Hazardous Substances Series

Mercury emissions from crematoria and their control in the OSPAR Convention Area

OSPAR Commission

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The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom and approved by the European Community and Spain.

La Convention pour la protection du milieu marin de l'Atlantique du nord-est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, la Finlande, la France, l'Irlande, l'Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d'Irlande du Nord, la Suède et la Suisse et approuvée par la Communauté européenne et l'Espagne.

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contents

EXECUTIVE SUMMARY

This report gives an overview of mercury emissions from crematoria in a limited part of the OSPAR Convention area and how these emissions are controlled. It also describes various abatement techniques which are available for reducing mercury emissions from crematoria and the costs associated with installing these.

RÉCAPITULATIF

Le présent rapport constitue une synthèse des émissions de mercure des crématoriums dans une partie limitée de la zone de la Convention OSPAR, ainsi que des conditions dans lesquelles ces émissions sont combattues. Il décrit aussi diverses techniques de réduction, qui sont disponibles pour faire baisser les émissions de mercure des crématoriums, et indique le coût des équipements correspondants.

1. INTRODUCTION

This work[1] on mercury emissions from crematoria and their control in the OSPAR Convention area follows up the OSPAR background document on mercury and organic mercury compounds prepared by the UK and published in 2000[2] in which crematoria are identified as a significant source of mercury. The information provided in this paper is derived from written contributions submitted to the UK by Norway, Sweden, Denmark, Germany, UK, Switzerland, Belgium, Portugal and the Netherlands and verbal communications from Iceland and Ireland in connection with the meetings of the OSPAR Working Group on Point and Diffuse Sources in 2000, 2001 and 2002. The technical information on the various techniques for controlling emissions, and the costs of installing mercury abatement equipment are mainly taken from a report submitted by the Netherlands[3]. Technical information supplied by Germany[4] also complements the Dutch report.

2. MERCURY EMISSIONS FROM CREMATORIA

The origin of mercury emissions from crematoria comes mainly from mercury amalgam fillings in human remains and potentially from metallic ornamental pieces on caskets (France). Research in the Netherlands indicates that the number of fillings in Dutch human remains will decrease from 5,4 to 4,9 over the 1995-2020 period. However, due to differences in the number of fillings in people of different age groups, the average amount of fillings will increase from 3,2 to 5,1. This trend means that mercury emissions in the Netherlands will double between now and 2020 unless abatement measures are introduced. Cremations in France are increasing (from 2% of deceased persons in the 1970s to 16% in 2000). The number of ovens has increased in the last two years by 20, resulting in 110 ovens in 80 crematoria.

Information provided on the estimated amount of mercury emitted from crematoria, the number of crematoria per country and the number of cremations per year are given in Table 1. This confirms that mercury from crematoria represent a significant source of mercury (approximately 1 tonne per annum just for the 8 Contracting Parties reporting). However, differences in the emissions factors for calculating releases mean that it is not possible to compare the results. Several Contracting Parties (Netherlands and Norway) report that emissions will increase in the next few years due to the increasing number of mercury amalgam fillings per corpse. Sweden reports that emissions of mercury from crematoria are now the most important point source. France has reported that mercury is concentrated principally in the dust.

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1 Following updates of technical information, this report replaces an earlier report which was published by OSPAR in 2002.

2 Available on the OSPAR website.

3 Study of Mercury Emissions from Crematoria and Available Flue Gas Treatment Techniques, carried out by Tauw Milieu, 1997.

4 The Verein Deutscher Ingenieure (VDI) Guideline, May 2001 on cremation processes and emission control measures.

Table 1: Summary of the information provided by Contracting Parties on mercury emissions from crematoria[5]

Contracting Party	Estimated Hg emissions per annum (kilos)	Number of crematoria	Number of cremations
Denmark	60		
Norway	70	42	
Sweden	122	71	65 002
Germany	42 - 168	130	333 800
Netherlands	80[6]		
UK	400[7]	242	
Belgium	3,7[8]		35 793[9]
Iceland		1[10]	215
Ireland		2	
Switzerland	45	26	40 000
France	200	80	87 000
Portugal	[11]	4[12]	2 311

3. CONTROLS FOR LIMITING EMISSIONS FROM CREMATORIA

Several Contracting Parties have regulations which cover crematoria and some set associated emission limit values for various parameters. In most cases these values do not cover mercury directly, but cover other parameters which are normally controlled in waste incineration (CO, dust, dioxins/furans and total organic carbon). Several Contracting Parties have associated BAT provisions which cover crematoria, such as the presence of after-burners, temperature, residence time and oxygen content of flue gasses, cleaning of exhaust gases and furnace operation. The size of the crematorium and the number of corpses incinerated per year will have a bearing on the nature of BAT and the practicability of what control measures are feasible. Switzerland, the Netherlands and Germany have provided detailed technical information of abatement processes. Table 2 summarises the information on controls on mercury emissions from crematoria supplied by Contracting Parties. One area which has not been examined is the materials and fittings used for coffins and funeral shrouds, which also have the potential for harmful emissions.

5 Note: In general, information was not supplied regarding how the mercury emissions were calculated, and whether the quoted figures were based on actual measurements or estimates from mercury per corpse.

6 Netherlands point out that "the tendency is an increase of the mercury emissions by crematoria from 80 to 160 kg per year in the next years if there are no measures".

7 Based on measurement of mercury emissions arising from cremations.

8 Note: This figure is based on the year 2000 and looks low compared with other countries. The emission is on average 103,7 mg hg per cremation.

9 Belgium reports that cremations are increasing by 10% per year.

10 The Icelandic crematorium operates once a week, if required.

11 No information available yet; a monitoring programme is under development.

12 Crematoria in Lisbon (2), Oporto (all operated continuously) and Ferreira do Alentejo (discontinuous operation). Type of installations: Shelton (two burners on propane gas, temperature of last chamber 1200 ^{o}C).

Table 2: Summary of the information provided by Contracting Parties on mercury emissions from crematoria

Contracting Party	**Emission limit values**	**BAT controls**	**Specific National Regulations on mercury**
Denmark[13]			
Norway			yes[14]
Sweden	0,1 mg/ Nm^3		
Germany	0,05 or 0,2 mg/Nm^3 [15]	BAT guidelines and standards[16]	
Netherlands	<0,2 mg/Nm^3 [17]	BAT provisions associated with mercury regulation	covers BAT and ELV
UK		Subject to air pollution regulation by local authorities	statutory guidance for crematoria issued in 1995[18]
Switzerland	0,2 mg/Nm^3 at a mass flow of 1 g/H or more [19]	BAT provisions associated with mercury regulation and limit values for other pollutants e.g. TOC, CO and dust	
France	note[20]		

4. RELEVANT ACTIVITIES ON THE CONTROL OF MERCURY IN THE EUROPEAN COMMUNITY

The following initiatives are underway in the EC which may indirectly increase pressure for measures to reduce mercury emissions from crematoria.

Adoption of mercury as a priority hazardous substance in the EC water Framework Directive

Mercury has now been adopted as a priority hazardous substance under the water Framework Directive, and consultants commissioned by the EC are currently drawing up an inventory of the sources of mercury which will need to meet the Directive's 20-year cessation target. It is expected that mercury from crematoria will be included in this inventory and that the scope for controlling emissions will be considered in the development of subsequent daughter directives;

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13 Denmark has considered the establishment of national regulations but decided that this was not an important issue.

14 On 1 January 2003, Norway has adopted a regulation for crematoria that includes emission limit values for mercury.

15 Set only by some local authorities according to the Ordinance for Incineration on Waste or the Technical Instruction on Air Quality Control. Germany also sets limit values for CO, dust, TOC and PCDD/PCDF.

16 Verein Deutscher Ingenieure (VDI) guidelines published in May 2001 on cremation processes and emission control measures.

17 For new installations after 1/7/1998.

18 Under revision.

19 Switzerland also sets an ELV for TOC.

20 Emissions from crematoria are regulated under Decree No. 94-1117 of 20 December 1994 on the requirements to be applied to crematoria, which is implemented by the National Order of 29 December 1994 on maximal concentrations of pollutants in atmospheric emissions from crematoria. Limit values apply to CO, chlorinated compounds, SOx, NOx and dust. There are no limit values for mercury at this time. However the inclusion of limits for mercury (and heavy metals in general) is under discussion in the context of the revision of the National Order of 29 December 1994.

Ambient Air Quality Directive on Heavy Metals

An EC Directive on ambient air quality with respect to arsenic, cadmium, nickel, PAH and mercury will be adopted shortly. It is unlikely that there will be a limit value set for mercury. However, in the most recent draft of the proposal, the Commission call for a mandatory monitoring network for total gaseous mercury in ambient air and mercury in precipitation in order to improve scientific knowledge.

5. TYPES OF CREMATORIA

The two basic types of crematoria are those which operate a cold start cycle and those which operate a warm start cycle. Those operating the cold start cycle (in which the furnace is not pre-heated to a temperature at which the human remains self ignite) are generally smaller and produce larger emissions of mercury per corpse. The size of crematoria varies from country to country and is somewhat dependent on cultural traditions for dealing with the dead. For example, the UK has a number of small crematoria (approx. 300 cremations per year) but the average number of cremations in UK crematoria is over 1 000 per year; whereas Germany has a smaller number of large ones (approx. 4 000 cremations per year). Cultural sensitivities also play into crematoria design. For example, large chimneys and smoke are not acceptable to the public in some countries.

6. ABATEMENT TECHNIQUES FOR REDUCING EMISSIONS OF MERCURY FROM CREMATORIA

There are a number of methods which limit the emission of mercury via flue gases. The following section, based on information supplied by the Netherlands and Germany, describes those which are currently available. All emission values in mg/Nm^3 mentioned in this chapter relate to an oxygen concentration of 11%.

6.1 Adsorption techniques

In various incineration processes, flue gas treatment based on adsorption is applied in order to remove mercury and PCDD/PCDF from flue gas flows. Various adsorption systems are applied in practice, the most important ones being solid bed filters and co-flow filters. A further distinction can be made in terms of the adsorbents applied: active carbon, cokes or zeolites. Examples for the environmental performance (mercury concentration in flue gas; reduction of mercury by means of abatement techniques) of different crematoria, which have installed these techniques, are given in an overview in Table 3.

The Co-flow filter

In this process an adsorbant is injected into the flue gases, after which adsorption of the mercury takes place in the flue gas channel or in an installed reaction chamber. The adsorbent is removed from the flue gases again in an "end of pipe" cloth filter. An adsorbent layer is formed on the cloth filter, so that extra filtering of the flue gases takes place. Removal efficiencies are in excess of 98% and mercury concentrations in flue gas are in the range of 0,001-0,1 mg/Nm^3; see also Table 3) are reported for this technique in large installations.

The Solid bed filter

In this process, the flue gases are guided through the filter material, whereby the pollutants are left behind in the adsorbent. The filter must be regularly replaced or regenerated on site. In practice, solid bed filters with adsorbents such as cokes or zeolites are applied for the removal of mercury and dioxins. It is reported that this type of filter can also achieve well over 90% removal of mercury (up to > 99,9 % or mercury concentration in flue gas of 0,005 mg/Nm; see also Table 3).

Gas Scrubbing

Traditional gas scrubbing and quenching are also used, and emission measurements for the flue gas treatment show that this technique reduces the mercury concentration in the flue gases to approx. 0,1-0,2 mg/m³.

6.2 Other techniques

Reaction with selenium

Metallic mercury reacts with selenium to form a stable compound, mercury selenide (HgSe). A technique developed in Sweden involves placing a capsule containing selenium on the coffin prior to cremation. It is reported that the use of selenium capsules in the process leads to 80-85% emission reduction of the mercury levels in the flue gases (Hogland, 1994), but doubts have been expressed in the Netherlands report about the emission measurements used to derive this figure.

Ceramic reactor

This technique involves the impregnation of a ceramic base material with reactive adsorbents which results in the removal of mercury from the flue gases. The removal efficiency is not known.

Gold filter

The gold filter is a renewable filter for treatment of relatively minor mercury content flue gas flows in crematoria. The operation of the filter is based on the formation of an alloy of metallic mercury and gold. The gold has been deposited onto the thin films applied in the filter. The filter can be regenerated by re-heating the material, through condensation of mercury. The filter must be preceded by a dust filter and is operated at temperatures of less than 60 °C. The removal efficiency is not known.

Honeycomb Catalytic Adsorber

This precious metal (gold/platinum) catalytic adsorber is specially designed for mercury removal (honeycomb structure). The functional principal is similar to the gold filters operation (see 4.3) with an operating temperature of 75 °C. An upstream removal of particulates (e.g. fabric filter) is also required. A removal efficiency of 99,9 % (mercury concentration of flue gas of = 0,005 – 0,013) is reported (see also Table 3).

6.3 Monitoring of mercury in flue gas

The monitoring of mercury in crematoria can be performed according to the standard EN 13211 (air quality; stationary source emissions; determination of the concentration of total mercury) which specifies a manual reference method for the determination of the mass concentration of mercury in exhaust gases from ducts or chimneys. The method is applicable for the concentration range of total mercury from 0,001 to 0,5 mg/m^3 in exhaust gases. Generally, mercury measurement is non-continuous and does not require a fitted measuring device. The samples are usually taken through an appropriately located slot in the stack.

Table 3: Examples of mercury removal efficiency of different types of abatement technology

Type of abatement technology	Process option	Adsorbing material	Achieved levels of mercury abatement	Applied in crematory	Producer
Solid- bed filter	Fabric filter - Fixed- bed reactor	activated carbon and inert material	Clean gas: 0,005 mg/ Nm³ percentage reduction of mercury >99,9%	Nordheim in Zürich (Switzerland)	?
Honeycomb adsorber	after Fabric filter	none	Clean gas: 0,005- 0,013 (guaranteed < 0,05) mg/Nm³; percentage reduction of mercury 99,9%	Hörnli in Basel (Switzerland)	Fa. SEU Schenkel Energie und Umwelttechnik (Switzerland)
Co - flow filter (dry sorption)	Waagner-Biro- Entrained- flow sorption process	Lime (e.g. CaO) and activated carbon	Clean gas: 0,022 mg/Nm³	Hohenems (Austria)	Waagner-Biro-Binder AG (Austria)
Co - flow filter (dry sorption)	Waagner-Biro- Entrained- flow sorption process	Lime (e.g. CaO) and activated carbon	Clean gas: 0,008 mg/Nm³	Innsbruck (Austria)	Waagner-Biro-Binder AG (Austria)
Co- flow filter (dry sorption)	Sorbens dosing unit – Multicyclon-reaktor – fabric filter	90 % white lime hydrate 10% activated carbon	Clean gas: 0,001 – 0,088 mg/ Nm³	Different crematories in Germany	Fa. Ruppmann (Germany)
Co - flow filter (dry sorption)	Cyclon- Sorbens dosing unit –mixing reactor - fabric filter	65 % white lime hydrate 35% activated coke	Raw gas: 0,0032- 0,0321 mg/ Nm³ Clean gas: 0,003- 0,004 mg/ Nm³	Hameln (Germany)	Fa. DISA GmbH (Germany)
Co - flow filter (dry sorption)	Cyclon- Sorbens dosing unit –mixing reactor - fabric filter	65 % white lime hydrate 35% activated coke Amount of adsorbens 0,8 kg/h and oven	Raw gas: 0,25- 0,4 mg/ Nm³ Clean gas: < 0,001 mg/ Nm³	Forst (Germany)	Fa. DISA GmbH (Germany)

Type of abatement technology	Process option	Adsorbing material	Achieved levels of mercury abatement	Applied in crematory	Producer
Co - flow filter (dry sorption)	Cyclon- Sorbens dosing unit –mixing reactor - fabric filter	Sodium bicarbonate and Activated carbon (ca. 100-200 g Activated carbon per cremation)	Raw gas: 0,769 - 2,784 mg/ Nm³ Clean gas: 0,0036- 0,11 mg/ Nm³ percentage reduction of mercury 96-99,5%	Uppsala, Växjö, Mora (Sweden)	Fa. DISA GmbH (Germany)
Co - flow filter (dry sorption)	Cyclon- Sorbens dosing unit –reactor - fabric filter	70 % Calcium hydroxide $Ca(OH)_2$ 30 % activated coke Amount of adsorbens 0,5 kg per cremation and oven	Clean gas: 0,00067- 0,00084 mg/ Nm³	Hannover (Germany)	Planungsbüro 2000 (Germany)
Co - flow filter (dry sorption)	Sorbens dosing unit - fabric filter	Calcium hydroxide $Ca(OH)_2$ and activated coke	Clean gas: < 0,005 mg/Nm³	Lindau (Germany)	IFE Gesellschaft mbH (Germany)

Annotations to Table 3:

All emission values in mg/Nm³ mentioned in this table relate to an oxygen concentration of 11%.

7. REFERENCES

VDI Wissensforum "Umsetzung der LRV in Krematorien", 18.- 19. Juni 2001 in Basel, Seminar 43 5102

VDI Bildungswerk "Umsetzung der 27. BImschV in Krematorien" 6-7.12.2000 in Düsseldorf, Seminar 43 5101

Oral information on Hg-concentrations (5th line) by Fa. Ruppmann (Germany). Capacity of ovens is not specified: on an average around 1000 cremations (per oven) per annum in Germany.

8. COSTS OF INSTALLING MERCURY ABATEMENT EQUIPMENT

The Netherlands' report provides some information about the costs of flue gas treatment on individual cremation furnaces. Costs vary slightly and range from €27 270 to €48 180 per year for cold start furnaces. Costs for hot start furnaces vary from €45 460 to €74 550 per year. These costs involve technical installation, which includes the cost of additional emission monitors, transport, assembly and civil engineering costs (for renovations). The referred additional costs amount to €18 180 per furnace per year.

Tables 4 and 5 summarise the cost effectiveness of avoided mercury emissions from crematoria and the cost increase per cremation which can be expected due to the installation of abatement equipment in the Netherlands.

Table 4: Cost effectiveness per gram of avoided mercury emission from crematoria

Furnace type	Number of cremations per year	Mercury emission (g/year)	Cost effectiveness per gram of avoided mercury emission (€)
Cold start furnace	300	450	100 to 145
Warm start furnace	850	1 275	50 to 73

Table 5: Cost increase per cremation due to mercury removal at crematoria

Furnace type	Number of cremations per year	Cost of flue gas treatment (€/year)	Cost increase per cremation (€)
Cold start furnace	300	45 460 to 66 360	150 to 225
Warm start furnace	850	63 640 to 92 730	75 to 110

Table 5 shows that the cost of cremations due to mercury removal would increase by around 15 - 20%, depending on the type of furnace. Cost increases will be substantially higher for cold starter furnaces in particular. Based on approx. 110 cremation furnaces in the Netherlands, the total investment for installing flue gas treatment installations (inclusive of structural alterations) in Dutch crematoria is roughly estimated at €37 - €55 million. Sweden reports that an ongoing study shows that preliminary cost estimates per cremation are approximately half of those shown in Table 5.