Category		Title
NFR:	**5.C.1.b.i, 5.C.1.b.ii, 5.C.1.b.iv**	**Industrial waste incineration including hazardous waste and sewage sludge**
SNAP:	**090202 090204 090205 090208**	**Incineration of industrial wastes (except flaring) Flaring in chemical industries Incineration of sludges from waste water treatment Incineration of waste oil**
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1 Overview

This chapter includes the volume reduction, by combustion, of industrial wastes and sludge resulting from municipal waste water treatment (sewage), as well as emissions from flaring and incineration of waste oil. The definition of industrial waste varies. In this case, we have decided to include all non-domestic chemical, hazardous and difficult wastes, and other industrial wastes. 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.

Emissions from flaring and incineration of waste oil are not explicitly discussed, since their contribution to the total national emissions is thought to be insignificant (i.e. less than 1 % of the national emissions of any pollutant). The remainder of this chapter will therefore mainly focus on emissions from incineration of industrial wastes and sludges from waste water treatment.

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 heat recovery in the incineration process, it is good practice to report the emissions in the relevant combustion sector in the combustion section (1.A). If no heat recovery is applied, it is good practice to report the emissions under the appropriate waste incineration sector.

When reporting in the combustion source categories, the emission factors provided in this chapter must be recalculated in terms of g/GJ (or equivalent energy units) by multiplying with the heating value of the waste. However, this heating value depends strongly on the kind of waste that is being burned. Therefore, the composition of the waste must be known in this case.

Most waste incinerators are small hazardous/chemical waste incinerators constructed on-site, intended for the industries' own use.

In general, industrial waste incinerators are unlikely to be a significant source of emissions, because the waste treated often has a high toxicity and efficient abatement is required to meet the stringent emission standards.

The relative proportion of emissions contributed by industrial waste incineration is likely to vary between pollutants. Emissions of carbon dioxide, volatile organic compounds (VOCs), hydrogen chloride 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 waste varies considerably. Industrial 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, animal and food wastes. Industrial waste sources include chemical plant, refineries, light and heavy manufacturing, etc.

Industrial waste is incinerated to reduce its volume and to save landfill costs, and 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 two principal sources (HMIP, 1992):

• the removal of solids from raw sewage. This primary sludge has a solids content of about 5 % and consists of both organic and inorganic substances;

• the removal by settlement of solids produced during biological treatment processes, i.e. surplus activated sludge and human sludge. This is known as secondary sludge.

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.

Figure 2-1 shows a process scheme for industrial waste incineration. Only combustion emissions arise from the incinerator. It is good practice to report the emissions as follows:

• in the combustion source category, 1.A, when energy recovery is applied (when the incinerated waste is used as a fuel for another combustion process);

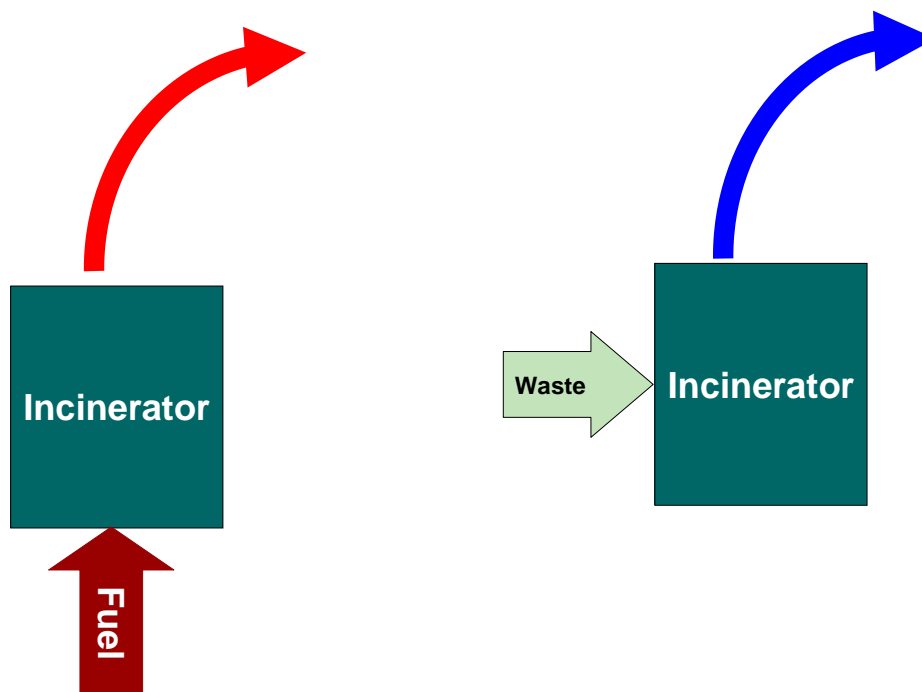• in this source category when no energy recovery is applied.

Figure 2-1   Process scheme 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, with energy recovery (left panel) and without energy recovery (right panel)

2.2 Techniques

There are many different furnace designs in use at industrial waste incinerators 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.

Small industrial waste incinerators with a restricted waste supply are often operated as batch processes. 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.

There are three main designs of furnace used for sludge incineration: rotary kiln, fluidised bed and multiple hearths. However the principal influence on the emission factors applicable to a plant is the degree of pollution abatement equipment fitted to the plant.

Virtually any material that can be burned can be combined with sludge in a co-incineration process. Common materials for co-combustion are coal, municipal solid waste (MSW), wood waste and agriculture waste. Thus, municipal or industrial waste can be disposed of while providing a self-sustaining sludge feed, thereby solving two disposal problems. There are two basic approaches to combusting sludge with MSW: use of MSW combustion technology by adding dewatered or dried sludge to the MSW combustion unit, and use of sludge combustion technology by adding processed MSW as a supplemental fuel to the sludge furnace (US Environmental Protection Agency (US EPA), 1994).

1. Fluidised bed furnace

Fluidised bed combustion (FBC) consist of 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).

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 condition, 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).

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).

2.3 Emissions

Industrial 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 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 process emissions from the incineration of industrial wastes. 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 more easy 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.i, 5.C.1.b.ii, 5.C.1.b.iv Industrial waste incineration including hazardous waste and sewage sludge**

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:

$$E_{pollutant} = AR_{production} \times EF_{pollutant} \tag{1}$$

This equation is applied at the national level. Information on the production statistics can be obtained from the national annual quantity of industrial waste incinerated.

The Tier 1 emission factors assume an averaged or typical technology and abatement implementation in the country. In cases where specific abatement options are to be taken into account, a Tier 1 method is not applicable and a Tier 2 or Tier 3 approach must be used.

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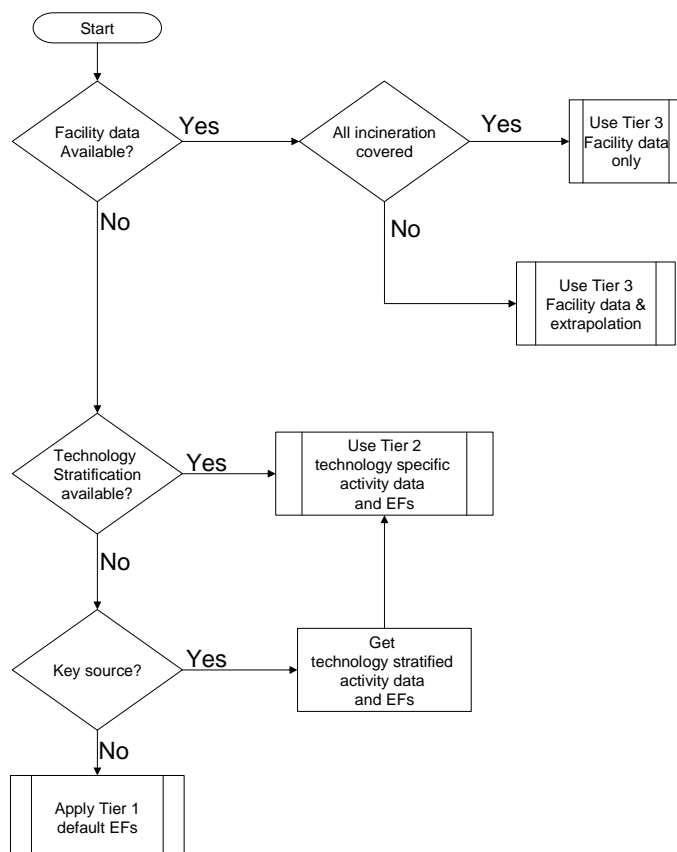
Table 3-1   Tier 1 emission factors for source category 5.C.1.b.i, 5.C.1.b.ii, 5.C.1.b.iv Industrial waste incineration including hazardous waste and sewage sludge

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 including hazardous waste and sewage sludge			
Fuel	NA				
Not applicable	HCH				
Not estimated	NH₃, Cr, Cu, Zn, Se, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, PCBs				
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)
SO₂	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)
PM₁₀	0.007	kg/Mg waste	0.0007	0.15	US EPA (1996) applied on TSP
PM₂.₅	0.004	kg/Mg waste	0.0004	0.1	US EPA (1996) applied on TSP
BC	3.5	% of PM₂.₅	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	350	µg I-TEQ/Mg waste	0.5	35000	UNEP (2005)
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 quantity of industrial waste incinerated is required.

3.3 Tier 2 technology-specific approach

3.3.1   Algorithm

The Tier 2 approach is similar to the Tier 1 approach. To apply the Tier 2 approach, both the activity data and the emission factors need to be stratified according to the different techniques that may occur in the country.

The approach followed to apply a Tier 2 approach is as follows.

Stratify the waste incineration in the country to model the different product and process types occurring in the national waste incineration industry into the inventory by:

defining the production using each of the separate product and/or process types (together called 'technologies' in the formulae below) separately; and

applying technology specific emission factors for each process type:

$$E_{pollutant} = \sum_{technologies} AR_{production,technology} \times EF_{technology,pollutant} \qquad (2)$$

where:

AR$_{production,technology}$ =   the production rate within the source category, using this specific technology,

EF$_{technology,pollutant}$ =   the emission factor for this technology and this pollutant.

A country where only one technology is implemented will result in a penetration factor of 100 % and the algorithm reduces to:

$$E_{pollutant} = AR_{production} \times EF_{technology,pollutant} \qquad (3)$$

where:

E$_{pollutant}$ =   the emission of the specified pollutant,

AR$_{production}$ =   the activity rate for the waste incineration,

EF$_{pollutant}$ =   the emission factor for this pollutant.

The emission factors in this approach still will include all sub-processes within the waste incineration.

3.3.2 Technology-specific emission factors

This section provides the Tier 2 technology-specific emission factors for incineration of sewage sludge (uncontrolled).

3.3.2.1 Incineration of sludges from water treatment

Table 3-2 presents the default uncontrolled emission factors for the incineration of sludges from waste water treatment (sewage).

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	HCH				
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	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	4.65	mg I-TEQ/Mg	0.465	46.5	US EPA (1995)
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)

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:

$$EF_{technology abated} = (1 - \eta_{abatement}) \times EF_{technology unabated} \qquad (4)$$

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

3.3.3.1 Industrial waste incineration plant

This section presents abatement efficiencies for industrial waste incineration plants. Abatement efficiencies for dioxins are taken from the United Nations Environment Programme (UNEP) Chemicals Toolkit (UNEP, 2005), while efficiencies for particulates are taken from US Environmental Protection Agency (US EPA, 1996); for a large extent these data are based on expert judgement.

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

Tier 2 Abatement efficiencies					
	Code	Name			
NFR Source Category	5.C.1.b.i, 5.C.1.b.ii, 5.C.1.b.iv	Industrial waste incineration including hazardous waste and sewage sludge			
Fuel	NA	not applicable			
SNAP (if applicable)	090202	Incineration of industrial wastes			
Abatement technology	**Pollutant**	**Efficiency**	**95% confidence**		**Reference**
		Default Value	**Lower**	**Upper**	
Controlled combustion; minimal APC system	PCDD/F	99%	98%	100%	UNEP (2005)
Controlled combustion; good APC system	PCDD/F	100%	100%	100%	UNEP (2005)
High technology combustion; sophisticated APC system	PCDD/F	100%	100%	100%	UNEP (2005)
Low energy scrubber / Fabric filter	particle > 10 µm	80%	0%	98%	US EPA (1996)
	10 µm > particle > 2.5 µm	77%	0%	98%	US EPA (1996)
	2.5 µm > particle	77%	0%	98%	US EPA (1996)
Medium energy scubber / Fabric filter	particle > 10 µm	97%	66%	100%	US EPA (1996)
	10 µm > particle > 2.5 µm	95%	47%	99%	US EPA (1996)
	2.5 µm > particle	92%	20%	99%	US EPA (1996)
Fabric filter	particle > 10 µm	96%	62%	100%	US EPA (1996)
	10 µm > particle > 2.5 µm	94%	42%	99%	US EPA (1996)
	2.5 µm > particle	94%	13%	99%	US EPA (1996)
Low energy scrubber	particle > 10 µm	38%	0%	94%	US EPA (1996)
	10 µm > particle > 2.5 µm	34%	0%	93%	US EPA (1996)
	2.5 µm > particle	96%	61%	100%	US EPA (1996)
High energy scrubber	particle > 10 µm	68%	0%	97%	US EPA (1996)
	10 µm > particle > 2.5 µm	65%	0%	93%	US EPA (1996)
	2.5 µm > particle	98%	80%	100%	US EPA (1996)
Dry sorbent injection / Fabric filter	particle > 10 µm	93%	27%	99%	US EPA (1996)
	10 µm > particle > 2.5 µm	89%	0%	99%	US EPA (1996)
	2.5 µm > particle	83%	0%	98%	US EPA (1996)
Dry sorbent injection / Carbon injection / Fabric filter	particle > 10 µm	98%	85%	100%	US EPA (1996)
	10 µm > particle > 2.5 µm	98%	76%	100%	US EPA (1996)
	2.5 µm > particle	96%	64%	100%	US EPA (1996)
Dry sorbent injection / Fabric filter / Scrubber	particle > 10 µm	42%	0%	94%	US EPA (1996)
	10 µm > particle > 2.5 µm	36%	0%	94%	US EPA (1996)
	2.5 µm > particle	96%	64%	100%	US EPA (1996)
Dry sorbent injection / Electrostatic precipitator	particle > 10 µm	84%	0%	98%	US EPA (1996)
	10 µm > particle > 2.5 µm	82%	0%	98%	US EPA (1996)
	2.5 µm > particle	82%	0%	98%	US EPA (1996)

3.3.3.2   Incineration of sludges from waste water treatment

This section presents abatement efficiencies for particulate matter emissions from the incineration of sludges. These are taken from US EPA (1996). Abatement efficiencies for SO_x and NMVOC are from US EPA (1995).

Table 3-4   Abatement efficiencies ($\eta_{abatement}$) for source category 5.C.1.b.iv Sewage sludge incineration

Tier 2 Abatement efficiencies					
	Code	Name			
NFR Source Category	5.C.1.b.iv	Sewage sludge incineration			
Fuel	NA	not applicable			
SNAP (if applicable)	090205	Incineration of sludges from waste water treatment			
Abatement technology	**Pollutant**	**Efficiency**	**95% confidence**		**Reference**
		Default Value	**Lower**	**Upper**	
Updated, continuously, some APC system	PCDD/F	92%	80%	100%	UNEP (2005)
state-of-the-art, full APC system	PCDD/F	99%	98%	100%	UNEP (2005)
Cyclone	TSP	96%	62%	100%	US EPA (1996)
	SOx	80%	40%	93%	US EPA (1995)
	NMVOC	44%	0%	81%	US EPA (1995)
Cyclone / impingement	TSP	99%	92%	100%	US EPA (1996)
Cyclone / venturi	TSP	100%	99%	100%	US EPA (1996)
	NMVOC	85%	56%	95%	US EPA (1995)
Cyclone / venturi / impingement	TSP	99%	94%	100%	US EPA (1996)
ESP - Fabric filter	TSP	100%	100%	100%	US EPA (1996)
ESP - Impingement	TSP	99%	98%	100%	US EPA (1996)
ESP - Venturi	TSP	97%	96%	100%	US EPA (1996)
Venturi / impingement	TSP	98%	97%	100%	US EPA (1996)
	SOx	99%	98%	100%	US EPA (1995)
Venturi / impingement / wet ESP	TSP	100%	96%	100%	US EPA (1996)
Impingement	SOx	98%	93%	99%	US EPA (1995)
	NMVOC	48%	0%	83%	US EPA (1995)
Venturi	SOx	84%	51%	95%	US EPA (1995)

3.3.4   Activity data

For industrial waste incineration, the national annual quantity of industrial waste incinerated is required. Subsequently, for sludge incineration, the national annual incineration of sewage sludge is required.

3.4 Tier 3 emission modelling and use of facility data

3.4.1   Algorithm

There are two different methods to apply emission estimation methods that go beyond the technology-specific approach described above:

detailed modelling of the process;

using facility-level emission reports.

3.4.1.1   Detailed process modelling

A Tier 3 emission estimate, using process details, will make separate estimates for the consecutive steps in the waste incineration process.

3.4.1.2   Facility-level data

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 indeed use these data. There are two possibilities:

the facility reports cover all waste incineration in the country;

facility level emission reports are not available for all incineration plants in the country.

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

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

Depending on the specific national circumstances 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 from the following possibilities, in decreasing order of preference:

technology-specific emission factors, based on knowledge of the types of technologies implemented at the facilities where facility level emission reports are not available;

the implied emission factor derived from the available emission reports:

$$EF = \left. \sum_{Facilities} E_{Facility, pollutant} \middle/ \sum_{Facilities} Production_{Facility} \right. \quad (6)$$

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

3.4.2   *Tier 3 emission modelling and use of facility data*

The detailed methodology involves the use of plant-specific emission factors calculated from regulatory emission measurement programmes and using plant-specific throughput data normally obtained by each plant. The detailed method will therefore involve the use of a similar equation to the ones in Tier 1, but the equation will be plant specific.

The more detailed method requires information on plant-specific waste throughput and abatement technology, obtained from the operators.

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

For HCB emissions, the emission factors for the incineration of industrial wastes are available for a number of wastes (Guidebook, 2006), see Table 3-5.

Table 3-5   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.

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 do 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, 2006) 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 this document. 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, 2006).

Table 4-1   BAT-derived emission factors for source category 5.C.1.b.i, 5.C.1.b.ii, 5.C.1.b.iv Industrial waste incineration including hazardous waste and sewage sludge

	Code	Name		
NFR Source Category	5.C.1.b.i, 5.C.1.b.ii, 5.C.1.b.iv	Industrial waste incineration including hazardous waste and sewage sludge		
Fuel	NA	not applicable		
Pollutant	**Value**	**Unit**	**95% confidence interval**	
			Lower	**Upper**
SO2	1 - 40	mg / Nm3		
NO2 (using SCR)	40 - 100	mg / Nm3		
NO2 (without SCR)	120 - 180	mg / Nm3		
CO	5 - 30	mg / Nm3		
Hg	0.001 - 0.02	mg / Nm3		
PCDD/F	0.01 - 0.1	mg I-TEQ / Nm3		
TSP	1 - 5	mg / Nm3		
NH3	< 10	mg / Nm3		

4.4 Developing a consistent time series and recalculation

No specific issues.

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.

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6 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.