Australian Government
Department of Sustainability, Environment, Water, Population and Communities

NATIONAL POLLUTANT INVENTORY

EMISSION ESTIMATION TECHNIQUE MANUAL FOR

CREMATORIA VERSION 1.0

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EMISSION ESTIMATION TECHNIQUES
FOR
CREMATORIA
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1 Introduction

The purpose of all emission estimation technique (EET) manuals is to assist Australian manufacturing, industrial and service facilities to report emissions of listed substances to the National Pollutant Inventory (NPI). This manual describes the procedures and recommended approaches for estimating emissions engaged in cremation activities.

EET MANUAL		crematoria
ANZSIC CODE	2006	9520 Funeral, Crematorium and Cemetery Services

Note that the ANZSIC code is part of NPI reporting requirements. The *NPI Guide* contains an explanation of the ANZSIC code.

This manual has been developed through a process of national consultation involving state and territory environmental authorities and key industry stakeholders. Particular thanks are due to the Australasian Cemeteries and Crematoria Association (ACCA) and Environmental Consultancy Services (ECS Pty Ltd).

NPI substances are those that when emitted at certain levels have potential to be harmful. Australian, state and territory governments have agreed, in response to international requirements, that industries will report these emissions on an annual basis. NPI substances are set out in the *NPI Guide* and are listed in categories which have a threshold; i.e. once annual 'use' of substances is above the threshold their emissions and transfers must be reported.

1.1 The process for NPI reporting

Crematoria that meet specific criteria are required to report emissions and transfers of designated substances to the NPI. Figure 1 outlines the steps used to determine whether these criteria have been meet, and an NPI report is required.

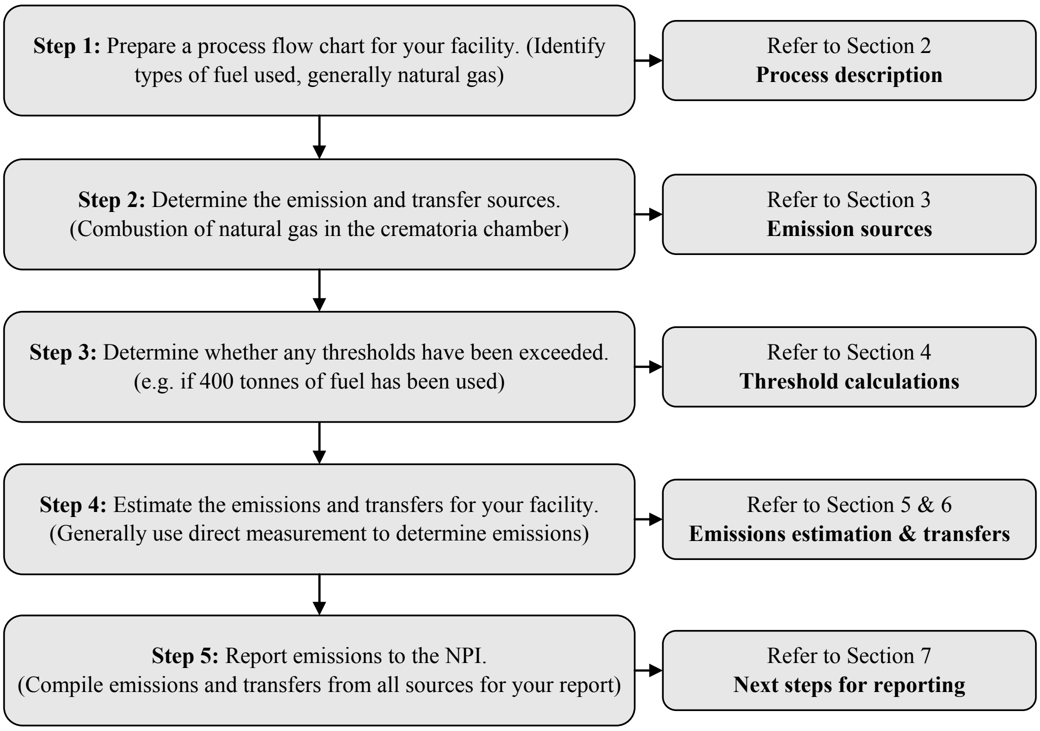

Figure 1: NPI reporting flowchart

1.2 Structured Approach to NPI Reporting

The first step in approaching NPI reporting is to download the NPI guide, it is available from the NPI website www.npi.gov.au/publications/guidetoreporting.html.

The guide contains important information that you will need to complete your NPI report including guidance on how to:

- determine if any thresholds have been tripped;
- estimate emissions and transfers in waste of NPI substances;
- report NPI emissions and transfers; and
- provide a complete list of the 93 NPI substances.

1.2.1 Information required to produce an annual NPI report

If any fuel burning equipment has been used on the facility, including boilers and furnaces, additional data will need to be collated, this includes the:

- number of cremations
- type and amount of fuel burned
- pollution control devices employed, and
- volume and throughput of fuels or organic liquids stored on site.

If any fuel burning equipment has been used on the facility, including on-site vehicles, additional data will need to be collated:

- type and amount of fuel burned
- pollution control devices employed, *and*
- volume and throughput of fuels or organic liquids stored on site.

Table 1: Typical data required to produce an annual NPI report

Process	Data to collect
• Materials inventory	• The mass of all materials that are 'used' at your facility (i.e. natural gas, diesel etc)
• Primary and secondary equipment operation	• The total amount of fuel combusted in each oven(s); • The total amount of fuel combusted in each stationary internal combustion engine(s); and • The type of internal combustion engine(s)
• Vehicle operation	• The total amount of fuel combusted in vehicles used on-site

1.3 Additional reporting materials

This manual is written to reflect the common processes employed in Crematoria. In many cases it will be necessary to refer to other EET manuals to ensure a complete report of the emissions for the facility can be made. Other applicable EET manuals may include, but are not limited to:

- *Combustion in boilers,*
- *Combustion in engines,*
- *Fuel and organic liquid storage*,
- *Fugitive emissions*, and
- Other industry-specific emission estimation technique manuals.

2 Process description and typical emissions

The first step when working out your NPI substance emissions at your facility is to create a process flow diagram that highlights process points where emissions may occur.

2.1 Crematoria process

A cremator is made from refractory (heat resistant) bricks and typically fuelled by natural gas. Cremators generally comprise two chambers – a primary and secondary combustion chamber – and a cooling tray (some cremators operate with three chambers and cooling tray). Each combustion chamber is fitted with a burner. Once the temperature in the secondary chamber reaches 300–800°C (after a preheating by the support fuel at 850°C), the primary chamber is heated reaching a temperature of 300–800°C. The primary chamber may have air lances to break up the main burner and promote combustion. The combustion gases from the primary chamber are then fed into the compartmentalised secondary chamber, which is heated with afterburners and supplied with secondary air to complete combustion. The secondary chamber has a residence time for the gases of typically 1–2 seconds.

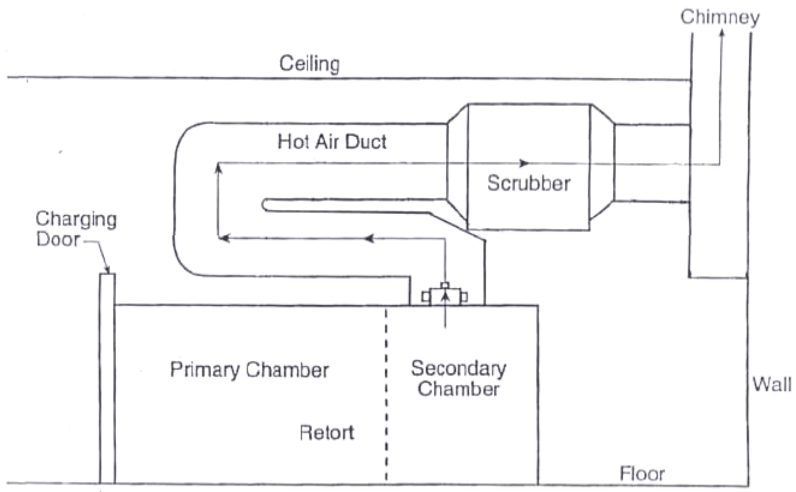

Figure 2: General cremator layout

Cremation begins immediately once the coffin is inserted into the first chamber and only one coffin is ever placed inside the chamber at any one time. Coffin handles are generally burnt with the coffin, however, some handles can hamper the cremation process. If handles are removed prior to cremation, they are typically buried within the grounds of the crematorium.

The time taken to cremate will depend on many factors including body mass, bone density and the materials from which the coffin is manufactured. However, the average time for an adult cremation is 90 minutes at a temperature between 800°C and 1,000°C.

2.2 Fuel types

The main fuels likely to be used in Australian crematoria include:
- Natural gas;
- LPG;
- Diesel;
- Petroleum products; also
- Some crematoria may also be electrically heated.

2.3 Expected Emissions

The volume and nature of the emissions from crematoria differs depending on the fuel composition, fuel consumption, cremation design and operation, and the emission and pollution control devices in use.

Emissions can include:
- Carbon monoxide (CO);
- Oxides of nitrogen (NOx);
- Sulfur dioxide (SO_2);
- Particulate matter (PM_{10} and $PM_{2.5}$);
- Volatile organic compounds (VOCs);
- Polychlorinated dioxins and furans (PCDFs TEQ);
- Polycyclic aromatic hydrocarbons (PAHs B[a]Peq); and
- Heavy metals including mercury, lead and cadmium

The storage of fuels onsite leads to emissions of volatile organic compounds which may contain a number of NPI substances depending on the type of fuel used at the facility.

2.4 Emission controls

A number of control techniques are available to reduce emissions from crematoria. These measures include:

2.4.1 Process Control

One of the best ways to control emissions is to measure certain properties of the air in the chamber and adjust these to meet the desired operating parameters. Temperature, opacity, carbon monoxide and oxygen are often measured during the process to ensure complete combustion. Monitors for emissions such as sulfur dioxide (SO_2) may also be installed.

2.4.2 Wet Scrubbers

A wet scrubber operates by collecting those gases that are exhausted from the cremator unit. The air is sprayed with water to remove emissions from the gas stream and the water droplets gather at the bottom of the wet scrubber and are drained out. The stream is then taken to a holding tank where the heavy particles settle out. The water can then be reused in the wet scrubber or can be disposed of.

2.4.3 Baghouses

Similar to a wet scrubber, air is directed from the cremator to a filter baghouse. The size of the filter bags depends on the emission concentration in the air stream as well as the airflow from the cremator. The bags usually have mechanical arms that are used to shake free the collected material when the bags need to be cleaned. The dust is collected at the bottom of the baghouse and is then disposed of. Crematoria that have a baghouse to reduce their emissions need to install a cooling system to cool the air stream before it reaches the baghouse.

2.4.4 Catalytic Filters

Some modern crematoria also have honeycomb catalytic chimney filters (typically selenium) that significantly reduce the amount of mercury vapour released into the atmosphere, which can have the co-benefit of reducing dioxin emissions and reduction of nitrogen oxides.

3 Emission sources

General information regarding emission sources can be located in the *NPI Guide*. However, it is important to note that emissions from crematoria will generally be directed through an air stack. (If there is a spill: discharge of listed substances to a sewer is not regarded as an emission but is reportable as a transfer to the NPI). Further guidance on reporting transfers is provided in Section 6 and the *NPI Guide.*

3.1 Emissions to air

Air emissions may be categorised as fugitive emissions or point-source emissions. Pollutants can be emitted from combustion and incomplete combustion of materials or via volatilisation of heavy metals.

3.1.1 Point source emissions

Point source emissions are directed into a vent or stack and emitted through a single stationary point source into the atmosphere. Most crematoria emissions would be point source emissions and hence have the potential for monitoring or sampling.

Air emission control technologies, such as scrubbers, can be installed to reduce the concentration of particulates. These can appear when processing off-gases, before emission, through a stack. The efficiency of the abatement equipment needs to be considered where such equipment has been installed, and where emission factors from uncontrolled sources have been used in emission estimations.

3.1.2 Fugitive emissions

These are emissions not released through a vent or stack. Examples of fugitive emissions include: volatilisation of vapour from storage and open vessels, windblown dusts, materials handling and also includes vehicles. The nature of fugitive emissions does not lend itself to the use of control devices.

Emission Estimation Techniques (EETs) are the usual method for determining losses from fugitive emission sources.

4 Threshold calculations

The NPI has six different threshold categories and each NPI substance has at least one reporting threshold. For a crematorium to determine whether it has exceeded an NPI threshold, the facility must determine both the number of cremations per reporting year, and the average quantity of fuel used per cremation or throughout the year.

If an NPI substance exceeds a threshold all emissions of that substance from the facility must be reported. The *NPI Guide* outlines detailed information on thresholds and identifying emission sources.

4.1 Category 1, 1a and 1b

The usage of each of the substances listed in these categories must be estimated to determine whether the category thresholds are exceeded. Once a threshold for a substance is exceeded, emissions of that substance must be reported for all operations and processes carried out at the facility, even if the actual emissions of the substances are very low or zero.

The thresholds for Category 1 substances are:

- Category 1 – 10 tonnes or more per year
- Category 1a – 25 tonnes or more per year of Total VOCs
- Category 1b – 5 kilograms or more per year of mercury and compounds

Mercury is not deliberately used by the crematoria industry. However during the cremation process, temperatures are sufficient to vaporise mercury from any dental amalgam fillings present, which can contain up to 50% mercury. Hence crematoria may exceed the 5 kg mercury threshold during a reporting year, and thus report this emission to the NPI (the minimum number of 3,226 cremations per year is based on the mercury emission factor in Appendix B). If the Category 1b mercury threshold is not exceeded, crematoria may still need to report mercury emissions under Category 2b.

A full list of Category 1 substances can be found in the *NPI Guide*.

4.2 Category 2a and 2b

The threshold for Category 2a is the burning of 400 tonnes or more of fuel in the reporting year. If your facility burns 400 tonnes or more of fuel, or more than 1 tonne of fuel in any one hour during the reporting year, reporting of emissions of all Category 2a NPI substances listed in Table 2 of the *NPI Guide* is required.

The threshold for Category 2b is the burning of 2,000 tonnes or more of fuel in the reporting year. If your facility burns 2,000 tonnes or more of fuel, or has a power rating of 20 MW or more, and uses 60,000 MW-hr or more of electricity, reporting of emissions of both Category 2a and 2b NPI substances listed in Table 3 of the *NPI Guide* is required.

Note that the annual threshold calculation must include the contribution from the cask and body (see Example 1).

A full list of Category 2 substances can be found in the *NPI Guide*.

Most publicly available technical specifications for modern cremators are given in British Thermal Units (BTUs), the quantity of heat required to raise one pound of water by one degree Fahrenheit from 60° to 61° Fahrenheit. The definition is dependant on water temperature, but 1 BTU is approximately 1,055 Joules or 2.93×10^{-4} kilowatt hours. Modern cremators typically use between 1 and 1.5 million BTUs per hour, equivalent to burning approximately 20 litres of fuel oil, approximately 27 litres of petrol or approximately 24 kg of natural gas. However, older, uncontrolled cremators can consume twice the energy of more modern facilities. Many fuels are not commonly measured in tonnes. *The NPI Guide* provides approximate amounts of fuel required to be burnt in order to trip category 2a and 2b thresholds, using alternative units of measure.

The fuel threshold calculation should include all hours of operation, including start-up, not just the hours where cremations took place. The contribution from the combustion of the cask and body must also be included in the threshold calculation. It is assumed that the average mass of a body is 70 kg and that the mass of wood is 20 kg per cask.

Example 1: Threshold Calculations

A modern crematorium running on natural gas operates 2 cremators for 10 hours a day, 6 days per week. The crematorium performs an average of 9 cremations per day. The process for calculating whether the facility trips NPI thresholds is set out below:

Fuel threshold calculation
Modern cremator at 1 BTU = 24 kg of natural gas per hour
Therefore two cremator units = 48 kg of natural gas per hour

Annual natural gas usage;
= (48 kg per hour) x (10 hours per day) x (6 days per week) x (52 weeks per year)
= 149,760 kg natural gas

Contribution from cremations
The crematorium performs a total average 9 cremations per day.
Mass contribution from each cremation = 70 kg body + 20 kg cask = 90kg

Annual contribution;
= (9 cremations) x (90 kg mass) x (6 days per week) x (52 weeks per year)
= 252,720 kg

Total Contribution = (fuel use) + (cremations)
= 149,760 + 252,720
= 402,480 kg

Thus the total contribution is 402 tonnes. This quantity of fuel exceeds the Category 2a 400 tonnes threshold as set out in the *NPI Guide*, but does not exceed the 2000 tonne threshold of Category 2b. Hence only NPI Category 2a emissions must be estimated and reported.

5 Emission estimation techniques

5.1 Direct measurement

You may wish to use direct measurement in order to report to the NPI, particularly if you already do so in order to meet other regulatory requirements. If this is the case, the NPI does not require you to undertake additional sampling and measurement, rather simply reporting the emissions will be adequate.

5.2 Emission factors

An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the environment with an activity associated with the release of that pollutant. Such factors facilitate the estimation of emissions from various sources of pollution. In most cases, these factors are averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category. Emission factors are represented by the equation

$$E = EF \times [A \times Op] \times [1 - (ER / 100)]$$ **Equation 1**

where

E = emission rate of pollutant (kg/year)
EF = uncontrolled emission factor of pollutant (kg/cremation)
A = activity rate (cremations/day)
Op = operation (days/yr)
ER = emission reduction efficiency for pollutant (%)

Emission factors are usually expressed as the weight of a substance emitted multiplied by the unit weight, volume, distance or duration of the activity emitting the substance (e.g. kilograms of substance per tonne of product).

When using emission factors, you should be aware of the associated emission factor rating (EFR) code and what the rating implies. An A or B rating indicates a greater degree of certainty than a D or E rating. The main criterion affecting the uncertainty of an emission factor remains the degree of similarity between the equipment/process selected in applying the factor and the target equipment/process from which the factor was derived.

The EFR system is:

A	Excellent
B	Above average
C	Average
D	Below average
E	Poor
U	Unrated

Emission factors applicable to this manual are listed in Appendix B. You must ensure that you estimate emissions for all substances relevant to your process.

Emission factors developed from measurements for a specific process may sometimes by used to estimate emissions at other sites. For example, a company may have several units of similar model and size, if emissions were measured from one facility, an emission factor could be developed and applied to similar sources. If you wish to use a site-specific emission factor, you should first seek approval from your state or territory environment agency before its use for estimating NPI emissions.

Example 2: Example of pollution control equipment calculation

This example shows how a facility with no pollution control equipment, which performs an average of 4 cremations per day, and operates 6 days a week, can use Equation 1 and the relevant emission factor from Appendix B to estimate its emissions of oxides of nitrogen (NOx) for Category 2a estimations.

Emission Rate E_{NOx} $= EF_{NOx} \times [A \times Op] \times [1 – (ER / 100)]$
$= 5.22x10\text{-}1 \times [4 \times (6 \times 52)] \times [1]$
$= 651.5$ kg/yr

This method can be used to estimate any of the Category 1b, 2a and 2b NPI substances, using the emission factors provided in Appendix B.

5.3 Approved alternative

You are able to use emission estimation techniques that are not outlined in this document. You must, however, seek the consent of your state or territory environmental agency. For example, if your company has developed site-specific emission factors, you may use these if they have been approved by your local environmental agency.

A list of all state and territory contact details can be found in the *NPI Guide*.

6 Transfers of NPI substances in waste

The NPI requires the mandatory reporting of NPI substances that are transferred as waste to a final destination. Transfers are required to be reported if a Category 1, Category 1b or Category 3 reporting threshold is exceeded. For example, if the threshold has been exceeded for the category 1b substance mercury as a result of use of this substance on site, transfers to final destination of mercury as well as emissions are reportable.

There is no requirement to report transfers of substances that are exclusively Category 2a or 2b in the event that they have been tripped only by the fuel and energy use threshold (i.e. there is no requirement to report transfers of oxides of nitrogen, particulate matter ≤10 µm (PM_{10}), particulate matter ≤2.5 µm ($PM_{2.5}$), polychlorinated dioxins and furans, or polycyclic aromatic hydrocarbons).

Both emissions and transfers are reportable in kilograms.

In the specific context of crematoria, the quantities of NPI substances contained in waste moved onsite or offsite (e.g. to landfill or other final destination) will need to be reported as a transfer.

Currently there are no generic transfer factors that are available for estimation of transfers from crematoria. Reporters are advised to estimate transfers based on monitoring, licensing arrangements (such as those for discharge to sewer), engineering calculations, or an appropriate alternative technique for the operation.

Further information regarding transfers of waste can be located in the *NPI Guide*.

7 Next steps for reporting

This manual has been written to reflect the common processes employed in crematoria. To ensure a complete report of the emissions for your facility, it may be necessary to refer to other EET manuals. These include:

- Combustion in boilers
- Combustion in engines
- Fuel and organic liquid storage
- Fugitive emissions

When you have a complete report of substance emissions from your facility, report these emissions according to the instructions in the *NPI Guide.*

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9 Appendix A: Definitions and abbreviations

Glossary of technical terms and abbreviations used in this manual

Term	Definition
ANZSIC	Australian and New Zealand Standard Industrial Classification
CEMS	Continuous Emission Monitoring System
°C	Degree Celsius
EET	Emission estimation technique
CO	Carbon monoxide
CO_2	Carbon dioxide
EFR	Emission factor rating
K	Kelvins (where 273 K = 0°C)
Kg	Kilograms
L	Litre
LPG	Liquid petroleum gas
MJ	Mega Joules (1 million Joules)
MW	Mega Watts (1 million Watts)
NPI	National Pollutant Inventory
NOx	Oxides of nitrogen
PAHs	Polycyclic aromatic hydrocarbons
PCDFs	Polychlorinated dioxins and furans
PM	Particulate Matter
PM_{10}	Particulate Matter smaller than 10 microns
$PM_{2.5}$	Particulate Matter smaller than 2.5 microns
SO_2	Sulfur dioxide
STP	Standard Temperature & Pressure (101.325 kPa at 0°C)
TSP	Total Suspended Particulates
Total VOCs	Total Volatile Organic Compounds
VOCs	Volatile Organic Compounds

10 Appendix B: Emission factors

Except where stated, these emission factors are for uncontrolled crematoria based on values from the USEPA FIRE and AP-42 databases, and direct sampling conducted at crematoria in Australia. All Emission Factors are assigned a rating of U.

Table 2: Category 1b emission factors

Category 1b	Emission Factor (kg/cremation)
Mercury and compounds*	1.55×10^{-3}

- *Based on Australian National Survey of Oral Health 2004-2006*
- *Mercury is also a Category 2b substance*

Table 3: Mercury Control efficiencies

Mercury Control Efficiencies	%
Wet scrubbers	55-65%
Wet scrubbers with conditioning agent	76-82%
Spray absorbers & Fabric Filter (limestone)	44-52%
Spray absorbers & Fabric Filter (absorbent)*	87-94%
ESP or Fabric Filter with carbon injection	50-90%
EPS or Fabric Filter & polishing web scrubber	85%

- *Special absorbents may be absorbents impregnated with sulfur or sulfur compounds or active carbon based absorbents, which increase the sorption of mercury on particles.*

Table 4: Category 2a and 2b emission factors

Category 2a	Emission Factor (kg/cremation)
Carbon monoxide	1.00×10^{-1}
Fluoride and compounds	1.46×10^{-3}
Oxides of nitrogen	5.22×10^{-1}
Particulate matter PM_{10}	3.86×10^{-2}
Particulate matter $PM_{2.5}$	3.47×10^{-2}
Polycyclic aromatic hydrocarbons (PAHs)	2.60×10^{-5}
Sulfur dioxide	7.39×10^{-2}
Total volatile organic compounds (Total VOCs)	1.02×10^{-1}

Category 2b	Emission Factor (kg/cremation)
Arsenic and compounds	1.36×10^{-5}
Beryllium and compounds	6.21×10^{-7}
Cadmium and compounds	5.03×10^{-6}
Chromium III and compounds	1.36×10^{-5}
Chromium VI and compounds	6.12×10^{-6}
Copper and compounds	1.24×10^{-5}
Formaldehyde	1.54×10^{-5}
Hydrochloric acid (HCl)	3.27×10^{-2}
Lead and compounds	3.00×10^{-5}
Magnesium oxide fume	No data available
Nickel and compounds	1.73×10^{-5}
Polychlorinated dioxins and furans (PCDFs)	4.90×10^{-9}

Table 5: Category 1 emission factors

Additional Emission Factors	Emission Factor (kg/cremation)
Acetaldehyde	5.90 x 10-5
Antimony and compounds	1.37 x 10-5
Cobalt and compounds	7.94 x 10-7
Selenium and compounds	1.98 x 10-5
Zinc and compounds	1.60 x 10-4