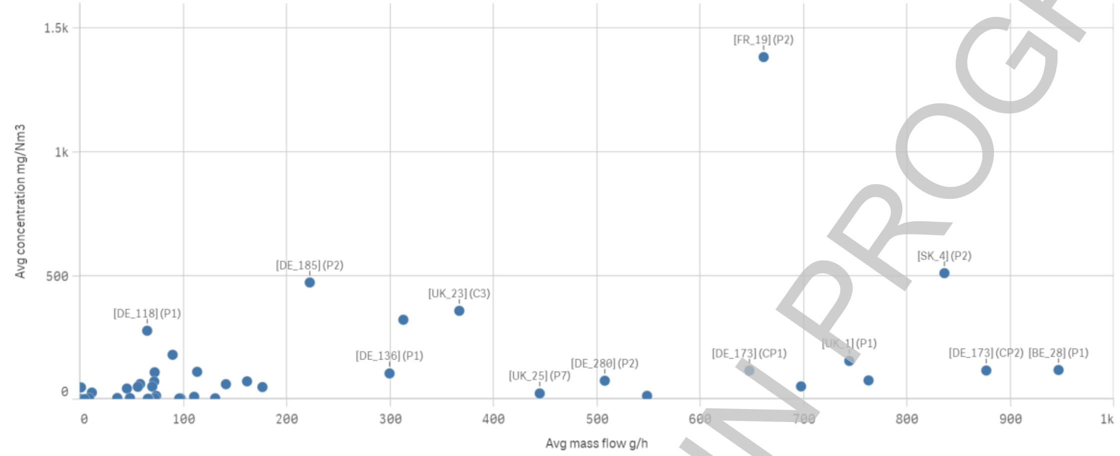
Source: [43, EIPPCB 2019]

Figure 3.14: Hydrogen cyanide concentration versus mass flow, for concentrations < 2 mg/Nm^3 when absorption is used as the final waste gas treatment

Nitrogen oxides

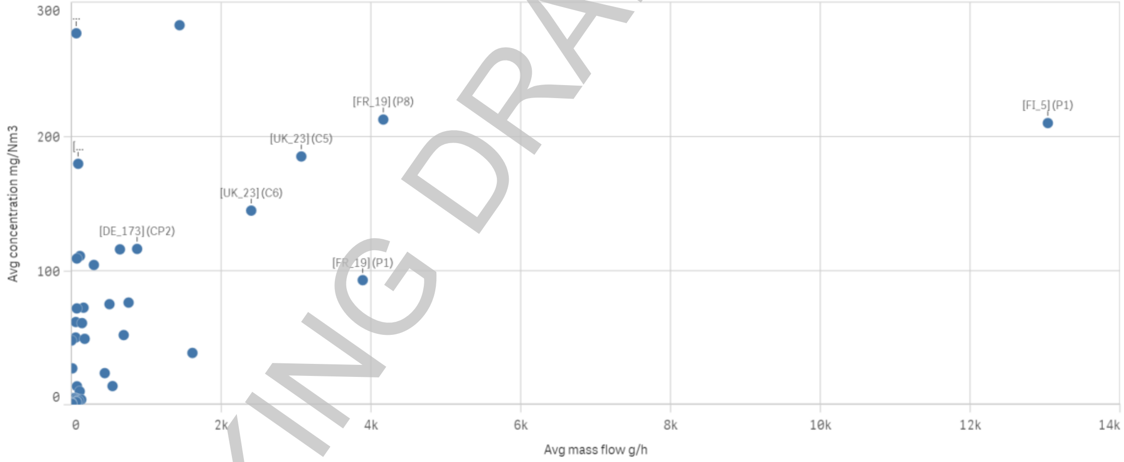
Absorption is often reported as the main technique to remove nitrogen oxides. Removal efficiencies for nitrogen oxides typically range from 80 % to more than 99 % [43, EIPPCB 2019].

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 1 000 g/h and Figure 3.16 shows data from emission points with a concentration of less than 300 mg/Nm^3.



Source: [43, EIPPCB 2019]

Figure 3.15: Nitrogen oxides concentration versus mass flow, for mass flows < 1 000 g/h when absorption is used as the final waste gas treatment



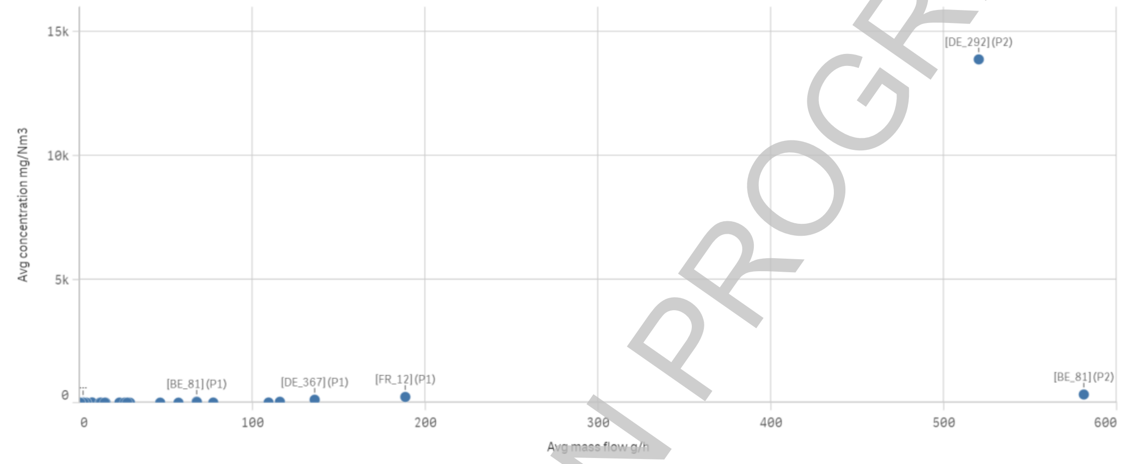
Source: [43, EIPPCB 2019]

Figure 3.16: Nitrogen oxides concentration versus mass flow, for concentrations < 300 mg/Nm^3 when absorption is used as the final waste gas treatment

Sulphur oxides

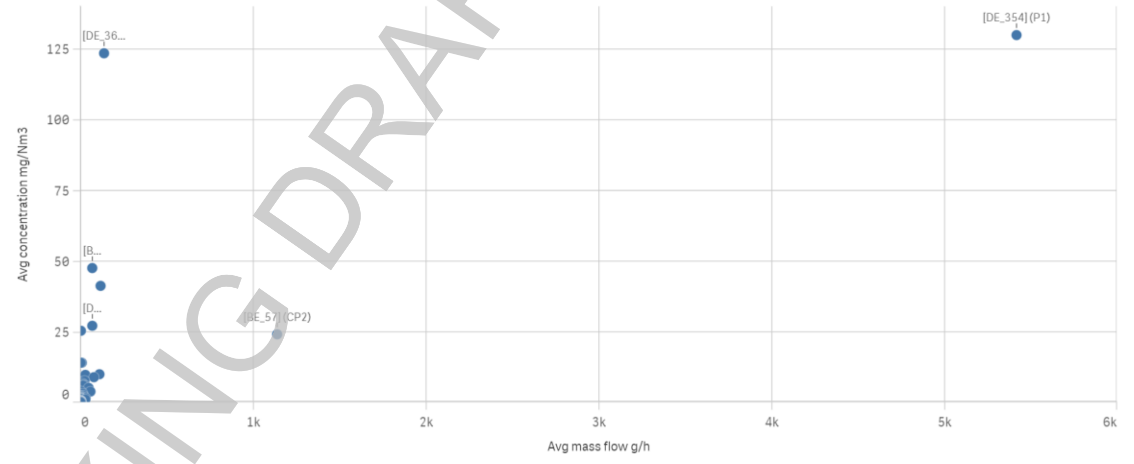
Absorption is often reported as the main technique to remove sulphur oxides. Removal efficiencies for sulphur oxides typically range from 98 % to more than 99 % [43,EIPPCB 2019].

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 1 000 g/h and Figure 3.18 shows data from emission points with a concentration of less than 150 mg/Nm^3.



Source: [43, EIPPCB 2019]

Figure 3.17: Sulphur oxides concentration versus mass flow, for mass flows < 1 000 g/h when absorption is used as the final waste gas treatment



Source: [43, EIPPCB 2019]

Figure 3.18: Sulphur oxides concentration versus mass flow, for concentrations < 150 mg/Nm^3 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, EIPPCB 2019]

3.3.2.2 Adsorption

Description

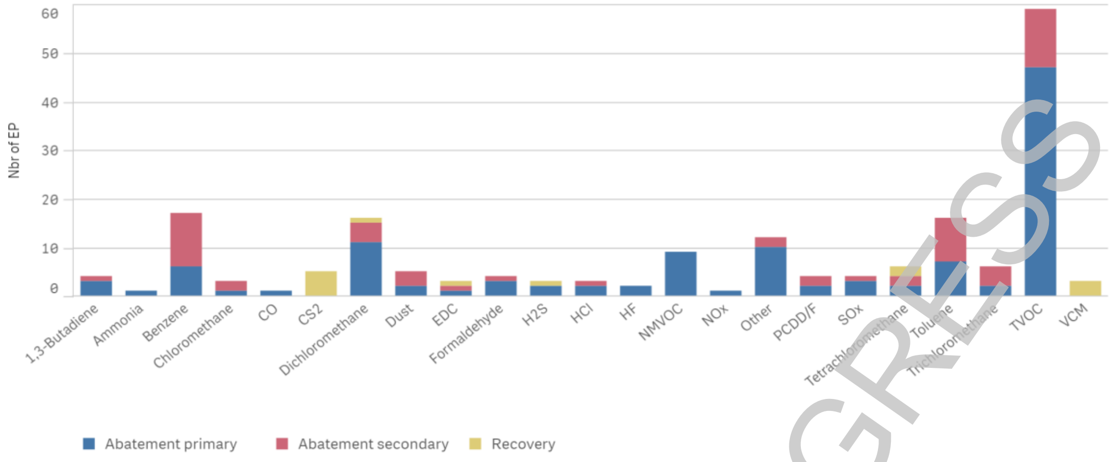
The removal of pollutants from a process off-gas or waste gas stream by retention on a solid surface (activated carbon is typically used as the adsorbent). Adsorption may be regenerative or non-regenerative.

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.



Source: [43, EIPPCB 2019]

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.

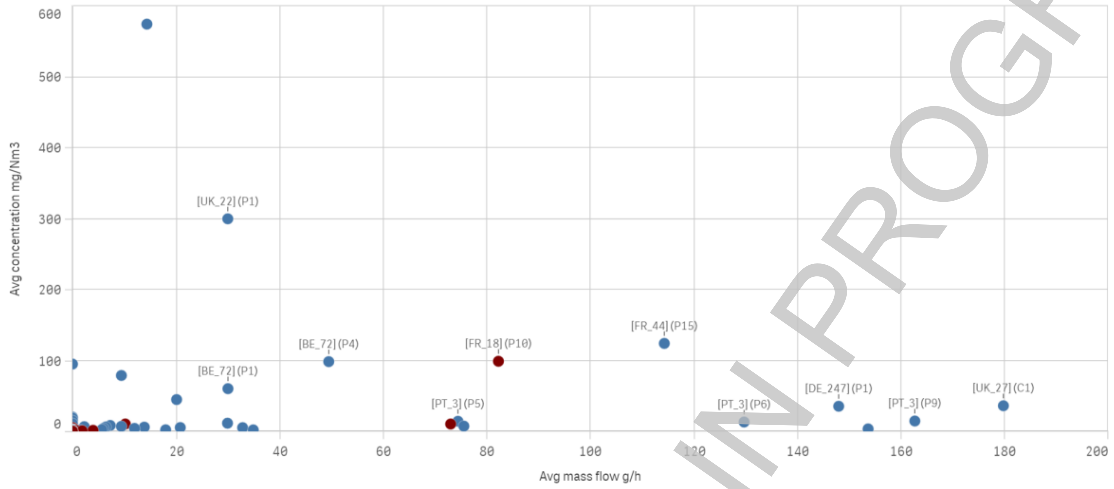
Table 3.3: Reported waste gas flows for adsorption

Type	Waste gas flows (Nm^3/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, EIPPCB 2019]

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, EIPPCB 2019].

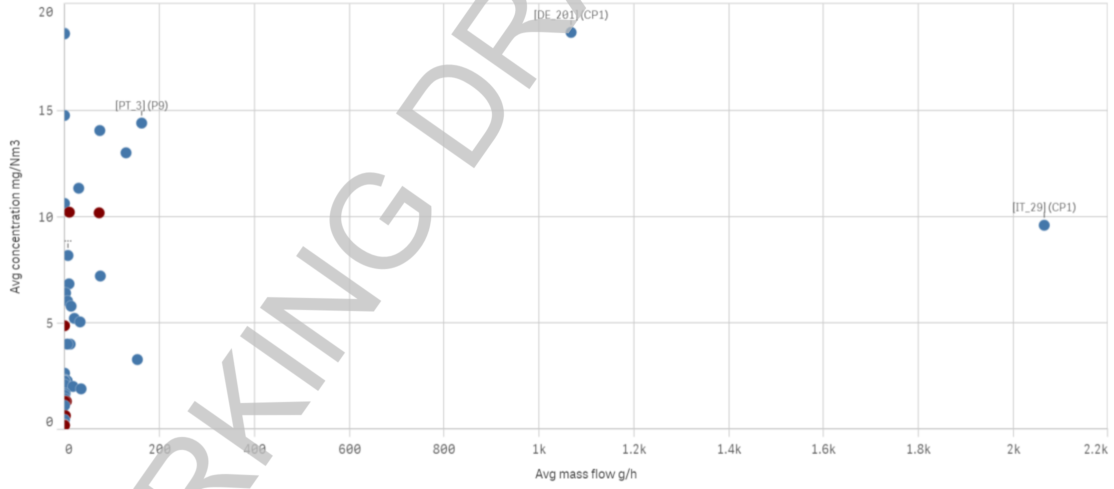
Figure 3.20 and Figure 3.21 show TVOC concentration versus mass flow when adsorption is used as the final waste gas treatment technique and thermal oxidation is not used. Figure 3.20 shows data from emission points with a mass flow of less than 200 g/h and Figure 3.21 shows data from emission points with a concentration of less than 20 mg/Nm^3.



NB: Some of the emissions were reported as NMVOC (red dots).

Source: [43, EIPPCB 2019]

Figure 3.20: TVOC concentration versus mass flow, for mass flows < 200 g/h when adsorption is used as the final waste gas treatment



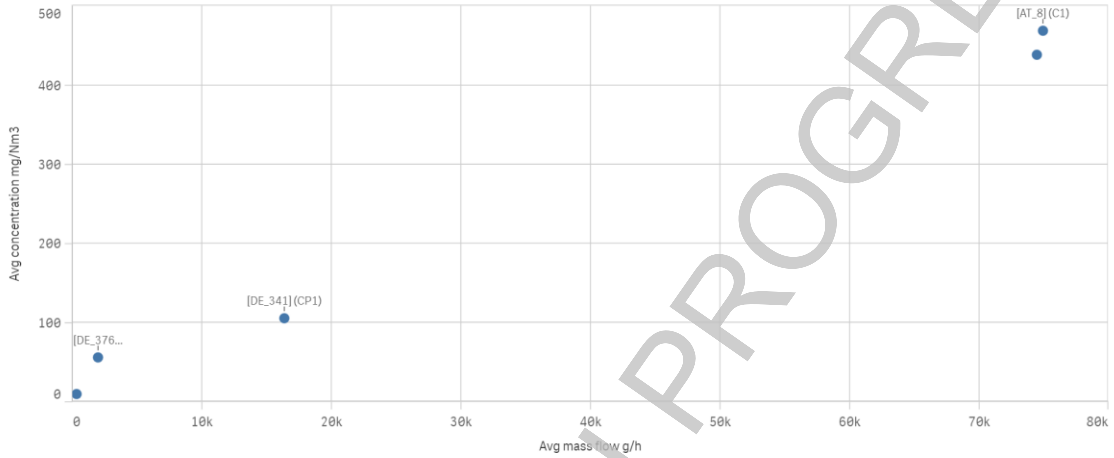
NB: Some of the emissions were reported as NMVOC (red dots).

Source: [43, EIPPCB 2019]

Figure 3.21: TVOC concentration versus mass flow, for concentrations < 20 mg/Nm^3 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, EIPPCB 2019].

Figure 3.22 shows carbon disulphide concentration versus mass flow when adsorption is used as the final waste gas treatment technique.



Source: [43, EIPPCB 2019]

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, EIPPCB 2019]

3.3.2.3 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_2 and dust.
- Change from liquid to gaseous fuels may also lead to lower NO_X 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_2 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_X 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]

3.3.2.4 Condensation

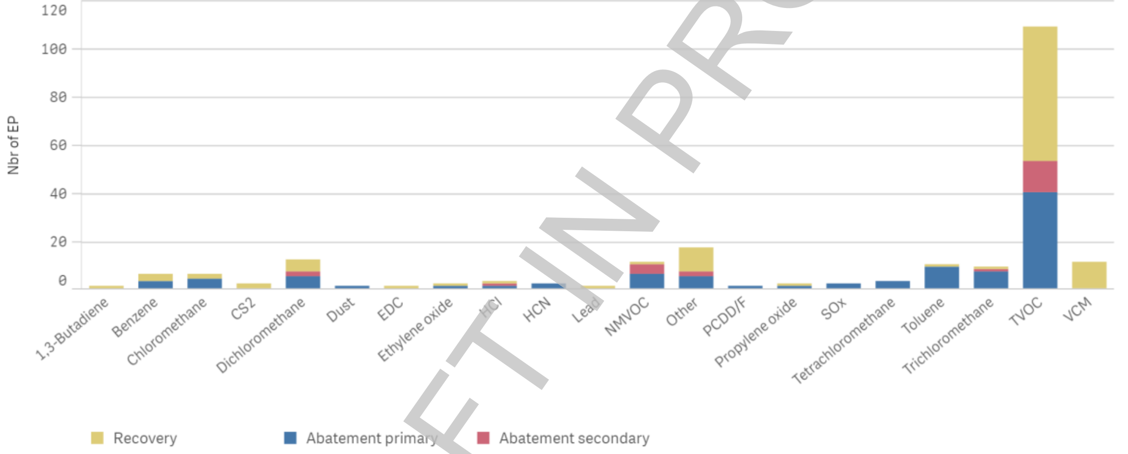
Description

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).



Source: [43, EIPPCB 2019]

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

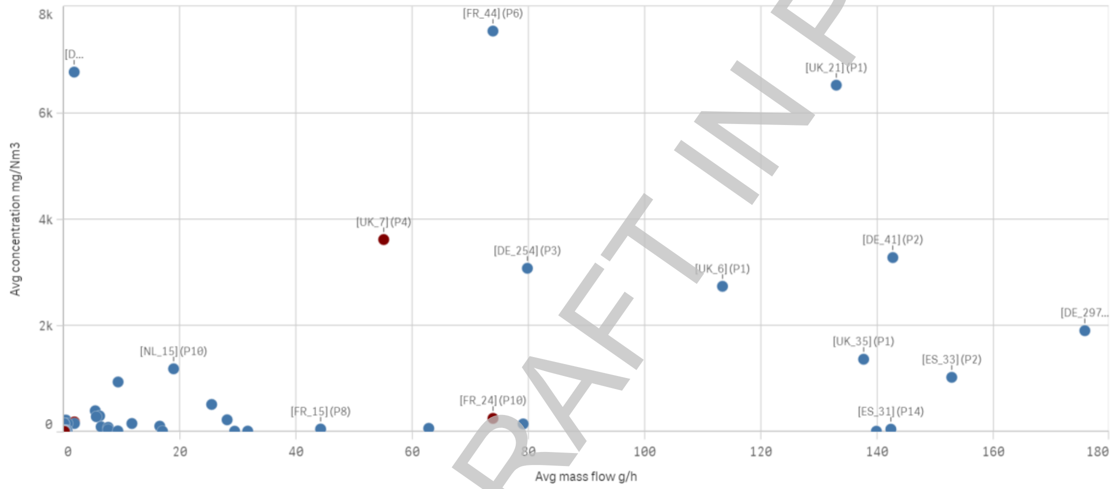
Condensation is often used in combination with other waste gas treatment techniques (e.g. combined with post-treatment by absorption, adsorption or thermal oxidation). Removal efficiencies for organic compounds typically range from 90 % to more than 99 % [43, EIPPCB 2019].

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^3/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, EIPPCB 2019]						

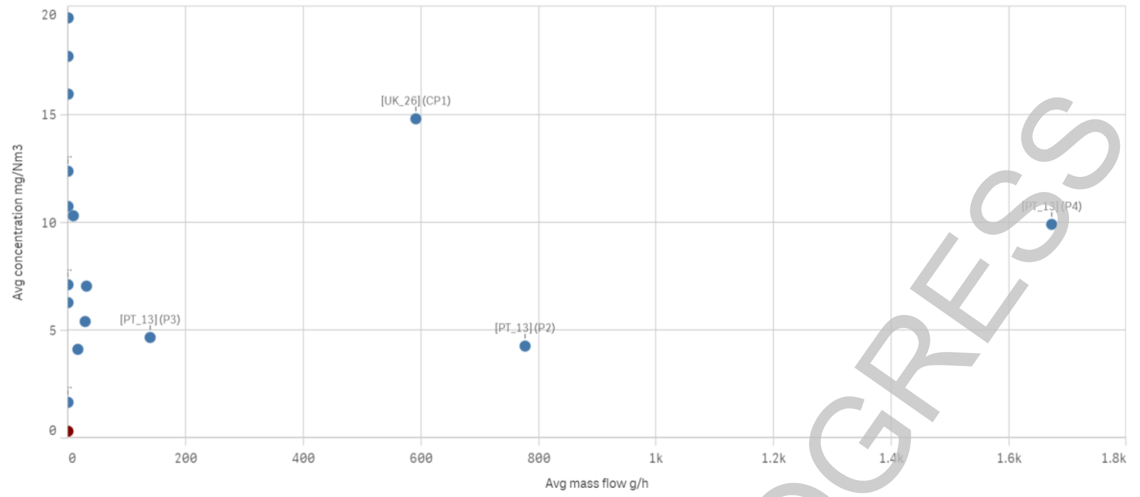
Figure 3.24 and Figure 3.25 show TVOC concentration versus mass flow when condensation is used as the only waste gas treatment technique. Figure 3.24 shows data from emission points with a mass flow of less than 200 g/h and Figure 3.25 shows data from emission points with a concentration of less than 20 mg/Nm^3.



NB: Some of the emissions were reported as NMVOC (red dots).

Source: [43, EIPPCB 2019]

Figure 3.24: TVOC concentration versus mass flow, for mass flows < 200 g/h when condensation is used as the only waste gas treatment technique



NB: Some of the emissions were reported as NMVOC (red dots).

Source: [43, EIPPCB 2019]

Figure 3.25: TVOC concentration versus mass flow, for concentrations < 20 mg/Nm^3 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, EIPPCB 2019]

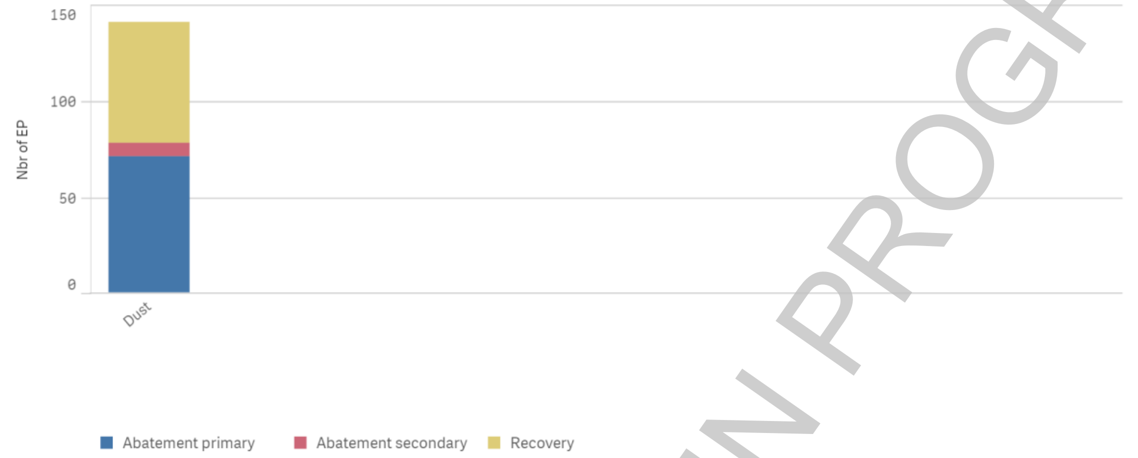
3.3.2.5 Cyclone

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).



Source: [43, EIPPCB 2019]

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

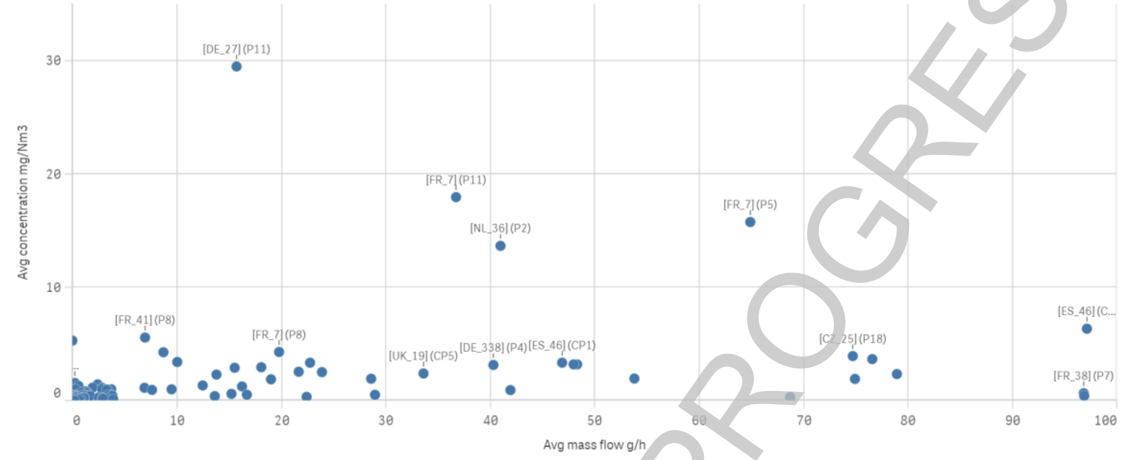
Cyclones can be used alone, but are often used in combination with other waste gas treatment techniques (e.g. combined with post-treatment by absorption or filtration). Removal efficiencies for dust typically range from 90 % to more than 99 % [43, EIPPCB 2019].

Reported waste gas flows for cyclones are shown in Table 3.5.

Table 3.5: Reported waste gas flows for cyclones

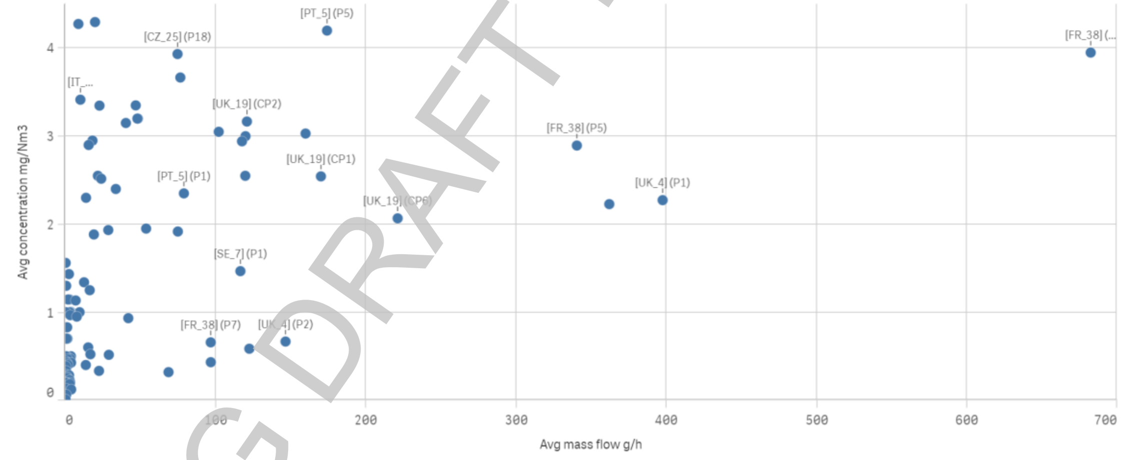
Type	Waste gas flows (Nm^3/h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	5	1 000	9 000	95 000	240 000	126
Source: [43, EIPPCB 2019]						

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 100 g/h and Figure 3.28 shows data from emission points with a concentration of less than 5 mg/Nm^3.



Source: [43, EIPPCB 2019]

Figure 3.27: Dust concentration versus mass flow, for mass flows < 100 g/h when cyclones are used as the final waste gas treatment



Source: [43, EIPPCB 2019]

Figure 3.28: Dust concentration versus mass flow, for concentrations < 5 mg/Nm^3 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, EIPPCB 2019]

3.3.2.6 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].

Source: [43, EIPPCB 2019]

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

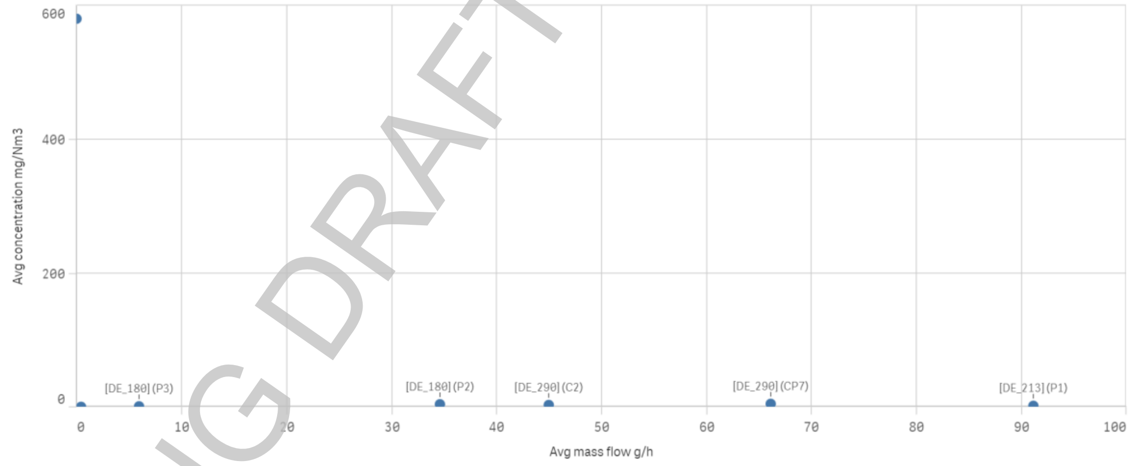
Electrostatic precipitation is used alone or in combination with other waste gas treatment techniques.

Reported waste gas flows for electrostatic precipitation are shown in Table 3.7.

Table 3.6: Reported waste gas flows for electrostatic precipitation

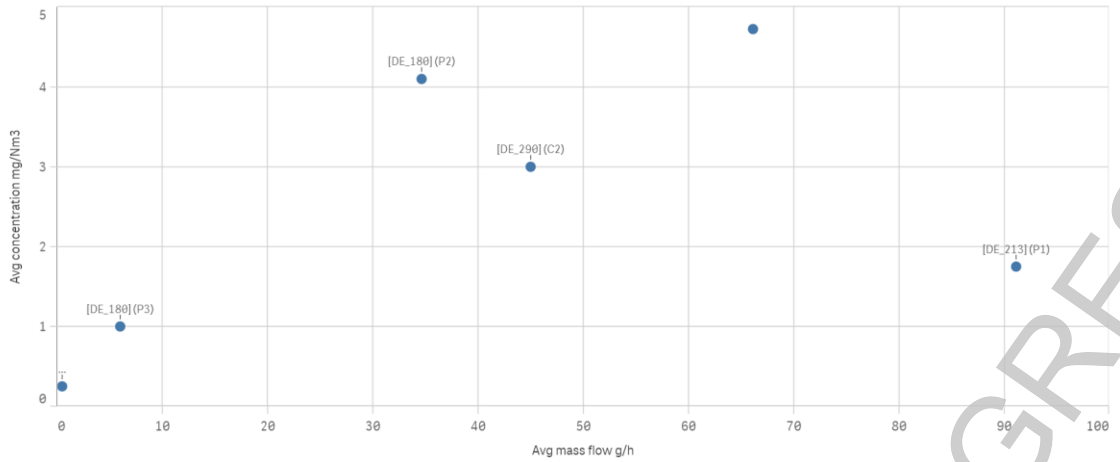
Type	Waste gas flows (Nm^3/h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	900	1 800	11 500	53 000	800 000	20
Source: [43, EIPPCB 2019]						

Figure 3.33 and Figure 3.34 show dust concentration versus mass flow when electrostatic precipitation is used as the final waste gas treatment technique. Figure 3.33 shows data from emission points with a mass flow of less than 100 g/h and Figure 3.34 shows data from emission points with a concentration of less than 5 mg/Nm^3.



Source: [43, EIPPCB 2019]

Figure 3.30: Dust concentration versus mass flow, for mass flows < 100 g/h when a electrostatic precipitation is used as the final waste gas treatment technique



Source: [43, EIPPCB 2019]

Figure 3.31: Dust concentration versus mass flow, for concentrations < 5 mg/Nm^3 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, EIPPCB 2019]

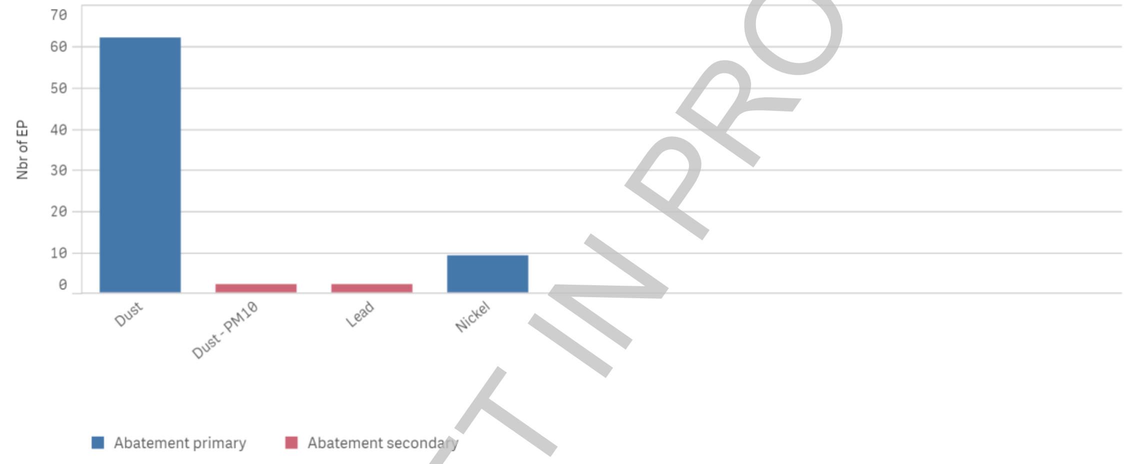
3.3.2.7 Absolute filter

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, EIPPCB 2019].



Source: [43, EIPPCB 2019]

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.

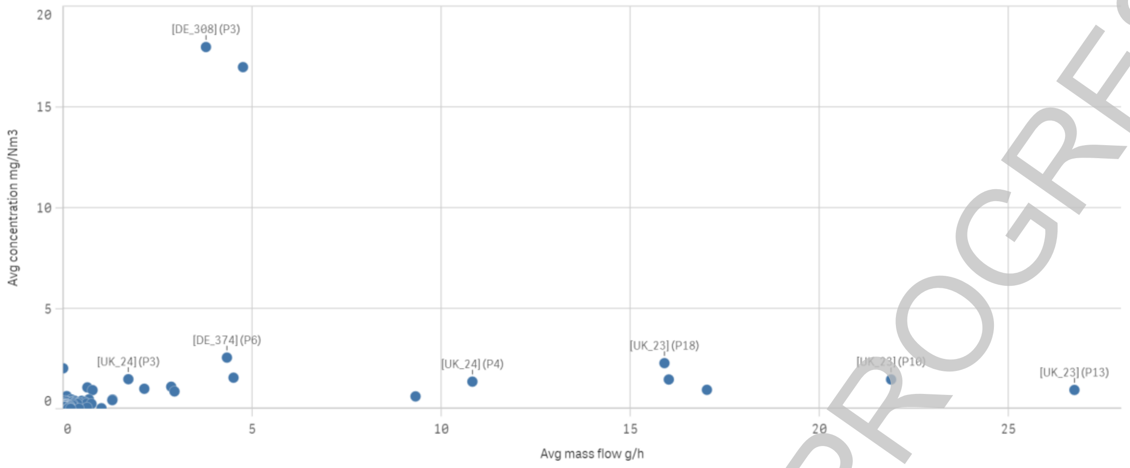
Reported waste gas flows for absolute filters are shown in Table 3.7.

Table 3.7: Reported waste gas flows for absolute filters

Type	Waste gas flows (Nm^3/h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	150	300	1 400	15 000	38 000	62

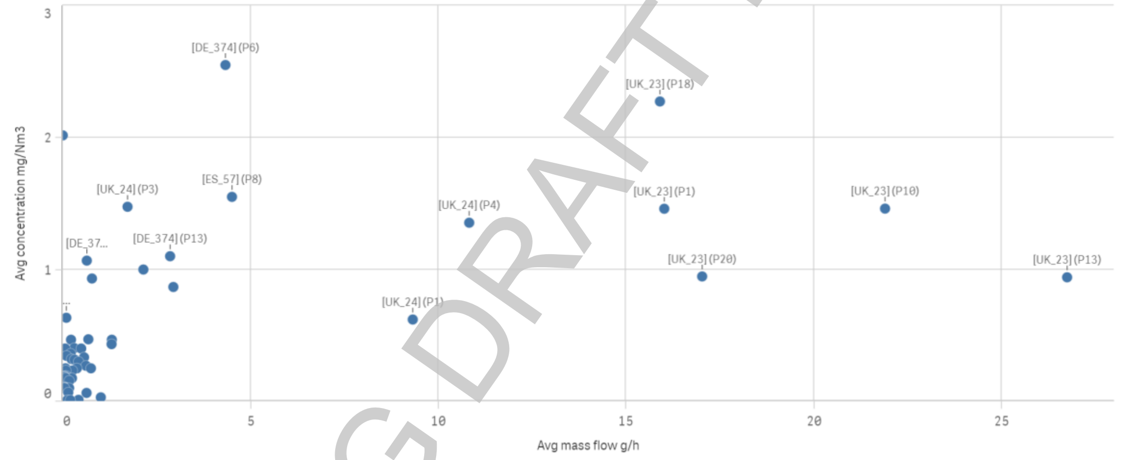
Source: [43, EIPPCB 2019]

Figure 3.33 and Figure 3.34 show dust concentration versus mass flow when an absolute filter is used as the final waste gas treatment technique. Figure 3.33 shows data from emission points with a mass flow of less than 100 g/h and Figure 3.34 shows data from emission points with a concentration of less than 5 mg/Nm^3.



Source: [43, EIPPCB 2019]

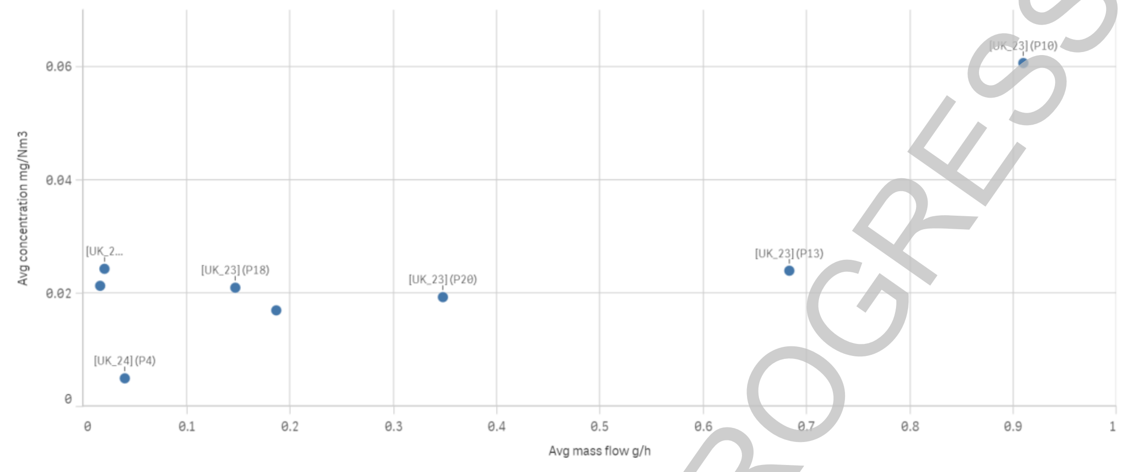
Figure 3.33: Dust concentration versus mass flow, for mass flows < 100 g/h when an absolute filter is used as the final waste gas treatment technique



Source: [43, EIPPCB 2019]

Figure 3.34: Dust concentration versus mass flow, for concentrations < 5 mg/Nm^3 when an absolute filter is used as the final waste gas treatment technique

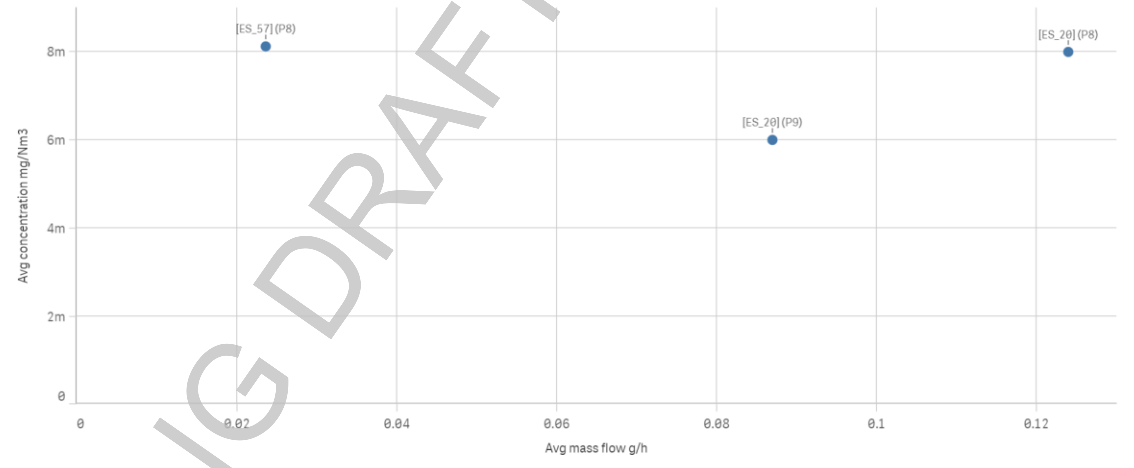
Figure 3.35 shows nickel concentration versus mass flow when an absolute filter is used as the final waste gas treatment technique.



Source: [43, EIPPCB 2019]

Figure 3.35: Nickel concentration versus mass flow when an absolute filter is used as the final waste gas treatment technique

Figure 3.36 shows lead concentration versus mass flow when an absolute filter is used as the final waste gas treatment technique.



Source: [43, EIPPCB 2019]

Figure 3.36: 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, EIPPCB 2019].

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, EIPPCB 2019]

3.3.2.8 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 (see Figure 3.37). Removal efficiencies are typically around 99 % for droplets and aerosols [13, COM 2016].

Source: [43, EIPPCB 2019]

Figure 3.37: Use of high-efficiency air filters for abatement

Further information is provided in the CWW BREF [13, COM 2016].

Achieved environmental benefits

Reduced dust emissions to air.

Environmental performance and operational data

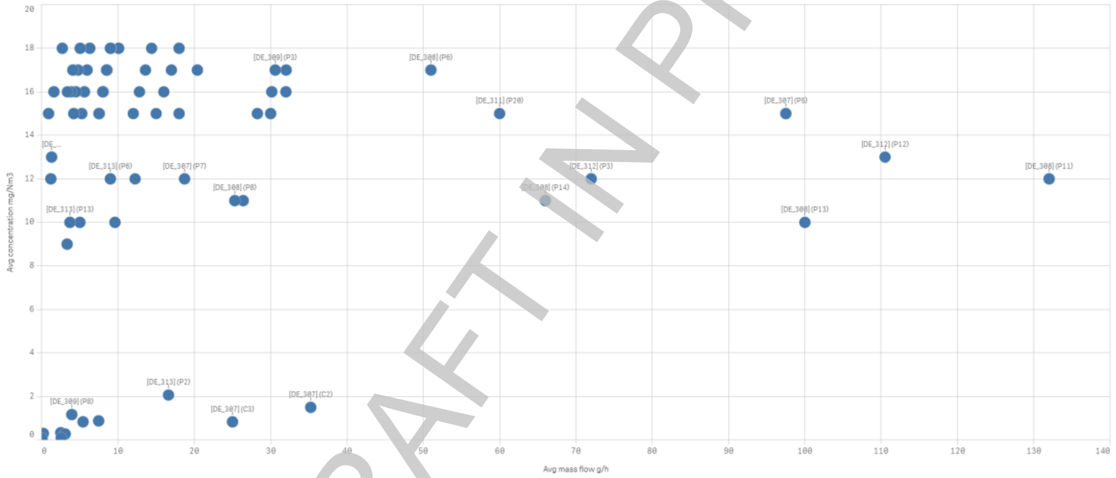
High-efficiency air filters are generally used alone.

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^3/h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	60	280	504	6 000	30 000	127
Source: [43, EIPPCB 2019]						

Figure 3.38 shows dust concentration versus mass flow when a high-efficiency air filter is used as the final waste gas treatment technique.



Source: [43, EIPPCB 2019]

Figure 3.38: 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, EIPPCB 2019]

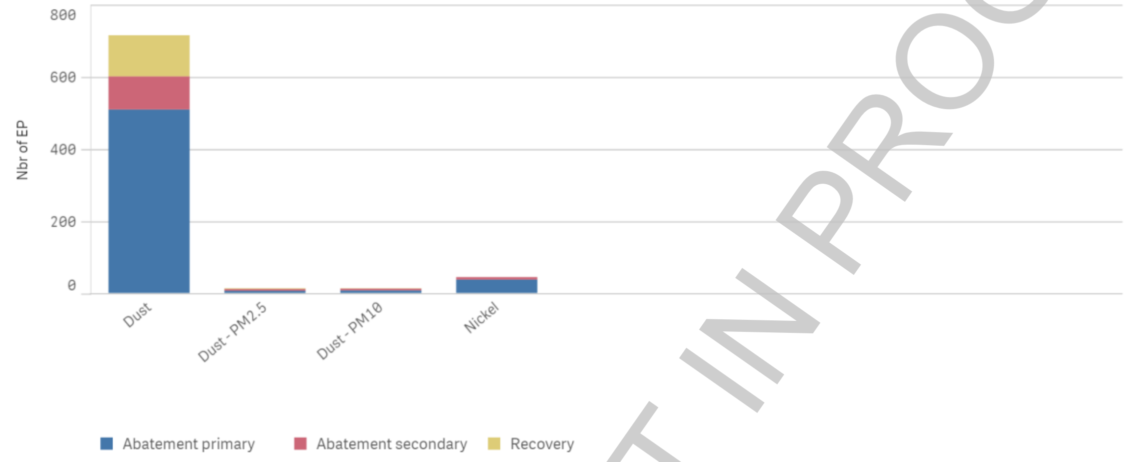
3.3.2.9 Fabric filter

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_{10} and $PM_{2.5}$) and particulate-bound metals, both as a recovery and as an abatement technique (see Figure 3.39). Removal efficiencies for dust typically range from 95 % to more than 99.9 % [43, EIPPCB 2019].



Source: [43, EIPPCB 2019]

Figure 3.39: 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.

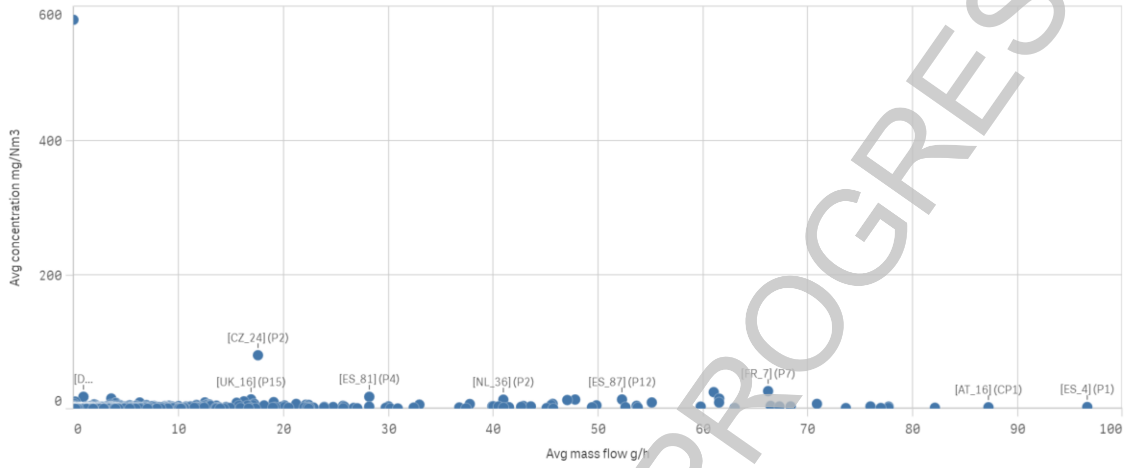
Reported waste gas flows for fabric filters are shown in Table 3.9.

Table 3.9: Reported waste gas flows for fabric filters

Type	Waste gas flows (Nm^3/h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	2	300	2 000	19 000	5 000 000	734

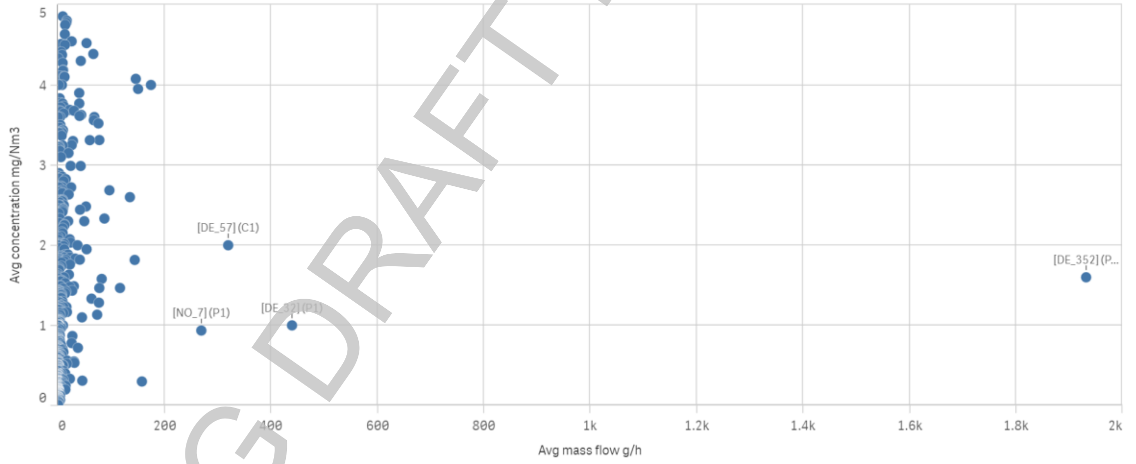
Source: [43, EIPPCB 2019]

Figure 3.40 and Figure 3.41 show dust concentration versus mass flow when a fabric filter is used as the final waste gas treatment technique. Figure 3.40 shows data from emission points with a mass flow of less than 100 g/h and Figure 3.41 shows data from emission points with a concentration of less than 5 mg/Nm^3.



Source: [43, EIPPCB 2019]

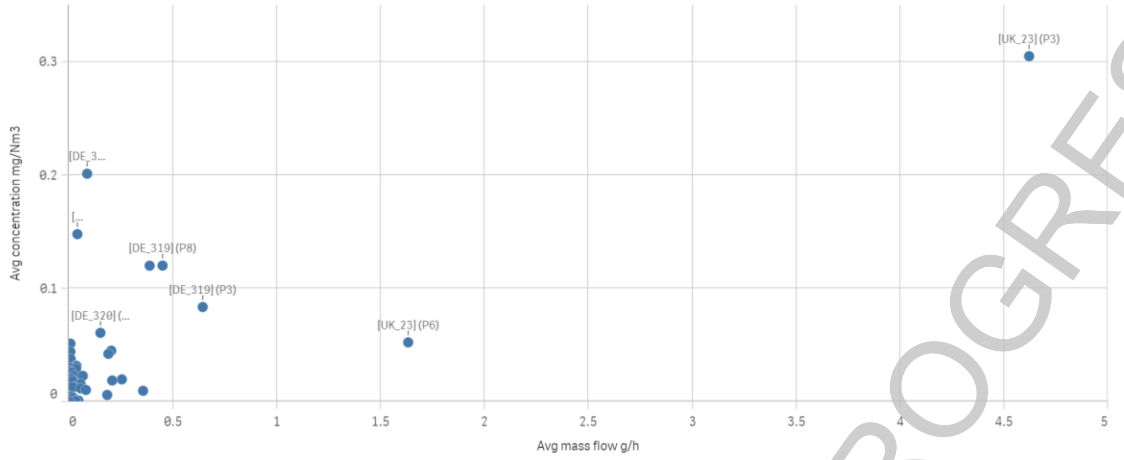
Figure 3.40: Dust concentration versus mass flow, for mass flows < 100 g/h when a fabric filter is used as the final waste gas treatment technique



Source: [43, EIPPCB 2019]

Figure 3.41: Dust concentration versus mass flow, for concentrations < 5 mg/Nm^3 when a fabric filter is used as the final waste gas treatment technique

Figure 3.42 shows nickel concentration versus mass flow when a fabric filter is used as the final waste gas treatment technique.



Source: [43, EIPPCB 2019]

Figure 3.42: 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, EIPPCB 2019].

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, EIPPCB 2019]

3.3.2.10 Low-NO_X burner

Description

The technique (including ultra-low-NO_X 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_X and the formation of thermal NO_X, while maintaining high combustion efficiency. The design of ultra-low-NO_X burners includes (air/)fuel staging and exhaust/flue-gas recirculation.

Technical description

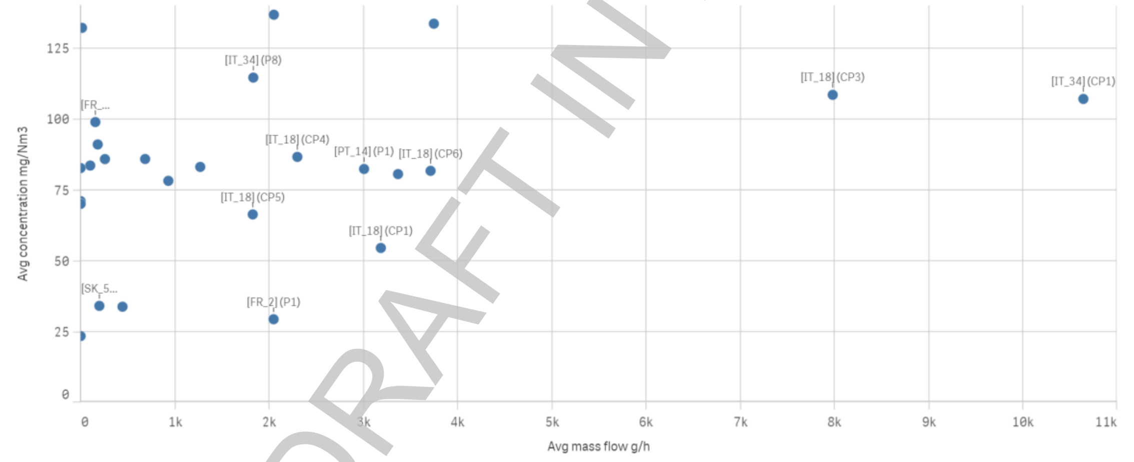
Descriptions of low-NO_X burners used for conventional fuels are given in the LCP BREF [17, COM 2017] (note: these may require specific modifications for use in chemical processes).

Achieved environmental benefits

Reduced NO_X emissions to air.

Environmental performance and operational data

Figure 3.41 shows NO_X concentration versus mass flow when a low-NO_X burner is used for process furnaces/heaters with a concentration of less than 150 mg/Nm^3.



Source: [43, EIPPCB 2019]

Figure 3.43: NO_X concentration versus mass flow, for concentrations < 150 mg/Nm^3 when a low-NO_X 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, EIPPCB 2019]

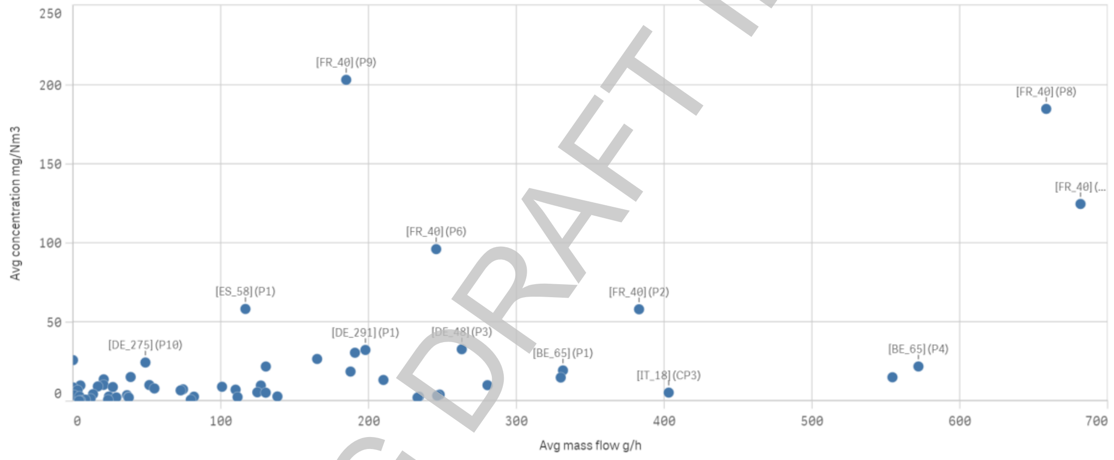
3.3.2.11 Optimised combustion

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_2, 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 3.41 shows CO concentration versus mass flow when optimised combustion is used for process furnaces/heaters.



Source: [43, EIPPCB 2019]

Figure 3.44: 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, EIPPCB 2019]

3.3.2.12 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.

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^3. One gas engine reported benzene emissions below 2.5 g/h and 2 mg/Nm^3. 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, EIPPCB 2019], [41, EIPPCB 2018]

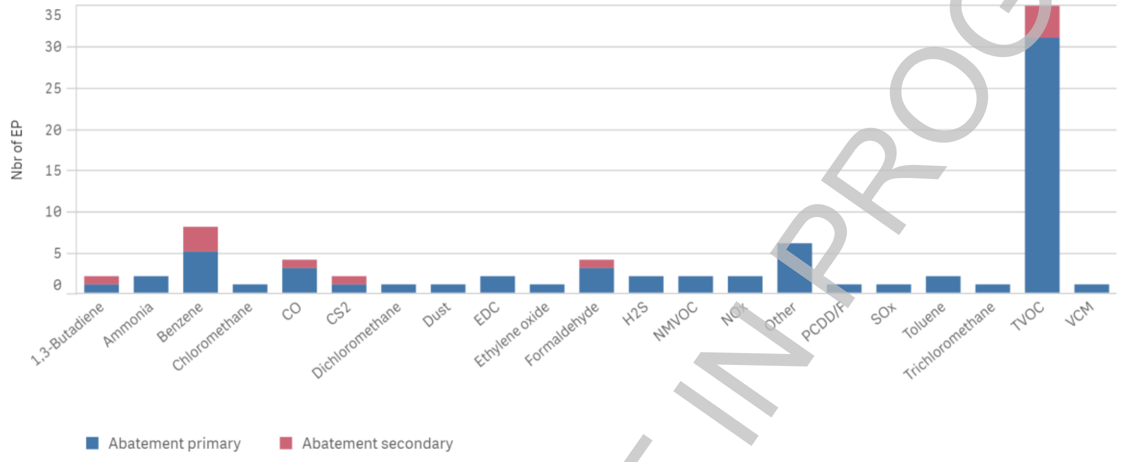
3.3.2.13 Catalytic oxidation

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.

Technical description

Catalytic oxidation is used as an abatement technique to reduce emissions of organic compounds (e.g. TVOC, benzene) (see Figure 3.45).



Source: [43, EIPPCB 2019]

Figure 3.45: 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, EIPPCB 2019].

Reported waste gas flows for catalytic oxidation are shown in Table 3.10.

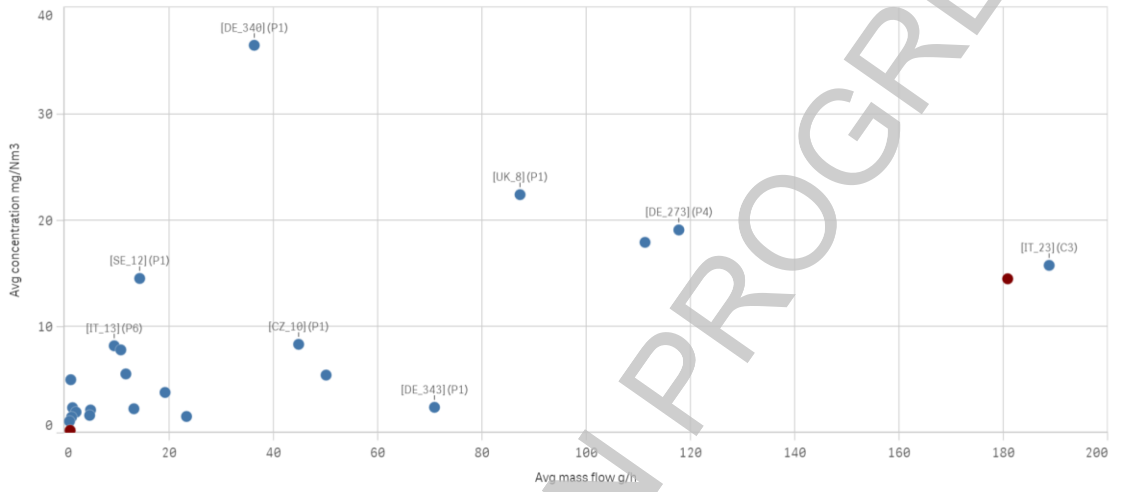
Table 3.10: Reported waste gas flows for catalytic oxidation

Type	Waste gas flows (Nm^3/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, EIPPCB 2019]

The combustion temperature reported by the data collection is typically between 200 °C and 600 °C. Some plants reported heat recovery.

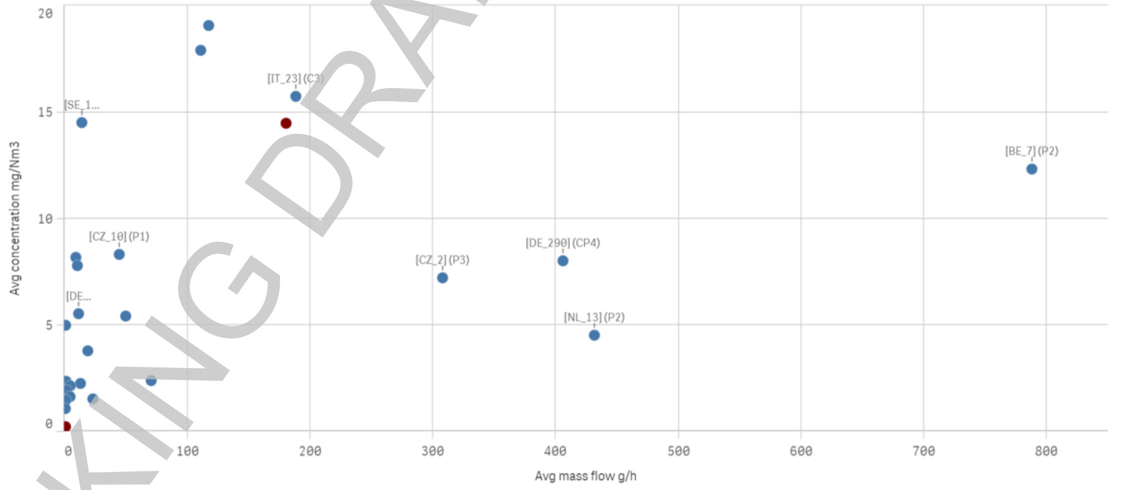
Figure 3.46 and Figure 3.47 show TVOC concentration versus mass flow when catalytic oxidation is used. Figure 3.46 shows data from emission points with a mass flow of less than 200 g/h and Figure 3.47 shows data from emission points with a concentration of less than 20 mg/Nm^3.



NB: Some of the emissions were reported as NMVOC (red dots).

Source: [43, EIPPCB 2019]

Figure 3.46: TVOC concentration versus mass flow, for mass flows < 200 g/h when catalytic oxidation is used



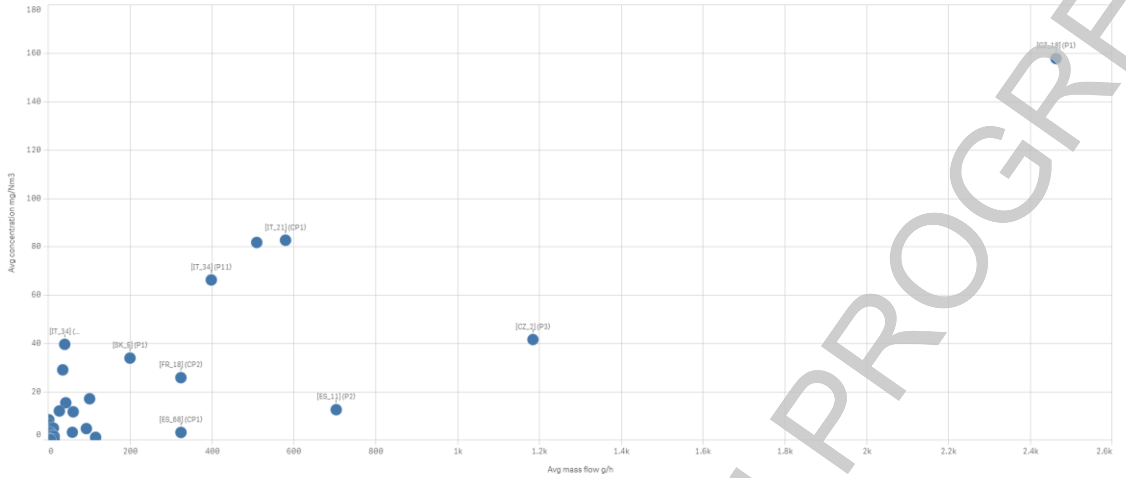
NB: Some of the emissions were reported as NMVOC (red dots).

Source: [43, EIPPCB 2019]

Figure 3.47: TVOC concentration versus mass flow, for concentrations < 20 mg/Nm^3 when catalytic oxidation is used

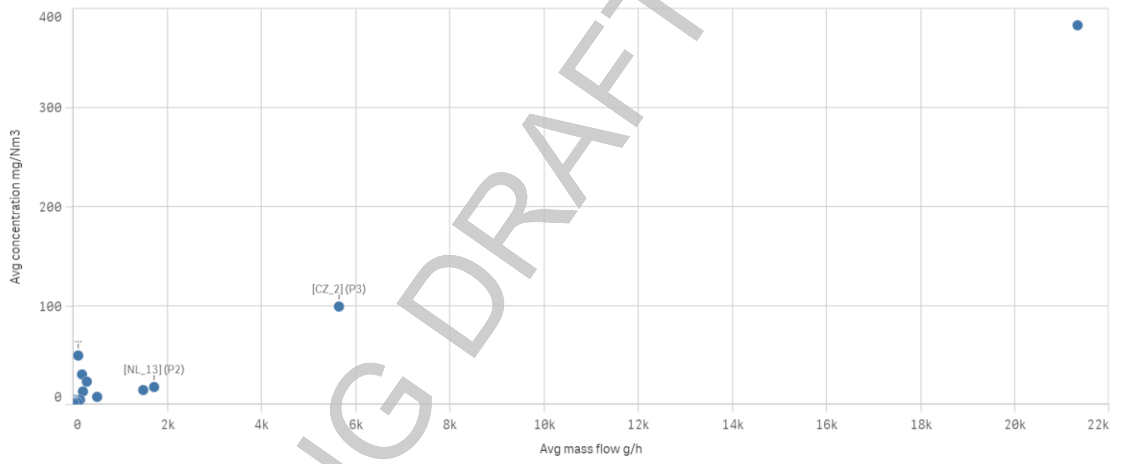
TVOC emissions from catalytic oxidation tend to be higher than those from thermal oxidation, particularly when compared with straight thermal oxidation (see Section 3.3.2.14).

The use of catalytic oxidation leads to the generation of NO_X and CO. Figure 3.48 and Figure 3.49 respectively shows NO_X concentration and CO concentration versus mass flow when catalytic oxidation is used.



Source: [43, EIPPCB 2019]

Figure 3.48: NO_X concentration versus mass flow when catalytic oxidation is used



Source: [43, EIPPCB 2019]

Figure 3.49: CO concentration versus mass flow when catalytic oxidation is used

NO_X emission levels from catalytic oxidation are generally lower than those from thermal oxidation (see Section 3.3.2.14).

Optimisation of the catalytic oxidation can reduce the emissions of NO_X and CO. This is carried out by:

- optimising the design of the oxidiser:
    - residence time;
    - mixing of the flows (e.g. natural diffusion between turbulent streams, changes in flow direction);
    - combustion chamber;

- monitoring the combustion parameters:
  - oxygen content;
  - carbon monoxide concentration;
  - temperature;
- inspecting the burners regularly, and cleaning them when necessary.

When the oxidised VOCs contain sulphur and/or halogens, further emissions of sulphur dioxide and/or hydrogen halides might be expected. This might require an additional waste gas treatment after catalytic oxidation (e.g. absorption).

Further information is provided in the CWW BREF [13, COM 2016].

Cross-media effects

- Generation of NO_X and CO and potentially of other pollutants (e.g. HCl, SO_2, PCDD/F).
- Consumption of fuel in the case of non-autothermal operation.

Technical considerations relevant to applicability

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, EIPPCB 2019]

3.3.2.14 Thermal oxidation

Description

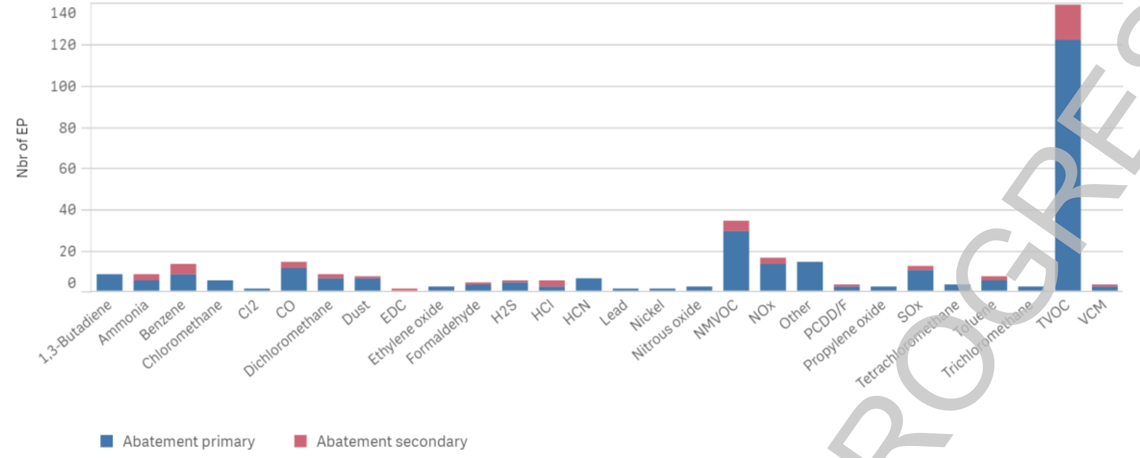
Abatement technique which oxidises combustible compounds in a waste gas stream with air or oxygen. The waste gas stream is heated above its auto-ignition point in a combustion chamber and maintained at a high temperature long enough to complete its combustion to carbon dioxide and water. The typical 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.

Technical description

Thermal oxidation is used as an abatement technique to reduce emissions of organic compounds (e.g. TVOC, benzene) (see Figure 3.50).



Source: [43, EIPPCB 2019]

Figure 3.50: 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, EIPPCB 2019].

Reported waste gas flows for thermal oxidation are shown in Table 3.11.

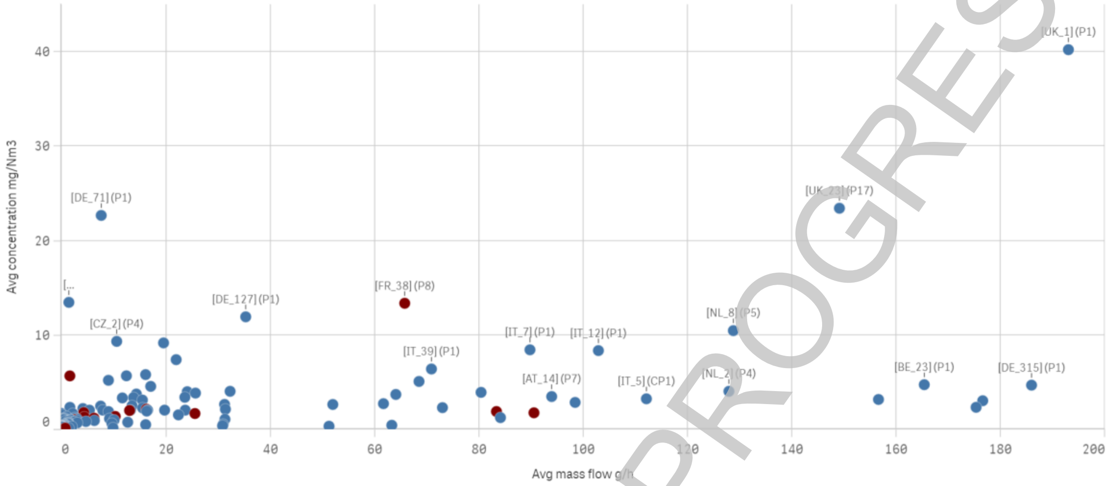
Table 3.11: Reported waste gas flows for thermal oxidation

Type	Waste gas flows (Nm³/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, EIPPCB 2019]

The combustion temperature reported by the data collection is typically between 600 °C and 1 200 °C.

Figure 3.51 and Figure 3.52 show TVOC concentration versus mass flow when thermal oxidation is used. Figure 3.51 shows data from emission points with a mass flow of less than 200 g/h and Figure 3.52 shows data from emission points with a concentration of less than 20 mg/Nm^3.

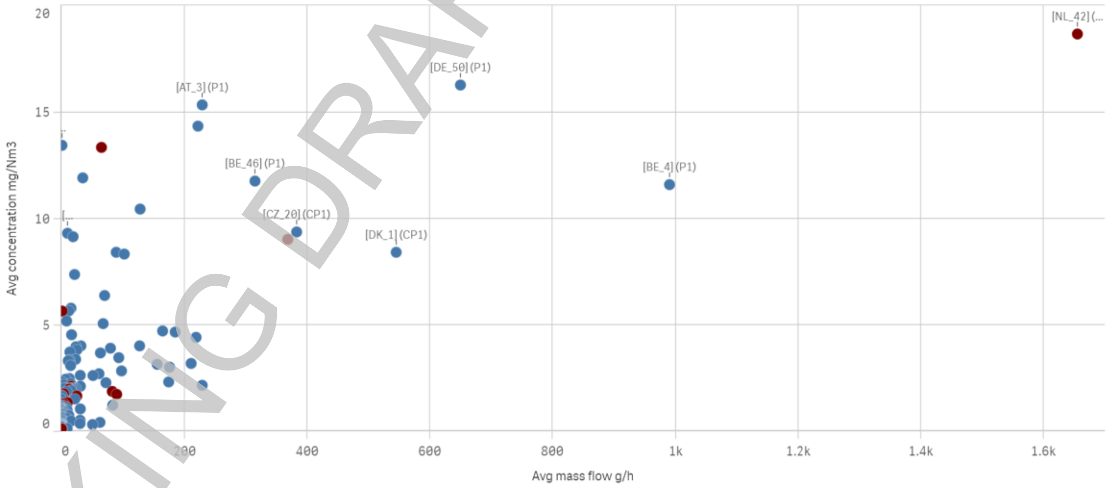


NB: Some of the emissions were reported as NMVOC (red dots).

For better visualisation, two emission points (average concentration > 150 mg/Nm^3) are not shown in the scatter plot: CZ_24_(P12) and DE_80_(P4).

Source: [43, EIPPCB 2019]

Figure 3.51: TVOC concentration versus mass flow, for mass flows < 200 g/h when thermal oxidation is used

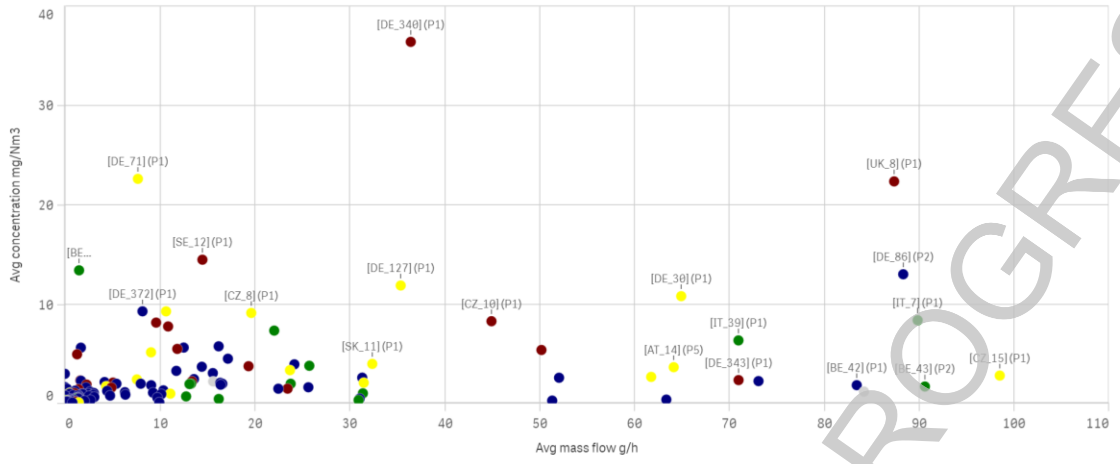


NB: Some of the emissions were reported as NMVOC (red dots).

Source: [43, EIPPCB 2019]

Figure 3.52: TVOC concentration versus mass flow, for concentrations < 20 mg/Nm^3 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 3.53).

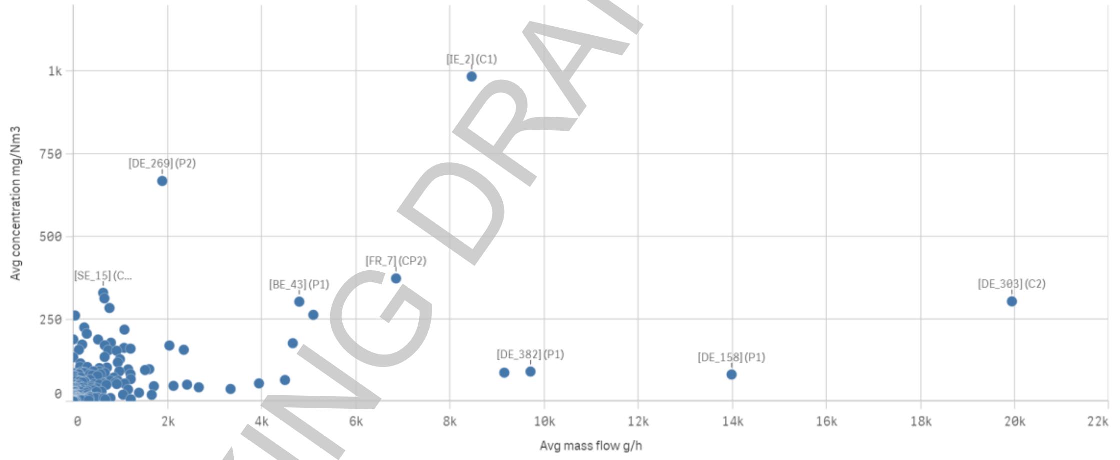


● Straight TO ● Catalytic oxidation ● Recuperative TO ● Regenerative TO ● Other type of TO

Source: [43, EIPPCB 2019]

Figure 3.53: Comparison of TVOC emission levels from catalytic oxidation and different types of thermal oxidation

The use of thermal oxidation leads to the generation of NO_X and CO. Figure 3.54 shows NO_X concentration versus mass flow when thermal oxidation is used.

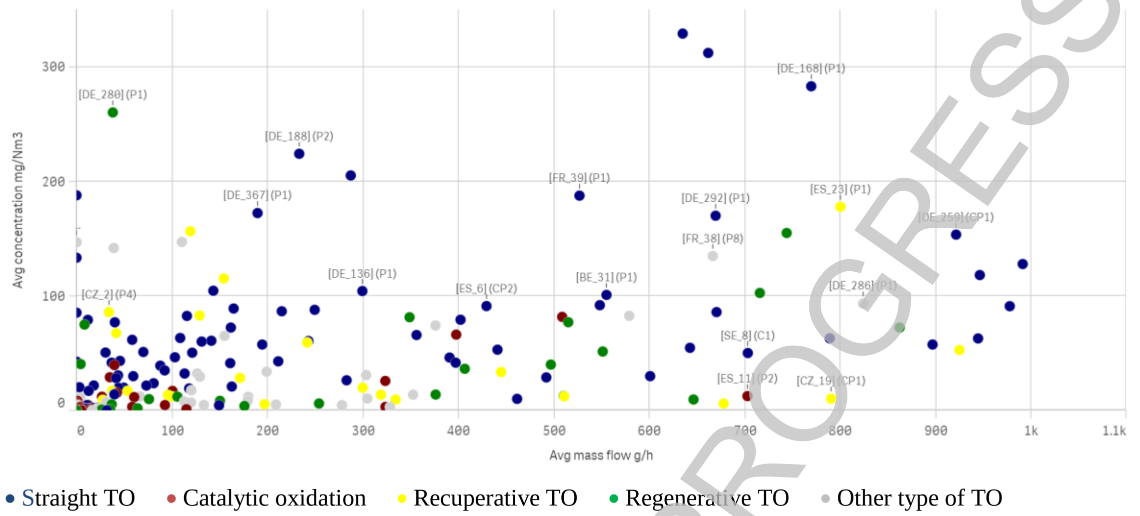


For better visualisation, one emission point (average concentration > 4 000 mg/Nm^3) is not shown in the scatter plot: FR_5_(P1)

Source: [43, EIPPCB 2019]

Figure 3.54: NO_X concentration versus mass flow when thermal oxidation is used

NO_X emission levels from thermal oxidation are generally higher than those from catalytic oxidation (see Figure 3.55).



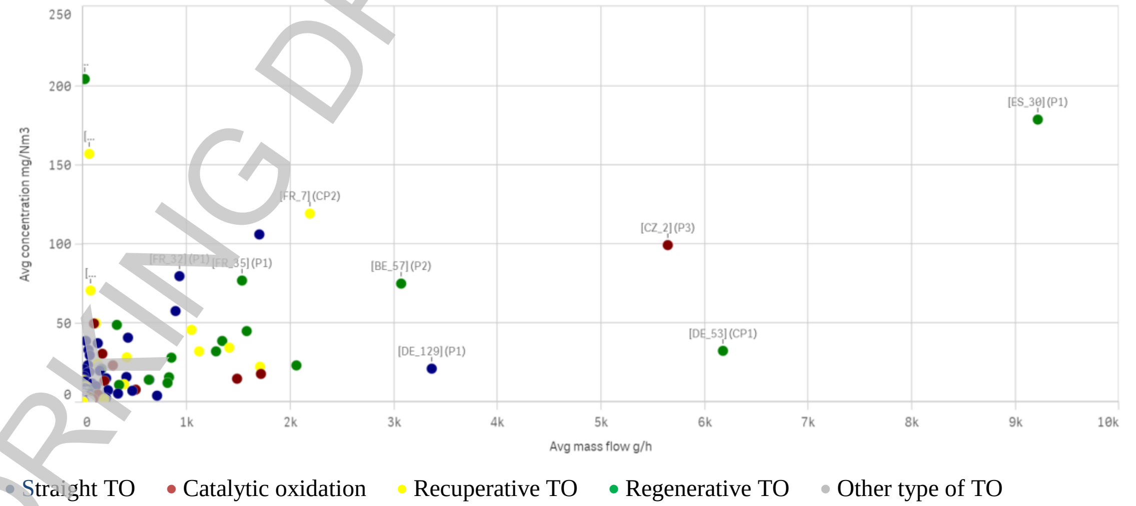
For better visualisation, only emission points with concentrations in the range of 0-400 mg NO_X/Nm^3 and mass flows in the range of 0-1 000 g NO_X/h are represented in the scatter plot.

Source: [43, EIPPCB 2019]

Figure 3.55: Comparison of NO_X emission levels from catalytic oxidation and different types of thermal oxidation

If preheating of waste gases and combustion air is necessary, regenerative and recuperative thermal oxidisers will show overall lower NO_X emissions than straight thermal oxidisers because of energy savings (indirect effect).

Figure 3.56 shows CO concentration versus mass flow when thermal oxidation is used.



For better visualisation, one emission point (average concentration > 4 000 mg/Nm^3) is not shown in the scatter plot: FR_5_(P1).

Source: [43, EIPPCB 2019]

Figure 3.56: Comparison of CO emission levels from catalytic oxidation and different types of thermal oxidation

Optimisation of thermal oxidation can reduce the emissions of NO_X and CO. This is carried out by:

- optimising the design of the oxidiser:
  - residence time;
  - mixing of the flows (e.g. natural diffusion between turbulent streams, changes in flow direction);
  - combustion chamber;
- monitoring the combustion parameters:
  - oxygen content;
  - carbon monoxide concentration;
  - temperature;
- inspecting the burners regularly, and cleaning them when necessary.

When the oxidised VOCs contain sulphur and/or halogens, further emissions of sulphur dioxide and/or hydrogen halides might be expected. This might require an additional waste gas treatment after thermal oxidation (e.g. absorption).

Further information is provided in the CWW BREF [13, COM 2016].

Cross-media effects

- Generation of NO_X and CO and potentially of other pollutants (e.g. HCl, SO2, 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, EIPPCB 2019]

3.3.2.15 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_X 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_X 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_X emissions (see Figure 3.57).

Source: [43, EIPPCB 2019]

Figure 3.57: Use of SCR 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.

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_X typically range from 50 % to more than 99 % [43, EIPPCB 2019].

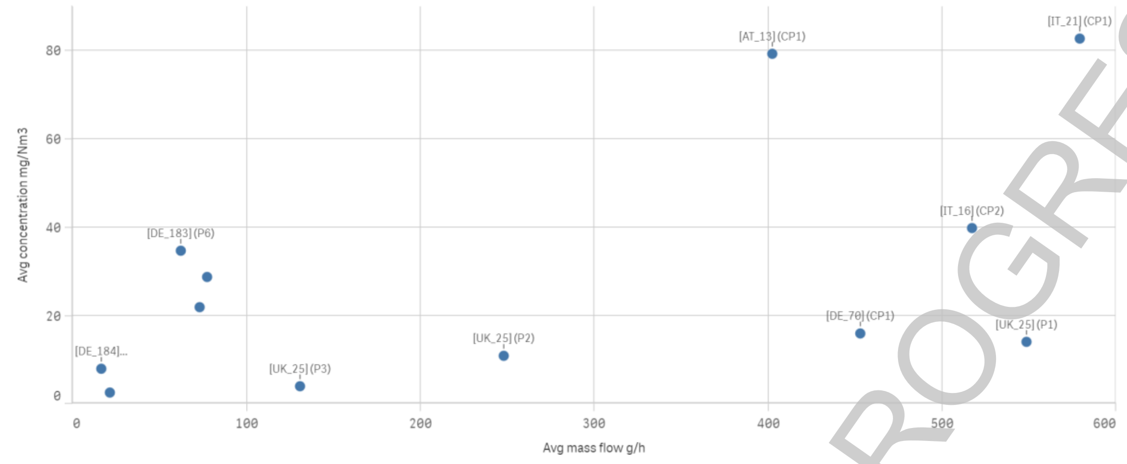
Reported waste gas flows for SCR are shown in Table 3.12.

Table 3.12: Reported waste gas flows for SCR

Type	Waste gas flows (Nm^3/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

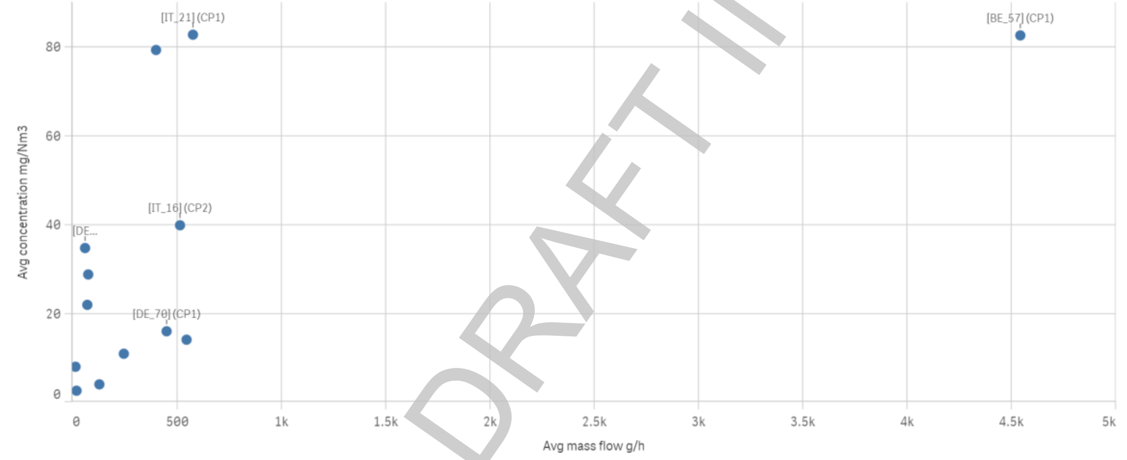
Source: [43, EIPPCB 2019]

Figure 3.58 and Figure 3.59 show NO_X concentration versus mass flow when SCR is used. Figure 3.58 shows data from emission points with a mass flow of less than 1 000 g/h and Figure 3.59 shows data from emission points with a concentration of less than 150 mg/Nm^3.



Source: [43, EIPPCB 2019]

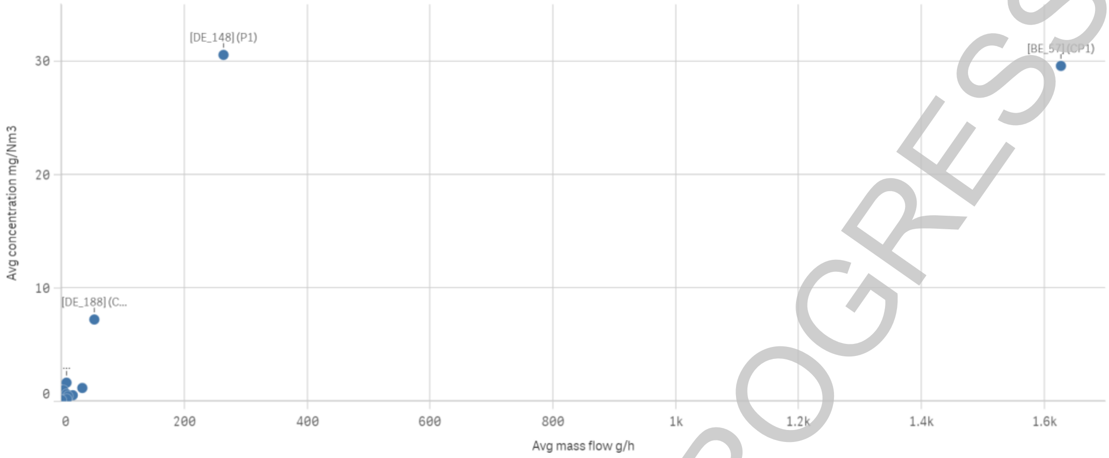
Figure 3.58: NO_X concentration versus mass flow, for mass flows < 1 000 g/h when SCR is used



Source: [43, EIPPCB 2019]

Figure 3.59: NO_X concentration versus mass flow, for concentrations < 150 mg/Nm^3 when SCR is used

The use of SCR leads to the generation of ammonia. Figure 3.60 shows ammonia concentration versus mass flow when SCR is used.



Source: [43, EIPPCB 2019]

Figure 3.60: 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, EIPPCB 2019]

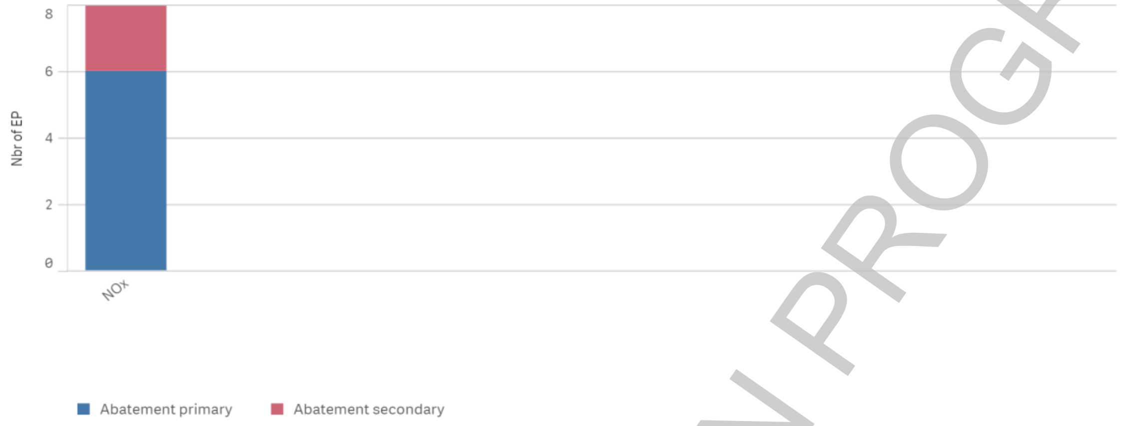
3.3.2.16 Selective non-catalytic reduction (SNCR)

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_X emissions (see Figure 3.61).



Source: [43, EIPPCB 2019]

Figure 3.61: Use of SNCR 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.

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_X typically range from 30 % to 80 % [43, EIPPCB 2019].

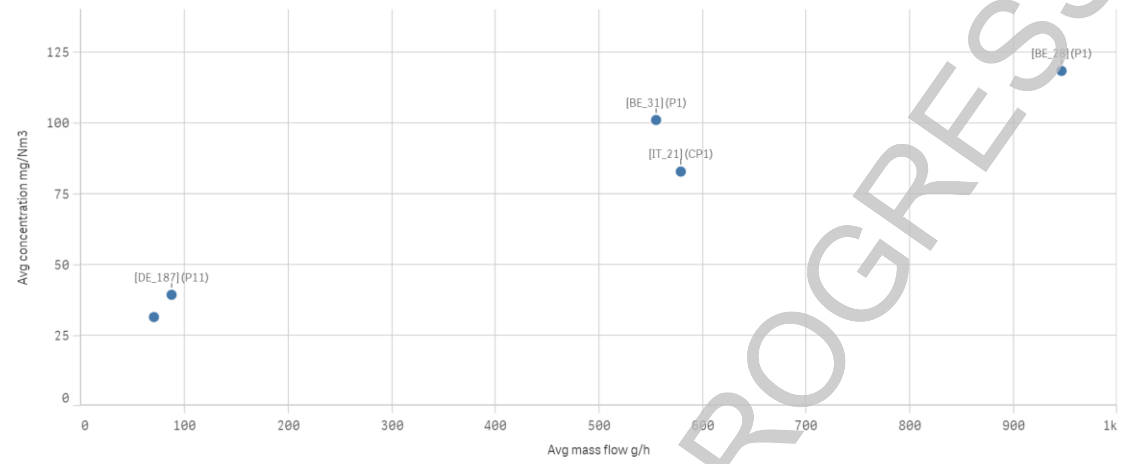
Reported waste gas flows for SNCR are shown in Table 3.13.

Table 3.13: Reported waste gas flows for SNCR

Type	Waste gas flows (Nm^3/h)					Number of emission points
	Min.	10th percentile	Median	90th percentile	Max.	
All types	1 500	2000	5 500	36 000	45000	9

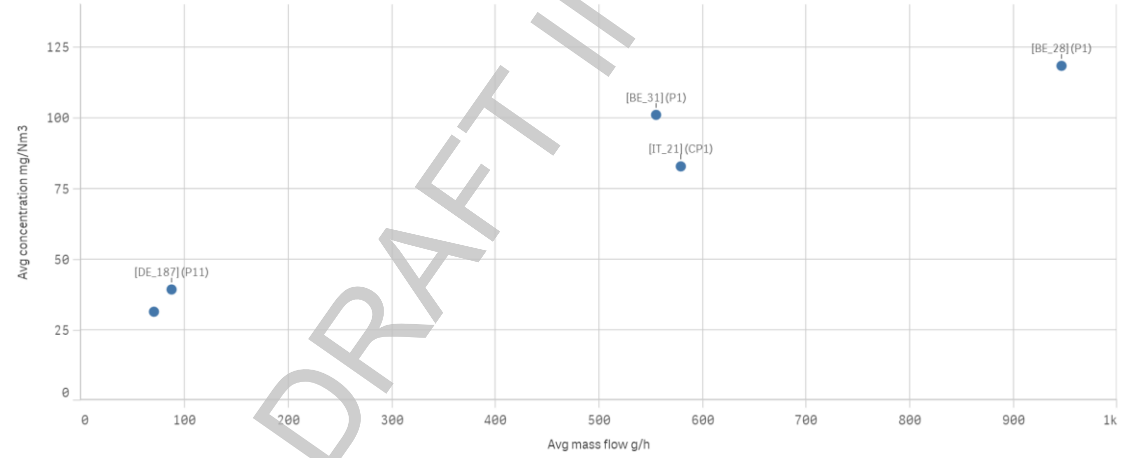
Source: [43, EIPPCB 2019]

Figure 3.62 and Figure 3.63 show NO_X concentration versus mass flow when SNCR is used. Figure 3.62 shows data from emission points with a mass flow of less than 1 000 g/h and Figure 3.63 shows data from emission points with a concentration of less than 150 mg/Nm^3.



Source: [43, EIPPCB 2019]

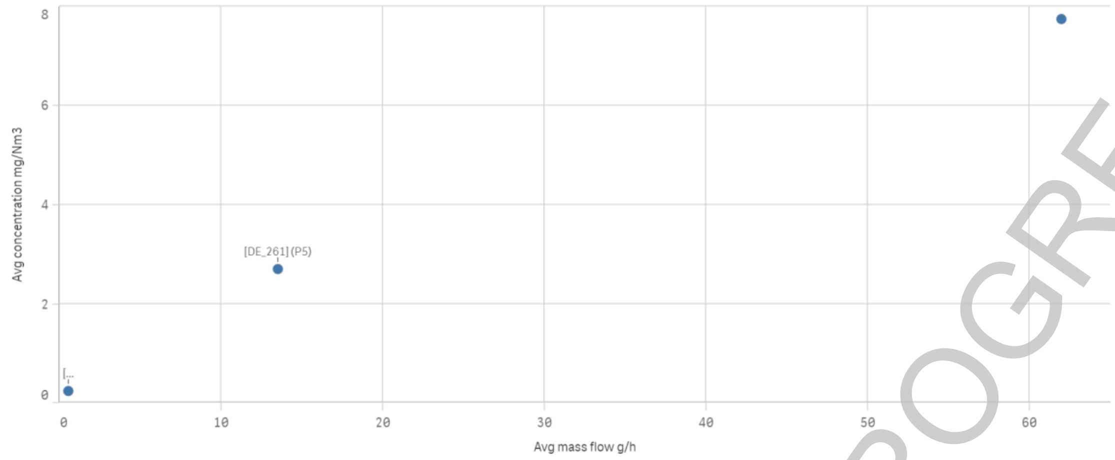
Figure 3.62: NO_X concentration versus mass flow, for mass flows < 1 000 g/h when SNCR is used



Source: [43, EIPPCB 2019]

Figure 3.63: NO_X concentration versus mass flow, for concentrations < 150 mg/Nm^3 when SNCR is used

The use of SNCR can lead to the generation of ammonia. Figure 3.64 shows ammonia concentration versus mass flow when SNCR is used.



Source: [43, EIPPCB 2019]

Figure 3.64: 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, EIPPCB 2019]

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 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, waste water treatment plants, flares or OTNOC.

Taken individually, the quantities emitted per source of diffuse emission are generally small. However, a chemical plant generally counts thousands of emission sources (or tens of thousands especially in the case of fugitive emissions) and the sum of all these small losses can lead to significant quantities of diffuse emissions.

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_X 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.

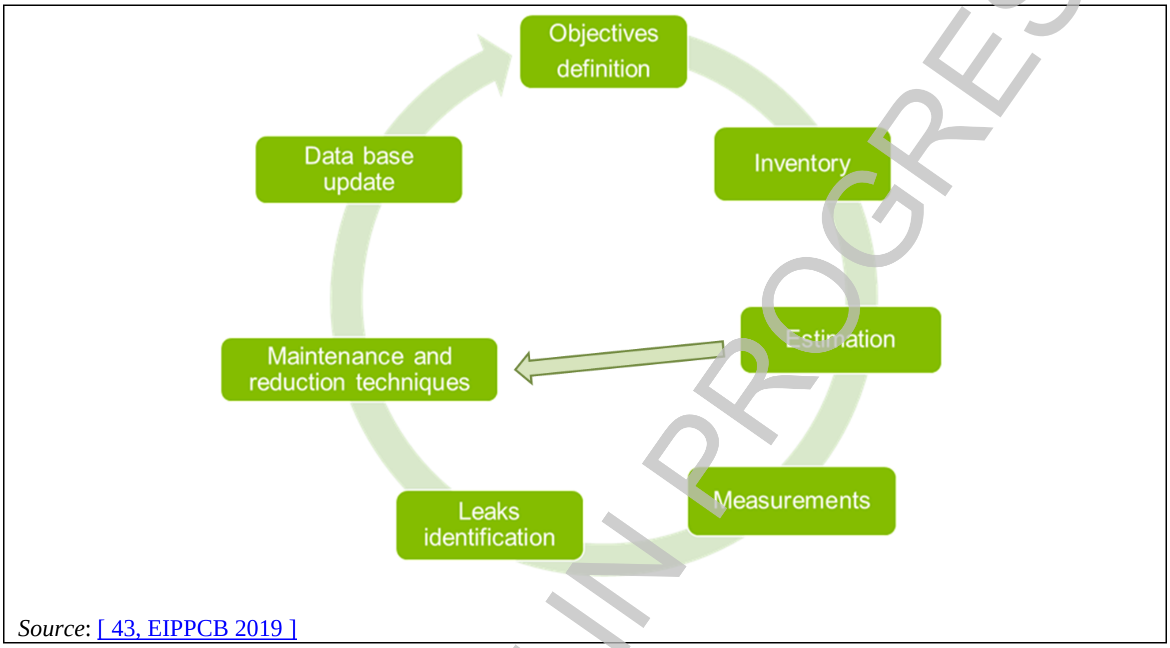
Technical description

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. LDAR is carried out as a campaign that typically lasts from 1 to 5 years. The LDAR programme includes all of the following features:
    a. Listing of equipment identified as relevant sources in the inventory of diffuse VOC emissions.
    b. Definition of a VOC concentration threshold above which equipment is considered leaky ('leak threshold').
    c. Definition of a VOC concentration threshold above which equipment maintenance is carried out ('maintenance threshold'). The maintenance threshold is generally higher than the leak threshold.
    d. Measuring fugitive VOC emissions from equipement listed under point a.
    e. Carrying out maintenance actions on equipment considered leaky when the measured VOC concentration is above the maintenance threshold. Maintenance actions are prioritised according to the hazardous properties of the emitted substance(s) and/or the significance of the emissions.
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 sources in the inventory of diffuse VOC emissions.
    b. Measuring non-fugitive VOC emissions from equipement 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) and/or the significance of the emissions.
v. Establishing and maintaining a data base 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. if applicable, the results of the measurements, including for each equipment identified as leaky: the emitted substance(s), their hazardous properties (if relevant, e.g. CMR 1A, 1B or 2), the concentration(s) of the emitted substance(s) from the leaky equipment and the date when the equiment was identified as leaky.
vi. Reviewing and updating the LDAR programme for the next campaign. This includes all of the following:
    a. lowering the leak and/or maintenance thresholds;
    b. reviewing the prioritisation of equipment to be monitored, giving higher priority to (the type of) equipment identified as leaky during the previous campaign;
    c. planning the maintenance, repair, upgrade or replacement of equipment that could not performed during the previous campaign due to operational constraints.
vii. Reviewing and updating the detection and reduction programme for non-fugitive VOC emissions. This includes all of the following:
    a. measuring 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.



Source: [43, EIPPCB 2019]

Figure 3.65: 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_28 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_28 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 forces for implementation

- Environmental legislation.
- Reduction in material losses.
- Minimisation of the environmental impact of diffuse VOC emissions.
- Health and safety for employees.

Example plants

Plants FR_28 and 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.

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:

Emission Rate = Emission Factor × 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 - 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.

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

No information provided.

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 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 hand-held 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 3.66: 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 3.67: 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 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 infra-red cameras equipped with a filter to selectively detect radiation at the specific C-H absorption band (3.2-3.4 µm). VOCs that can absorb infrared radiation in this spectral range 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. New systems using drones are currently under development and could improve the accessibility of emission sources. [44, SENSIA 2019]

An OGI camera does not directly provide the concentration of the emitted VOC. Nevertheless, knowing the detection limit of the camera may give an indication of the leak rate. Usually, the OGI camera detection limit is between below 1 g/h and 10 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).

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 3.68: Optical gas imaging

Achieved environmental benefits
Identification from a distance of leaks above the detection limit. OGI is particularly suitable in facilities with a significant number of potential leak points under insulation or that are not easily accessible.

Environmental performance and operational data
The detection limit of the OGI depends on the nature of the substance(s) to be detected. 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.

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 Optical absorption-based techniques (DIAL and SOF)

Description
In order to assess the effectiveness of all the techniques applied to prevent/reduce diffuse VOC emissions, two monitoring methods are available for use as described below.

Technical description
Differential absorption LIDAR (DIAL) method
The DIAL method can target one or two species at a time. It can be used to estimate VOC concentrations in general by targeting a generic wavelength that is representative of the carbon-hydrogen bond within the species of interest. This generic measurement will yield information on C_2 to C_8 compounds.

DIAL systems have both an infrared and an ultraviolet component. The infrared DIAL method is used primarily for alkanes although it can identify most species with absorption in the infrared spectral region between 2.5 µm and 4 µm – including, for example, hydrogen chloride, nitrous oxide, and methanol. Limits of detection for the alkanes are in the 10-50 ppb range at distances up to about 800 metres. The UV/Visible DIAL method can identify and specify benzene, toluene, and xylenes in the 10-20 ppb range and can also be used for measuring elemental mercury, ozone, sulphur dioxide, nitrogen dioxide, and nitrogen monoxide.

Limits of detection are very dependent upon site conditions at the time of measurement. To obtain mass emission fluxes, the concentration data across the plume section are multiplied by the wind velocity perpendicular to the measurement plane. Wind data availability, accuracy and representativeness are essential for reducing measurement uncertainties. The overall uncertainty in industrial field conditions is evaluated at around 30-50 %, most of it originating from wind speed evaluation [13, COM 2016].
The DIAL method may provide a conservative estimate because it does not necessarily capture the whole plume. Nonetheless, DIAL studies of 100-plus facilities executed under different climatic, environmental, and operating conditions all show that the facilities have higher emissions than are reported [13, COM 2016].

Solar occultation flux (SOF) method
The solar occultation flux (SOF) method uses a passive FTIR system mounted on a truck. This method measures olefins and alkanes, but not aromatics. Also, some other restrictions exist on the range of hydrocarbons that can be measured, i.e. those heavier than C_8 to C_{10}. Its use is limited to sunny days, and the wind must blow in the same direction for a long period of time.

The overall uncertainty for quantification in industrial field conditions is evaluated at around 35-40 %. Most of it originates from wind (speed and direction) evaluation uncertainty and retrieval uncertainty (combined effect of instrumentation and retrieval stability on the retrieved total columns during the course of a plume transect).

While each approach is different, the DIAL and SOF methods both produce roughly equivalent emission estimates.

Achieved environmental benefits
The facilitation of the prevention and reduction of diffuse VOC emissions.

Cross-media effects
None.

Operational data
In Sweden, both the DIAL (until 1988, once every 3 years) and SOF (after 1998) methods have been used to make site-level assessments at petrochemical installations.

Applicability
Generally applicable to plants where large amounts of VOCs are handled.

Economics
Depending upon the size of the site, a typical DIAL survey cost is reported to be between EUR 75 000 and EUR 150 000.

Driving force for implementation

- Reporting requirements imposed by authorities.
- Reduction in material losses.
- Minimisation of the environmental impact of diffuse VOC emissions.

Example plants
Petrochemical installations and refineries in Sweden.

Reference literature
[13, COM 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:

<u>Estimation</u>
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.

<u>Measurement</u>
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.

<u>Calculation</u>
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
No reference literature provided.

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 non-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 know 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 and/or OGI campaign may be conducted.

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_28 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_28 and PT_5.

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 efficient equipment; bellow valves are especially recommended to handle highly toxic substances;
- 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;
- 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 a floating roof on tanks.

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.

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 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]

3.5.1.2 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

No information provided.

Reference literature

[18, COM 2007]

3.5.2 PVC

3.5.2.1 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]

3.5.2.2 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

No information provided.

Reference literature

[18, COM 2007]

3.5.2.3 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

No information provided.

Reference literature

[18, COM 2007]

3.5.3 Solution-polymerised rubbers

3.5.3.1 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
No information provided.

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_2 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_2 is recycled.

Further information is provided in the POL BREF [18, COM 2007]

Achieved environmental benefits
Minimisation of CS_2 emissions from spinning.

Environmental performance and operational data
No information provided.

Cross-media effects
Recovery of CS_2 reduces the amount of fresh chemicals needed in the process.

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.
- Reduction of CS_2 emissions to air.
- Reduction of CS_2 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.

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;
   - aromatics: production of benzene, toluene, ortho-, meta- and para-xylene as well as cyclohexane from the pygas by-product of steam crackers and from reformate/naphtha produced in catalytic reformers;
   - ethlybenzene using either the zeolite- or $AlCl_3$-catalysed alkylation process;
   - styrene monomer either by ethylbenzene dehydrogenation or by co-production with propylene oxide;
   - formaldehyde;
   - ethylene oxide and ethylene glycols;
   - phenol from cumene;
   - ethanolamines;
   - 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_X) 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 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);
- 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;
- urea.

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 may be covered by the BAT conclusions for Large Combustion Plants (LCP), the BAT conclusions for the Refining of Mineral Oil and Gas and/or by Directive (EU) 2015/2193 of the European Parliament and of the Council[3].
   - Process furnaces/heaters with a total rated thermal input below 1 MW.

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. This may be covered by the BAT conclusions 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 these BAT conclusions provided that these processes are directly associated with the chemical production process.

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).

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[3] 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).

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);
- 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).

Definitions

For the purposes of these BAT conclusions, the following definitions apply:

General terms	
Term used	**Definition**
Channelled emissions to air	Emissions of pollutants into the air through an emission point such as a stack or a chimney.
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 treatment of waste gases (i.e. using thermal or catalytic oxidation).
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.
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: • moving equipment, such as agitators, compressors, pumps, valves (manual and automatic); • static equipment, such as flanges and other connections, open-ended lines, sampling points.
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 e.g. atmospheric vents, bulk storage, loading/unloading systems, vessels and tanks (on opening), open gutters, sampling systems, tank venting, waste, sewers, waste water treatment plants, flares or other than normal operating conditions (OTNOC).
NO_X precursors	Nitrogen-containing compounds (e.g. ammonia, nitrous gases, nitrogen-containing organic compounds) in the input to a thermal or catalytic oxidation that lead to NO_X emissions. Elementary nitrogen is not included.

Operational constraint	Limitation or restriction connected, for example, to: - process design (e.g. substances that cannot be substituted, very corrosive substances); - operating conditions (e.g. very high temperature or pressure); - the functioning of the plant; - resource availability (e.g. availability of spare parts when replacing a piece of equipment, availability of qualified manpower); - expected environmental benefits (e.g. giving priority to maintenance, repair or replacement actions with the highest environmental benefit).
Periodic measurement	Measurement at specified time intervals using manual or automated methods.
Process furnace/heater	Process furnaces or heaters are: - combustion units used for the treatment of objects or feed material through direct contact, e.g. in drying processes or chemical reactors; or - 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 such as steam cracker furnaces. 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 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.
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.

Substances and parameters	
Term used	**Definition**
$AlCl_3$	Aluminium trichloride.
Cl_2	Elementary chlorine.
CO	Carbon monoxide.
CS_2	Carbon disulphide.
Dust	Total particulate matter (in air).
EDC	Ethylene dichloride.
HCl	Hydrogen chloride.
HCN	Hydrogen cyanide.
HF	Hydrogen fluoride.
H_2S	Hydrogen sulphide.
NH_3	Ammonia.
Ni	Nickel.
NMVOC	Non-methane volatile organic compound.
N_2O	Dinitrogen oxide (also referred to as nitrous oxide).
NO_X	The sum of nitrogen monoxide (NO) and nitrogen dioxide (NO_2), expressed as NO_2.
Pb	Lead.
PCDD/F	Polychlorinated dibenzo-*p*-dioxins and -furans.

$PM_{2.5}$	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.
PM_{10}	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_2	Sulphur dioxide.
SO_X	The sum of sulphur dioxide (SO_2), sulphur trioxide (SO_3), and sulphuric acid aerosols, expressed as SO_2.
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.

Acronyms

For the purposes of these BAT conclusions, the following acronyms apply:

Acronym	Definition
CMR	Carcinogenic, mutagenic or toxic for reproduction.
CMR 1A	CMR substance of category 1A as defined in Regulation (EC) No 1272/2008 as amended.
CMR 1B	CMR substance of category 1B as defined in Regulation (EC) No 1272/2008 as amended.
CMR 2	CMR substance of category 2 as defined in Regulation (EC) No 1272/2008 as amended.
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.
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.

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.

[Note to the TWG: Whilst cross-references are provided to other parts of this document in order to aid the work of the TWG, they will not be included in the final BAT conclusions themselves. Such cross-references are consequently displayed in italics in square brackets.]

[Note to the TWG: In order to avoid repetition, this section contains general considerations that are essential to the understanding of the BAT conclusions taken as a stand-alone document, such as:

- *reference conditions for emissions to air (e.g. dry gas, standard temperature/pressure, oxygen concentration);*
- *averaging periods;*
- *sampling times;*
- *conversions to reference conditions;*
- *units in which environmental performance levels are expressed.]*

Emission levels associated with the best available techniques (BAT-AELs) and indicative emission levels for channelled emissions to air

The emission levels associated with the best available techniques (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^3, µg/Nm^3, or ng I-TEQ/Nm^3.

When a mass flow threshold is indicated, the BAT-AELs only apply if the mass flow of the given substance or parameter emitted from the emission point is above the associated mass flow threshold.

The averaging periods associated with the BAT-AELs and with the indicative emission levels for channelled emissions to air are defined as follows.

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 measurements of at least 30 minutes each (^{1}).
(^{1}) For any parameter where, due to sampling or analytical limitations, a 30-minute sampling/measurement and/or an average of three consecutive measurements is inappropriate, a more suitable procedure may be employed. For PCDD/F, a sampling period of 6 to 8 hours is used.		

BAT-AELs for diffuse VOC emissions to air

For diffuse VOC emissions from the use of 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 total emissions to air of a substance or parameter from the production of polymers, the BAT-AELs in these BAT conclusions are given as specific load (i.e. mass of the emitted substance or parameter per production output), in the unit g/kg of product.

The BAT-AELs for total emissions to air from the production of polymers refer to yearly averages. The total emissions include channelled and diffuse emissions from the storage, transfer and handling of VOCs and polymer products, as well as from polymerisation and finishing.

Channelled emissions to air are monitored according to BAT 8.

*[Request to the TWG for the production of **polyolefin** and **solution-polymerised rubbers**: to provide information on the production of **polyolefins** and **solution-polymerised rubbers**, in particular:*

- *information on the monitoring of the monomer concentration in the polymer (e.g. which analytical methods are used and at which stage of the process the measurements are carried out);*
- *information on the methodology for estimating/calculating total emissions;*
- *information on the parameters monitored for total and diffuse emissions: TVOC (total volatile organic carbon), total VOCs or NMVOCs;*
- *information on the measurement methods used for total and diffuse emissions of organic compounds.]*

*[Request to the TWG for the production of **viscose**: to provide information on the monitoring of CS_2 and H_2S **as total sulphur**]*

4.1 General BAT conclusions

4.1.1 Environmental management systems

[Note to the TWG: the following description of the general EMS features is based on standard text agreed at the level of the IED Article 13 Forum and used in recent documents such as the BAT conclusions for FDM, WI and STS. The possibilities for changes are therefore limited to the section dealing specifically with WGC issues]

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).

Note
Regulation (EC) No 1221/2009 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.

[This BAT conclusion is based on information given in Section 3.1.1]

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 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 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, NOX, SOX, Cl2, 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);

iii. information 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), including CMR properties.

Description

The information about diffuse emissions covers all emission sources in contact with:

- liquids containing more than 20 wt-% organic substances with a vapour pressure greater than 0.3 kPa at 293.15 K; or
- gases containing more than 10 vol-% organic substances with a vapour pressure greater than 0.3 kPa at 293.15 K.

Sources of diffuse emissions connected to pipes whose diameter is smaller than 12.7 mm (i.e. 0.5 inch) may be excluded from the inventory.

Note

The information about diffuse emissions to air is particularly relevant to activities producing large volumes of organic chemicals or using large amounts of solvents (e.g. for the production of pharmaceuticals).

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, etc.);
iii. set-up and implementation of a preventive maintenance plan for critical equipment (see BAT 1);
iv. monitoring (i.e. estimating or, where this is possible, measuring) and recording of emissions and associated circumstances during OTNOC (see BAT 7 and BAT 8);
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 a. following the periodic assessment of point v.

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 of channelled and diffuse emissions to air (see BAT 2). It takes into account the consumption 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, BAT is to limit 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 extent to which the number of emission points can be limited depends on technical (e.g. compatibility of the individual waste gas streams) and economic factors (e.g. geographical distance between different production units).

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.

4.1.3.2 Monitoring

BAT 7. BAT is to continuously monitor key process parameters (including 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 (1)	**Emission points**	**Standard(s)**	**Minimum monitoring frequency**	**Monitoring associated with**
Ammonia (NH_3)	All emission points	No EN standard available	Once every year (2) (3)	BAT 17, BAT 18
Benzene	All emission points	No EN standard available	Once every 6 months (2) (4)	BAT 11
1,3-Butadiene	All emission points	No EN standard available	Once every 6 months (2) (4)	BAT 11
Carbon monoxide (CO)	All emission points with a mass flow of ≥ 2 kg/h	Generic EN standards (5)	Continuous	BAT 16, BAT 18, BAT 36
	All emission points with a mass flow of < 2 kg/h	EN 15058	Once every year (2) (3)	
Chloromethane	All emission points	No EN standard available	Once every year (2) (3)	BAT 11
Dichloromethane	All emission points	No EN standard available	Once every year (2) (3)	BAT 11
Dust	All emission points	EN 13284-1	Once every year (2) (3)	BAT 14
Elementary chlorine (Cl_2)	All emission points	No EN standard available	Once every year (2) (3)	BAT 18
Ethylene dichloride (EDC)	All emission points	No EN standard available	Once every 6 months (2) (4)	BAT 11
Ethylene oxide	All emission points	No EN standard available	Once every 6 months (2) (4)	BAT 11
Formaldehyde	All emission points	No EN standard available	Once every 6 months (2) (4)	BAT 11
Gaseous chlorides	All emission points	EN 1911	Once every year (2) (3)	BAT 18
Gaseous fluorides	All emission points	No EN standard available	Once every year (2) (3)	BAT 18
Hydrogen cyanide (HCN)	All emission points	No EN standard available	Once every year (2) (3)	BAT 18
Lead and its compounds	All emission points	EN 14385	Once every year (2) (3)	BAT 14
Nickel and its compounds	All emission points	EN 14385	Once every year (2) (3)	BAT 14
Nitrous oxide (N_2O)	All emission points	EN ISO 21258	Once every year (2) (3)	—

Nitrogen oxides (NO_X)	All emission points with a mass flow of ≥ 5 kg/h	Generic EN standards (5)	Continuous	BAT 16, BAT 18, BAT 36
	All emission points with a mass flow of < 5 kg/h	EN 14792	Once every year (2) (3)	
PCDD/F	All emission points from catalytic and thermal oxidation of waste gases	EN 1948-1, EN 1948-2, EN 1948-3	Once every 6 months (2) (4)	BAT 12
$PM_{2.5}$ and PM_{10}	All emission points	EN ISO 23210	Once every year (2) (3)	BAT 14
Propylene oxide	All emission points	No EN standard available	Once every 6 months (2) (4)	BAT 11
Sulphur dioxide (SO_2)	All emission points	EN 14791	Once every year (2) (3)	BAT 16, BAT 18, BAT 36
Tetrachloromethane	All emission points	No EN standard available	Once every year (2) (3)	BAT 11
Toluene	All emission points	No EN standard available	Once every year (2) (3)	BAT 11
Trichloromethane	All emission points	No EN standard available	Once every year (2) (3)	BAT 11
Total volatile organic carbon (TVOC)	All emission points with a mass flow of ≥ 2 kg/h	Generic EN standards (5)	Continuous	BAT 11
	All emission points with a mass flow of < 2 kg/h	EN 12619	Once every year (2) (3)	BAT 11

(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) To the extent possible, the measurements are carried out at the highest expected emission state under normal operating conditions.

(3) The minimum monitoring frequency may be reduced to once every three years if the emission levels are proven to be sufficiently stable.

(4) The minimum monitoring frequency may be reduced to once every year 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.

[This BAT conclusion is based on information given in Section 2.3]

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
Applicability may be restricted where the costs are excessive due to the low concentration of the compound concerned in the process off-gas(es).

[This BAT conclusion is based on information given in Section 2.3.2]

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. BAT 9 has priority over sending process off-gases to a combustion unit.

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. Straight thermal oxidation is generally applicable.

Table 4.1: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of organic compounds

Substance/Parameter	BAT-AEL (mg/Nm^3) (Daily average or average over the sampling period)	Mass flow threshold (g/h)
Total volatile organic carbon (TVOC)	< 1-20	200
Total volatile organic carbon (TVOC) containing substances classified as CMR 1A or 1B	< 1-5	2.5
Total volatile organic carbon (TVOC) containing substances classified as CMR 2	< 1-10	100
Benzene	< 0.5-1	2.5
1,3-Butadiene		
Ethylene dichloride		
Ethylene oxide		
Propylene oxide		
Formaldehyde	1-5	
Chloromethane	< 0.5-1	100
Dichloromethane		
Tetrachloromethane		
Toluene		
Trichloromethane		

The associated monitoring is given in BAT 8.

[This BAT conclusion is based on information given in Section 2.3.2]

BAT 12. In order to reduce channelled emissions to air of PCDD/F from thermal treatment of waste gases (i.e. using thermal or catalytic oxidation) containing chlorine and/or chlorinated compounds, BAT is to use techniques a. and b., if necessary followed by technique c., given below.

Technique		Description
a.	Optimised catalytic or thermal oxidation	See Section 4.4.1.
b.	Rapid waste-gas cooling	Rapid cooling of waste gases from temperatures above 400 °C to below 250 °C to prevent the *de novo* synthesis of PCDD/F.
c.	Adsorption using activated carbon	See Section 4.4.1.

Table 4.2: BAT-associated emission level (BAT-AEL) for channelled emissions to air of PCDD/F from thermal treatment of waste gases (i.e. thermal or catalytic oxidation) containing chlorine and/or chlorinated compounds

Substance/Parameter	BAT-AEL (ng I-TEQ/Nm^3) (Average over the sampling period)	Mass flow threshold (µg I-TEQ/h)
PCDD/F	< 0.01-0.05	0.25

The associated monitoring is given in BAT 8.

[This BAT conclusion is based on information given in Section 2.3.2.11]

4.1.3.4 Dust (including PM_{10} and $PM_{2.5}$) 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**	**Applicabiliy**
a.	Absolute filter	See Section 4.4.1.	Applicability may be limited in the case of sticky dust or if the waste gas after the absolute filter needs to be treated at temperatures above 150 °C.
b.	Cyclone	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 if the waste gas after the fabric filter needs to be treated at temperatures above 250 °C.

Applicability

Applicability may be restricted where the costs are excessive due to the low content in the process off-gas(es).

[This BAT conclusion is based on information given in Section 2.3.3]

BAT 14. In order to reduce channelled emissions to air of dust and particulate-bound metals, BAT is to use one of the techniques given below.

Technique		**Description**	**Applicabiliy**
a.	Absolute filter	See Section 4.4.1.	Applicability may be limited in the case of sticky dust.
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.
d.	High-efficiency air filter	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^3) (Daily average or average over the sampling period)**	**Mass flow threshold (g/h)**
Dust	< 1-5 (1)	100
Dust containing substances classified as CMR 1A or 1B	< 1-2.5	2.5
Dust containing substances classified as CMR 2	< 1-2.5	15
Lead and its compounds, expressed as Pb	< 0.01-0.5	0.15
Nickel and its compounds, expressed as Ni	< 0.02-0.5	0.15
(1) The upper end of the range is 20 mg/Nm^3 when an absolute or fabric filter is not applicable.		

The associated monitoring is given in BAT 8.

[This BAT conclusion is based on information given in Section 2.3.3]

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
Applicability may be restricted where the costs are excessive due to the low concentration of the compound(s) concerned in the process off-gas(es).

BAT 16. In order to reduce channelled emissions to air of CO, NO_X and SO_X from the use of catalytic and thermal oxidation for the abatement of emissions of organic compounds, BAT is to use one or a combination of the techniques given below.

	Technique	Description	Main inorganic compounds targeted	Applicability
a.	Choice of fuel	See Section 4.4.1.	NO_X, SO_X	Generally applicable.
b.	Low-NO_X burner	See Section 4.4.1.	NO_X	Applicability to existing plants may be restricted by design and/or operational constraints.
c.	Optimised catalytic or thermal oxidation	See Section 4.4.1.	CO, NO_X	Generally applicable.
d.	Removal of high levels of NO_X precursors	Remove (if possible, for reuse) high levels of NO_X precursors prior to thermal or catalytic oxidation, e.g. by absorption, adsorption or condensation.	NO_X	Generally applicable.
e.	Absorption	See Section 4.4.1.	SO_X	Generally applicable.
f.	Selective catalytic reduction (SCR)	See Section 4.4.1.	NO_X	Applicability to existing plants may be restricted by space availability.
g.	Selective non-catalytic reduction (SNCR)	See Section 4.4.1.	NO_X	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 NOX from the use of catalytic or thermal oxidation

Substance/Parameter	BAT-AEL (mg/Nm^3) (Daily average or average over the sampling period)	Mass flow threshold (g/h)
Nitrogen oxides (NO_X) from catalytic oxidation	10-50	1 000
Nitrogen oxides (NO_X) from thermal oxidation	50-150 (1)	1 000

(1) The upper end of the range is 250 mg/Nm^3 if the process off-gas(es) contain(s) high levels of NO_X precursors.

The associated monitoring is given in BAT 8.

BAT-AELs for channelled emissions to air of SO_X and an indicative emission level for channelled emissions to air of CO: See Table 4.6.

[This BAT conclusion is based on information given in Section 2.3.4]

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_X emissions, BAT is to optimise the design and/or operation of SCR or SNCR (e.g. optimised reagent to NO_X 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

Substance/Parameter	BAT-AEL (mg/Nm^3) (Average over the sampling period)
Ammonia (NH_3) from SCR/SNCR	< 0.5-8 (1)

(1) The upper end of the range may be up to 30 mg/Nm^3 in the case of:
- thermal or catalytic oxidation of waste gases containing high levels of NO_X precursors; or
- if the waste gases contain high levels of NO_X prior to treatment with SCR or SNCR.

The associated monitoring is given in BAT 8.

[This BAT conclusion is based on information given in Section 2.3.4]

BAT 18. In order to reduce channelled emissions to air of inorganic compounds, BAT is to use one or a combination of the techniques given below.

	Technique	Description	Main inorganic compounds targeted	Applicability
a.	Absorption	See Section 4.4.1.	Cl_2, HCl, HCN, HF, NH_3, NO_X, SO_X	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_3, SO_X	Generally applicable.
c.	Selective catalytic reduction (SCR)	See Section 4.4.1.	NO_X	Applicability to existing plants may be restricted by space availability.
d.	Selective non-catalytic reduction (SNCR)	See Section 4.4.1.	NO_X	Applicability to existing plants may be restricted by the residence time needed for the reaction.

Table 4.6: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of inorganic compounds and indicative emission level for channelled CO emissions to air

Substance/Parameter	BAT-AEL (mg/Nm^3) (Daily average or average over the sampling period)	Mass flow threshold (g/h)
Ammonia (NH_3)	2-30 (1)	100
Carbon monoxide (CO)	No BAT-AEL (2)	Not applicable
Elementary chlorine (Cl_2)	< 0.5-2	5
Gaseous fluorides, expressed as HF	< 1-2	
Hydrogen cyanide (HCN)	< 0.1-1	
Gaseous chlorides, expressed as HCl	< 1-10	50
Nitrogen oxides (NO_X)	50-150 (3) (4)	1 000
Sulphur oxides (SO_X)	50-150 (5)	

(1) The BAT-AEL does not apply to channelled emissions to air of ammonia from the use of SCR or SNCR (see BAT 17).
(2) As an indication, the emission levels for carbon monoxide are 20-100 mg/Nm^3, as daily average or average over the sampling period.
(3) The upper end of the range is 300 mg/Nm^3 when NO_X are recovered from process off-gases to produce nitric acid.
(4) The BAT-AEL does not apply to channelled emissions to air of NO_X from the use of catalytic or thermal oxidation (see BAT 15) or from process furnaces/heaters (see BAT 36).
(5) 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.

[This BAT conclusion is based on information given in Section 2.3.4]

4.1.4 Diffuse VOC emissions to air

4.1.4.1 General techniques

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. LDAR is carried out as a campaign, which typically lasts from 1 to 5 years. The LDAR programme includes all of the following features:
    a. Listing of equipment identified as relevant emission sources in the inventory of diffuse VOC emissions (see BAT 2).
    b. Definition of a VOC concentration threshold above which equipment is considered leaky (‘leak threshold’). For the first LDAR campaign, the leak threshold is lower than or equal to 10 000 ppmv.
    c. Definition of a VOC concentration threshold above which equipment maintenance is carried out (‘maintenance threshold’). The maintenance threshold is generally higher than the leak threshold, but not higher than 10 000 ppmv.
    d. Measuring fugitive VOC emissions from equipement listed under point a. (see BAT 22).
    e. Carrying out maintenance actions on equipment considered leaky when the measured fugitive VOC concentration is above the maintenance threshold (see BAT 23 e. and f.), typically within 30 days from the date when the equipment was identified as leaky. Maintenance actions are prioritised according to the hazardous properties of the emitted substance(s) and/or the significance of the emissions.
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 emission sources in the inventory of diffuse VOC emissions (see BAT 2).
    b. Measuring non-fugitive VOC emissions from equipement listed under point a. (see BAT 22).
    c. Planning and implementing techniques to reduce non-fugitive VOC emissions (see BAT 23). The planning and implementation of techniques are prioritised according to the hazardous properties of the emitted substance(s) and/or the significance of the emissions.
v. Establishing and maintaining a data base 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. if applicable, the results of the measurements, including for each piece of equipment identified as leaky: the emitted substance(s), their hazardous properties (if relevant, e.g. CMR 1A, 1B or 2), the concentration(s) of the emitted substance(s) from the leaky equipment and the date when the equiment was identified as leaky.
vi. Reviewing and updating the LDAR programme for the next campaign. This includes all of the following:
    a. lowering the leak and/or maintenance thresholds;
    b. reviewing the prioritisation of equipment to be monitored, giving higher priority to (the type of) equipment identified as leaky during the previous campaign;

   c. planning the maintenance, repair, upgrade or replacement of equipment that could not be performed during the previous campaign due to operational constraints.

vii. Reviewing and updating the detection and reduction programme for non-fugitive VOC emissions. This includes all of the following:
   a. measuring 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 iii, iv, vi and vii are only applicable to sources of diffuse VOC emissions for which measurements according to BAT 22 are 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.

[This BAT conclusion is based on information given in Section 3.4.1]

4.1.4.2 Monitoring

BAT 20. BAT is to estimate diffuse VOC emissions to air at least once every year by using 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.

Technique		**Description**	**Applicability**
Diffuse emissions			
a.	Estimation of diffuse emissions from processes by using emission factors	An emission factor is a representative value that attempts to relate the quantity of a substance emitted to a process associated with the emission of that substance. Emission factors are usually expressed as the mass of a substance emitted divided by the throughput of the process emitting the substance.	Only applicable to processes for which emission factors have been derived according to nationally or internationally recognised guidance.
b.	Estimation of diffuse emissions from the whole plant by using a mass balance	Diffuse emissions are calculated from the difference of the substance inputs to and outputs from the plant, taking into account the generation and destruction of the substance in the plant. Mass balances are applied by plants using solvents (see BAT 21).	Generally applicable.
c.	Estimation of diffuse emissions from processes or equipment by using 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: • chemical properties of the substance (e.g. vapour pressure, molecular mass); • process operating data (e.g. operating time, product quantity, ventilation); • characteristics of the emission source (e.g. tank diameter, colour, shape).	Generally applicable.
Fugitive emissions			
d.	Estimation of fugitive emissions from equipment leaks by using emission factors	An emission factor is a representative value that attempts to relate the quantity of a substance emitted from a type of equipment. Emission factors are usually expressed as the mass of a substance emitted per hour and per equipment.	Only applicable to types of equipment for which emission factors have been derived according to nationally or internationally recognised guidance.
e.	Estimation of fugitive emissions from gasketed circular flange connections by calculations	Calculations according to EN 1591.	Generally applicable.

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	This includes: • identification and documentation of solvent inputs and outputs (e.g. channelled and diffuse emissions to air, emissions to water, solvent output in waste); • 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); • identification of the main sources of uncertainty of the aforementioned quantification, and implementation of corrective actions to reduce the uncertainty; • regular update of solvent input and output data.
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	Any change that could influence the uncertainty of the solvent mass balance data is recorded, such as: • malfunctions of the waste gas treatment system: the date and period of time are recorded; • changes that may influence air/gas flow rates (e.g. replacement of fans): the date and type of change are recorded.

Applicability

The technique 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 measure 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 (1) (2)	Type of VOCs	Standard(s)	Minimum measurement frequency
Sources of fugitive emissions	VOCs classified as CMR 1A or 1B	EN 15446	Once every year (3)
	VOCs not classified as CMR 1A or 1B		Once every LDAR campaign
Sources of non-fugitive emissions	VOCs classified as CMR 1A or 1B	No EN standard available	Once every year
	VOCs not classified as CMR 1A or 1B		Once every 5 years

(1) The measurements only apply to emission sources that are identified as relevant in the inventory given in BAT 2.
(2) The measurements do not apply to high-integrity equipment (see BAT 23 d.) or to equipment operated under subatmospheric pressure.
(3) In the case of inaccessible sources of fugitive VOC emissions (e.g. if the measurements require the removal of insulation or the use of scaffolding), the measurement frequency may be reduced to once every LDAR campaign.

Note

Optical gas imaging (OGI) is a useful complementary technique to identify sources of diffuse VOC emissions and is particularly relevant to identify inaccessible sources (see Section 4.4.2).

Where large amounts of VOCs are handled, the quantification of total VOC emissions from the plant 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).

Applicability

BAT 22 only applies when the annual quantity of diffuse VOC emissions from the plant estimated according to BAT 20 is greater than:

- 2 tonnes per year in the case of VOCs classified as CMR 1A or 1B, or
- 10 tonnes per year in the case of VOCs not classified as CMR 1A or 1B.

[This BAT conclusion is based on information given in Section 3.4]

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.

Technique		Description	Applicability
Fugitive emissions and non-fugitive emissions			
a.	Limiting the number of emission sources	This includes: • 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.	Applicability may be restricted by operational constraints in the case of existing plants.
b.	Collection of 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).	Applicability may be restricted: • for existing plants; and/or • by safety concerns (avoiding concentrations close to the lower explosive limit).
Fugitive emissions			
c.	Facilitating access to potentially leaky equipment	To ease maintenance and/or monitoring activities, the access to potentially leaky equipment is facilitated, e.g. by installing platforms or using drones for monitoring.	Applicability may be restricted by operational constraints in the case of existing plants.
d.	Use of high-integrity equipment	High-integrity equipment includes: • valves with bellow or double packing seals or equally efficient equipment; • 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 is tightened according to technique e.; • corrosion-resistant equipment.	
e.	Tightening	This includes: • 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); • installing tight caps on open ends.	Generally applicable.
f.	Replacement of leaky equipment parts	This includes the replacement of: • gaskets; • sealing elements (e.g. tank lid); • packing material (e.g. valve stem packing material).	

Non-fugitive emissions			
g.	Review and update of process design	This includes: • reducing the use of solvents and/or using solvents with lower volatility; • reducing the formation of side products containing VOCs; • lowering the operating temperature; • lowering the VOC content in the final product.	Applicability may be restricted in the case of existing plants.
h.	Review and update of operating conditions	This includes: • reducing the frequency and duration of reactor and vessel openings; • preventing corrosion by lining or coating of equipment, painting pipes to prevent external corrosion and by using corrosion inhibitors for materials in contact with equipment.	Generally applicable.
i.	Use of closed systems	This includes: • vapour balancing (see Section 4.4.3); • closed systems for solid/liquid and liquid/liquid phase separations; • closed systems for cleaning operations; • closed sewers and/or waste water treatment plants; • closed sampling systems; • closed storage areas. Off-gases from closed systems are sent to recovery (see BAT 9 and BAT 10) and/or abatement (see BAT 11).	Applicability may be restricted by operational constraints in the case of existing plants and by safety concerns.
j.	Use of techniques to minimise emissions from surface areas	This includes: • installing oil creaming systems on open surfaces; • periodically skimming open surfaces (e.g. removing floating matter); • installing anti-evaporation floating elements on open surfaces; • treating waste water streams to remove VOCs and send them to recovery (see BAT 9 and BAT 10) and/or abatement (see BAT 11); • installing floating roofs on tanks.	Applicability may be restricted by operational constraints in the case of existing plants.

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.

Table 4.7: BAT-associated emission level (BAT-AEL) for diffuse VOC emissions to air from the use of solvents

Parameter	BAT-AEL (percentage of the solvent inputs) (yearly average) (1) (2)
Diffuse VOC emissions	≤ 5 %

(1) The BAT-AEL does not include solvents sold as part of products or mixtures in a sealed container.
(2) 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 21.

[This BAT conclusion is based on information given in Section 3.4]

4.2 Polymers

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 monomer concentration in polyolefins 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.

Polyolefin product	Polyolefin monomer(s)	Standard(s)	Minimum monitoring frequency	Monitoring associated with
HDPE	Ethylene	No EN standard available	Once every month	BAT 25
LDPE				
LLDPE				
EVA copolymers	Ethylene and vinyl acetate			
PP	Propylene			

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.

Technique		Description
a.	Chemical agents with low boiling points	Solvents and suspension agents with low boiling points are used.
b.	Lowering the VOC content in the polymer	The VOC content in the polymer is lowered by e.g. using low-pressure separation, stripping or closed-loop nitrogen purge systems. The techniques for lowering the VOC content depend on the type of polymer product and production process.
c.	Collection and treatment of process off-gases	Process off-gases from the use of technique b. as well as from extrusion and degassing silos are collected and sent to recovery (see BAT 9 and BAT 10) and/or abatement (see BAT 11).

[This BAT conclusion is based on information given in Section 3.5.1]

Table 4.8: BAT-associated emission levels (BAT-AELs) for total emissions to air of VOCs from the production of polyolefins

Polyolefin product	Unit	BAT-AEL (Yearly average)
HDPE	g VOCs per kg of polyolefin produced	0.3–1.8
LDPE		0.2–1.9
LLDPE		0.3–1.3
EVA copolymers		2.7–16
PP		0.2–2
GPPS and HIPS		< 0.085
EPS		< 0.6

The associated monitoring is given in BAT 8, BAT 20 and BAT 22.

As an alternative to the BAT-AELs in Table 4.8, the BAT-AELs in Table 4.9 may be used.

Table 4.9: BAT-associated emission levels (BAT-AELs) for the monomer concentration in the polyolefin

Polyolefin product	Monomer(s)	Unit	BAT-AEL (Yearly average)
HDPE	Ethylene	g monomer per kg of polyolefin produced	< 0.5
LDPE			< 3
LLDPE			No BAT-AEL
EVA copolymers	Sum of ethylene and vinyl acetate		< 10
PP	Propylene		< 1
GPPS and HIPS	Styrene		No BAT-AEL
EPS			No BAT-AEL

Note: The monomer concentration in the polyolefin is measured after lowering the VOC content in the polymer (see BAT 25 b.).

The associated monitoring is given in BAT 24.

[This BAT conclusion is based on information given in Section 2.5]

[Request to the TWG to provide information on:

- *the monitoring of the monomer concentration in the polymer (e.g. which analytical methods are used and at which stage of the process the measurements are carried out);*
- *the methodology for estimating/calculating total emissions;*
- *the parameters monitored for total and diffuse emissions: TVOC (total volatile organic carbon), total VOCs or NMVOCs;*
- *the measurement methods used for total and diffuse emissions of organic compounds.]*

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	Monitoring associated with
Vinyl chloride monomer (VCM)	All emission points with a mass flow of ≥ 25 g/h	Generic EN standards (1)	Continous	BAT 29
	All emission points with a mass flow of < 25 g/h	No EN standard available	Once every 6 months (2) (3)	

(1) Generic EN standards for continuous measurements are EN 14181, EN 15267-1, EN 15267-2 and EN 15267-3.
(2) To the extent possible, the measurements are carried out at the highest expected emission state under normal operating conditions.
(3) The minimum monitoring frequency may be reduced to once every year if the emission levels are proven to be sufficiently stable.

[This BAT conclusion is based on information given in Section 2.6]

BAT 27. BAT is to monitor the VCM concentration in PVC 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	Standard(s)	Minimum monitoring frequency	Monitoring associated with
Vinyl chloride monomer (VCM)	EN ISO 6401	Once every month	BAT 30

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

Applicability may be restricted where the costs are excessive due to the low concentration of VCM in the process off-gas(es).

BAT 29. In order to reduce channelled emissions to air of vinyl chloride monomer, BAT is to use one or a combination of the techniques given below.

	Technique	Description
a.	Absorption	See Section 4.4.1.
b.	Adsorption	See Section 4.4.1.
c.	Condensation	See Section 4.4.1.
d.	Thermal oxidation	See Section 4.4.1.

Table 4.10: BAT-associated emission level (BAT-AEL) for channelled emissions to air of VCM from the production of PVC

Substance	BAT-AEL (mg/Nm^3) (Daily average or average over the sampling period)	Mass flow threshold (g/h)
Vinyl chloride monomer (VCM)	< 0.5-1	2.5

The associated monitoring is given in BAT 26.

BAT 30. In order to reduce VCM emissions to air, BAT is to use all of the techniques given below.

	Technique	Description
a.	Appropriate VCM storage facilities	This includes: • storing VCM in refrigerated tanks at atmospheric pressure or in pressurised tanks at ambient temperature; • using refrigerated reflux condensers or connecting tanks to VCM recovery (see BAT 28) and/or abatement (see BAT 29).
b.	Vapour balancing	See Section 4.4.3.
c.	Minimisation of emissions of residual VCM from equipment	This includes: • reducing the frequency and duration of reactor openings; • venting off-gases from connections to VCM recovery (see BAT 28) and/or abatement (see BAT 29) prior to decoupling; • 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); • draining the liquid content of the reactor to closed vessels prior to opening the reactor; • cleaning the reactor with water prior to opening the reactor and draining it to the stripping system.
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).

[This BAT conclusion is based on information given in Section 3.5.2]

Table 4.11: BAT-associated emission levels (BAT-AELs) for total emissions to air of VCM from the production of PVC

PVC type	Unit	BAT-AEL (Yearly average)
S-PVC	g VCM per kg of PVC produced	0.01-0.05
E-PVC		0.1-0.5

The associated monitoring is given in BAT 20, BAT 22 and BAT 26.

As an alternative to the BAT-AELs in Table 4.11, the BAT-AELs in Table 4.12 may be used.

Table 4.12: BAT-associated emission levels (BAT-AELs) for the monomer concentration in the PVC

PVC type	Unit	BAT-AEL (Yearly average)
S-PVC	g VCM per kg of PVC produced	0.001 - 0.3
E-PVC		0.005 - 0.5

Note: The VCM concentration in the PVC is measured after lowering the VCM content in the polymer (see BAT 30 d.).

The associated monitoring is given in BAT 27.

[This BAT conclusion is based on information given in Section 2.6]

4.2.3 BAT conclusions for the production of solution-polymerised rubber

BAT 31. BAT is to monitor the VOC concentration in solution-polymerised rubber 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	Standard(s)	Minimum monitoring frequency	Monitoring associated with
VOCs	No EN standard available	Once every month	BAT 32

BAT 32. In order to reduce emissions to air of organic compounds, BAT is to use both 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 from the use of technique a. are collected and sent to recovery (see BAT 9 and BAT 10) and/or abatement (see BAT 11).

Table 4.13: BAT-associated emission levels (BAT-AELs) for total emissions to air of VOCs and 1,3-Butadiene from the production of solution-polymerised rubber

Substance/Parameter	Unit	BAT-AEL (Yearly average)
VOCs	g VOCs per kg of solution-polymerised rubber produced	0.2–11
1,3-Butadiene		< 0.007

The associated monitoring is given in BAT 8, BAT 20 and BAT 22.

As an alternative to the BAT-AELs in Table 4.13, the BAT-AEL in Table 4.14 may be used.

Table 4.14: BAT-associated emission level (BAT-AEL) for the VOC concentration in the solution-polymerised rubber after treatment (see BAT 32)

Unit	BAT-AEL (Yearly average)
g VOCs per kg of solution-polymerised rubber produced	0.005–25

Note: The VOC concentration in the solution-polymerised rubber is measured after lowering the VOC content in the polymer (see BAT 32 a.).

The associated monitoring is given in BAT 31.

[This BAT conclusion is based on information given in Sections 2.7 and 3.5.3]

[Request to the TWG to provide information on:

- *the monitoring of the monomer concentration in the polymer (e.g. which analytical methods are used and at which stage of the process the measurements are carried out);*
- *the methodology for estimating/calculating total emissions;*
- *the parameters monitored for total and diffuse emissions: TVOC (total volatile organic carbon), total VOCs or NMVOCs;*
- *the measurement methods used for total and diffuse emissions of organic compounds.]*

4.2.4 BAT conclusions for the production of viscose using CS_2

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	Emission points	Standard(s)	Minimum monitoring frequency	Monitoring associated with
Carbon disulphide (CS_2)	All emission points with a mass flow of ≥ 1 kg/h	Generic EN standards (1)	Continuous	BAT 35
	All emission points with a mass flow of < 1 kg/h	No EN standard available	Once every year (2) (3)	
Hydrogen sulphide (H_2S)	All emission points with a mass flow of ≥ 50 g/h	Generic EN standards (1)	Continuous	
	All emission points with a mass flow of < 50 g/h	No EN standard available	Once every year (2) (3)	

(1) Generic EN standards for continuous measurements are EN 14181, EN 15267-1, EN 15267-2 and EN 15267-3.
(2) To the extent possible, the measurements are carried out at the highest expected emission state under normal operating conditions.
(3) The minimum monitoring frequency may be reduced to once every three years if the emission levels are proven to be sufficiently stable.

[This BAT conclusion is based on information given in Section 2.8]

BAT 34. In order to increase resource efficiency and to reduce the mass flow of CS_2 and H_2S sent to the final waste gas treatment, BAT is to recover CS_2 from process off-gases from spinning lines by using one or a combination of the techniques a., b. or c. given below and to reuse the CS_2, or, alternatively, to use technique d.

	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.
d.	Production of sulphuric acid	Process off-gases containing CS_2 and H_2S are used to produce sulphuric acid.

Applicability
Applicability may be restricted where the costs are excessive due to the low concentration of CS_2 and H_2S in the process off-gas(es).

[This BAT conclusion is based on information given in Section 3.3]

BAT 35. In order to reduce channelled emissions to air of CS_2 and H_2S, BAT is to use one or a combination of the techniques given below.

Technique		Description
a.	Absorption	See Section 4.4.1.
b.	Adsorption	See Section 4.4.1.
c.	Condensation	See Section 4.4.1.
d.	Thermal oxidation	See Section 4.4.1.

Table 4.15: BAT-associated emission levels (BAT-AELs) for channelled emissions to air of CS_2 and H_2S from the production of viscose using CS_2

Substance	BAT-AEL (mg/Nm^3) (Daily average or average over the sampling period)	Mass flow threshold (g/h)
CS_2	150-400	100
H_2S	1-10	5

The associated monitoring is given in BAT 33.

BAT-AELs for channelled emissions to air of SO_X when thermal oxidation is used: See Table 4.6.

Table 4.16: BAT-associated emission levels (BAT-AELs) for emissions to air of H_2S and CS_2 from the production of staple fibres and filament yarn

Parameter	Process	Unit	BAT-AEL (Yearly average)
Sum of H_2S and CS_2 (expressed as Total S)	Production of staple fibres	g Total S per kg of product	9.5-12
	Production of filament yarn		70-250

The associated monitoring is given in BAT 20, BAT 22 and BAT 33.

[This BAT conclusion is based on information given in Section 3.5.4]

[Request to the TWG for the production of ***viscose****: to provide information on the monitoring of CS_2 and H_2S* ***as total sulphur****]*

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. They apply in addition to the general BAT conclusions given in Section 4.1.

BAT 36. In order to reduce channelled emissions to air of CO, dust, NO_X and SO_X, BAT is to use a combination of the techniques given below.

	Technique	Description	Main inorganic compounds targeted	Applicability
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_X, SO_X, 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_X burner	See Section 4.4.1.	NO_X	For existing process furnaces/heaters, the applicability may be restricted by their design.
c.	Optimised combustion	See Section 4.4.1.	CO, NO_X	Generally applicable.
d.	Absorption	See Section 4.4.1.	SO_X, 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_X	Applicability to existing process furnaces/heaters may be restricted by space availability.
g.	Selective non-catalytic reduction (SNCR)	See Section 4.4.1.	NO_X	Applicability to existing process furnaces/heaters may be restricted by the temperature window (900-1 050 °C) and the residence time needed for the reaction.

Table 4.17: BAT-associated emission level (BAT-AEL) for channelled NO_X emissions to air from process furnaces/heaters

Parameter	BAT-AEL (mg/Nm^3) (Daily average or average over the sampling period)	Mass flow threshold (g/h)
Nitrogen oxides (NO_X)	50-150 (1)	1 000
(1) The upper end of the range may be up to 400 mg/Nm^3 if the combustion temperature is higher than 1 200 °C.		

The associated monitoring is given in BAT 8.

BAT-AELs for channelled emissions to air of dust and SO_X as well as an indicative emission level for channelled emissions to air of CO are given in Table 4.6.

[This BAT conclusion is based on information given in Sections 2.9 and 3.3]

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 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.
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.
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. HEAF is 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_X burner	The technique (including ultra-low-NO_X 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_X and the formation of thermal NO_X, while maintaining high combustion efficiency. The design of ultra-low-NO_X 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_2, CO, fuel to air ratio, and unburnt substances).
Optimised 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_X 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.
Thermal oxidation	Abatement technique which oxidises combustible compounds in a waste gas stream by heating it with air or oxygen to above its auto-ignition point in a combustion chamber and maintaining it at a high temperature long enough to complete its combustion to carbon dioxide and water. The typical combustion temperature is between 800 °C and 1 000 °C. Several types of thermal oxidation are operated: • Straight thermal oxidation: thermal oxidation without energy recovery from the combustion. • Recuperative thermal oxidation: thermal oxidation using the heat of the waste gases by indirect heat transfer. • Regenerative thermal oxidation: thermal oxidation where the incoming waste gas stream is heated when passing through a ceramic-packed bed before entering the combustion chamber. The purified hot gases exit this chamber by passing through one (or more) ceramic-packed bed(s) (cooled by an incoming waste gas stream in an earlier combustion cycle). This reheated packed bed then begins a new combustion cycle by preheating a new incoming waste gas stream.
Selective catalytic reduction (SCR)	Selective reduction of nitrogen oxides with ammonia or urea in the presence of a catalyst. The technique is based on the reduction of NO_X 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_X 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.
Selective non-catalytic reduction (SNCR)	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.

4.4.2 Techniques to monitor diffuse emissions

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.
Optical gas imaging (OGI) methods	Optical gas imaging uses small lightweight hand-held 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 infra-red 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 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

[Note to the TWG: This section will be updated according to the work progress.]

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
Collection of information by installation-specific questionnaires and bulk information	27 July 2018 – 28 February 2019
Workshop on data evaluation	4 – 5 June 2019
First draft of the WGC BREF	November 2019
End of commenting period	28 February 2018
Final TWG meeting	–

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 95th and 97th 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 presented in Chapter 2

Data	Type of monitoring	Description
Avg. concentration	Continuous	Depending on the availability of the data, according to the following priority: 1. the average of all values reported as yearly averages over the 3 years; 2. the average over the 3 years of all 97th percentile daily average values; 3. the average over the 3 years of all 95th percentile daily average values; 4. the average over the 3 years of all 97th percentile half-hourly average values; 5. the average over the 3 years of all 95th percentile half-hourly average values.
	Periodic	Average of all values reported over the 3 years.
Avg. volume flow	Continuous and periodic	• Average of all volume flows if several values were reported; or • reported volume flow.
Avg. mass flow	Continuous	$\frac{Avg\ concentration * Avg\ volume\ flow}{1000}$
	Periodic	

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
Member States **([*])**	
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
UK	United Kingdom
Non-member countries	
NO	Norway
([*]) 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 ([1])	Country/territory	Currency
Member State currencies		
EUR	Euro area ([2])	euro (pl. euros)
Other currencies		
USD	United States	US dollar

([1]) ISO 4217 codes.
([2]) 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 Δ (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
µ	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^2
bar	bar	Pressure (P)	1.013 bar = 100 kPa = 1 atm
°C	degree Celsius	Temperature (T) temperature difference (ΔT)	–
d	day	Time	–
g	gram	Weight	–
h	hour	Time	–
K	Kelvin	Temperature (T) temperature difference (ΔT)	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^2	square metre	Area	–
m^3	cubic metre	Volume	–
mg	milligram	Weight	1 mg = 10^{-3} g
mm	millimetre	Length	1 mm = 10^{-3} m
min	minute	Time	–
MW_e	megawatts electric (energy)	Electric energy	–
MW_{th}	megawatts thermal (energy)	Thermal energy Heat	–
µm	micrometre	Length	1 µm = 10^{-6} m
nm	nanometre	Length	1 nm = 10^{-9} m
Nm^3	normal cubic metre	Volume	at 101.325 kPa, 273.15 K
Pa	pascal	Pressure (P)	1 Pa = 1 N/m^2
ppm	parts per million	Composition of mixtures	1 ppm = 10^{-6}
ppmv	parts per million by volume	Composition of mixtures	–
s	second	Time	–
t	metric tonne	Weight	1 t = 1 000 kg or 10^6 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_3	Ammonia
C_6H_6	Benzene
C_4H_6	1,3-Butadiene
CS_2	Carbon disulphide
CO	Carbon monoxide
CH_3Cl	Chloromethane
CH_2Cl_2	Dichloromethane or methylene chloride (DCM)
Cl_2	Elementary chlorine
$C_2H_4Cl_2$	Ethylene dichloride (EDC)
C_2H_4O	Ethylene oxide
CH_2O	Formaldehyde
HCl	Hydrochloric acid
HF	Hydrofluoric acid
HCN	Hydrogen cyanide
H_2S	Hydrogen sulphide
$NaOH$	Sodium hydroxide. Also called caustic soda
N_2O	Nitrous oxide
C_3H_6O	Propylene oxide
CCl_4	Tetrachloromethane
C_7H_8	Toluene
$CHCl_3$	Trichloromethane
C_2H_3Cl	Vinyl chloride. Also called vinyl chloride monomer (VCM)

VII. Acronyms

Acronym	Definition
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.
CMR 1B	CMR substance of category 1B as defined in Regulation (EC) No 1272/2008 as amended.
CMR 2	CMR substance of category 2 as defined in Regulation (EC) No 1272/2008 as amended.
DIAL	Differential absorption LIDAR.
EMS	Environmental Management System.
EP	Emission point (refers to channelled emissions).
E-PVC	PVC produced by emulsion polymerisation.
EU	European Union.
EVA	Ethylene-vinylacetate.
HDPE	High-density polyethylene.
HEAF	High-efficiency air filter.
HEPA	High-efficiency particle air.
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.
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.
OGI	Optical gas imaging.
OTNOC	Other than normal operating conditions.
PP	Polypropylene.
PVC	Polyvinyl chloride.
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.

VIII. Definitions

Term used	Definition
Channelled emissions	Emissions of pollutants into the environment through an emission point such as a stack or a chimney.
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 treatment of waste gases (i.e. using thermal or catalytic oxidation).
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, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Ireland, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom
EU-28	EU-27 and Croatia
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: • moving equipment, such as agitators, compressors, pumps, valves (manual and automatic); • static equipment, such as flanges and other connections, open-ended lines, sampling points.
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 can arise from atmospheric vents, bulk storage, loading/unloading systems, vessels and tanks (on opening), open gutters, sampling systems, tank venting, waste, sewers, waste water treatment plants, flares or other than normal operating conditions (OTNOC).

Term used	Definition
NO_X precursors	Nitrogen-containing compounds (e.g. ammonia, nitrous gases and nitrogen-containing organic compounds) in the input to a thermal or catalytic oxidation that lead to NO_X emissions. Elementary nitrogen is not included.
Operational constraint	Limitation or restriction connected, for example, to: • process design (e.g. substances that cannot be substituted, very corrosive substances); • operating conditions (e.g. very high temperature or pressure); • the functioning of the plant; • resource availability (e.g. availability of spare parts when replacing a piece of equipment, availability of qualified manpower); • expected environmental benefits (e.g. giving priority to maintenance, repair or replacement actions with the highest environmental benefit).
Periodic measurement	Measurement at specified time intervals using manual or automated methods.
Process furnace/heater	Process furnaces or heaters are: • combustion units used for the treatment of objects or feed material through direct contact, e.g. in drying processes or chemical reactors; or • 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 such as steam cracker furnaces. 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 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.
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.

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