Mercury emission from crematoria

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Summary. The purpose of this study, undertaken at a cremator representing an example of current equipment and cremation practices in use in Italy, is to assess the possible mercury emitted during cremation and substantiate the current data available. This paper reports some preliminary results concerning mercury and total particulate matter emissions during three cremation processes. The obtained results gave a mercury concentration ranging from 0.005 to 0.300 mg/m\(^3\) and a mercury emission factor ranging from 0.036 to 2.140 g/corpse cremated. The total particulate matter concentration range was 1.0 to 2.4 mg/m\(^3\).

Key words: cremation, mercury, emission factor, dental amalgam fillings, corpse.

INTRODUCTION

Mercury has been recognized as having adverse effects on the environment and human health. Solid scientific evidence has justified the need for international agreements for the reduction of mercury emission [1].

The environmental impact of mercury may not only be limited to areas in close proximity to the source of emission. Mercury can easily volatilize and related emissions could spread over long distances from the source. Therefore, some mercury pollution of a local nature, viewed in the short term, adds to global mercury pollution in the long term, as it can be transported through air and through the food chain (especially via fish).

Mercury is used in a broad range of products and processes. Dental amalgam has been recognized as a large global consumer of Hg, after chlor-alkali, small-scale gold mining, and batteries [2].

Within the framework of the Convention for the Protection of the Marine Environment of the North-East Atlantic (known as the “OSPAR Convention”) [3], the OSPAR Background Document on Mercury and Organic Mercury Compounds [4] recognizes that the mercury emitted from crematoria arises from the volatilization of the dental amalgam in teeth of corpses during cremation.

Emissions from crematoria are not covered by European Union (EU) regulations, but have been the subject of the OSPAR Recommendation. In fact, the OSPAR document, namely OSPAR Recommendation 2003/4 on Controlling the Dispersal of Mercury from Crematoria [5] in the OSPAR Convention Area, published in 2003, identifies crematoria as producing a significant source of mercury in the environment and lists various options, in terms of the best available technologies (BAT) to reduce and control mercury emissions. The reports on emissions made by parties involved with this Recommendation, will provide an indication of the effectiveness and if further action is needed.

Similar checks are encouraged in other EU member states where cremation takes place, although currently, matters of crematoria are the responsibility of local Authorities.

There is a lack of literature on emissions from crematoria and the amount of available data is sparse and based primarily on rough estimates. One possible reason could be that the mercury emissions are small and therefore there is no need to undertake such research; the other reason being the great difficulty in performing such a study due to various cultural, societal confidential and ethical reasons. This does not permit the dental status of individuals to be made known prior to cremation for studies. In fact, the practice of cremation raises sensitive cultural, ethical, and societal issues, since there are different attitudes and approaches among the countries that have to be respected.

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Available data on the estimates of the mean amount of mercury emitted during cremation, give different data with a wide range (from less than 1 g/cremation to 13 g/cremation and more for those mercury tests where it was fairly sure that amalgams were present) [6-9] of concentrations emitted per cremation.

The large differences in the data taken from cremation to cremation, do not permit an accurate assessment of mercury emission from crematoria.

Up to now, mercury emissions from crematoria have been rarely measured, due to the unpopularity of cremation in Italy. In this respect spot-check measurements are sufficient to assess possible emissions and to verify the currently available data.

However, the number of cremators is set to grow in Italy [10], and therefore systematic checks are necessary to predict future trends in mercury emission.

The aim of this study, undertaken at a cremator in Italy with current equipment and cremation practices, was to:

- quantify the mean amount of mercury emitted during cremation and to estimate, on the basis of the emission factor (grams of mercury per corpse cremated) and activity rates (number of cremations per year), the annual mercury emissions from crematoria;
- substantiate the measured concentrations with currently available data.

A verification of the compliance of the obtained concentrations with the standard limits set by the Directive 00/76/EC [11] was also made. Such a Directive could be applied, crematoria should be considered, in the future, as pollution source point.

In fact, the cremation frequency is increasing in most Western countries and reducing the flue gas emissions of mercury from cremation ovens is receiving increased scrutiny in many countries (http://www.defra.gov.uk/corporate/consult/crematoria/consultation.pdf)

In reality, cremation is a small-scale incineration process, occurring in a single ended unit (the cremator) which processes one coffin at a time, it gives rise to emissions that could be considered to be equivalent to any type of incineration unit.

In this regard, considering a human corpse cremation under the same light as an incineration process, mercury concentration on emission should be subjected to a limit of 0.05 mg/m² set by the European Directive 00/76/EC on the incineration of waste.

MATERIALS AND METHODS

Cremator design and process

The current studied cremator is a single ended unit which processes one coffin at a time. It comprises a primary and secondary combustion chamber with after-burners, each fitted with a natural-gas-fired 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 to a temperature of 300-800 °C and charged with the coffin. The combustion gases from the primary chamber are then fed into the secondary chamber, which is heated with after-burners and supplied with secondary air to complete combustion. The secondary chamber has a residence time for the gases of 1 to 2 s.

The time required to complete the cremation is 2 h. A subsequent cremation begins once the cremator is cooled to about 300 °C. The flue gases generated during cremation are discharged into the atmosphere via an insulated chimney.

The construction parameters are the following:
- height of the stack: 8 m;
- diameter of stack: 0.300 m;
- flow emission rate dried volume: 3500 m³/h;
- gas emission velocity at stack: 22 m/s;
- gas emission temperature: 165 °C.

The cremator is equipped with a flue-gas cleaning system that comprises a heat exchanger, sorbent dosing package, bag filter, induced draught fan and stack. The heat exchanger is situated immediately after the secondary combustion chamber for reducing the flue gas temperature from 800 °C to below 200 °C. The sorbent dosing package introduces a mixture of powdered activated carbon and lime (or activated carbon and sodium bicarbonate). Filtration occurs at the surface of the bag filter and over time the pressure drop across the bag increases. The bag filter removes total particulate matter including the entrained sorbent. The cleaned flue gas is then discharged by means of the fan into the atmosphere via the stack.

Sampling sites and specimens

Sampling access fittings were installed in a straight length of the flue in the stack of the cremator, at about 2 meters from the outlet opening to the atmosphere.

The sampling was carried out on three cremations that took place on different days.

Sampling methods

All sampling was performed over the duration of the cremation (one coffin at a time), lasting approximately 2 hours, as follows:
- total particulate matter: 1 sample during 1 cremation process;
- mercury (Hg): 1 sample during 1 cremation process;
- number of cremation processes: 3.

Measurements began after charging the coffin and closing the door, and stopped when the calcinated remains were ready for removal (as soon as the cooling phase began).

Sampling of total particulate matter

The sampling procedure of total particulate matter was carried out according to UNI 10263 [12].

A sharp-edged nozzle was positioned in the duct facing inwards into the flowing gas stream and a sample of gas flow was extracted isokinetically for a measured period of time. To allow for non-uniformity of the distribution of particulate concentration in the duct, samples were taken at a pre-selected number of given positions in the duct cross-section. The particulate matter entrained in the gas samples was separated by a filter.
medium, then dried and weighed. The particulate concentration was calculated from the weighed particulate mass and gas sample volume.

**Determination of velocity and flow rate**

The determination of velocity and flow rate was carried out according to UNI 10169 [13].

A Darcy tube was used for the measurement of the duct gas velocity. The duct gas flow was calculated from the product of the gas velocity and the sampling plane area.

**Sampling and analysis of mercury**

The sampling procedure of mercury was carried out according to the European Standard EN 13211[14].

A sample stream of flue gas was extracted representatively from a duct for a measured period of time with a controlled flow and known volume. Dust in the sampled gas was collected on a filter whereafter the gas stream was passed through a series of absorbers, which contain a solution of potassium permanganate and sulfuric acid for the collection of gaseous mercury. The sampling train is illustrated in Figure 1.

At the end of the sampling period, the filter and absorption solutions were collected and taken to the laboratory.

The collected dust on the filter was digested in nitric acid (HNO$_3$ 65 % v/v) in such a way that the mercury contained in the dust fraction is dissolved and it was then analyzed by FI/HG/AAS. The absorption solutions from the absorbers were prepared for the analysis and analyzed by FI/HG/AAS.

**RESULTS AND DISCUSSION**

Table 1 lists the results of the total particulate matter and mercury concentration for each cremation process.

The derived cremation plant emission parameters values were as follows:
- mercury flow mass: 0.018-1.050 g/h;
- mercury flow mass: 0.025-1.449 kg/year;
- mercury emission factor: 0.036-2.140 g/corpse;
- total particulate matter flow mass: 3.5-8.4 g/h.

![Materials](image)
Measurements from the three cremations gave a range of mercury concentration between 0.005 and 0.300 mg/m³ and an emission factor range between 0.036 and 2.140 g/corpse.

The cremation performance with regard to the emission of mercury was widely variable, ranging from around 0.005 to 0.300 mg/m³. This variability was also evident from previously taken measurements [15]. In fact, data from previous mercury emission concentration measurements from some crematoria in Italy ranged from less than 0.02 to 0.3 mg/m³ (calculation basis: 3500 m³ air per cremation, 55 cremations and a cremation duration of 2 h) and the related range of emission factor from 0.07 to 1.05 g/corpse.

In comparing the above-obtained mercury concentration ranges with the current study, we noted that the mercury concentration does not exceed the value of 0.3 mg/m³.

However, it cannot be assumed that such a value is the maximum possible mercury concentration on cremation, as most of the mercury in the corpses is attributable to dental amalgam fillings, and as the number of fillings varies from person to person, a wide range of mercury emissions must be expected.

In any case, the mentioned results do not guarantee an emission compliance with the standard limit of 0.05 mg/m³ set for the mercury concentration by the Directive 00/76/EC, which could be taken into consideration if crematoria are treated as pollution point sources in the near future.

Currently, crematoria are certainly not of relevance for the total emission of mercury in Italy. However, a more systematic survey involving a greater number of crematoria is needed to draw firm conclusions on the level of crematoria mercury emission that may arise in the future.

Neither previously calculated emission factors nor currently calculated emission factors can be stipulated in estimating mercury emission from crematoria in Italy. In fact, apart from the small number of available cremations, it is difficult to determine the average mercury content on cremation, as dental records are not available.

Hence, future trends in mercury emission are also difficult to predict since they are strongly affected by the following variables:

- the number of cremations per year;
- the number of amalgam fillings and the related mercury content present at cremation.

In conclusion, the investigation of the following should be necessary for the assessment of current and future mercury emission factors:

- the amalgam fillings and related dentistry practices used in the past, those currently used and those to be used in the near future;
- the distribution of dental amalgams within the population.

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References


![Table 1](image)

<table>
<thead>
<tr>
<th>Cremation process</th>
<th>Total particulate matter (TPM) mg/m³</th>
<th>Mercury (Hg) mg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cremation n. 1</td>
<td>2.4 ± 0.24</td>
<td>0.005 ± 0.001</td>
</tr>
<tr>
<td>Cremation n. 2</td>
<td>1.0 ± 0.10</td>
<td>0.300 ± 0.06</td>
</tr>
<tr>
<td>Cremation n. 3</td>
<td>2.0 ± 0.20</td>
<td>0.080 ± 0.016</td>
</tr>
</tbody>
</table>

All concentrations are expressed with the reference conditions of 273 °K, 101.3 kPa, 11% O₂, and dry gas volume. The detection limit is calculated by estimating the errors in the intercept of the regression line.


