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European Environment Agency

Category		Title
NFR	5.C.1.b.iii	Clinical waste incineration
SNAP	090207	Incineration of hospital wastes
ISIC		
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Coordinator

Carlo Trozzi

Contributing authors (including to earlier versions of this chapter)

Ole-Kenneth Nielsen, Katja Hjelgaard, Jessica Sully and Mike Woodfield

Contents

1 Overview

This section includes the volume reduction, by combustion, of hospital wastes. Principally, this section covers the emissions from chimneys and ductwork because of the availability of measurement data.

In some cases hospital waste is combusted in municipal waste incinerators, or in 'hazardous waste incinerators' along with hazardous/chemical wastes from industrial processes. Users of this chapter should be aware of the potential for double counting of activity data with this chapter and the chapters about industrial and domestic/municipal wastes (chapters 5.C.1.a Municipal waste incineration and 5.C.1.b.i Industrial waste incineration, respectively).

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 emission in the relevant combustion sector in the combustion section (1.A). If no heat recovery is applied, it is good practice to report the emission 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.

The relative proportion of emissions contributed by hospital waste incineration varies between pollutants. The process is likely to be a source (0.1-1 % of total European emissions) of some persistent organic pollutants (POPs), such as polychlorinated dibenzo-dioxins and polychlorinated dibenzo-furans (PCDD/Fs), hexachlorobenzenes (HCBs), polycyclic aromatic hydrocarbons (PAHs) and some heavy metals (HM) such as cadmium, mercury, etc. (European Topic Centre on Air Emissions (ETC/AEM)-CITEPA-RISOE 1997).

Emissions of compounds such as volatile organic compounds (VOCs), sulphur dioxide and nitrogen oxides and particulate matter (PM) from hospital waste incineration are unlikely to contribute significantly to total emissions (< 0.1 %) (ETC/AEM-CITEPA-RISOE 1997).

2 Description of sources

2.1 Process description

Hospital waste may be identified as 'specific hospital waste' and 'other hospital waste'. Specific hospital waste includes human anatomic remains and organ parts, waste contaminated with bacteria, viruses and fungi, and larger quantities of blood.

Incineration of hospital wastes has been banned in some European countries. In countries where the process is allowed, for the most part incinerators are currently small facilities located on-site at hospitals. However, there is generally a move towards larger, centralised facilities.

Figure 2-1 shows a process scheme for the incineration of clinical waste. Only combustion emissions arise from the incinerator. It is good practice to report emissions in the following way:

- in a combustion source category 1.A when energy recovery is applied (when the incinerated waste is used as a fuel for another combustion process, see left panel of Figure 2-1);

- in this source category 5.C.1.b.iii when no energy recovery is applied (see right panel of Figure 2-1).

Figure 2-1 **Process schemes for source category 5.C.1.b.iii Clinical waste incineration; the left panel is applicable when the heat is recovered; the right panel when the heat is not recovered**
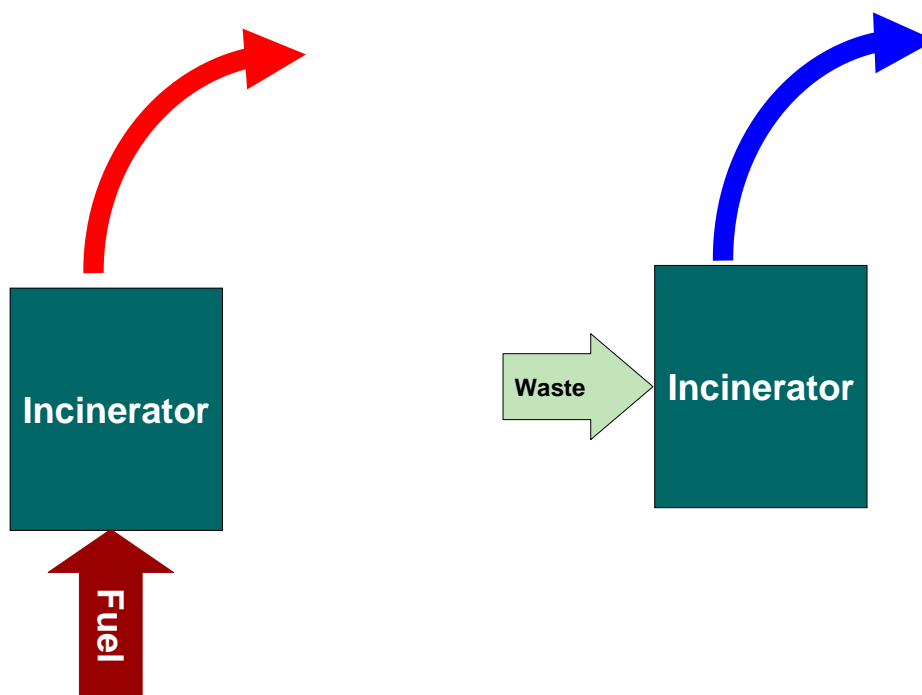
2.2 Techniques

There are many different furnace designs and combustion techniques used in Europe for hospital waste incineration. Generally, incinerators consist of the following components:

- a lidded charge box or feed hopper where the batch is first deposited;

- a hydraulic ram/feeder which pushes the charge into the furnace;

- a pyrolysis furnace where the waste is degassed, releasing moisture and volatile components (at temperatures 800–900 $^{\circ}$C);

- an after-burning chamber or secondary combustion chamber where the volatile components and products of incomplete combustion are completely destroyed by thermal oxidation in the presence of excess air, at temperatures above 1 000 $^{\circ}$C and with a gas residence time of two seconds;

- burners to heat up the plant when started, initiate combustion and to regulate the temperature in all parts, especially the secondary combustion chamber;

- a residue handling system.

Incinerator size

Small incinerators (< 1 tonne/hr) may be designed to be operated during the day only, and tend to be used to incinerate batches. At start-up, the furnace is heated using support burners and, if required, the burning of domestic hospital waste. Daily, after the last waste input, the furnaces are maintained at temperature for a further 2–4 hours using the burners. The furnace is then cooled by leading ambient air through it for a number of hours before manual de-ashing is carried out.

Larger incinerators (> 1 tonne/hr) normally employ continuous operation. Conditions are adapted to ensure that there is effective combustion throughout, e.g. by using multi-hearth plant or rotary kilns under appropriate conditions of temperature/ air.

The main influences on the total emission expected from these incinerators are the waste burning capacity of the incinerator, the type of plant, the way in which it is operated (e.g. whether it includes heat recovery), its gas phase combustion efficiency and the degree of abatement fitted to the plant.

2.3   Emissions

The most significant pollutants from this process are certain heavy metals (e.g. Pb, Cu, Cd, Cr, Ni and Hg). A variety of organic compounds, including PCDD/Fs, chlorobenzenes, chloroethylenes and polycyclic aromatic hydrocarbons (PAHs), are present in hospital waste or can be formed during the combustion and post-combustion processes. Organics in the flue gas can exist in the vapour phase or can be condensed or absorbed on fine particulates.

Other pollutants released are sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (non-methane VOCs and methane (CH_4)), carbon monoxide (CO), carbon dioxide (CO_2) and nitrous oxide (N_2O).

Carbon monoxide emissions result when carbon in the waste is not completely oxidised to carbon dioxide (CO_2). High levels of CO normally indicate that the combustion gases were not held at a sufficiently high temperature in the presence of oxygen (O_2) for a long enough time to convert CO to CO_2, or that quenching has occurred. Because O_2 levels and air distributions vary among combustor types, CO levels also vary among combustor types. Carbon monoxide concentration is a good indicator of gas phase combustion efficiency, and is an important criterion for indicating instabilities and non-uniformities in the combustion process.

Nitrogen oxides are products of all fuel/air combustion processes. Nitric oxide (NO) is the primary component of NO_x; however, nitrogen dioxide (NO_2) and nitrous oxide (N_2O) are also formed in smaller amounts. Nitrogen oxides are formed during combustion through oxidation of nitrogen in the waste, and oxidation of atmospheric nitrogen. Conversion of nitrogen in the waste occurs at relatively low temperatures (less than 1 090 °C), while oxidation of atmospheric nitrogen occurs at higher temperatures. NO_x from hospital waste incineration is typically lower than from other waste incineration processes.

2.4   Controls

Emissions may be controlled by modification of process techniques and physical parameters to optimise combustion conditions, or by employment of abatement techniques. The level of abatement at an incinerator plant varies, depending on the size of the plant, age and emission regulations, etc.

Mainly for economic reasons, in recent years there has been a move towards larger, modern plant. Such plant includes emission abatement equipment, which aim to ensure compliance with emission regulations, addressing the three main environmental impacts of waste incineration/ products of incomplete combustion: acid gas, heavy metal and dioxin emissions. Typical approaches used include:

- good combustion practice — optimal conditions of time/ temperature/ turbulence/ air to ensure complete oxidation of products of incomplete combustion;
- wet scrubbers (acid gas removal);
- fabric filters (particle control);
- electrostatic precipitators (particle control);
- semi-dry scrubbers/spray absorber systems (acid gas removal);
- dry sorbent injection systems (acid gas removal);
- adsorption using activated carbon/activated lignite coke (PCDD/F and mercury removal).

These control systems are described in subsection 3.3 of the present chapter. These systems are usually needed in combination.

3 Methods

3.1 Choice of method

Figure 3-1 presents the procedure to select the methods for estimating emissions from incineration of clinical waste. The basic ideas behind this procedure are:

- 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 category 5.C.1.b.iii Clinical waste incineration
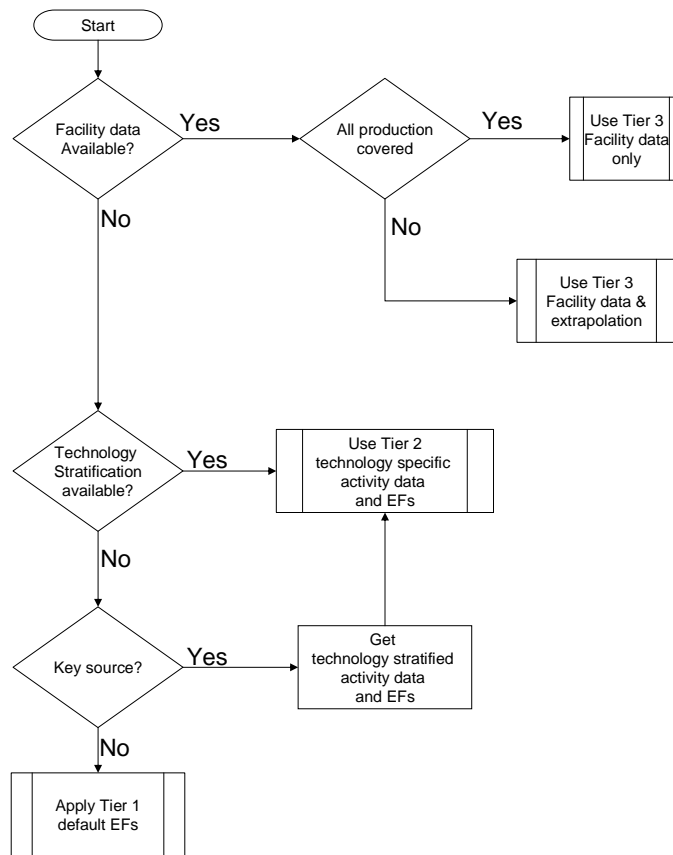
3.2   Tier 1 default approach

3.2.1   Algorithm

The simpler methodology relies on the use of a single emission factor for each pollutant species combined with a national hospital waste incineration statistic:

$$\text{Total emission} = \text{mass of hospital waste incinerated (tonnes)} \times \text{overall emission factor (emission per tonne of waste incinerated)} \quad (1)$$

N.B.: There are no emission factors available for $PM_{2.5}$. The source is < 0.1 % of the total PM emissions for most countries.

3.2.2   Default emission factors

Default emission factors for Tier 1 are given in this section. Table 3-1 provides technology-specific emission factors for uncontrolled emissions from rotary kilns. The data are taken from US EPA (1993) and applicable for the USA.

Users of the Guidebook are advised to consider that from country to country the composition of the incinerated waste may vary due to differences in waste definitions and fractionation. This could lead to country-specific emission factors that are not comparable to those of other countries.

Table 3-1 **Tier 1 emission factors for source category 5.C.1.b.iii Clinical waste incineration, uncontrolled rotary kiln incinerator**

Tier 1 emission factors					
	Code	Name			
NFR Source Category	5.C.1.b.iii	Clinical waste incineration (d)			
Fuel	NA				
Not applicable					
Not estimated	NH_3, PM_{10}, $PM_{2.5}$, Se, Zn, 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	2.3	kg/Mg waste	0.2	23	US EPA (1993)
CO	0.19	kg/Mg waste	0.002	2	US EPA (1993)
NMVOC	0.7	kg/Mg waste	0.3	1.4	Aasestad (2007)
SO_2	0.54	kg/Mg waste	0.05	5	US EPA (1993)
TSP	17	kg/Mg waste	1.7	170	US EPA (1993)
BC[1]	2.3	% of TSP*	1.8	2.8	Olmez et al. (1988)
Pb	62	g/Mg waste	6	600	US EPA (1993)
Cd	8	g/Mg waste	0.8	80	US EPA (1993)
Hg	43	g/Mg waste	4	400	US EPA (1993)
As	0.2	g/Mg waste	0.02	2	US EPA (1993)
Cr	2	g/Mg waste	0.2	20	US EPA (1993)
Cu	98	g/Mg waste	10	1000	US EPA (1993)
Ni	2	g/Mg waste	0.2	20	US EPA (1993)
PCB	0.02	g/Mg waste	0.002	0.2	US EPA (1993)
PCDD/F	40	mg I-TEQ/Mg waste	20	80	UNEP (2005)
Total 4 PAHs	0.04	mg/Mg waste	0.02	0.1	Aasestad (2007)
HCB	0.1	g/Mg waste	0.01	0.9	EMEP/EEA (2006)

Note: * Olmez et al. (1988) provides the BC emission factor both as 3.5 % of $PM_{2.5}$ and 2.3 % of TSP, the latter is chosen for this table since no emission factor for $PM_{2.5}$ is available.

3.2.3 Activity data

For the simpler methodology the national annual incineration of hospital waste is required. In addition, a more reliable estimate can be made if information is available on the typical levels of abatement technology used and on the associated overall abatement efficiency.

In determining the emissions from the incineration of hospital waste, one of the most difficult tasks for the user is to correctly derive the fraction of waste actually being incinerated from the overall clinical waste being produced in a country.

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.

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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.

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 the plant type controlled air incineration (uncontrolled).Emission factor data are not available for all pollutants for this technology. Wherever an emission factor is not available, the emission factor used is identical to the Tier 1 emission factor to complete the table (PCB, Total 4 PAHs, HCB). This may, however, lead to inconsistencies between tables and within one table. Therefore, care should be taken in applying the Tier 2 emission factors.

Controlled air incinerator

This subsection provides Tier 2 technology-specific emission factors for uncontrolled emissions from controlled air incinerators. The data are taken from US EPA (1993) and applicable for the USA. When abatement measures are in place, the table below, in combination with the relevant abatement efficiencies (provided in subsection 3.3.3 of the present chapter), can be used to estimate the emissions.

Table 3-2   Tier 2 emission factors for source category 5.C.1.b.iii Clinical waste incineration, controlled air incinerator

Tier 2 emission factors					
	Code	Name			
NFR Source Category	5.C.1.b.iii	Clinical waste incineration (d)			
Fuel	NA				
SNAP (if applicable)	090207	Incineration of hospital wastes			
Technologies/Practices	Controlled air incineration				
Region or regional conditions	United States				
Abatement technologies	uncontrolled				
Not applicable					
Not estimated	NH$_3$, PM$_{10}$, PM$_{2.5}$, Se, Zn, 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$_x$	1.8	kg/Mg waste	1.4	2.1	US EPA (1993)
CO	1.5	kg/Mg waste	1.2	1.8	US EPA (1993)
NMVOC	0.7	kg/Mg waste	0.3	1.4	Aasestad (2007)
SO$_2$	1.1	kg/Mg waste	0.7	1.5	US EPA (1993)
TSP	2.3	kg/Mg waste	1.4	3.3	US EPA (1993)
BC[2]	2.3	% of TSP*	1.8	2.8	Olmez et al. (1988)
Pb	36	g/Mg waste	20	50	US EPA (1993)
Cd	3	g/Mg waste	2	4	US EPA (1993)
Hg	54	g/Mg waste	27	100	US EPA (1993)
As	0.1	g/Mg waste	0.06	0.14	US EPA (1993)
Cr	0.4	g/Mg waste	0.24	0.56	US EPA (1993)
Cu	6	g/Mg waste	0.6	60	US EPA (1993)
Ni	0.3	g/Mg waste	0.18	0.42	US EPA (1993)
PCB	0.02	g/Mg waste	0.002	0.2	US EPA (1993)
PCDD/F	40	mg I-TEQ/Mg waste	20	80	UNEP (2005)
Total 4 PAHs	0.04	mg/Mg waste	0.02	0.1	Aasestad (2007)
HCB	0.1	g/Mg waste	0.01	0.9	EMEP/EEA (2006)

Note: * Olmez et al. (1988) provides the BC emission factor both as 3.5 % of PM$_{2.5}$ and 2.3 % of TSP, the latter is chosen for this table since no emission factor for PM$_{2.5}$ is available.

3.3.3 Abatement

A typical emission factor for hospital waste incinerators within a country can be estimated from the emission factors given in the following sections combined with knowledge of the typical level of abatement and its efficiency:

$$\text{Typical overall emission factor} = \text{baseline emission factor (uncontrolled)} \times (1 - \text{overall abatement efficiency}) \qquad (4)$$

Data are taken from US EPA (1993) and are applicable to controlled facilities, with various types of abatement (not further specified). Data are available for selected pollutants only.

The abatement efficiencies provided in this section can only be applied when using Tier 2 emission factors from Table 3-2 or Table 3-3.

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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.

Table 3-3 Abatement efficiencies (η_{abatement}) for source category 5.C.1.b.iii Clinical waste incineration, controlled air incinerator

Tier 2 Abatement efficiencies					
	Code	Name			
NFR Source Category	5.C.1.b.iii	Clinical waste incineration			
Fuel	NA	not applicable			
SNAP (if applicable)	090207	Incineration of hospital wastes			
Technology		Controlled air incinerator			
Abatement technology	**Pollutant**	**Efficiency**	**95% confidence interval**		**Reference**
		Default Value	Lower	Upper	
Controlled by various types of abatement	SOx	92%	5%	99%	US EPA (1993)
	TSP	90%	38%	98%	US EPA (1993)
	As	99%	30%	100%	US EPA (1993)
	Cd	96%	0%	100%	US EPA (1993)
	Cr	96%	20%	100%	US EPA (1993)
	Cu	59%	0%	83%	US EPA (1993)
	Pb	100%	89%	100%	US EPA (1993)
	Hg	97%	72%	100%	US EPA (1993)
	Ni	0%	0%	67%	US EPA (1993)

Table 3-4 Abatement efficiencies (η_{abatement}) for source category 5.C.1.b.iii Clinical waste incineration, rotary kiln

Tier 2 Abatement efficiencies					
	Code	Name			
NFR Source Category	5.C.1.b.iii	Clinical waste incineration			
Fuel	NA	not applicable			
SNAP (if applicable)	090207	Incineration of hospital wastes			
Technology		Rotary kiln			
Abatement technology	**Pollutant**	**Efficiency**	**95% confidence interval**		**Reference**
		Default Value	Lower	Upper	
Controlled by various types of abatement	NOx	0%	0%	12%	US EPA (1993)
	CO	88%	84%	90%	US EPA (1993)
	SOx	59%	40%	72%	US EPA (1993)
	TSP	99%	98%	100%	US EPA (1993)
	Cd	100%	100%	100%	US EPA (1993)
	Cr	98%	98%	98%	US EPA (1993)
	Cu	100%	100%	100%	US EPA (1993)
	Pb	100%	100%	100%	US EPA (1993)
	Hg	73%	23%	91%	US EPA (1993)
	Ni	99%	98%	99%	US EPA (1993)

Control on dioxin emissions

The abatement efficiencies given in Table 3-5 are for dioxins and furans (PCDD/F) only and related to an uncontrolled batch type combustion plant without air pollution control (APC) equipment, which has an emission factor of 40 000 μg TEQ/Mg waste burned.

The values are taken from the PCDD/PCDF toolkit (United Nations Environment Programme (UNEP), 2005), which defines four classes of emission factors for medical waste incinerators. These can be used in combination with the Tier 2 emission factors for controlled air and rotary kiln plants (Table 3-2 and Table 3-3 only. The efficiencies are calculated with respect to an uncontrolled plant.

Table 3-5 **Abatement efficiencies (η_{abatement}) for source category 5.C.1.b.iii Clinical waste incineration**

Tier 2 Abatement efficiencies					
	Code	Name			
NFR Source Category	5.C.1.b.iii	Clinical waste incineration			
Fuel	NA	not applicable			
SNAP (if applicable)	090207	Incineration of hospital wastes			
Technology	Rotary kiln				
Abatement technology	**Pollutant**	**Efficiency**	**95% confidence interval**		**Reference**
		Default Value	**Lower**	**Upper**	
Batch type conversion, no/minimal APC	PCDD/F	93%	78%	98%	UNEP (2005)
Batch type conversion, good APC	PCDD/F	99%	96%	100%	UNEP (2005)
High technology, continuous, controlled combustion, sophisticated	PCDD/F	100%	100%	100%	UNEP (2005)

3.3.4 Activity data

For the simpler methodology, the national annual incineration of hospital waste is required. In addition, a more reliable estimate can be made if information is available on the typical levels of abatement technology used and on the associated overall abatement efficiency.

In determining the emissions from the incineration of hospital waste, one of the most difficult tasks for the user is to correctly derive the fraction of waste actually being incinerated from the overall clinical waste being produced in a country.

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.

Detailed process modelling

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

Facility level data

Where facility-level emission data of sufficient quality (see General Guidance 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.

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 clinical 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 compliant emission factors for source category 5.C.1.b.iii Clinical waste incineration

BAT compliant emission factors				
	Code	Name		
NFR Source Category	5.C.1.b.iii	Clinical waste incineration		
Fuel	NA	not applicable		
			95% confidence interval	
Pollutant	**Value**	**Unit**	**Lower**	**Upper**
SO2	1 - 40	mg/Nm3		
NO2 (using SCR)	40 - 100	mg/Nm3		
NO2 (not using 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

It is good practice to consider that from country to country the composition of the incinerated waste may vary due to differences in waste definitions and fractionation. This could lead to country-specific emission factors that are not comparable to those of other countries.

4.5.1 Emission factor uncertainties

Emission factors are likely to vary considerably between different incinerators, depending on the operating conditions and on which of the many combinations of gas cleaning equipment is in use on the plant. The variability at just a single plant for PCDD/Fs, for example, can be an order of magnitude between different sampling periods. The ranges in emission factors and the data quality ratings (mainly C, D or E) demonstrate the high uncertainty.

4.5.2 Activity data uncertainties

No specific issues.

4.6   Inventory quality assurance/quality control QA/QC

No specific issues.

4.7   Gridding

No specific issues.

4.8   Reporting and documentation

No specific issues.

5 Glossary

APC	Air pollution control.
BAT	Best Available Techniques.
HCB	Hexachlorobenzene.
I-TEQ	International toxic equivalent (of PCDD/Fs).
NMVOCs	Non-methane volatile organic compounds.
PAHs	Polycyclic aromatic hydrocarbons.
PCBs	Polychlorinated biphenyls.
PCDD/Fs	Polychlorinated dibenzo-para-dioxins/polychlorinated dibenzo furans — a series of chlorinated aromatic compounds, commonly known as 'dioxins'.
POPs	Persistent organic pollutants.
Adsorption using activated carbon/ activated lignite coke	Several different technologies have been developed for dioxin and mercury control. These systems can also be fairly effective at removing HCl and SO_2 and act as a useful polisher for these acid gases.
Controlled air incinerators	Also known as modular-starved air incinerators, are commonly used units, which consist of two stages. During the first stage (starved air section), the air-to-fuel ratio is kept low to promote drying and volatilisation at temperatures of ~ 800–900 °C. In the second stage (secondary combustion chamber), excess

	air is added and temperatures elevated to > 1 000 °C by support burners to ensure complete gas phase combustion. The relatively low bed temperature and combustion air velocities mean that metal species tend to remain in the bed and, together with particulates, are less likely to be entrained in the flue gases than with other types of incinerator (e.g. excess air incinerators).
Electrostatic precipitators (ESP)	Use the principle of electrostatic attraction to remove entrained particles from the flue gases. They consist of rows of discharge electrodes (wires or thin metal rods), through which a high voltage is applied, and which run between an array of parallel rows of metal plates which collect the charged particles (note: not very common in clinical waste incinerators).
Energy recovery	The removal of heat from the exhaust gases so as to provide heat and/or electricity for use in the plant or elsewhere.
Excess air incinerators	Also referred to as batch incinerators, are typically small modular units consisting of a series of internal chambers and baffles. They are usually operated batch wise, but can be operated continuously. Excess air incinerators generally consist of two main chambers; a primary combustion chamber where drying and volatilisation occurs and a secondary chamber to ensure complete gas phase combustion. These plant are operated at lower temperatures than controlled air incinerators (secondary chamber temperature ~ 900 °C), with complete combustion promoted by maintaining excess air levels of up to 300 % throughout (usually ~ 100 % for burning pathological waste only).
Fabric filters	Consist of semi-permeable material in the form of bags or sleeves, which trap particles and are mounted in an airtight housing (baghouse) which is divided into a number of compartments. Fabric filters are also used as a second stage in acid-gas control systems.
Rotary kiln	Waste is fed into a slightly inclined, rotating, refractory-lined drum which acts as a grate surface. The rotating action of the drum mixes it with air supplied through the walls.
Semi-dry scrubbers/ spray absorber systems (spray drying)	Make use of an alkaline reagent slurry (usually calcium hydroxide) which is introduced into the flue gases as a spray of fine droplets. The acid gases are absorbed into the aqueous phase on the surface of these droplets and neutralised to form a dry product, which is collected in an electrostatic precipitator or fabric filter. Spray absorbers tend to use a reaction tower; of the several different designs available, the gas suspension absorber is the most commonly employed in hospital waste incinerators. This involves a re-circulation of particulate matter and unreacted lime back into the reaction tower.
Wet scrubbers	Remove acid gases (e.g. HCl, HF and SO_2) by washing the flue gases in a reaction tower. Designed to provide a high gas-liquid contact. In the first stage, the gases are quenched by water sprays to remove HCl, HF, some particulates and some heavy metals. In the second stage, calcium hydroxide or another suitable alkali is used to remove SO_2 and any remaining HCl.

6 References

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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.