SNAP CODE: **090201**

SOURCE ACTIVITY TITLE: **WASTE INCINERATION**
Incineration of Domestic or Municipal Wastes

NOSE CODE: **109.03.01**

NFR CODE: **6 C**

1 ACTIVITIES INCLUDED

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.

The combustion of hazardous or chemical waste is covered in the chapter on SNAP 090202.

2 CONTRIBUTION TO TOTAL EMISSIONS

The relative proportion of emissions contributed by waste incineration varies between pollutants. The emissions of compounds such as volatile organic compounds (VOCs), sulphur dioxide, hydrogen chloride and particulate matter (Table 2.3) from waste incineration are unlikely to contribute significantly to total emissions. However waste incinerators have been a major source of emissions of 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.

The CORINAIR90 inventory indicates the contribution of emissions released from the incineration of domestic/municipal waste to total emissions in countries (Table 1).

Table 2.1 Contribution to total emissions of the CORINAIR90 inventory *(up to 28 countries)*

Source-activity	SNAP-code	Contribution to total emissions [%], (including emissions from nature)							
		SO_2	NO_x	NMVOC	CH_4	CO	CO_2	N_2O	NH_3
Incineration of Domestic or Municipal Wastes	090201	0.1	0.2	0	0	0.2	0.4	-	-

0 = emissions are reported, but the exact value is below the rounding limit of 0.1 per cent
\- = no emissions are reported

Limited data are available regarding the exact contribution to total emissions of POPs and heavy metals from MSW incineration. Table 2 gives an indication of the contribution of all types of waste incineration to total emissions of heavy metals and POPs.

Table 2.2 Contribution to total POP and heavy metal emissions of the OSPARCOM-HELCOM-UNECE emission inventory *(up to 39 countries)*

Source-activity	SNAP-code	Contribution to total emissions (including emissions from nature) [%]												
		As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	PCBs	PCDD/Fs	PAH	HCB	PCP
Incineration of Domestic or Municipal Wastes	090201	0.2	3.2	2.3	0.7	11	0.3	1.0	2.7	0	23	0	0.9	0

Incineration of domestic or municipal wastes is unlikely to be a significant source of sulphurhexafluoride (SF_6), hydrofluorocarbons (HFCs) or perfluorocarbons (PFCs), (ETC/AEM-CITEPA-RISOE 1997).

Table 2.3: Contribution to total particulate matter emissions from 2004 EMEP database (WEBDAB)†

NFR Sector*	Data	PM_{10}	$PM_{2.5}$	TSP
6 C - Waste Incineration	No. of countries reporting	13	11	14
	Lowest Value	0.0%	0.0%	0.0%
	Typical Contribution	1.2%	1.6%	0.8%
	Highest Value	5.8%	7.3%	5.9%

*Includes contribution from Chapters 922, 925, 927, 970 and 991

†These activities are not believed to be a significant source of $PM_{2.5}$ for the majority of countries. Data reported for 2004, however, indicates that it may be significant for in some cases. See relevant chapter B111 supplementary chapter for PM emission factors for co-firing/co-incineration activities.

3 GENERAL

3.1 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; paper, plastics, and quantity produced per person varies with the effectiveness of the material recove food waste, glass, defunct household appliances and other non-hazardous. The composition ry 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;
- and, increasingly, to recover energy from its combustion, either for district / process heating and/or for electricity generation.

3.2 Definitions

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 (eg waste that has been sorted, shredded, pelletised 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 (ie 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 (eg 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.

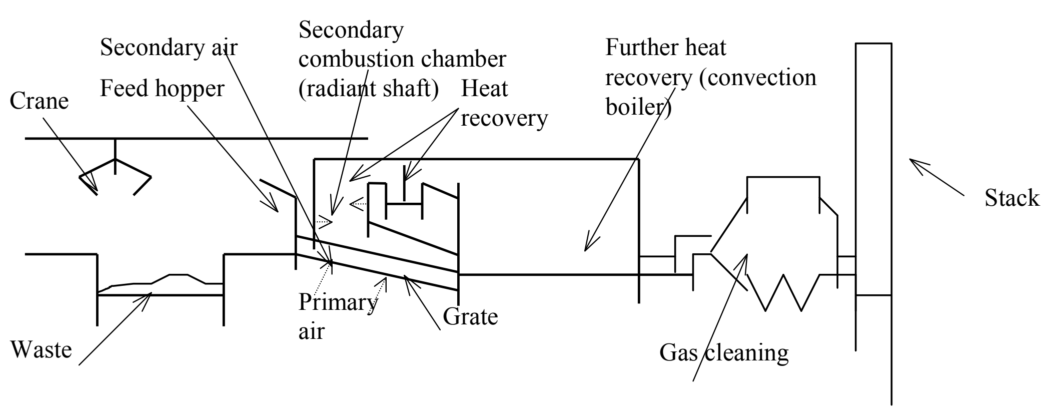
Dry injection systems - involve the injection of an alkaline reagent (eg calcium hydroxide or sodium bicarbonate) as a fine, dry powder to remove and neutralise acid gases. The neutralised product is normally collected in a fabric filter.

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.

3.3 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 (eg whether it includes heat recovery) and the degree of abatement fitted to the plant. Figure 1 shows a simple diagram of the components of a typical MSW incinerator.

Figure 1 - 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, eg 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 (eg shredded) in order to obtain a suitable size.

Waste, in whatever form, enters the combustion chamber via the feeder hopper (figure 1). 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 2 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 plant 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.

3.4 Emissions

As well as persistent organic pollutants (eg dioxins), and some heavy metals (eg 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 (CH_4)), carbon monoxide (CO), carbon dioxide (CO_2), nitrous oxide (N_2O), hydrogen chloride (HCl) and ammonia (NH_3). According to CORINAIR90 (which does not include emissions of dioxins and heavy metals), the main pollutants are NO_x, CO and CO_2 (see also table 1).

Carbon monoxide emissions result when carbon in the waste is not oxidised to carbon dioxide (CO_2). High levels of CO 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. 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 combustion efficiency, and is an important criterion for indicating instabilities and non-uniformities in the combustion process (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 (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. 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.

3.5 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 section 3.2. 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 the chapter B111 (Combustion Plant).

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 plant 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.

4 SIMPLER METHODOLOGY

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

Total emission	=	mass of waste incinerated (tonnes)	x	overall emission factor (emission per tonne of waste incinerated)	(1)

Default emission factors for MSW incinerators to facilitate this approach are provided in section 8.1

5 DETAILED METHODOLOGY

The detailed methodology involves the use of plant specific emission factors calculated from regulatory emission measurement programmes required, for example, by the EC Directives on Waste incineration, and also using plant specific throughput data normally obtained by each plant. The detailed method will therefore involve the use of a similar equation to the one in section 4, but the equation will be plant specific

Reference emission factors for comparison with User's own estimates, are provided for selected pollutant releases, in Section 8.2

Should a key source analysis indicate this to be a major source of particulate matter (TSP, PM_{10} or $PM_{2.5}$) then installation level data should be collected using a protocol such as that illustrated in the Measurement Protocol Annex.

6 RELEVANT ACTIVITY STATISTICS

6.1 Simpler methodology

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.

6.2 Detailed methodology

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

If neither of these values are available the mass burn rate of each incinerator should be multiplied by an estimated operating time.

7 POINT SOURCE CRITERIA

Within Europe there is a range of incinerator size distributions. In the UK and Germany, for example, the majority of plant are over 10 tonne per hour capacity and there are a limited number of sites in operation. Hence it is possible to treat those incinerators over 5 tonne waste per hour as point sources.

8 EMISSION FACTORS

Table 8.1 Default Emission Factors For Use With Simpler Methodology

Compound	Emission factor	Abatement type
SO_2	1.7 kg/tonne of MSW	Baseline emission factor (no acid gas abatement)
SO_2	0.4 kg/tonne of MSW	Acid gas abatement
NOx	1.8 kg/tonne of MSW	Baseline emission factor (no NOx abatement)
NM VOC	0.02 kg/tonne of MSW	Baseline emission factor (uncontrolled)
CO	0.7 kg/tonne of MSW	Baseline emission factor
N_2O	0.1 kg/tonne of MSW	No NOx abatement
HCl	2.3 kg/tonne of MSW	Baseline emission factor (no acid gas abatement)
HCl	0.5 kg/tonne of MSW[2,3]	Acid gas abatement
TSP	18.3 kg/tonne of MSW	Baseline emission factor (no particle abatement)
TSP	0.3 kg/tonne of MSW	Particle abatement only
TSP	0.05 kg/tonne of MSW	WID compliant plant (<10 $mg.m^{-3}$)
Pb	104 g/tonne of MSW	Baseline emission factor (no particle or acid gas abatement
Pb	0.8 g/tonne of MSW	Particle and acid gas abatement
Cd	3.4 g/tonne of MSW	Baseline emission factor No Particle and acid gas abatement
Cd	0.1 g/tonne of MSW	Particle and acid gas abatement
Hg	2.8 g/tonne of MSW	Baseline emission factor (no particle or acid gas abatement)
Hg	1.1 g/tonne of MSW	Particle and acid gas abatement
PCDD/Fs	25-1000 µg I-TEQ/tonne of MSW	No PCDD/F abatement
PCDD/Fs	0.5 µg I-TEQ/tonne of MSW	Particle abatement plus acid gas abatement with carbon injection
PCB		
IUPAC No. 77	1.6 µg /tonne of MSW	Particle and acid gas abatement

IUPAC No. 126	1.7 µg /tonne of MSW	Particle and acid gas abatement
IUPAC No. 169	1.2 µg /tonne of MSW	Particle and acid gas abatement
Fluoranthene	145 mg/tonne of MSW	Particle and acid gas abatement
Benz[a] anthracene	4.2 mg/tonne of MSW	Particle and acid gas abatement
Benzo[bk] fluoranthene	6.3 mg/tonne of MSW	Particle and acid gas abatement
Benzo[a] pyrene	0.7 mg/tonne of MSW	Particle and acid gas abatement
Dibenzo[ah] anthracene	3.5 mg/tonne of MSW	Particle and acid gas abatement

A TSP factor for a modern MSW operating below the WID half hourly limit concentration (10 mg m^{-3} at 11% Oxygen) has been added based on a flue gas volumes in the BAT Reference document (BREF, 2003). No data are available for PM_{10} and $PM_{2.5}$ for MSW incineration but the following estimates are provided based on 'expert judgment' of abatement characteristics.

Table 8.2 Default PM Emission Factors For Use With Simpler Methodology

Activity	**Abatement**	**Emission factor, kg/tonne MSW**		
		TSP	**PM_{10}**	**$PM_{2.5}$**
MSW Incineration	Uncontrolled	18.3	13.7	9.2
	Particulate abatement only	0.3	0.23	0.15
	WID* compliant plant	0.05	0.05	0.05

*WID is EU Waste Incineration Directive or equivalent

8.2 Reference Emission Factors For Use With Detailed Methodology

Reference emission factors for comparison with User's own estimates, are provided for selected pollutant releases in Annex 1. In the absence of more appropriate data, PM size speciation data are provided in Table 8.2.

9 SPECIES PROFILES

The dioxin profile for the relative emissions of the individual isomers measured to make up the Toxic Equivalence does not vary in overall shape between most combustion samples. The profile is dominated by octa chlorinated dioxins and furans.

10 UNCERTAINTY ESTIMATES

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. Hence any emission factor is subject to an uncertainty considerably greater than a factor of 2.

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

Further work should be invested to develop emission factors, both to reduce the uncertainty of the emission factors in section 8, and to include important pollutants for which no information is available (e.g. other POPs). Improvements to emission factors would be easier if the measurement information collected by national regulatory authorities needs was collated.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

All sources should be considered point sources if greater than 5 tonnes per hour capacity.

13 TEMPORAL DISAGGREGATION CRITERIA

The large incinerators operate as continuously as possible and should be treated as 24 hour 7 days a week emitters. The smaller plant operating at less than 5 tonne per hour should be treated as 8 hour 5 days a week processes unless information available suggests otherwise.

14 ADDITIONAL COMMENTS

No additional comments.

15 SUPPLEMENTARY DOCUMENTS

No supplementary documents are required.

16 VERIFICATION PROCEDURES

Verification is through comparison with emission estimates from different countries together with a measurement programme for selected sites, except for the trace organics as residual historical soil levels may greatly influence present day air concentrations.

17 REFERENCES

Clayton 1991, Review of Municipal Solid Waste Incineration in the UK, Warren Spring Laboratory Report LR 776, Department of Trade and Industry, London UK.

DoE (1995) A Review of Dioxin Emissions in the UK. Department of the Environment Research Report No. DOE/HMIP/RR/95/004.

ETC/AEM-CITEPA-RISOE (1997) Selected nomenclature for air pollution for CORINAIR94 inventory (SNAP 94), version 0.3 (Draft).

Holtmann T, Rentz O, Samaras Z, Zachariadis T, Kulicke K and Zierock KH (1995) Development of a Methodology and a Computer Model for Forecasting Atmospheric Emissions from Relevant Mobile and Stationary Sources.

Leech 1993 UK Atmospheric Emissions of Metals and Halides 1970-1991, Warren Spring Laboratory Report LR 923, Department of Trade and Industry, London UK.

Parma Z, Vosta J, Horejs J, Pacyna J and Thomas D (1995) Atmospheric Emission Inventory Guidelines for POPs. Prague, Czech Republic.

Passant N (1993) Emissions of VOCs from Stationary Sources in the UK. Report LR990. National Environmental Technology Centre Library, Culham, Abingdon, Oxfordshire UK.

UK NAEI (1997). UK National Atmospheric Emission Inventory, personal communication to G Salway, AEA Technology, Culham, Abingdon, Oxfordshire UK

US EPA (1995): Compilation of Air Pollutant Emission Factors AP42 (CD-Rom)

Winsey G (1997) Personal communication - estimated emission factors based on emission limits in regulations which have been proven to be achievable by modern technology.

Reference document on the Best Available Techniques for Waste Incineration, European IPPC Bureau, 2005.

18 BIBLIOGRAPHY

APARG (1995) Report on the Abatement of Toxic Organic Micropollutants (TOMPs) from Stationary Sources. Air Pollution Abatement Review Group, DoE, UK. Available from National Environmental Technology Centre, Culham, Abingdon, Oxfordshire, OX14 3DB, UK.

Bouscaren R and Houllier C (1988) Réduction des émissions de métaux lourds et de poussières . Technologies-efficacité-coûts. Tome 1 - Incinération des déchets. CITEPA, France.

Bremmer HJ, Troost LM, Kuipers G, de Koning J and Sein AA (1994) Emissions of Dioxins in The Netherlands. TNO / RIVM Report 770501018.

De Soete, G.: Nitrous oxide from combustion and industry: Chemistry and Control, pp. 324-325; Working Group Report: Methane Emissions from Biomass Burning, in: A. R. van Amstel (ed.): Proceedings of an International IPCC Workshop on Methane and Nitrous Oxide: Methods in National Emission Inventories and Options for Control; RIVM Report No. 48 150 7 003; Bilthoven (The Netherlands); 1993; published in: IPCC/OECD (ed.): Greenhouse Gas Inventory Reference Manual; Vol. 3

EMEP MSC-E. (1996) Belarusian Contribution - Annual Report. (MSC-E, Moscow / Institute fro Problems of Use of Natural Resources and Ecology, Minsk).

Kolar, J.: Stickstoffoxide und Luftreinhaltung; Berlin; 1990

Loader 1991 Review of Pollution Control at Municipal Waste Incinerator Works, A Loader, D Mitchell D Scott P Wheeler, Warren Spring Laboratory Report LR 801, Department of Trade and Industry, London UK.

Magulova K (1996) Experiences with the Heavy Metals Inventory in Slovakia. Slovak Hydrometeorological Institute.

Quaβ U, Fermann M and Broker G (1995) Identification of Relevant Industrial Sources of Dioxins and Furans : Quantification of their Emissions and Evaluation of Abatement Technologies.

Rijpkema LPM (1993) The Impact of a Major Change in EC Legislation on the Combustion of MSW. TNO Reference number 93-312

Royal Commission on Environmental Pollution (1993) Incineration of Waste, 17th Report. HMSO London.

Vereniging Lucht 1991, Expertise on the Measurement and Control of Dioxins, Society for Clean Air in the Netherlands.

WHO 1987, Heavy Metal and PAH Compounds from Municipal Incinerators, World Health Organisation, Regional Office for Europe.

Wormgoor JW and Temmink HMG (1993) Inventory of International MSW Incineration Technologies. TNO Reference number 93-387

19 RELEASE VERSION, DATE AND SOURCE

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20 POINT OF ENQUIRY

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ANNEX 1 - BACKGROUND INFORMATION ON EMISSION FACTORS, QUALITY CODES AND REFERENCES

Table A1.1 - Emission Factors for SO_2

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference [1]
SO_2	Mass burn excess air combustor	1.7 kg/tonne of MSW	B	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
SO_2	Mass burn excess air combustor	1.4 kg/tonne of MSW	E	Particle abatement only	Not given	MSW	Europe	Holtmann et al. 1995 [2]
SO_2	Mass burn excess air combustor	1.7 kg/tonne of MSW	D	Particle abatement only	Not given	MSW	UK	Clayton et al. 1991
SO_2	Mass burn excess air combustor	0.5 kg/tonne of MSW	D	Dry injection system with ESP	Not given	MSW	USA	US EPA 1995
SO_2	Mass burn excess air combustor	0.3 kg/tonne of MSW	B	Spray dryer with ESP	Not given	MSW	USA	US EPA 1995
SO_2	Mass burn excess air combustor	0.7 kg/tonne of MSW	D	Dry injection system with fabric filter	Not given	MSW	USA	US EPA 1995
SO_2	Mass burn excess air combustor	0.1 kg/tonne of MSW	C	Dry injection system with fabric filter	Not given	MSW	EU	Winsey 1997
SO_2	Mass burn excess air combustor	0.3 kg/tonne of MSW	B	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995
SO_2	Mass burn excess air combustor	0.1 kg/tonne of MSW	C	Dry injection system with fabric filter	Not given	MSW	EU	Winsey 1997
SO_2	Modular starved air combustor	1.6 kg/tonne of MSW	E	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
SO_2	Modular starved air combustor	1.6 kg/tonne of MSW	E	ESP	Not given	MSW	USA	US EPA 1995
SO_2	Refuse-derived fuel combustor	2.0 kg/tonne of MSW	D	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
SO_2	Refuse-derived fuel combustor	0.8 kg/tonne of MSW	D	Spray dryer with ESP	Not given	MSW	USA	US EPA 1995
SO_2	Refuse-derived fuel combustor	0.2 kg/tonne of MSW	E	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995

1. For emission factors taken from US EPA 1995 (AP-42), data quality ratings have been assumed to be one grade lower than given in the reference because of uncertainty as to whether the emission factors are reliable for European plant.

2. Data quality rating and type of particle abatement not given in reference - assume data quality rating of E.

Table A1.2 - Emission Factors for NOx

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference [1]
NOx	Mass burn water wall combustor	1.8 kg/tonne of MSW	B	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
NOx	Mass burn water wall combustor	1.8 kg/tonne of MSW	B	ESP	Not given	MSW	USA	US EPA 1995
NOx	Mass burn water wall combustor	2.3 kg/tonne of MSW	C	ESP	Not given	MSW	EU	Winsey 1997
NOx	Mass burn water wall combustor	1.8 kg/tonne of MSW	B	Spray dryer with ESP	Not given	MSW	USA	US EPA 1995
NOx	Mass burn water wall combustor	1.8 kg/tonne of MSW	B	Dry injection system with fabric filter	Not given	MSW	USA	US EPA 1995
NOx	Mass burn water wall combustor	1.8 kg/tonne of MSW	B	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995
NOx	Mass burn water wall combustor	2.2 kg/tonne of MSW	C	Spray dryer with fabric filter	Not given	MSW	EU	Winsey 1997
NOx	Mass burn rotary water wall combustor	1.1 kg/tonne of MSW	E	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
NOx	Mass burn rotary water wall combustor	1.1 kg/tonne of MSW	E	ESP	Not given	MSW	USA	US EPA 1995
NOx	Mass burn rotary water wall combustor	1.1 kg/tonne of MSW	E	Dry injection system with fabric filter	Not given	MSW	USA	US EPA 1995
NOx	Mass burn rotary water wall combustor	1.1 kg/tonne of MSW	E	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995
NOx	Modular starved air combustor	1.6 kg/tonne of MSW	C	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
NOx	Modular starved air combustor	1.6 kg/tonne of MSW	C	ESP	Not given	MSW	USA	US EPA 1995
NOx	Refuse-derived fuel combustor	2.5 kg/tonne of MSW	B	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference [1]
NOx	Refuse-derived fuel combustor	2.5 kg/tonne of MSW	B	ESP	Not given	MSW	USA	US EPA 1995
NOx	Refuse-derived fuel combustor	2.5 kg/tonne of MSW	B	Spray dryer with ESP	Not given	MSW	USA	US EPA 1995
NOx	Refuse-derived fuel combustor	2.5 kg/tonne of MSW	B	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995

1. For emission factors taken from US EPA 1995 (AP-42), data quality ratings have been assumed to be one grade lower than given in the reference because of uncertainty as to whether the emission factors are reliable for European plant.

Table A1.3 - Emission Factors for VOC[1]

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference
NM VOC	Mass burn excess air combustor	0.02 kg/tonne of MSW	D	Baseline emission factor (uncontrolled)	N/A	MSW	EU	Winsey 1997

[1] Includes CH_4

Table A1.4 - Emission Factors for CO

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference
CO	Mass burn water wall combustor	0.2 kg/tonne of MSW	B	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
CO	Mass burn water wall combustor	0.2 kg/tonne of MSW	B	ESP	Not given	MSW	USA	US EPA 1995
CO	Mass burn water wall combustor	1.1 kg/tonne of MSW	B	ESP	Not given	MSW	UK	Clayton et al. 1991
CO	Mass burn water wall combustor	0.2 kg/tonne of MSW	B	Spray dryer with ESP	Not given	MSW	USA	US EPA 1995
CO	Mass burn water wall combustor	0.2 kg/tonne of MSW	B	Dry injection system with fabric filter	Not given	MSW	USA	US EPA 1995
CO	Mass burn water wall combustor	0.04 kg/tonne of MSW	C	Dry injection system with fabric filter	Not given	MSW	EU	Winsey 1997
CO	Mass burn water wall combustor	0.2 kg/tonne of MSW	B	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference
CO	Mass burn water wall combustor	0.1 kg/tonne of MSW	C	Spray dryer with fabric filter	Not given	MSW	EU	Winsey 1997
CO	Mass burn rotary water wall combustor	0.4 kg/tonne of MSW	D	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
CO	Mass burn rotary water wall combustor	0.4 kg/tonne of MSW	D	ESP	Not given	MSW	USA	US EPA 1995
CO	Mass burn rotary water wall combustor	0.4 kg/tonne of MSW	D	Dry injection system with fabric filter	Not given	MSW	USA	US EPA 1995
CO	Mass burn rotary water wall combustor	0.4 kg/tonne of MSW	D	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995
CO	Modular starved air combustor	0.2 kg/tonne of MSW	C	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
CO	Modular starved air combustor	0.2 kg/tonne of MSW	C	ESP	Not given	MSW	USA	US EPA 1995
CO	Refuse-derived fuel combustor	1.0 kg/tonne of MSW	B	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
CO	Refuse-derived fuel combustor	1.0 kg/tonne of MSW	B	ESP	Not given	MSW	USA	US EPA 1995
CO	Refuse-derived fuel combustor	1.0 kg/tonne of MSW	B	Spray dryer with ESP	Not given	MSW	USA	US EPA 1995
CO	Refuse-derived fuel combustor	1.0 kg/tonne of MSW	B	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995

1. For emission factors taken from US EPA 1995 (AP-42), data quality ratings have been assumed to be one grade lower than given in the reference because of uncertainty as to whether the emission factors are reliable for European plant.

Table A1.5 - Emission Factors for N_2O

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference
N_2O	Not given	0.1 kg/tonne of MSW	E	Not given	Not given	MSW	Europe	Holtmann et al. 1995

Table A1.6 - Emission Factors for NH_3

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference
NH_3	Not given	0 kg/tonne of MSW (ie assume negligible emission)	E	Not given	Not given	MSW	Europe	Holtmann et al. 1995

Table A1.7 - Emission Factors for HCl

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference [1]
HCl	Mass burn excess air combustor	3.2 kg/tonne of MSW	B	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
HCl	Mass burn excess air combustor	3.6 kg/tonne of MSW	E	Particle abatement only	Not given	MSW	Europe	Holtmann et al. 1995 [2]
HCl	Mass burn excess air combustor	3.5 kg/tonne of MSW	C	Particle abatement only	Not given	MSW	UK	Clayton et al. 1991
HCl	Mass burn excess air combustor	0.1 kg/tonne of MSW	D	Dry injection system with ESP	Not given	MSW	USA	US EPA 1995
HCl	Mass burn excess air combustor	0.08 kg/tonne of MSW	B	Spray dryer with ESP	Not given	MSW	USA	US EPA 1995
HCl	Mass burn excess air combustor	0.3 kg/tonne of MSW	D	Dry injection system with fabric filter	Not given	MSW	USA	US EPA 1995
HCl	Mass burn excess air combustor	0.1 kg/tonne of MSW	D	Dry injection system with fabric filter	Not given	MSW	EU	Winsey 1997
HCl	Mass burn excess air combustor	0.1 kg/tonne of MSW	B	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995
HCl	Mass burn excess air combustor	0.03 kg/tonne of MSW	D	Spray dryer with fabric filter	Not given	MSW	EU	Winsey 1997
HCl	Modular starved air combustor	1.1 kg/tonne of MSW	E	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
HCl	Modular starved air combustor	1.1 kg/tonne of MSW	E	ESP	Not given	MSW	USA	US EPA 1995
HCl	Refuse-derived fuel combustor	3.5 kg/tonne of MSW	E	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference [1]
HCl	Refuse-derived fuel combustor	3.5 kg/tonne of MSW	E	ESP	Not given	MSW	USA	US EPA 1995

1. For emission factors taken from US EPA 1995 (AP-42), data quality ratings have been assumed to be one grade lower than given in the reference because of uncertainty as to whether the emission factors are reliable for European plant.
2. Data quality rating and type of particle abatement not given in reference - assume data quality rating of E.

Table A1.8 - Emission Factors for total particulate matter [1] (PM)

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference [2]
PM	Mass burn excess air combustor	12.6 kg/tonne of MSW	B	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
PM	Mass burn excess air combustor	0.1 kg/tonne of MSW	B	ESP	Not given	MSW	USA	US EPA 1995
PM	Mass burn excess air combustor	0.5 kg/tonne of MSW	C	ESP	Not given	MSW	UK	Clayton et al. 1991
PM	Mass burn excess air combustor	0.03 kg/tonne of MSW	E	Dry injection system with ESP	Not given	MSW	USA	US EPA 1995
PM	Mass burn excess air combustor	0.04 kg/tonne of MSW	B	Spray dryer with ESP	Not given	MSW	USA	US EPA 1995
PM	Mass burn excess air combustor	0.09 kg/tonne of MSW	B	Dry injection system with fabric filter	Not given	MSW	USA	US EPA 1995
PM	Mass burn excess air combustor	0.01 kg/tonne of MSW	C	Dry injection system with fabric filter	Not given	MSW	EU	Winsey 1997
PM	Mass burn excess air combustor	0.03 kg/tonne of MSW	B	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995
PM	Mass burn excess air combustor	0.01 kg/tonne of MSW	C	Spray dryer with fabric filter	Not given	MSW	EU	Winsey 1997
PM	Modular starved air combustor	1.7 kg/tonne of MSW	C	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
PM	Modular starved air combustor	0.2 kg/tonne of MSW	C	ESP	Not given	MSW	USA	US EPA 1995
PM	Refuse-derived fuel combustor	34.8 kg/tonne of MSW	B	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference [2]
PM	Refuse-derived fuel combustor	0.5 kg/tonne of MSW	B	ESP	Not given	MSW	USA	US EPA 1995
PM	Refuse-derived fuel combustor	0.05 kg/tonne of MSW	C	Spray dryer with ESP	Not given	MSW	USA	US EPA 1995
PM	Refuse-derived fuel combustor	0.07 kg/tonne of MSW	C	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995

1. Total particulate matter as measured with EPA Reference Method 5.
2. For emission factors taken from US EPA 1995 (AP-42), data quality ratings have been assumed to be one grade lower than given in the reference because of uncertainty as to whether the emission factors are reliable for European plant.

Table A1.9 - Emission Factors for lead (Pb)

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference [1]
Pb	Mass burn excess air combustor	107 g/tonne of MSW	B	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
Pb	Mass burn excess air combustor	1.5 g/tonne of MSW	B	ESP	Not given	MSW	USA	US EPA 1995
Pb	Various [2]	45 g/tonne of MSW	D	ESP	Not given	MSW	UK	Clayton et al. 1991
Pb	Mass burn excess air combustor	1.5 g/tonne of MSW	E	Dry injection system with ESP	Not given	MSW	USA	US EPA 1995
Pb	Mass burn excess air combustor	0.5 g/tonne of MSW	B	Spray dryer with ESP	Not given	MSW	USA	US EPA 1995
Pb	Mass burn excess air combustor	0.1 g/tonne of MSW	D	Dry injection system with fabric filter	Not given	MSW	USA	US EPA 1995
Pb	Mass burn excess air combustor	0.1 g/tonne of MSW	C	Dry injection system with fabric filter	Not given	MSW	EU	Winsey 1997
Pb	Mass burn excess air combustor	0.1 g/tonne of MSW	B	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995
Pb	Mass burn excess air combustor	0.5 g/tonne of MSW	C	Spray dryer with fabric filter	Not given	MSW	EU	Winsey 1997
Pb	Modular starved air combustor	1.4 g/tonne of MSW	D	ESP	Not given	MSW	USA	US EPA 1995

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference [1]
Pb	Refuse-derived fuel combustor	100 g/tonne of MSW	D	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
Pb	Refuse-derived fuel combustor	1.8 g/tonne of MSW	B	ESP	Not given	MSW	USA	US EPA 1995
Pb	Refuse-derived fuel combustor	0.6 g/tonne of MSW	C	Spray dryer with ESP	Not given	MSW	USA	US EPA 1995
Pb	Refuse-derived fuel combustor	0.5 g/tonne of MSW	E	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995

1. For emission factors taken from US EPA 1995 (AP-42), data quality ratings have been assumed to be one grade lower than given in the reference because of uncertainty as to whether the emission factors are reliable for European plant.
2. Emission factor of 45 g/t is mean for measurements carried out at several UK plant before 1991. The emission factor range was 0.4-189 g/t.

Table A1.10 - Emission Factors for cadmium (Cd)

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference [1]
Cd	Mass burn excess air combustor	5.5 g/tonne of MSW	B	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
Cd	Mass burn excess air combustor	0.3 g/tonne of MSW	C	ESP	Not given	MSW	USA	US EPA 1995
Cd	Various [2]	2.5 g/tonne of MSW	D	ESP	Not given	MSW	UK	Clayton et al. 1991
Cd	Mass burn excess air combustor	0.04 g/tonne of MSW	E	Dry injection system with ESP	Not given	MSW	USA	US EPA 1995
Cd	Mass burn excess air combustor	0.004 g/tonne of MSW	B	Spray dryer with ESP	Not given	MSW	USA	US EPA 1995
Cd	Mass burn excess air combustor	0.01 g/tonne of MSW	D	Dry injection system with fabric filter	Not given	MSW	USA	US EPA 1995
Cd	Mass burn excess air combustor	0.01 g/tonne of MSW	C	Dry injection system with fabric filter	Not given	MSW	EU	Winsey 1997
Cd	Mass burn excess air combustor	0.01 g/tonne of MSW	B	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference [1]
Cd	Mass burn excess air combustor	0.01 g/tonne of MSW	C	Spray dryer with fabric filter	Not given	MSW	EU	Winsey 1997
Cd	Mass burn excess air combustor	0.2 g/tonne of MSW	D	Semi-dry scrubber with fabric filter	Not given	MSW	UK	UK NAEI 1997
Cd	Modular starved air combustor	1.2 g/tonne of MSW	E	Baseline emission factor (uncontrolled)	Not given	MSW	USA	US EPA 1995
Cd	Modular starved air combustor	0.2 g/tonne of MSW	E	ESP	Not given	MSW	USA	US EPA 1995
Cd	Refuse-derived fuel combustor	4.4 g/tonne of MSW	D	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
Cd	Refuse-derived fuel combustor	0.1 g/tonne of MSW	D	ESP	Not given	MSW	USA	US EPA 1995
Cd	Refuse-derived fuel combustor	0.04 g/tonne of MSW	E	Spray dryer with ESP	Not given	MSW	USA	US EPA 1995
Cd	Refuse-derived fuel combustor	0.02 g/tonne of MSW	B	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995

1. For emission factors taken from US EPA 1995 (AP-42), data quality ratings have been assumed to be one grade lower than given in the reference because of uncertainty as to whether the emission factors are reliable for European plant.
2. Emission factor of 2.5 g/t is mean for measurements carried out at several UK plant before 1991. The emission factor range was 0.01-12.5 g/t.

Table A1.11 - Emission Factors for mercury (Hg)

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference [1]
Hg	Mass burn excess air combustor	2.8 g/tonne of MSW	B	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
Hg	Mass burn excess air combustor	2.8 g/tonne of MSW	B	ESP	Not given	MSW	USA	US EPA 1995
Hg	Various [2]	1.8 g/tonne of MSW	D	ESP	Not given	MSW	UK	Clayton et al. 1991
Hg	Mass burn excess air combustor	2.0 g/tonne of MSW	E	Dry injection system with ESP	Not given	MSW	USA	US EPA 1995
Hg	Mass burn excess air combustor	1.6 g/tonne of MSW	B	Spray dryer with ESP	Not given	MSW	USA	US EPA 1995

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference [1]
Hg	Mass burn excess air combustor	1.1 g/tonne of MSW	D	Dry injection system with fabric filter	Not given	MSW	USA	US EPA 1995
Hg	Mass burn excess air combustor	0.1 g/tonne of MSW	C	Dry injection system (with carbon injection) with fabric filter	Not given	MSW	EU	Winsey 1997
Hg	Mass burn excess air combustor	1.1 g/tonne of MSW	B	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995
Hg	Mass burn excess air combustor	0.1 g/tonne of MSW	C	Spray dryer (with carbon injection) with fabric filter	Not given	MSW	EU	Winsey 1997
Hg	Mass burn excess air combustor	0.2 g/tonne of MSW	D	Semi-dry scrubber with fabric filter	Not given	MSW	UK	UK NAEI 1997
Hg	Modular starved air combustor	2.8 g/tonne of MSW	B	Baseline emission factor (uncontrolled)	Not given	MSW	USA	US EPA 1995
Hg	Modular starved air combustor	2.8 g/tonne of MSW	B	ESP	Not given	MSW	USA	US EPA 1995
Hg	Refuse-derived fuel combustor	2.8 g/tonne of MSW	E	Baseline emission factor (uncontrolled)	N/A	MSW	USA	US EPA 1995
Hg	Refuse-derived fuel combustor	2.8 g/tonne of MSW	E	ESP	Not given	MSW	USA	US EPA 1995
Hg	Refuse-derived fuel combustor	2.1 g/tonne of MSW	C	Spray dryer with ESP	Not given	MSW	USA	US EPA 1995
Hg	Refuse-derived fuel combustor	1.5 g/tonne of MSW	E	Spray dryer with fabric filter	Not given	MSW	USA	US EPA 1995

1. For emission factors taken from US EPA 1995 (AP-42), data quality ratings have been assumed to be one grade lower than given in the reference because of uncertainty as to whether the emission factors are reliable for European plant.
2. Emission factor of 1.8 g/t is mean for measurements carried out at several UK plant before 1991. The emission factor range was 0.03-3 g/t.

Table A1.12 - Emission Factors for PCDD/Fs

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference
PCDD/Fs	Not specified	25-1000 µg I-TEQ/tonne of MSW [1]	B	ESP only	Not given	MSW	EU	Winsey 1997
PCDD/Fs	Not specified	0.5 µg I-TEQ/tonne of MSW	D	Modern plant (particle abatement plus scrubber with carbon injection)	Not given	MSW	EU	Winsey 1997

[1] Recommended emission factor 50 µg I-TEQ/tonne of MSW, depending on operating conditions

Table A1.13 - Emission Factors for PCBs

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference
Sum PCBs	Poor combustion; plant type not specified	5.3 mg /tonne of MSW	D	Multi-step flue gas cleaning [1]	Not given	MSW	Czech Republic	Parma et al. 1995
IUPAC No. 77	Poor combustion; plant type not specified	2.5 µg /tonne of MSW	E	Multi-step flue gas cleaning[1]	Not given	MSW	Czech Republic	Parma et al. 1995
IUPAC No. 126	Poor combustion; plant type not specified	4.1 µg /tonne of MSW	E	Multi-step flue gas cleaning[1]	Not given	MSW	Czech Republic	Parma et al. 1995
IUPAC No. 169	Poor combustion; plant type not specified	1.9 µg /tonne of MSW	E	Multi-step flue gas cleaning[1]	Not given	MSW	Czech Republic	Parma et al. 1995
Sum PCBs	Good combustion; plant type not specified	6.3 mg /tonne of MSW	D	Equipped with one or two step cleaning [2]	Not given	MSW	Czech Republic	Parma et al. 1995
IUPAC No. 77	Good combustion; plant type not specified	0.8 µg /tonne of MSW	E	Equipped with one or two step cleaning [2]	Not given	MSW	Czech Republic	Parma et al. 1995
IUPAC No. 126	Good combustion; plant type not specified	1.2 µg /tonne of MSW	E	Equipped with one or two step cleaning [2]	Not given	MSW	Czech Republic	Parma et al. 1995
IUPAC No. 169	Good combustion; plant type not specified	0.6 µg /tonne of MSW	E	Equipped with one or two step cleaning [2]	Not given	MSW	Czech Republic	Parma et al. 1995

1. e.g. combination of catalytic DeNOx unit, alkaline wet scrubber-venturi, bag filter, coke box
2. e.g. alkaline venturi washer, injection of lime and bag filter

Table A1.14 - Emission Factors for PAHs

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Reference
Fluoranthene	Poor combustion; plant type not specified	145 mg /tonne of MSW	D	Multi-step flue gas cleaning [1]	Not given	MSW	Czech Republic	Parma et al. 1995
Benz[a] anthracene	Poor combustion; plant type not specified	4.2 mg /tonne of MSW	D	Multi-step flue gas cleaning[1]	Not given	MSW	Czech Republic	Parma et al. 1995
Benzo[bk] fluoranthene	Poor combustion; plant type not specified	6.3 mg /tonne of MSW	D	Multi-step flue gas cleaning[1]	Not given	MSW	Czech Republic	Parma et al. 1995
Benzo[a] pyrene	Poor combustion; plant type not specified	0.7 mg /tonne of MSW	D	Multi-step flue gas cleaning[1]	Not given	MSW	Czech Republic	Parma et al. 1995
Dibenzo[ah] Anthracene	Poor combustion; plant type not specified	3.5 mg /tonne of MSW	D	Multi-step flue gas cleaning[1]	Not given	MSW	Czech Republic	Parma et al. 1995

1. e.g. combination of catalytic DeNOx unit, alkaline wet scrubber-venturi, bag filter, coke box