

Category		Title
NFR:	6.C.c	Municipal waste incineration
SNAP:	090201	Incineration of domestic or municipal wastes (without energy recovery)
ISIC:		
Version	Guidebook 2009	

Coordinator

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1 Overview

This section includes the volume reduction, by combustion, of domestic and commercial refuse (often referred to as 'municipal solid waste' (MSW)). Principally, this section includes the emissions from chimneys and duct work because of the availability of measurement data.

Care must be taken to prevent double counting of emissions reported here and in the relevant combustion chapter in the relevant source category in 1.A. All the activities and emission factors with regard to the incineration of waste are explained in the waste incineration sector, 6.C. If there is heat recovery in the incineration process, it is good practice to report the emissions in the relevant combustion sector in 1.A. If no heat recovery is applied, it is good practice to report the emissions in the waste incineration sector, 6.C.

The emissions of compounds such as volatile organic compounds (VOCs), sulphur dioxide, hydrogen chloride and particulate matter (PM) from waste incineration are unlikely to contribute significantly to total emissions. However, waste incinerators have been a major source of emissions of polychlorinated dibenzo-dioxins and polychlorinated dibenzo-furans PCDD/Fs, other persistent organic pollutants (POPs) and some heavy metals such as cadmium and mercury (Leech, 1993). MSW incinerators in many countries now apply extensive abatement techniques and comply with emission limits, and in these cases the contribution of MSW incinerators to total emissions of PCDD/Fs and heavy metals has greatly decreased.

2 Description of sources

2.1 Process description

Municipal solid waste is the unwanted material collected from households and commercial organisations. It consists of a mix of combustible and non-combustible materials, such as paper, plastics, food waste, glass, defunct household appliances and other non-hazardous materials. The quantity produced per person varies with the effectiveness of the material recovery scheme in place and with the affluence of the neighbourhood from which it is collected.

Municipal waste can be incinerated to:

- reduce its volume;
- save landfill space and costs;
- recover energy from its combustion, either for district/process heating and/or for electricity generation.

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

- in the relevant combustion source category 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.

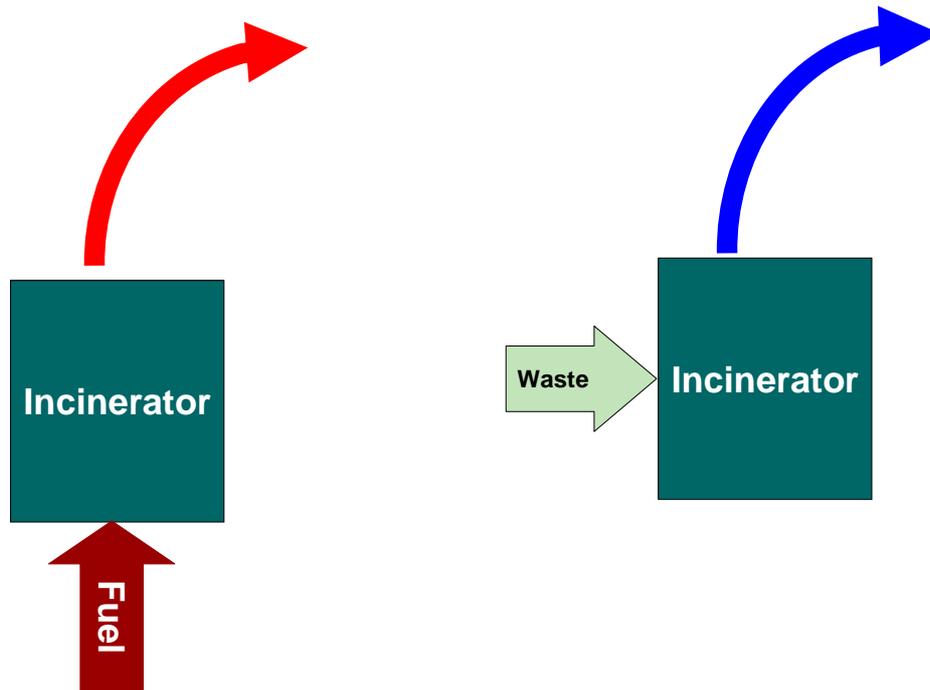


Figure 2-1 Process scheme for source category 6.C.c Municipal waste incineration, with energy recovery (left panel) and without energy recovery (right panel)

2.2 Techniques

There are many different furnace designs and combustion techniques in use in Europe for MSW incineration. However, the main influences on the total emission expected from these incinerators are the waste burning capacity of the incinerator, the type of incinerator (mass burn excess air or modular starved air), the way in which it is operated (e.g. whether it includes heat recovery) and the degree of abatement fitted to the plant. Figure 2-2 shows a simple diagram of the components of a typical MSW incinerator.

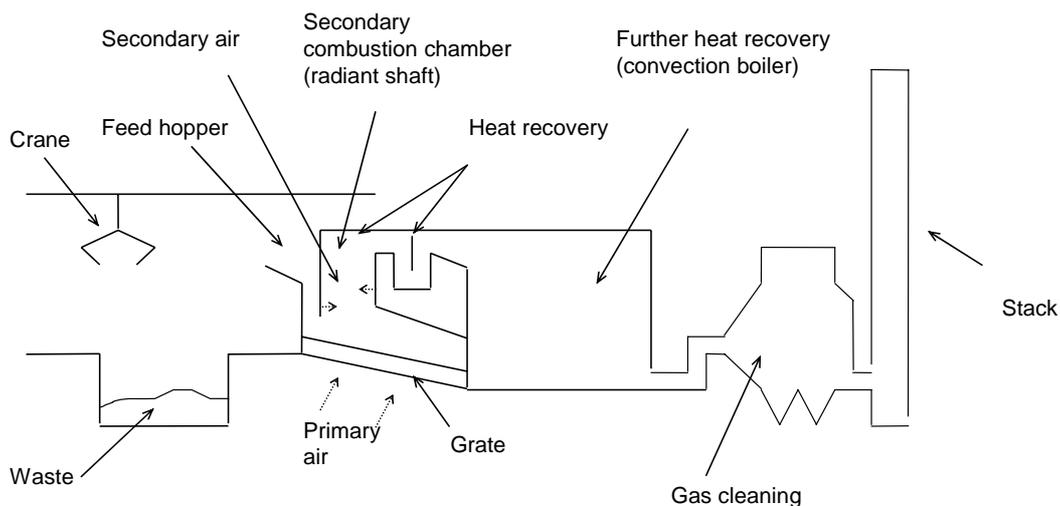


Figure 2-2 Components of a typical mass burn, excess air MSW incinerator

There are 3 key classes of MSW incineration technology which depend on the quantity and form of the waste burned. These are mass burn units, modular combustors and fluidised bed combustors.

- Mass burn units

In mass burn units, the MSW is incinerated without any pre-processing other than the removal of items too large to go through the feed system and removal of hazardous items, e.g. compressed gas cylinders. Mass burn combustors usually range in size from e.g. 45 to 900 tonnes waste/day. Operation of mass burn units typically includes the introduction of excess air. Designs of mass burn combustors include mass burn water wall, mass burn rotary water wall combustor, and mass burn refractory wall.

- Modular combustors

Modular combustors are similar to mass burn combustors as they burn waste that has not been pre-processed, but they are typically shop fabricated and generally smaller, ranging in size from 4 to 130 tonnes waste/day. One of the most common types of modular combustors is the starved air or controlled air type. They are used where start-ups occur each day and/or where throughputs are low, for example at commercial/factory sites or in rural areas.

- Fluidised bed combustors (FBC)

Fluidised bed combustors have a bed of sand or similar inert material which is agitated or 'fluidised' by an upward flow of air through a porous plate below it. Combustion occurs within the bed. For the combustion of MSW in FBC, the fuel has to be treated (e.g. shredded) in order to obtain a suitable size.

Waste, in whatever form, enters the combustion chamber via the feeder hopper. In a typical incinerator, refuse is placed on a grate that moves the waste through the combustor, mixing the waste thoroughly with the hot air to ensure effective combustion. Grate-firing installations are capable of burning a range of wastes, which is useful as the composition of the waste varies widely. They can also operate at a range of flow rates. Apart from fluidised bed, there are two main types of grate:

- moving grate;
- rotary furnace.

The main combustion technique used for the incineration of MSW is the moving grate. Fluidised bed combustion (FBC) or rotary furnace techniques have had a more limited use for the incineration of MSW.

Many incinerator designs have two combustion chambers. Air is supplied to the primary chamber through the waste (primary air). The incomplete combustion products (CO and organic compounds) pass into the secondary combustion chamber where additional air (secondary air) is added and combustion is completed.

Incinerator size

Small incinerator plants 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 excessive.

2.3 Emissions

As well as persistent organic pollutants (e.g. dioxins), and some heavy metals (e.g. Pb, Cu, Cd, Cr, Ni, Hg), pollutants released are sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (non-methane VOCs and methane (CH₄)), carbon monoxide (CO), carbon dioxide (CO₂), nitrous oxide (N₂O), hydrogen chloride (HCl) and ammonia (NH₃).

Carbon monoxide emissions result when carbon in the waste is not oxidised to carbon dioxide (CO₂). High levels of CO indicate that the combustion gases were not held at a sufficiently high temperature in the presence of oxygen (O₂) for a long enough time to convert CO to CO₂. Because O₂ levels and air distributions vary among combustor types, CO levels also vary among combustor types. Carbon monoxide concentration is a good indicator of combustion efficiency, and is an important criterion for indicating instabilities and non-uniformities in the combustion process (Environmental Protection Agency (EPA), 1995).

Nitrogen oxides are products of all fuel/air combustion processes. Nitric oxide (NO) is the primary component of NO_x; however, nitrogen dioxide (NO₂) and nitrous oxide (N₂O) 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. Because of the relatively low temperatures at which municipal waste furnaces operate, 70 to 80 percent of NO_x formed in municipal waste furnaces is associated with nitrogen in the waste.

A variety of organic compounds, including chlorobenzenes, polychlorinated biphenyls (PCB), chlorophenols, polycyclic aromatic hydrocarbons (PAH) and PCDD/Fs are present in MSW or can be formed during the combustion and post-combination processes. Organics in the flue gas can exist in the vapour phase or can be condensed or absorbed on fine particulates.

2.4 Controls

The level of abatement at an incinerator plant varies, depending on the size of the plant, emission regulations, etc.

Modern plant, and many older plant which have been updated, have a range of different emission abatement equipment which aim to ensure compliance with emission regulations and address the three main environmental impacts of waste incineration: acid gas, heavy metal and dioxin emissions. Typical approaches used include:

- fabric filters (particle control);
- electrostatic precipitators (particle control);
- wet scrubbers (acid gas removal);
- semi-dry scrubbers/spray absorber systems (acid gas removal);
- dry injection systems (acid gas removal);
- adsorption using activated carbon/activated lignite coke (PCDD/F and mercury removal).

These control systems are described in the glossary. They are commonly needed in combination; the fabric filter has a secondary function for acid gas control and similarly the wet scrubber for particle control.

NO_x emissions are controlled by using primary or secondary measures as described in chapter 1.A.1.a, Public electricity and heat production (Combustion in energy and transformation industries chapter).

In the past, many small incinerators have had negligible emission control equipment and the older large plant have had particle control only, frequently by electrostatic precipitator. This abates emissions of heavy metals but may increase the PCDD/F emissions over unabated plant. Older plants also have less ash burn out as the waste combustion is less efficient and this reduces the carbon dioxide emission factor. Although later decay of the ash may lead to carbon dioxide and VOC emission, this has not been considered here.

3 Methods

3.1 Choice of method

Figure 3-1 presents the procedure to select the methods for estimating emissions from 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.

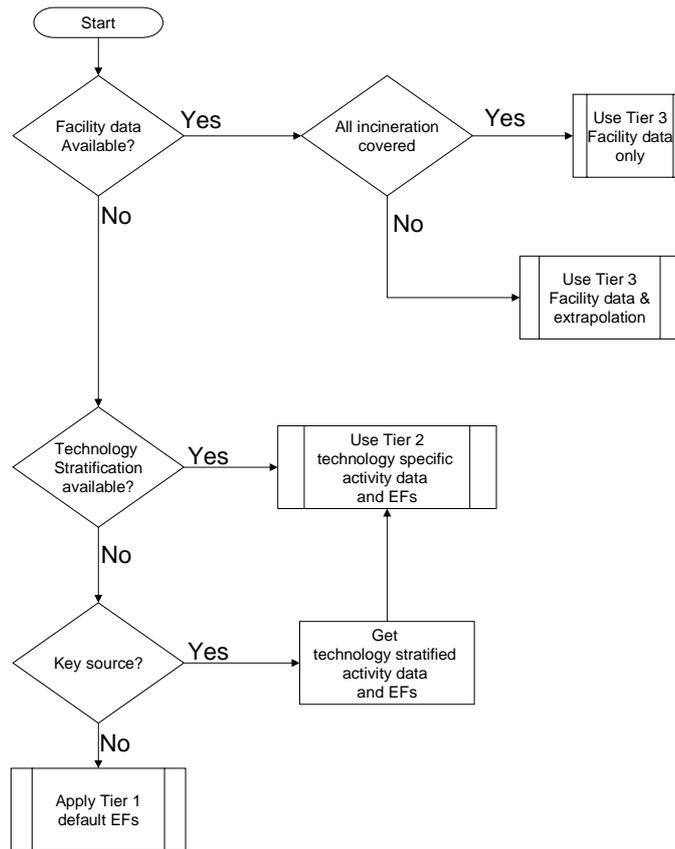


Figure 3-1 Decision tree for source category 6.C.c Municipal waste incineration

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 waste incineration statistic. The general equation can be written as:

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

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

Table 3-1 presents the Tier 1 default emission factors for the incineration of municipal wastes. For the Tier 1 emission factors, it is assumed that acid gas abatement and particle abatement are in place. Factors are taken from an earlier version of the Guidebook and have no other reference to literature. 95 % confidence intervals are estimated by expert judgement.

Table 3-1 Tier 1 emission factors for source category 6.C.c Municipal waste incineration

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	6.C.c	Municipal waste incineration (d)			
Fuel	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	NH ₃ , Se, Indeno(1,2,3-cd)pyrene, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NO _x	1.8	kg/Mg waste	0.2	20	Guidebook (2006)
CO	0.7	kg/Mg waste	0.07	7	Guidebook (2006)
NMVOG	0.02	kg/Mg waste	0.002	0.2	Guidebook (2006)
SO _x	0.4	kg/Mg waste	0.04	4	Guidebook (2006)
TSP	0.3	kg/Mg waste	0.03	3	Guidebook (2006)
PM10	0.23	kg/Mg waste	0.002	2	Guidebook (2006)
PM2.5	0.15	kg/Mg waste	0.015	1.5	Guidebook (2006)
Pb	0.8	g/Mg waste	0.08	8	Guidebook (2006)
Cd	0.1	g/Mg waste	0.01	1	Guidebook (2006)
Hg	1.1	g/Mg waste	0.11	11	Guidebook (2006)
As	0.01	g/Mg waste	0.005	2.14	US EPA (1996)
Cr	0.185	g/Mg waste	0.127	0.243	Morselli et al. (2002)
Cu	0.093	g/Mg waste	0.064	0.122	Morselli et al. (2002)
Ni	0.12	g/Mg waste	0.08	0.16	Morselli et al. (2002)
Zn	0.9	g/Mg waste	0.8	1	Morselli et al. (2002)
PCB	5.3	mg/Mg waste	0.5	50	Guidebook (2006)
PCDD/F	350	µg I-TEQ/Mg waste	0.5	3500	UNEP (2005)
Benzo(a)pyrene	4.2	mg/Mg waste	0.4	40	Guidebook (2006)
Benzo(b)fluoranthene	3.2	mg/Mg waste	0.3	30	Guidebook (2006)
Benzo(k)fluoranthene	3.1	mg/Mg waste	0.3	30	Guidebook (2006)
HCB	0.002	g/Mg waste	0.0002	0.02	Berdowski et al. (1997)

Note:

The source of these numbers only lists the emission factor sum: benzo(bk)fluoranthene has an emission factor of 6.3 mg/Mg municipal waste burned. These have been equally distributed over the two substances.

3.2.3 Activity data

For the simpler methodology the national annual incineration of waste if 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.

Emission factors are presented in mass per unit mass of waste burned. For recalculation in terms of energy (g/GJ), a default NCV (net calorific value) is available from the Introduction of the Energy volume of the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines (IPCC, 2006) and is 10 TJ/Gg (range 7–18 TJ/Gg).

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:

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

where:

$AR_{\text{production,technology}}$ = the production rate within the source category, using this specific technology,

$EF_{\text{technology,pollutant}}$ = 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:

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

where:

$E_{\text{pollutant}}$ = the emission of the specified pollutant,

$AR_{\text{production}}$ = the activity rate for the waste incineration,

$EF_{\text{pollutant}}$ = 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*

The table below lists the uncontrolled emission factors for use with municipal or domestic waste incineration activities. The abatement efficiencies in subsection 3.3.3 of the present chapter may be used to calculate appropriate emission factors when abatement is in place.

Table 3-2 Tier 2 emission factors for source category 6.C.c Municipal waste incineration

Tier 2 emission factors					
	Code	Name			
NFR Source Category	6.C.c	Municipal waste incineration (d)			
Fuel	NA				
SNAP (if applicable)	090201	Incineration of domestic or municipal wastes (without energy recovery)			
Technologies/Practices					
Region or regional conditions					
Abatement technologies	uncontrolled				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	NH ₃ , Se, Indeno(1,2,3-cd)pyrene, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	1.8	kg/Mg waste	0.6	5.4	Guidebook (2006)
CO	0.7	kg/Mg waste	0.233	2.1	Guidebook (2006)
NM VOC	0.02	kg/Mg waste	0.00667	0.06	Guidebook (2006)
SOx	1.7	kg/Mg waste	0.567	5.1	Guidebook (2006)
TSP	18.3	kg/Mg waste	6.1	54.9	Guidebook (2006)
PM10	13.7	kg/Mg waste	4.57	41.1	Guidebook (2006)
PM2.5	9.2	kg/Mg waste	3.07	27.6	Guidebook (2006)
Pb	104	g/Mg waste	34.7	312	Guidebook (2006)
Cd	3.4	g/Mg waste	1.13	10.2	Guidebook (2006)
Hg	2.8	g/Mg waste	0.933	8.4	Guidebook (2006)
As	2.14	g/Mg waste	2	2.3	US EPA (1996)
Cr	0.185	g/Mg waste	0.127	0.243	Morselli et al. (2002)
Cu	0.093	g/Mg waste	0.064	0.122	Morselli et al. (2002)
Ni	0.12	g/Mg waste	0.08	0.16	Morselli et al. (2002)
Zn	0.9	g/Mg waste	0.8	1	Morselli et al. (2002)
PCB	5.3	mg/Mg waste	1.77	15.9	Guidebook (2006)
PCDD/F	3.5	mg I-TEQ/Mg waste	2	7	UNEP (2005)
Benzo(a)pyrene	4.2	mg/Mg waste	1.4	12.6	Guidebook (2006)
Benzo(b)fluoranthene	3.2	mg/Mg waste	1.07	9.6	Guidebook (2006)
Benzo(k)fluoranthene	3.1	mg/Mg waste	1.03	9.3	Guidebook (2006)
HCB	0.002	g/Mg waste	0.0002	0.02	Berdowski et al. (1997)

Note:

The source of these numbers only lists the emission factor sum: benzo(bk)fluoranthene has an emission factor of 6.3 mg/Mg municipal waste burned.

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:

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

This section presents default abatement efficiencies for a number of different abatement techniques applied in the municipal waste incineration. Additional information on PM and heavy metal emission factors with abatement in place is available from USEPA AP42, Chapter 2, Section 1 on Refuse Combustion (USEPA, 1996).

Most of the abatement efficiencies are derived from an assessment of abated emission factors in earlier versions of the Guidebook. No full literature references are provided.

The abatement efficiencies of dioxins and furans (PCDD/F) with a description mentioning Air Pollution Control (APC) are taken from the United Nations Environment Programme (UNEP) Chemicals Toolkit for Dioxins and Furans (UNEP, 2005). These are related to a low technology combustion plant without APC system, which has a PCDD/F emission factor of 3 500 µg TEQ/Mg MSW burned (see Tier 2 technology-specific emission factor table).

Table 3-3 Abatement efficiencies ($\eta_{\text{abatement}}$) for source category 6.C.c Municipal waste incineration

Tier 2 Abatement efficiencies					
NFR Source Category	Code	Name			
6.C.b		Industrial waste incineration			
Fuel	NA	not applicable			
SNAP (if applicable)	090202	Incineration of industrial wastes			
Abatement technology	Pollutant	Efficiency	95% confidence interval		Reference
		Default Value	Lower	Upper	
Acid gas abatement	SO ₂	76%	29%	92%	Guidebook (2006)
Particle abatement only	TSP	98%	95%	99%	Guidebook (2006)
	PM ₁₀	98%	95%	99%	Guidebook (2006)
	PM _{2.5}	98%	95%	99%	Guidebook (2006)
Particle and acid gas abatement	TSP	99.99%	99%	99.99%	Guidebook (2006)
	PM ₁₀	99.99%	99%	99.99%	Guidebook (2006)
	PM _{2.5}	99%	98%	99.99%	Guidebook (2006)
EU Waste Incineration Directive (WID) compliant plant	TSP	97%	91%	99%	Guidebook (2006)
	PM ₁₀	61%	0%	87%	Guidebook (2006)
	PM _{2.5}	99%	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)
High technology 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/m³ at 11 % oxygen, from BAT reference document (European Commission, 2006).

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.

Emission factors are presented in mass per unit mass of waste burned. For recalculation in terms of energy (g/GJ), a default NCV (net calorific value) is available from the Introduction of the Energy volume of the 2006 IPCC Guidelines (IPCC, 2006) and is 10 TJ/Gg (range 7–18 TJ/Gg).

3.4 Tier 3 Emission modelling and use of facility data

A Tier 3 method is not available for this source.

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, 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 municipal 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 6.C.c Municipal waste incineration

BAT compliant emission factors				
	Code	Name		
NFR Source Category	6.C.c	Municipal waste incineration		
Fuel	NA	not applicable		
Pollutant	Value	Unit	95% confidence interval	
			Lower	Upper
SO ₂	1 - 40	mg/Nm ³		
NO ₂ (using SCR)	40 - 100	mg/Nm ³		
NO ₂ (not using SCR)	120 - 180	mg/Nm ³		
CO	5 - 30	mg/Nm ³		
Hg	0.001 - 0.02	mg/Nm ³		
PCDD/F	0.01 - 0.1	mg I-TEQ/Nm ³		
TSP	1 - 5	mg/Nm ³		
NH ₃	< 10	mg/Nm ³		

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

Municipal solid waste (MSW)	A mix of unwanted waste material from households and commercial organisations.
Mass burn units	Incinerators which burn waste without any major pre-processing. These are typically fed with excess air.
Mass burn water wall	Designs have water-filled tubes in the furnace walls that are used to recover heat for production of steam and/or electricity.
Mass burn rotary water wall	Combustors use a rotary combustion chamber constructed of water-filled tubes followed by a water wall furnace.
Mass burn refractory	Designs are older and typically do not include any heat recovery.
Modular combustors	Similar to mass burn units, but are generally pre-fabricated and smaller, and are typically starved air.
Refuse-derived fuel (RDF) combustors	Incinerate processed waste (e.g. waste that has been sorted, shredded, pelletized, etc.).
Moving grate	A grate on which the waste is burned. Primary air is introduced through the grate and passes through the mass of waste material. The moving grate agitates the waste and promotes thorough distribution of air.
Fluidised bed combustors (FBC)	Have a bed of sand or similar inert material which is agitated or 'fluidised' by an upward flow of air through a porous plate below it. Combustion occurs within the bed. MSW is only burned if it has been sorted or shredded (i.e. as RDF).
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.
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.
PAHs	Polycyclic aromatic hydrocarbons.
PCBs	Polychlorinated biphenyls.

PCDD/Fs	Polychlorinated dibenzo-para-dioxins and polychlorinated dibenzo furans — a series of chlorinated aromatic compounds, commonly known as 'dioxins'.
POPs	Persistent organic pollutants.
NMVOCs	Non-methane volatile organic compounds.
HCB	Hexachlorobenzene.
Fabric filters	Consist of semi-permeable material in the form of bags or sleeves which trap particles and which are mounted in an airtight housing (baghouse) which is divided into a number of sections. Fabric filters are also used as a second stage in acid gas control systems.
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.
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 cooled by water sprays, removing 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.
Semi-dry scrubbers/ spray absorber systems (spray drying)	Make use of an alkaline reagent slurry (usually calcium hydroxide) which is introduced 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.
Dry injection systems	Involve the injection of an alkaline reagent (e.g. calcium hydroxide or sodium bicarbonate) as a fine, dry powder to remove and neutralise acid gases. The neutralised product is normally collected in a fabric filter.
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.

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.