Category		Title
NFR	5.C.1.b.i, 5.C.1.b.ii, 5.C.1.b.iv	Industrial waste incineration Hazardous waste incineration Sewage sludge incineration
SNAP	090202 090205 090208	Incineration of industrial wastes (except flaring) Incineration of sludges from waste water treatment Incineration of waste oil
ISIC		
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Contents

1 Overview

This chapter includes the volume reduction, by combustion, of industrial waste, hazardous waste and sewage sludge. The definition of industrial waste varies, but for the purposes of this chapter we typically refer to it as non-hazardous waste that cannot otherwise be defined as municipal (5.C.1.a) or clinical (5.C.1.b.iii) by its origin.

Often, non-hazardous industrial waste is collected and incinerated together with municipal solid waste, with or without energy recovery and, as in this case, emissions can be estimated and reported together (5.C.1.a or 1.A.1). If treated separately in facilities dedicated to industrial waste, emissions can be estimated and reported in 5.C.1.b.i.

Emissions from flaring and incineration of waste oil are not explicitly discussed in this chapter, since their contribution to the total national emissions is thought to be insignificant.

The remainder of this chapter will therefore mainly focus on emissions from incineration of industrial waste (5.C.1.b.i), hazardous wastes (5.C.1.b.ii) and sludges from waste water treatment (5.C.1.b.iv).

Principally, this section includes emissions from chimneys and duct work because of the availability of measurement data, but excludes fugitive emission from waste or residue handling.

Care must be taken to prevent double counting of emissions reported here and in the relevant combustion chapter in 1.A. All the activities and emission factors with regard to the incineration of waste are explained in the waste incineration chapters. If there is energy recovery (heat or electricity) in the incineration process, it is good practice to report the emissions in the relevant combustion sector in the combustion section (1.A) regardless of the efficiency of the recovery. If no energy recovery is applied, it is good practice to report the emissions under the appropriate waste incineration sector. In most cases, the emission factors provided in this chapter will need to be recalculated in terms of g/GJ (or equivalent energy units) by multiplying dividing with the Net Calorific Value(s) (NCV) of the waste. NCV can vary significantly depending on waste composition so obtaining detailed activity data will assist compilers in developing more accurate emission estimates.

Most waste incinerators are small hazardous waste incinerators constructed on-site, intended for the industries’ own use (chemical plants, refineries, light and heavy manufacturing, etc.). Some large facilities are specifically designed for incineration of various hazardous waste.

In general, because the waste treated often has a high toxicity, efficient abatement is required for hazardous waste incinerators to meet the stringent emission standards.

The relative proportion of emissions contributed by industrial waste, hazardous waste and sludge incineration is likely to vary between pollutants. Emissions of carbon monoxide, volatile organic compounds (VOCs), and particulate matter from industrial waste incinerators are likely to be less significant than from other sources. However, industrial waste incinerators are likely to be more significant emitters of dioxins, cadmium and mercury than many other sources. This depends on the type of waste, the combustion efficiency and the degree of abatement.

2 Description of sources

2.1 Process description

The composition of industrial and hazardous waste varies considerably. Non-hazardous industrial waste generated by industrial establishments includes organic waste, paper and cardboard, plastics and rubber, wood, glass, metal, mineral waste. Hazardous waste includes any unwanted hazardous/chemical waste such as acids and alkalis, halogenated and other potentially-toxic compounds, fuels, oils and greases, used filter materials.

Combustible industrial waste may be incinerated to reduce its volume and to save landfill costs, whereas hazardous waste is incinerated to prevent the release of chemical and toxic substances to the environment. In some cases, energy is recovered from the waste combustion either for heating or electricity generation. In these cases, it is good practice to report the emissions in the relevant combustion sector in the combustion section (1.A). If no energy recovery is applied, it is good practice to report the emissions in the waste incineration sector.

Sewage sludge arises from the removal of organic and inorganic solids from raw sewage (primary sludge) and the removal by settlement of solids produced during biological treatment processes, i.e. surplus activated sludge and human sludge (secondary sludge) (HMIP, 1992).

Sewage sludge is incinerated to reduce its volume to lower disposal costs and, in some instances, to recover energy from its combustion either for heating or electricity generation.

2.2 Techniques

There are many different furnace designs in use to incinerate industrial waste, hazardous waste and sludge in Europe. A range of grate designs and fluidised beds are used, but the exact furnace design depends on the type of wastes burned, their composition and the throughput of waste. The principal influences of the incinerator type on the level of atmospheric emissions are the waste burning capacity of the incinerator, the operational techniques and the degree of abatement included in the process design.

There are three main designs of furnace used for industrial waste incineration: rotary kiln, fluidised bed and multiple hearths (short descriptions are presented in annex). However, the principal influence on the emission factors applicable to a plant is the degree of pollution abatement equipment fitted to the plant.

Large facilities specifically designed for hazardous waste incineration are typically rotary kiln design that operates at temperatures above 1100°C along with an advanced abatement technology.

Small industrial / hazardous waste incinerators with limited waste supply are often operated as batch processes with some abatement technologies. This increases the frequency of start-up and burn-out emissions, which are often significant.

At all operational plants the wet sludge is de-watered prior to incineration (HMIP, 1992). Several dewatering processes are available: centrifuges, belt or plate presses.

Virtually any material that can be burned can be combined with sludge (often dewatered or dried) in a co-incineration process. Common materials for co-combustion are coal, municipal solid waste (MSW), wood waste and agriculture waste.

2.3 Emissions

Waste incinerators are likely to be more significant emitters of dioxins, cadmium and mercury than many other sources, depending on the type of waste, the combustion efficiency and the degree of abatement.

As for incineration of sludges, pollutants released are sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (non-methane VOC and methane (CH_4)), carbon monoxide (CO), carbon dioxide (CO_2) and nitrous oxide (N_2O).

However, sewage sludge incinerators potentially emit significant quantities of pollutants on a local basis. Major pollutants emitted are particulate matter, metals, CO, NO_x, SO_2, and unburned hydrocarbons. Partial combustion of sludge can result in emissions of intermediate products of incomplete combustion, including toxic organic compounds such as dioxins (US EPA, 1979, 1982, 1984, 1995).

Nitrogen and sulphur oxide emissions are primarily the result of oxidation of nitrogen and sulphur in the sludge. Therefore, these emissions can vary greatly based on local and seasonal sewage characteristics (US EPA, 1995).

Emissions of volatile organic compounds also vary greatly with incinerator type and operation. Incinerators with counter-current air flow such as multiple hearth designs provide the greatest opportunity for unburned hydrocarbons to be emitted (US EPA, 1995).

Carbon monoxide is formed when available oxygen is insufficient for complete combustion or when excess air levels are too high, resulting in lower combustion temperatures (US EPA, 1995).

Polycyclic organic matter (POM) emissions from sewage sludge incineration potentially originate from the combustion of carbonaceous material in the sludge, from the combustion POM precursors that may exist in the sludge, and from the combustion of supplemental incinerator fuel (typically natural gas or fuel oil) (US EPA, 1994).

Waste incineration is one of the major sources of dioxin emissions. Emissions may vary by order of magnitude dependent on the abatement options in place.

2.4 Controls

Emissions can be considerably reduced by ensuring efficient combustion, including the control of the temperature, residence time and turbulence in the incinerator furnace. Auxiliary burners and a secondary combustion zone are often included in incinerator designs to ensure effective combustion and burn-out. In addition, a range of end-of-process abatement techniques can be applied to reduce emissions. Control of particulates, including heavy metals, can be achieved by fabric filters, electrostatic precipitators or high energy venturi scrubbers. Acid gas emissions can be controlled by wet and dry scrubbing techniques.

The options available for acid gas removal include spray drying and wet or dry scrubbing. Where the emission levels of nitrogen oxides are high, due to the design of the incinerator or because of co-incineration of wastes, urea can be injected into the flue gases to reduce oxides of nitrogen levels by about 30 % (HMIP, 1992).

The exhaust gases of the furnaces containing volatile compounds are taken through an afterburner or similar combustion chamber to ensure complete combustion of residual organic material in the vent gas, and to prevent the emission of smoke and odour (HMIP, 1992).

As there is the possibility of the formation of dioxins/furans between 200 and 450 °C, it is important that when gases are cooled, it is done as rapidly as possible through this critical temperature range. Such cooling may be accomplished by the use of a heat exchanger/waste heat boiler (of special design) or water spray cooling (HMIP, 1992).

In general, older plants have particle arrestment, frequently using an electrostatic precipitator. This will abate the emissions of heavy metal species but may increase dioxin emissions. Modern plant or older plant which have been updated, have a range of different emission abatement equipment which addresses the three main environmental impacts of sewage sludge incineration: acid gas, heavy metal and dioxin emissions.

Typical units fitted include fabric filters, wet scrubbers, lime slurry spray dryer towers, carbon injection with the lime to control mercury and dioxins and activated carbon or coke beds.

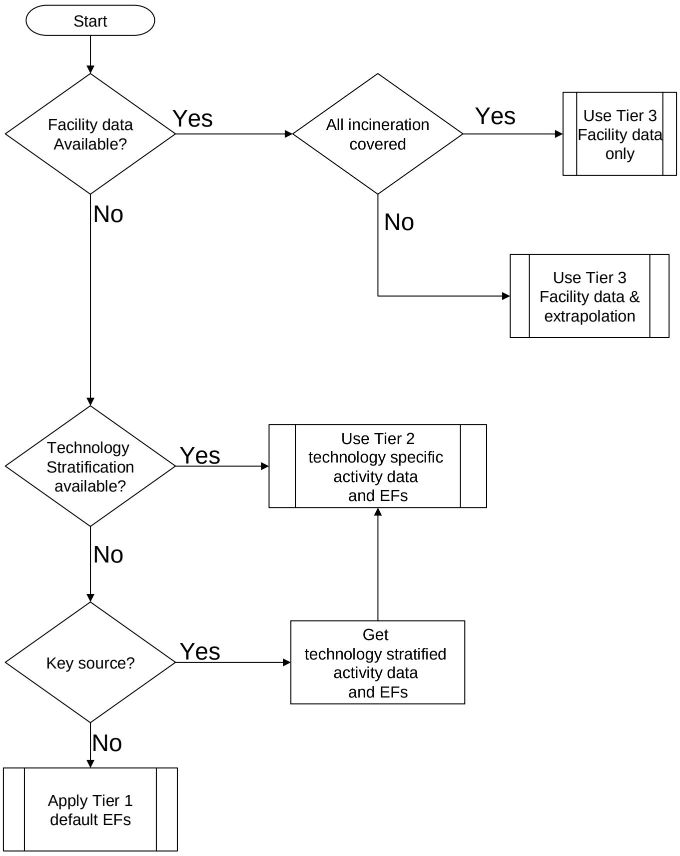
3 Methods

3.1 Choice of method

Figure 3-1 presents the procedure to select the methods for estimating emissions from the incineration of industrial waste, hazardous waste and sewage sludge. The basic idea is:

- if detailed information is available, use it;
- if the source category is a key category, a Tier 2 or better method must be applied and detailed input data must be collected. The decision tree directs the user in such cases to the Tier 2 method, since it is expected that it is easier to obtain the necessary input data for this approach than to collect facility level data needed for a Tier 3 estimate;
- the alternative of applying a Tier 3 method, using detailed process modelling, is not explicitly included in this decision tree. However, detailed modelling will always be done at facility level and results of such modelling could be seen as ‘facility data’ in the decision tree.

Figure 3-1 Decision tree for source categories 5.C.1.b.iIndustrial waste incineration, 5.C.1.b.ii hazardous waste incineration and 5.C.1.b.iv sewage sludge incineration



3.2 Tier 1 default approach

3.2.1 Algorithm

The simpler methodology relies on the use of a single emission factor for each pollutant species, combined with a national waste incineration statistic. The general equation can be written as:

$$E_{pollutant} = AR_{production} \times EF_{pollutant} \qquad (1)$$

This equation is applied at the national level.

The Tier 1 emission factors assume an averaged or typical technology and abatement implementation in the country and therefore is not applicable for incineration without abatement technique. A Tier 2 or Tier 3 approach must be used where specific abatement techniques are adopted and data is available to disaggregate emissions and/or activity between technologies or facilities.

3.2.2 Default emission factors

The Tier 1 emission factors presented in Table 3-1 are assumed to be typical emission factors for a modern industrial waste incineration plant, using desulphurisation, NO_x abatement and particle abatement equipment for controlling the emissions.

Table 3-1 Tier 1 emission factors for source category 5.C.1.b.i Industrial waste incineration, 5.C.1.b.ii hazardous waste incineration and 5.C.1.b.iv sewage sludge incineration

Tier 1 emission factors					
	Code	Name			
NFR Source Category	5.C.1.b.i, 5.C.1.b.ii, 5.C.1.b.iv	Industrial waste incineration, hazardous waste incineration and sewage sludge incineration			
Fuel	NA				
Not applicable	PCB				
Not estimated	NH_3, Cr, Cu, Zn, Se, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NO_x	0.87	kg/Mg waste	0.087	8.7	European Commission (2006)
CO	0.07	kg/Mg waste	0.007	0.7	European Commission (2006)
NMVOC	7.4	kg/Mg waste	0.74	74	Passant (1993)
SO_2	0.047	kg/Mg waste	0.0047	0.47	European Commission (2006)
TSP	0.01	kg/Mg waste	0.001	2.3	European Commission (2006)
PM_{10}	0.007	kg/Mg waste	0.0007	0.15	US EPA (1996) applied on TSP
$PM_{2.5}$	0.004	kg/Mg waste	0.0004	0.1	US EPA (1996) applied on TSP
BC[1]	3.5	% of $PM_{2.5}$	1.8	7	Olmez et al. (1988)
Pb	1.3	g/Mg waste	0.48	1.9	Theloke et al. (2008)
Cd	0.1	g/Mg waste	0.048	0.15	Theloke et al. (2008)
Hg	0.056	g/Mg waste	0.04	0.08	European Commission (2006)
As	0.016	g/Mg waste	0.01	0.019	Theloke et al. (2008)
Ni	0.14	g/Mg waste	0.048	0.19	Theloke et al. (2008)
PCDD/F	10	µg I-TEQ/Mg waste	0.5	35000	UNEP (2013)
Total 4 PAHs	0.02	g/Mg waste	0.007	0.06	Wild (1995)
HCB	0.002	g/Mg waste	0.0002	0.02	Berdowski et al. (1997)

Emission factors in the BREF documents are mostly given in ranges (European Commission, 2006). The range is interpreted as the 95 % confidence interval, while the geometric mean of this range is chosen as the value for the emission factor.

3.2.3 Activity data

To apply Tier 1, the national annual quantities of industrial waste, hazardous waste and sewage sludge (wet basis) incinerated are required.

3.3 Tier 2 technology-specific approach

3.3.1 Algorithm

To apply the Tier 2 approach, both the activity data (amount of waste incinerated) and the emission factors need to be stratified according to the different technologies that may occur in the country. A technology must be understood here as the combination of the type of waste, the furnace design and the abatement technique.

The approach followed to apply a Tier 2 approach is to stratify the amount of waste incinerated into 'technologies' (e.g. hazardous waste incinerated in a rotary kiln equipped with desulphurisation,

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(1) For the purposes of this guidance, BC emission factors are assumed to equal those for elemental carbon (EC). For further information please refer to Chapter 1.A.1 Energy Industries.

good APC system, NO_x abatement and fabric filter for particle abatement) and then to apply technology specific emission factors:

$$E_{pollutant} = \sum_{technologies} AD_{technology} \times EF_{technology,pollutant} \quad (2)$$

where:

$AD_{technology}$ = Amount of waste incinerated in facilities for this specific technology

$EF_{technology,pollutant}$ = Emission factor for this technology and this pollutant, estimated as in Equation (3)

The stratification of waste into different technology categories may evolve over the time series, especially because of the progressive penetration of abatement techniques.

3.3.2 Technology-specific emission factors

This section provides the Tier 2 technology-specific emission factors to estimate emissions for incineration, as a combination of EFs for uncontrolled incinerators and technology specific abatement efficiencies. Sludge incineration is well documented in (US EPA, 1995) but there is limited information in the literature regarding industrial waste and hazardous waste incineration especially regarding uncontrolled facilities.

Incineration of sludges from water treatment

Uncontrolled emission rates vary widely depending on the type of incinerator, the volatiles and moisture content of the sludge, and the operating practices employed (US EPA, 1995).

Table 3-2 presents the default uncontrolled emission factors that could be applied for the uncontrolled incineration of sewage sludges.

Table 3-2 Tier 2 emission factors for source category 5.C.1.b.iv Sewage sludge incineration

Tier 2 emission factors					
	Code	Name			
NFR source category	5.C.1.b.iv	Sewage sludge incineration			
Fuel	NA				
SNAP (if applicable)	090205	Incineration of sludge from waste water treatment			
Technologies/Practices					
Region or regional conditions					
Abatement technologies	Uncontrolled				
Not applicable					
Not estimated	NH_3				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NO_x	2.5	kg/Mg	0.25	25	US EPA (1995)
CO	15.5	kg/Mg	1.55	155	US EPA (1995)
NMVOC	0.84	kg/Mg	0.084	8.4	US EPA (1995)
SO_2	14	kg/Mg	1.4	140	US EPA (1995)
TSP	52	kg/Mg	5.2	520	US EPA (1995)
PM_{10}	4.1	kg/Mg	0.41	41	US EPA (1995)
$PM_{2.5}$	1.1	kg/Mg	0.11	11	US EPA (1995)

BC[2]	3.5	% of $PM_{2.5}$	1.8	7	Olmez et al. (1988)
Pb	50	g/Mg	5.0	500	US EPA (1995)
Cd	16	g/Mg	1.6	160	US EPA (1995)
Hg	2.3	g/Mg	0.23	23	US EPA (1995)
As	4.7	g/Mg	0.47	47	US EPA (1995)
Cr	14	g/Mg	1.4	140	US EPA (1995)
Cu	40	g/Mg	4.0	400	US EPA (1995)
Ni	8	g/Mg	0.8	80	US EPA (1995)
Se	0.15	g/Mg	0.015	1.5	US EPA (1995)
Zn	66	g/Mg	6.6	660	US EPA (1995)
PCBs	4.5	mg/Mg	0.45	45	US EPA (1987)
PCDD/F	50	µg I-TEQ/Mg	0.465	46.5	UNEP (2013)
Benzo(a)pyrene	0.51	mg/Mg	0.051	5.1	US EPA (1998)
Benzo(b)fluoranthene	0.07	mg/Mg	0.007	0.7	US EPA (1998)
Benzo(k)fluoranthene	0.61	mg/Mg	0.061	6.1	US EPA (1998)
Indeno(1,2,3-cd)pyrene	0.1	mg/Mg	0.01	1.0	US EPA (1998)
HCB	4.7	mg/Mg	0.47	47	Bailey (2001)

Emission factors from the US EPA (1995) refer to a multiple hearth furnace and, as a first approach, can be applied to other furnace designs of sewage sludge incinerator.

Incineration of industrial waste and hazardous waste

There is very limited information in the literature regarding industrial waste and hazardous waste incineration, especially regarding uncontrolled facilities.

Therefore, in absence of data at facility level permitting to apply the Tier 3 method, as a first approach, inventory compilers may wish to apply default emission factors for uncontrolled municipal waste incinerator to (non-hazardous) industrial waste incinerators (see chapter 5.C.1.a) and default emission factors for uncontrolled sludge incineration (Table 3-2) to hazardous waste incineration except for PCDD-F for which 40 mg/Mg waste can be used (UNEP (2013).

3.3.3 *Abatement*

A number of add-on technologies exist that are aimed at reducing the emissions of specific pollutants. The resulting emission can be calculated by replacing the technology-specific emission factor with an abated emission factor as given in the formula:

$$EF_{technology,abated} = (1 - \eta_{abatement}) \times EF_{technology,uncontrolled} \qquad (3)$$

$\eta_{abatement}$: Abatement efficiency

$EF_{technology,\ uncontrolled}$: Emission factor of the technology for an uncontrolled situation

This section presents default abatement efficiencies for a number of abatement options, applicable in this sector.

Industrial waste, hazardous waste and sewage sludge incinerators

This section presents abatement efficiencies for industrial waste, hazardous waste and sewage sludge incineration facilities when there is limited information on the type of abatement technologies in place and therefore a limited stratification of incinerated waste into technologies.

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(2) For the purposes of this guidance, BC emission factors are assumed to equal those for elemental carbon (EC). For further information please refer to Chapter 1.A.1 Energy Industries.

Abatement efficiencies for industrial waste, hazardous waste and sludge incineration are considered as identical as abatement efficiencies in Municipal waste incineration (Chapter 5.C.1.a of the Guidebook).

Table 3-3 Abatement efficiencies ($\eta_{abatement}$) for source category 5.C.1.b.i Industrial waste incineration, 5.C.1.b.ii hazardous waste incineration and 5.C.1.b.iv sewage sludge incineration

NFR Source Category	**5.C.1.b**	**Waste incineration**			
Fuel	NA				
SNAP (if applicable)	0902	Incineration of waste			
Abatement technology	**Pollutant**	**Efficiency**	**95% confidence interval**		**Reference**
		Default Value	**Lower**	**Upper**	
Acid gas abatement	SO2	76%	29%	92%	Guidebook (2006)
Particle abatement only	TSP	98.4%	95%	99%	Guidebook (2006)
	PM10	98.3%	95%	99%	Guidebook (2006)
	PM2.5	98.4%	95%	99%	Guidebook (2006)
EU Waste Incineration Directive (WID) compliant plant	TSP	99.7%	98%	99.99%	Guidebook (2006)
	PM10	99.6%	98%	99.99%	Guidebook (2006)
	PM2.5	99.5%	98%	99.99%	Guidebook (2006)
Controlled combustion; minimal APC system	PCDD/F	90%	70%	97%	UNEP (2005)
Controlled combustion; good APC system	PCDD/F	99%	97%	99.99%	UNEP (2005)
Controlled combustion; sophisticated APC system	PCDD/F	99.99%	99.99%	99.99%	UNEP (2005)

Note:

WID compliant plant: half hourly limit concentration of 10 mg/m^3 at 11 % oxygen, from BAT reference document (European Commission, 2006).

3.3.4 Activity data

For sludge incineration, the national annual amount of sewage sludge is required as well as the penetration rate of abatement techniques.

Subsequently, for industrial and hazardous waste incineration, the national annual quantity of waste incinerated per technology is required.

3.4 Tier 3 use of facility data

3.4.1 Algorithm

The Tier 3 level is a detailed technology-specific approach, for instance using a detailed modelling of the process or facility-level emission data. The approach based on facility-level data is described hereafter.

Facility-level data

The Tier 3 methodology involves the use of plant-specific emission factors calculated from regulatory emission measurement programmes and using plant-specific throughput data normally collected by each facility.

Where facility-level emission data of sufficient quality (see Chapter 6, Inventory management, improvement and QA/QC, in part A) are available, it is good practice to use these data. There are two possibilities:

- facility emission data cover all waste incinerated in the country;
- facility level emission data are not available for all incineration plants in the country.

If facility-level data cover all waste incineration in the country, it is good practice to compare the implied emission factors (reported emissions divided by the national incineration) with the default emission factor values or technology-specific emission factors. If the implied emission factors are outside the 95 % confidence intervals for the values given below, it is good practice to explain the reasons for this in the inventory report.

If facility-level emission data reported by operators does not cover the total annual incineration in the country covered, it is good practice to estimate the missing part of the national total emissions from the source category, using extrapolation by applying:

$$E_{Total,\,pollutant} = \sum_{Facilities} E_{Facility,\,pollutant} + \left(National\ Production - \sum_{Facilities} Production_{Facility} \right) \times EF \qquad (5)$$

Where "Production" must be understood as the amount of waste incinerated.

3.4.2 Emission factors

Depending on the specific national circumstances, the confidence in the methodology used by operators to report their emissions and the coverage of the facility level reports as compared to the total national incineration, it is good practice to choose the emission factor (*EF*) in this equation (5) from the following possibilities, in decreasing order of preference:

- technology-specific emission factors, based on knowledge of the types of waste or technologies implemented at the facilities where facility level emission reports are not available;
- the implied emission factor derived from the available emission reports:

$$EF = \sum_{Facilities} E_{Facility,\,pollutant} \Big/ \sum_{Facilities} Production_{Facility} \qquad (6)$$

- the default Tier 1 emission factor. This option should only be chosen if the facility-level emission reports cover more than 90 % of the total national production

Usually, when facility data are used to report emissions, emissions factors must be estimated for the period when data are not available yet (see 0
Developing a consistent time series and recalculation).

For HCB emissions, the emission factors for the incineration of industrial wastes are available for a number of wastes (EMEP/EEA, 2006), see Table 3-4.

Table 3-4 Waste type specific emission factors for HCB emissions from the incineration of industrial wastes

Waste type	Emission factor (g/Mg waste)
Tetrachloromethane	8
Trichloroethylene	3
Tetrachloroethylene	6
Polyvinyl chloride	5
Hazardous wastes (including paint production wastes and chlorine-containing wastes)	0.01
Contaminated wood	0.002
Other solid wastes	0.0001

3.4.3 Activity data

The more detailed method requires information on plant-specific waste throughput and abatement technology, obtained from the operators. There is normally a record kept of tonnage burnt as incinerator operators charge waste generators on that basis.

If neither of these values is available, it is good practice to multiply the mass burn hourly rate of each incinerator by an estimated operating time.

4 Data quality

4.1 Completeness

Care should be taken to include emissions from waste incineration either in this source category or in the relevant 1.A combustion chapter. It is good practice to check if this is indeed the case.

4.2 Avoiding double counting with other sectors

Care should be taken not to double count emissions from waste incineration. It is good practice to check that emissions not included in this source category (because the heat from the incineration is recovered and the waste is subsequently used as a fuel) are reported in the relevant 1.A combustion chapter.

4.3 Verification

4.3.1 Best Available Technique emission factors

The IPPC Reference Document on Best Available Techniques on Waste Incineration (European Commission, 2019) describes achievable emission levels and the technologies necessary to achieve those levels in the process of waste incineration. However, no specific emission limit values for industrial waste incineration are given in the BAT conclusions for waste incineration. Some generic emission concentrations for waste incineration are given in the table below. More information is available from the BREF document for Best Available Techniques in Waste Incineration (European Commission, 2019).

Table 4-1 BAT-derived emission factors applicable for source categories 5.C.1.b.i, 5.C.1.b.ii, 5.C.1.b.iv Industrial waste incineration including hazardous waste and sewage sludge (BREF 2019)BAT compliant emission factors (BREF 2019)

	Code	Name
NFR Source Category	5.C.1	Waste incineration
Fuel	NA	not applicable
Pollutant	**Value**	**Unit**
NOx	50 - 120 (new plant) 5 – 150 (existing plant)	mg/Nm^3 (daily average)
CO	10-50	mg/Nm^3 (daily average)
TSP	< 2–51	mg/Nm^3 (average over the sampling period)
SO2	5 - 30 (new plant) 5 – 40 (existing plant)	mg/Nm^3 (daily average)
Hg	1-10	mg/Nm3 (long-term sampling period)
PCDD/F	< 0.01–0.06 (new plant) < 0.01–0.08 (existing plant)	ng I-TEQ/Nm3 (long-term sampling period)

[1] For existing plants dedicated to the incineration of hazardous waste and for which a bag filter is not applicable, the higher end of the BAT-AEL range is 7 mg/Nm3.

4.4 Developing a consistent time series and recalculation

Inventory compilers need to consider whether abatement technology application varies across the national reporting timeseries and therefore the abatement techniques and associated abatement efficiency may evolve across inventory years.

Moreover, inventory compilers also need to consider whether data availability change across the national reporting timeseries (e.g. measurement data at facility level on recent years) and therefore the method may also require amendment across inventory years and application of splicing techniques. In order to derive emissions factors for the period when facility level data are not available yet, inventory compilers may for instance use abatement efficiencies provided in Table 3-3 Abatement efficiencies ($\eta_{abatement}$) for source category 5.C.1.b.i Industrial waste incineration, 5.C.1.b.ii hazardous waste incineration and 5.C.1.b.iv sewage sludge incineration) and estimate historical emission factors on the basis of information regarding the current situation (emission factors and abatement techniques in place).

Any inconsistency of method and/or emission factors should be clearly documented in the inventory report.

4.5 Uncertainty assessment

No specific issues.

4.5.1 Emission factor uncertainties

Data are taken from measurements at a wide range of older industrial and clinical waste incineration plants. Little information is available on measurements of emissions from advanced plants. There are wide differences in measured emissions of dioxins and heavy metals depending on both the type of plant and on which of the many combinations of gas-cleaning equipment was used in the plant. Therefore, each emission factor is currently subject to an uncertainty considerably greater than a factor of 2.

4.5.2 Activity data uncertainties

No specific issues.

4.6 Inventory quality assurance/quality control QA/QC

No specific issues.

4.7 Gridding

Spatial disaggregation requires knowledge about the location of industrial waste incinerators. In the absence of such data, it is good practice to disaggregate the national totals on the basis of population.

4.8 Reporting and documentation

No specific issues.

5 Annex: types of furnaces

5.1 Fluidised bed furnace

- Fluidised bed combustion (FBC) consists of a vertically-oriented outer-shell constructed of steel and lined with refractory. Nozzles (designed to deliver blasts of air) are located at the base of the furnace within a refractory-lined grid. A bed of sand, approximately 0.75 meters thick, rests upon the grid. Two general configurations can be distinguished on the basis of how the fluidising air is injected into the furnace. In the ‘hot windbox’ design, the combustion air is first preheated by passing through a heat exchanger where heat is recovered from the hot flue gases. Alternatively, ambient air can be injected directly into the furnace from a cold windbox. Partially dewatered sludge is fed into the lower portion of the furnace. Air injected through the nozzles simultaneously fluidises the bed of hot sand and the incoming sludge. Temperatures of 750 to 925 °C are maintained in the bed. As the sludge burns, fine ash particles are carried out the top of the furnace (US EPA, 1994).

- A fluidised bed incinerator is a single stage process. Examples of the advantages of fluidised bed incinerators include the disposal of solids, liquids, aqueous waste and gases, and the simplicity of the furnace with no moving parts. Disadvantages include the fact that bed diameters and height are limited by design technology and high levels of dust carryover in the flue gas (HMIP, 1992).

5.2 Multiple hearth furnace

- The design principle of a multiple-hearth furnace (MHF) is a vertical cylinder. The outer shell is constructed of steel, lined with refractory, and surrounds a series of horizontal refractory hearths. Burners, providing auxiliary heat, are located in the sidewalls of the hearths (US EPA, 1994).

- Scum may also be fed to one or more hearths of the incinerator. Scum is the material that floats on wastewater. It is generally composed of vegetable and mineral oils, grease, hair, waxes, fats, and other materials that will float. Quantities of scum are generally small compared to those of other wastewater solids (US EPA, 1994).

- Under normal operating conditions, 50 to 100 % excess air must be added to a MHF in order to ensure complete combustion of the sludge. Besides enhancing contact between fuel and oxygen in the furnace, these relatively high rates of excess air are necessary to compensate for normal variations in both the organic characteristics of the sludge feed and the rate at which it enters the incinerator. When an inadequate amount of excess air is available, only partial oxidation of the carbon will occur, with a resultant increase in emissions of carbon monoxide, soot, and hydrocarbons. Too much excess air, on the other hand, can cause increased entrainment of particulate and unnecessarily high auxiliary fuel consumption (US EPA, 1994).

- MHF may be operated with an afterburner. The advantages of multiple hearth furnace incinerators include the fact that the retention and residence time is higher for low volatility materials than in other types of incinerator, the handling of high water content wastes and of a wide range of wastes with different chemical and physical properties. Disadvantages include the fact that, due to the longer residence times of the waste materials, temperature response throughout the incinerator when the burners are adjusted is usually very slow, variations in feed can alter the temperature profile and thus the positions of the zones, and difficulties in achieving complete oxidation of volatile organic materials placing an additional load on an afterburner can occur (HMIP, 1992).

5.3 Other kiln types

- Rotary kilns are used for small capacity applications. The kiln is inclined slightly with the upper end receiving both the sludge feed and the combustion air. A burner is located at the lower end of the kiln (US EPA, 1994).

- Electric infrared incinerators consist of a horizontally-oriented, insulated furnace. A woven wire belt conveyor extends the length of the furnace and infrared heating elements are located in the roof above the conveyor belt. Combustion air is preheated by the flue gases and is injected into the discharge end of the furnace. Electric infrared incinerators consist of a number of prefabricated modules, which can be linked together to provide the necessary furnace length (US EPA, 1994). The use of electric infrared furnaces is not so common (US EPA, 1995).

- The cyclonic reactor is designed for small capacity applications. It is constructed of a vertical cylindrical chamber that is lined with refractory. Preheated combustion air is introduced into the chamber tangentially at high velocities. The sludge is sprayed radially towards the hot refractory walls (US EPA, 1994).

The wet oxidation process is not strictly one of incineration; it utilises instead oxidation at elevated temperature and pressure in the presence of water (flameless combustion). Thickened sludge, at about 6 % solids, is first ground and mixed with a stoichiometric amount of compressed air. The slurry is then pressurised. The mixture is then circulated through a series of heat exchangers before entering a pressurised reactor. The temperature of the reactor is held between 175 and 315 °C. Steam is usually used for auxiliary heat. Off-gases must be treated to eliminate odours; wet scrubbing, afterburning or carbon absorption may be used (US EPA, 1994).

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7 Point of enquiry

Enquiries concerning this chapter should be directed to the relevant leader(s) of the Task Force on Emission Inventories and Projection’s expert panel on Combustion and Industry. Please refer to the TFEIP website (www.tfeip-secretariat.org/) for the contact details of the current expert panel leaders.