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MEASUREMENTS OF MERCURY EMISSIONS FROM THE CHREMATORIUM IN THE NORTH CEMETERY IN LUND

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Waste Management and Recovery

Dept of Water Resources Engineering
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Foreword

This report gives an account of preliminary measurements of the emission of mercury during cremation. An attempt has been made to reduce the emission of mercury by the use of selenium.

The research has been financed by the Environmental Delegation of West Scania and the Cemetery Administration Board of Lund.

Measurements were carried out by SEMTECH Metallurgy AB. Magnus von Platen (Emcoplate AB) is responsible for the selenium technique.

A consultative group consisting of Staffan Larsson (Cemetery Administration Board), Erik Nord (SYSAV AB), Johan Zander (Environmental Delegation of West Scania) and myself have followed the project.

I would herewith like to extent my thanks to all involved.

Lund April 1994

William Hogland.

Contents

Introduction

The population in the vicinity of the crematorium at the North Cemetery in Lund has expressed considerable anxiety concerning emissions. The desire for a survey of emissions together with the installation of purification equipment has been expressed by the residents.

Approximately 1000 cremations take place each year at the crematorium, which theoretically should be expected to give an emission of about 4 kg of mercury to the surrounding area in 1990. Even emissions of other common gases occur during cremation. The extent of these emissions is difficult to assess.

As a result of the anxiety which has existed in this area of Lund, together with a desire of the Cemetery Administration Board and the Environmental Delegation of West Scania to attempt to find solutions, a seminar was arranged to clarify the problem. Together with the Dept of Waste Management and Recovery at the Lund Institute of Technology a seminar was helt on the 23rd of January 1990, "Working seminar on flue gases (especially mercury) from crematoria".

As the subject of the seminar embraced a number of disciplines, the ethical, medical, scientific, technical and economic aspects were taken up by experts who were specially invited as lecturers.

A group consisting of representatives from the Cemetery Administration Board, the Environmental Delegation of West Scania, the Waste Management Company, SYSAV AB and Lund University was appointed to provide expert opinions on tenders for different types of purification equipment for the separation of mercury from crematorium flue gases. This group was responsible for the measurement of emissions carried out at the crematorium. In the following paper we describe the background to the mercury problem and the measurements which were made at the crematorium in Lund.

Purpose

The purpose of these measurements was to register mercury emission during 'normal' cremations and with the addition of an Emcoplate selenium ampoule. The material should provide the basis for assessing tenders for purification equipment and ensuring that the company provide the necessary guarantees for the effectiveness of their purification methods.

Mercury in flue gases

The emission of mercury in connection with incineration has been discussed for many years. This has resulted in a considerable reduction of emissions. The emission from waste incineration plants is today 0.3 - 0.5 tons per year. The Association of Public Cleansing Depts. estimates that these emissions can be reduced to 0.1 - 0.2 tons per year (7). This should be possible the day the Energy from Waste demands are met in this country. (< 0.08 mg Hg/nm^3 is the present limit but the goal should be 0.3 mg Hg/nm^3).

The emission of mercury from crematoria in Sweden has been estimated at about 0.3 tons per year. This figure is expected to be doubled or even trebled up to the year 2020 if no measures are taken to decrease the emissions (4). The cause of the expected increase is that those people who are now in the 35 - 45 year age group have the largest amount of amalgam in their teeth

(amalgam contains about 50 % mercury). Even if amalgam is replaced by other materials in dental repair work an increase in emissions is expected in the future.

The West Scania region has one of the highest densities of crematoria in the country. The mercury emission into the atmosphere is today about 28 kg. This can be expected to increase to 75 kg by the year 2020 if no preventative measures are taken.

The Swedish Environmental Protection Board has as its target the decrease of mercury emissions directly into the air by 55 % by the year 1995, based on 1988 figures (8). Measures taken at crematoria can contribute to the attainment of the Swedish Environmental Protection Board's goals. Lund crematorium is one of the 73 crematoria in operation which can contribute to this decrease.

The design of Lund crematorium

The crematorium in Lund is situated just north of the central part of the town. Photo 1 shows the crematorium and parts of the chimney. The crematorium is equipped with two furnaces. Only one of these is used as the other is out of operation. The furnace in use is an SWAB (see fig. 1).

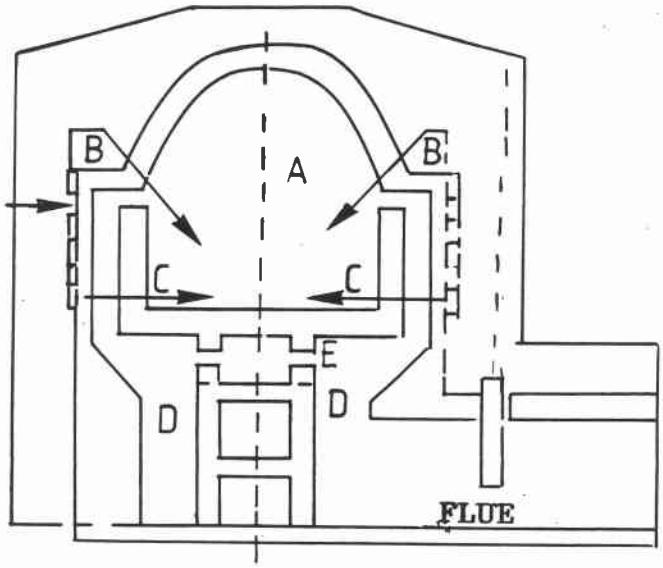

Fig. 1 Diagram of SWAB furnace

The oxygen flow to the furnace can be regulated by 10 manually operated dampers, the openings of which are situated at regular distances along both sides of the furnace (see photo 2). Two of the air intakes are used for cooling the ashes. The air intake is fed by a Svenska Fläkt Luftfilter AB fan. Heating is generated with the help of an oil burner, consuming 10 - 23 litres an hour. The flue gases are conducted via a flue to the chimney. An ejector fan is situated in the flue near the foot of the chimney, approximately equidistant from the furnace and the mouth of the chimney. The height of the chimney is 12 m above ground level.

Cremation

Before a cremation the furnace is heated to a temperature of 700 - 750° C. Then the coffin is inserted. Directly following this, the temperature sinks (by about 20° C), to rise successively to maximum 1000 - 1100° C. When the coffin is inserted, the air flow is increased to start combustion. When the coffin ignites, an increased airflow is required. After about 7 - 10 minutes in the furnace the coffin collapses. Then a further increase in air supply is needed. Soon after the collapse of the coffin the temperature drops by about 20 - 50 ° C. The air flow is then increased until maximum temperature is attained, which usually takes about 30 - 40 minutes. Combustion takes place in a partial vacuum. About an hour after the insertion of the coffin the cremation is complete and the ashes can be raked out for cooling.

The quality of the coffin, the weather conditions and the medical history of the deceased eg. whether he has suffered from cancer, all affect the combustion process in the furnace and the air flow requirements. Air flow to crematoria furnaces varies between 400 - 800 nm^3 /h during cremation according to the Swedish Environmental Protection Board (3).

The body to be cremated can be assumed to have the following composition (2).

Assumed weight 70.55 kg

Water content	67.87 %	giving	47.87 kg
Fatty tissue, not dry	13.63 %	giving	9.62 kg
Water content of fat	50.09 %		
of which the fat totals			4.80 kg
Remaining dry substance (excluding fat)			17.88 kg

Measuring equipment and measurements

SEMTECH QUICKY measuring equipment was used for analysis of mercury in the flue gases (see photo 3). The meter detects atomic mercury optically. A mercury lamp which emits a resonant line for Hg, 254 nm (ultra violet), is used as a light source. When the light is transmitted through the measuring cells (which have different lengths depending on the mercury content of the fumes) this wavelength is absorbed by mercury fumes in the gas but also by other broad-banded absorbing compounds such as sulphur dioxide, ozone, etc. By subjecting the lamp to a powerful magnetic field we produce light with a somewhat different wavelength to the resonant line. This light is not absorbed by the mercury in the gas but by the other compounds. When the magnetic field pulsates we therefore obtain a signal which can be related solely to the Hg fumes. For measurements at the crematorium a range of 0 - 60 mg Hg/m^3 was used.

During the measuring process the mercury content of the flue gas was measured every second. An average figure from six measurement points, i.e. 6 seconds, was used in the graphic presentation of the results.

Gases from the crematorium furnace were collected by means of a 6 mm pyrex tube inserted in a stainless steel tube mounted in the chimney stack, some meters before the ejector fan (fig. 2). At this point in the system all mercury still is elementary (Hg^o) because of the high temperature. The gases are sucked through the measuring equipment without the use of a cold

trap or particle filter. During the period of measurement the flow was 1 - 3 litres per min. which means that it took about 5 seconds for the gases to be carried from the pyrex tube to the measuring equipment. A certain condensation was noted in the teflon pipes during cremation.

A FLUMASTER anemometer was used for the measurement of air flow to the furnace (see photo 4). Measurements were made during two cremations and were taken at the fan at the fresh air intake.

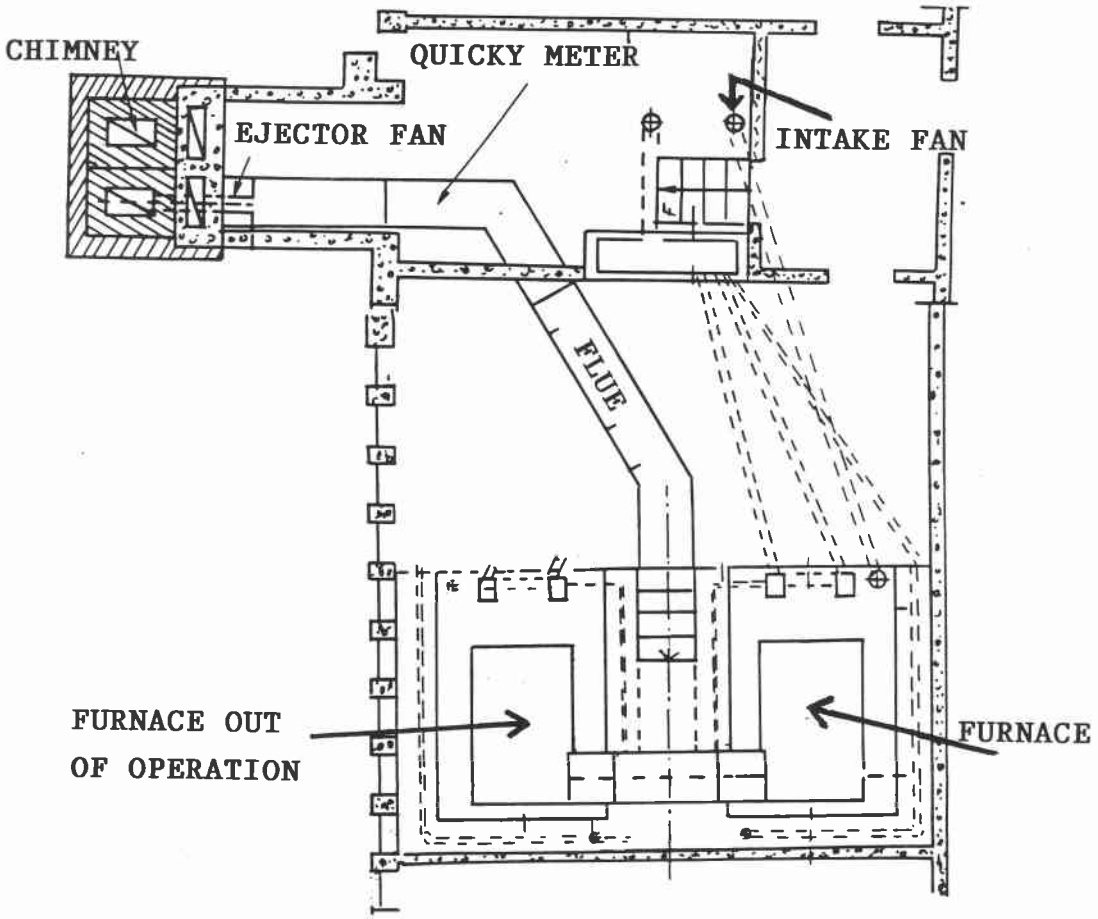

Fig. 2 Location of measuring equipment

Measurement programme

Measurements of the mercury contents of emissions were taken as follows:

a) "Normal" cremation, no additives
b) Cremation with the addition of an Emcoplate Ampoule (selenium ampoule) containing 10 g selenium
c) Cremation with an additional 20 g amalgam (10 g Hg) in a wooden ampoule on the lid of the coffin
d) Cremation with an additional 20 g amalgam (10 g Hg) in a wooden ampoule together with an Emcoplate Ampoule containing 10 g selenium.

Measurements were taken during a total of 22 cremations (initially 23, but one measurement did not give any usuable result). Fig. 3 shows the age distribution of the cremated.

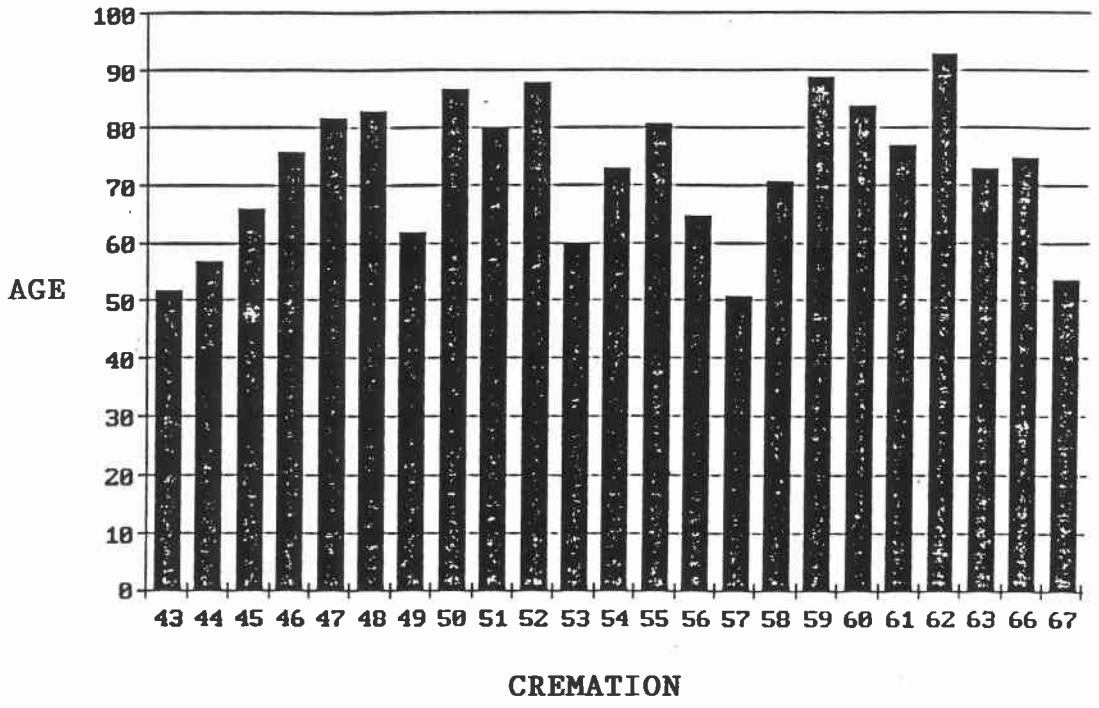

Fig. 3 The age of the cremated in the series of tests

The Emcoplate ampoule

The selenium ampoule used in the tests is manufactured by Emcoplate in Malmö. The Emcoplate ampoule has an outer casing of wood measuring 150 x 30 x 30 mm and a sealed inner casing of aluminium (see photo 5). The selenium content in the tested ampoules was 10 g, of which 8 g was in the aluminium inner casing and 2 g loose in the outer casing. The ampoule is designed so that the selenium is released into the furnace at the same time as the Hg is released in gas form from the amalgam, which occurs at 650° C. The wooden casing acts as a time delay mechanism, as the casing is designed to be destroyed at the same speed as the coffin lid. The aluminium inner casing acts as the temperature control of the ampoule, only releasing selenium fumes when a temperature of 658° C has been attained. The melting point of aluminium is 650° C and the boiling point of selenium is about 680° C. A synchronization of these releases should thus be assured according to the manufacturers, Emcoplate AB in Malmö. It has not, however, been possible to check this during the course of the tests. The factors which influence the effectiveness of the reaction are:

- the placing of the selenium ampoule, or where the selenium is injected
- the thickness of the selenium ampoule and its component materials
- the amount of selenium added
- temperature and pressure conditions.

At cremation the selenium ampoule is placed on the coffin lid, level with the head of the deceased (see photo 6).

Selenium and mercury

Selenium (Se) and mercury (Hg) react chemically with each other to form mercury selenide (HgSe) as follows (1), (5), (6):

$$Hg + Se \rightarrow HgSe$$

The requirements for the formation of HgSe are that there is an excess of selenium and that the reaction is accelerated with the increased temperature and increased pressure within the temperature/pressure relation limits that exist in the crematorium furnace. The reaction is strongly balanced to the right in the absence of oxygen (O_2). With an excess of oxygen the HgSe can oxidize to $Hg + SeO_2$ (9).

Mercury selenide which occurs in the form of greyish, discshaped crystals, is a very stable compound. There are differing opinions as to whether selenium compounds can be found in the residual ash and the airborne ash after combustion within the temperature and pressure conditions in which cremation takes place.

Results

Table 1 shows a list of the cremations which took place during the test period. + Se and + Hg means that either a seleniumn or an amalgam ampoule was used. Hg ampoules contained 20 g amalgam and consisted of a similar wooden casing to the selenium ampoule but lacked the sealed aluminium inner casing.

To test the measuring equipment and to ascertain whether the mercury fumes contaminated the measuring equipment at high mercury levels, measurements were made with only the amalgam ampoule in the furnace. These measurements can be seen in Fig. 4. A very rapid rise after about 4 mins. is followed by an equally rapid fall 4 - 6 mins. later. This shows that Hg does not accumulate neither in the flue nor in the measurement system.

Table 1 List of completed cremation tests

		Before the start of cremation			During the later part or cremation		
Cremation	Temp	+ Se	+ Hg	+ Se + Hg	Extra Hg	Extra Se, Extra Hg	Notes
		1	2	3	4	5	
21943	700						
21944	750						*)
21945	700						
21946	740						*)
21947			x				
21948	700		x		x		
21949	710						
21950	750		x				
21952	750	x				x	*)
21953	720	x					
21954	720	x					
21955	700			x		x	
21956	700	x					*)
21959	700			x	x		
21962	720				x		*)
21963	800	x					
21966							
21967	700	x					

1) + Se = A 10 g selenium ampoule
2) + Hg = A 20 g amalgam ampoule
3) + Se + Hg = 1) + 2)
4) Extra Hg = ca. 20 g of amalgam
5) Extra Hg + extra Se = 4) + ca. 10 g of selenium

*) No Hg detected during cremation

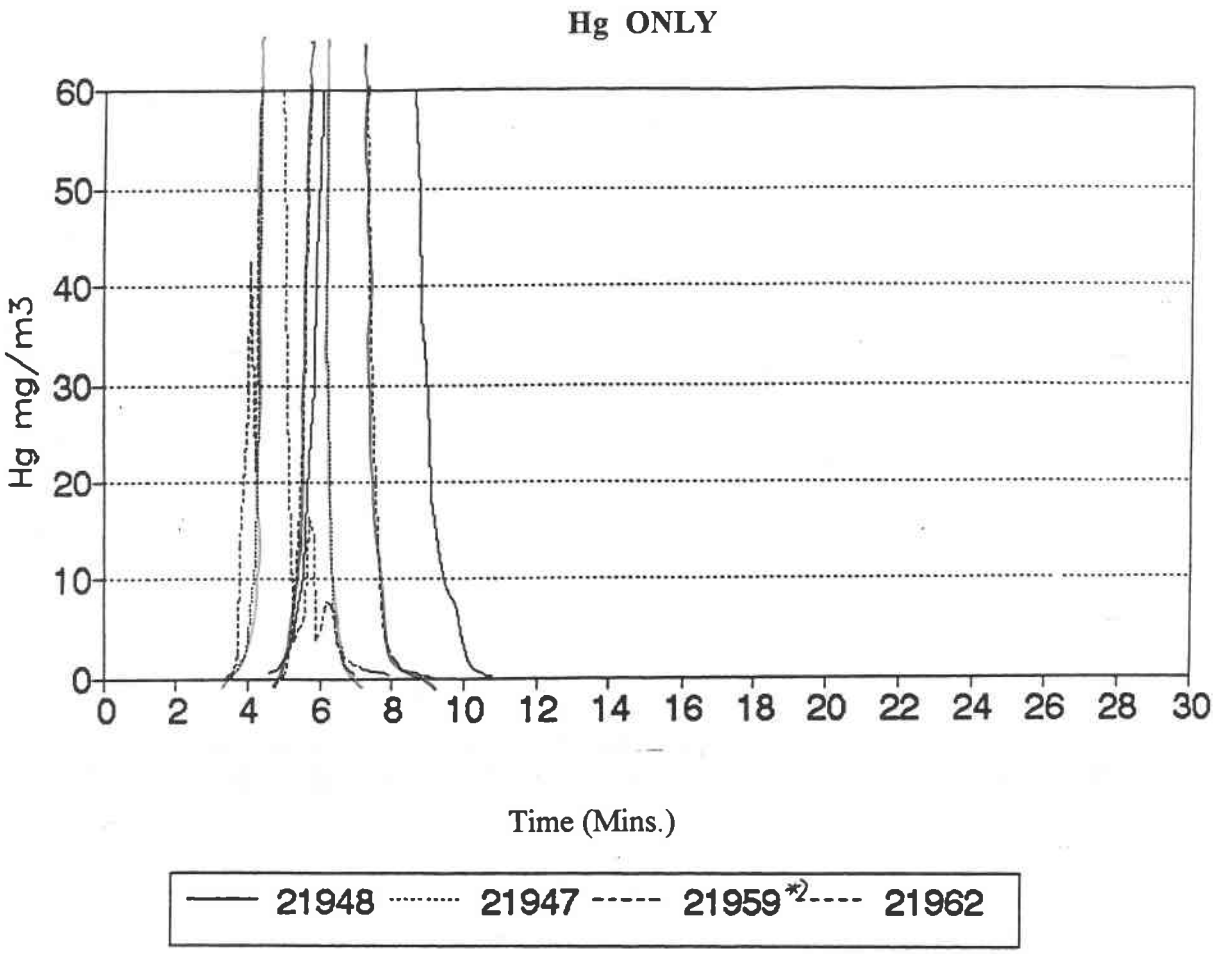

Fig. 4 Combustion of wood ampoule containing 20 g amalgam (10 g Hg)

*) Before the start of cremation No 21959 selenium and amalgam ampoules were placed on the coffin lid (see Fig. 8 and Table 1). During the later part of this cremation when the selenium and the mercury had vapourized and disappeared from the oven and the flue, another amalgam ampoule was inserted (see Fig. 4 and Table 1).

On six occasions measurements were taken at cremations without the addition of ampoules i.e. "normal" cremations. During four of these Hg fumes were detected. These results are shown in fig. 5. The mercury fumes began to be released between 8 - 11 mins. after the insertion of the coffin. The duration is about 10 mins. The content varies considerable, as shown in the graphs. The maximum content measured was 60 Hg/nm^3 at one of the cremations which corresponds to a mercury release of 12.5 mg/s. At three cremations no mercury release was registered, probably due to the fact that the deceased had no teeth containing amalgam fillings. The average release from the six cremations was 0.6 g per cremation. Cremation no. 21943 was a cancer case.

WITHOUT ADDITIVES

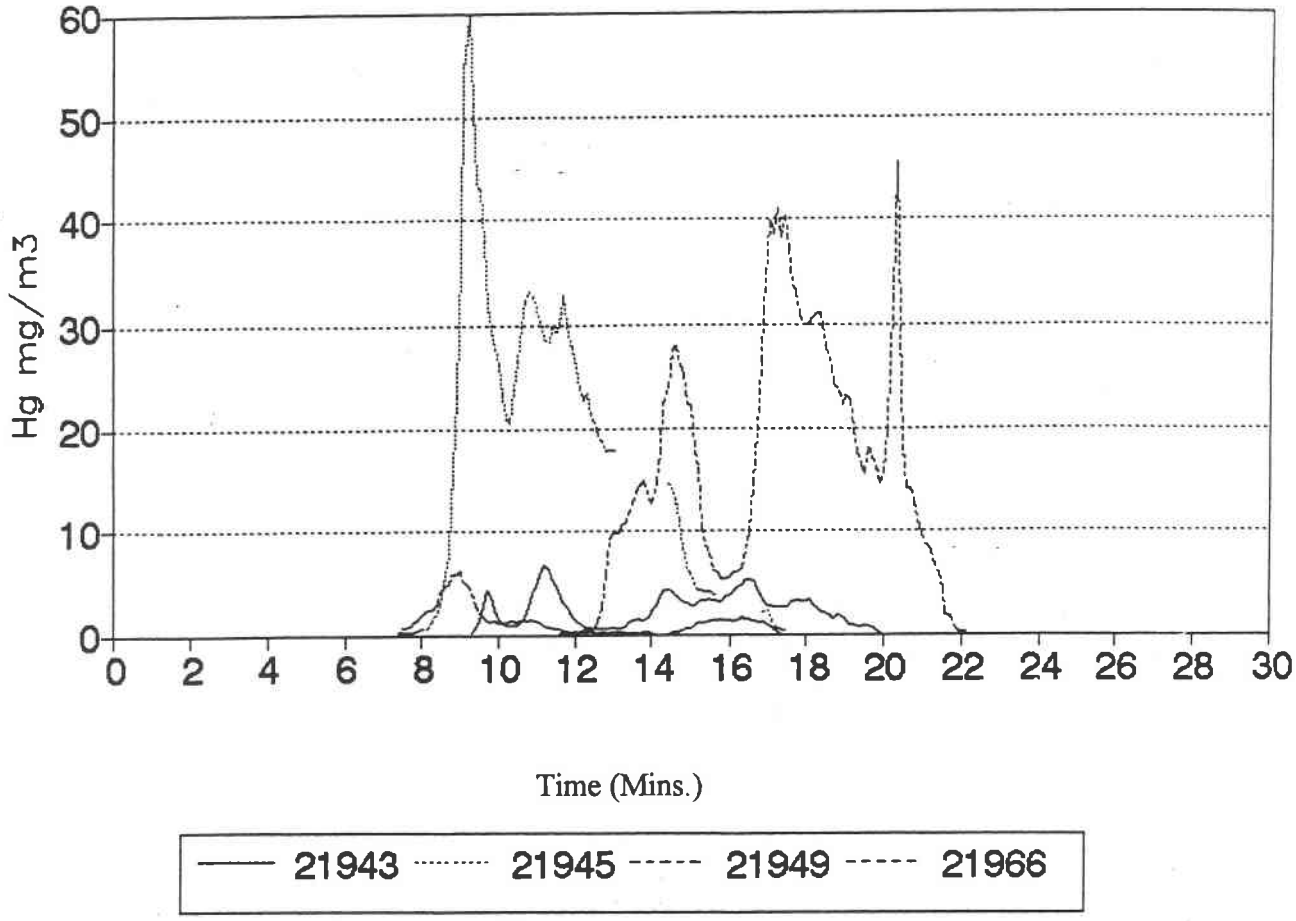

Fig. 5 Measurements at cremations without added ampoules

Cremation with selenium ampoules were carried out on six occasions. In four of these mercury fumes were detected. Hg was detected after 8 - 14 mins. with a duration of 4 - 14 mins. These results are shown in fig. 6. The maximum mercury release on these occasions was measured at 11 mg Hg/nm^3 which corresponds to a mercury release of 2.3 mg/s. On two of these occasions no release of mercury was registered. The average release during these six cremations was 0.17 g per cremation. As regards combustion, cremation no. 21963 was not completely normal. The same applies to cremation no. 21967 which was a cancer case. The release of mercury was, in these two cases, more prolonged than in the other two cases where mercury release was detectable. In the last mentioned case the highest mercury count came 26 mins. after the insertion of the coffin.

WITH ADDED SELENIUM

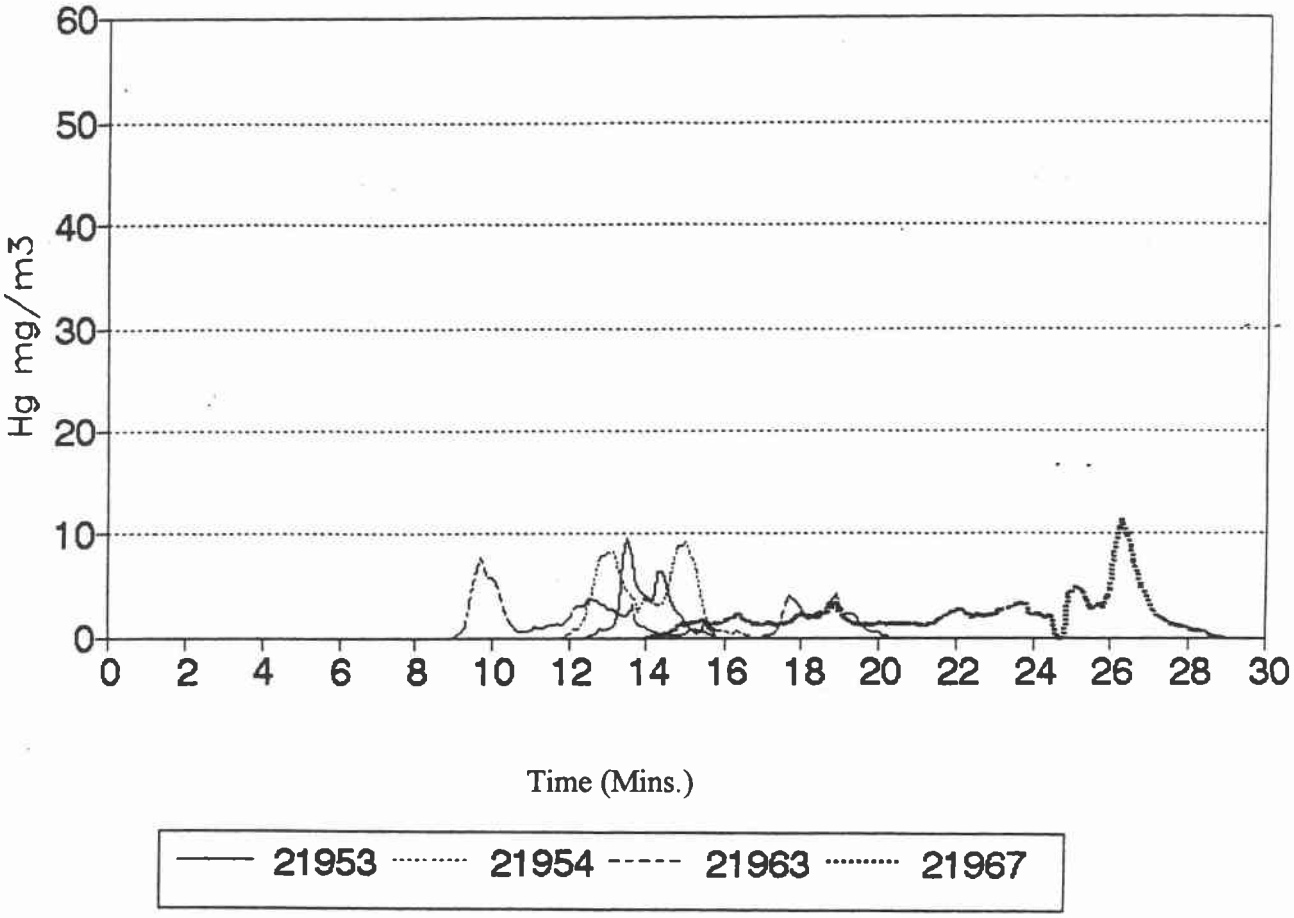

Fig. 6 Measurements with added Emcoplate selenium ampoule

Fig. 7 shows the emission in grams of mercury per cremation for the series of tests under "normal" conditions and for the tests with the selenium ampoule. The ages of the cremated are also shown.

The emissions of mercury during "normal" cremations varied between 0 and 2.1 grams per cremation and during the series of tests with selenium ampoules the variation was between 0 and 0.4 grams per cremation. Here the volume of flue gas from the incineration has not been taken into account. Supposing the decreased to weigh about 70 kg and the coffin about 40 kg, the additional volume is estimated to be about 115 nm^3 on combustion. Supposing further that about 50 % of this volume is released during the first 10 mins. of mercury release, we are left with a figure for mercury release which is 1.9 times higher than that given in Fig. 7. The highest emission during "normal" cremation in this series was then 4 grams.

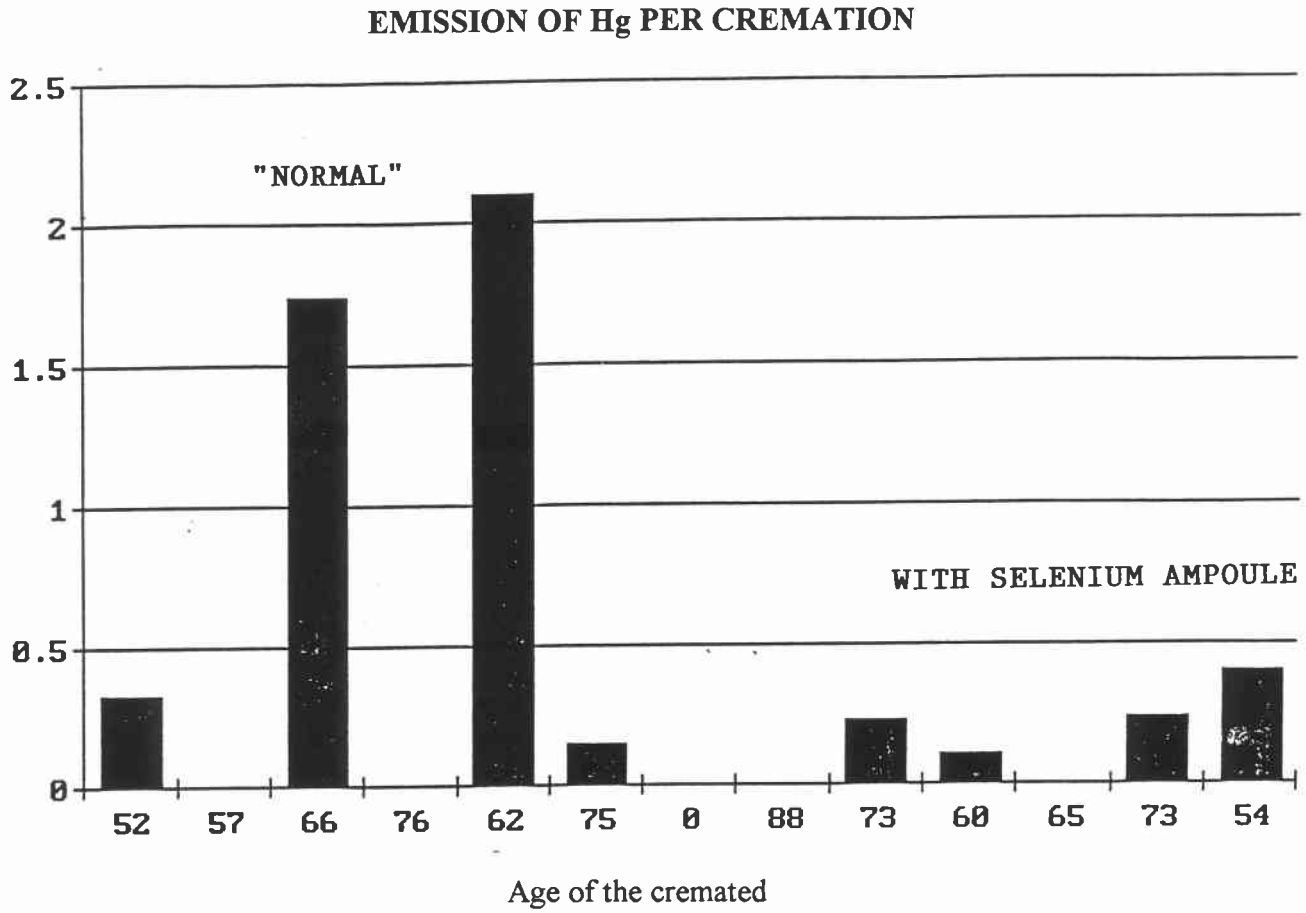

Fig. 7 Emission of mercury per cremation under "normal" conditions and per cremation with selenium ampoule

The average in the "normal" series of cremations was 64.7 years while in the series where selenium was used it was 68.8. The figure shows that even persons under 60 years of age can be without amalgam fillings. Thus we cannot state with certainty, based on these two series of trials alone, that the selenium ampoule reduces the amount of atomic mercury in the flue gas. There is, however, nothing which would suggest the contrary. In order to ascertain the effect of the selenium ampoule an ampoule containing a known amount of mercury in the form of amalgam was placed on the coffin for cremation. Fig. 8 shows the results from two cremations under such condisions. Consequently there was at least 20 g amalgam (10 g Hg) in the furnace. Both tests showed that the selenium ampoule reduced the amount of atomic mercury by at least 80 - 85 %. It is possible that the reduction was greater, namely in the case of the deceased having amalgam fillings, and signs of this can be discerned. The time during which mercury release was measurable in both cases was 6 - 8 min., i.e. somewhat shorter than with normal cremations. The maximum emission of mercury was in both cases just under 60 Hg/nm^3 .

The characteristic mercury release found in normal cremations (see fig. 5), which can be associated with mercury release from the upper and lower jaws of the deceased and which can be recognised as the two high points on the graph, is also apparent here. It cannot therefore be ruled out that more than 10 g mercury was present and that the reduction of atomic mercury has thereby exceeded 85 %. The measurements also indicate that the highest measured amount of emission is reduced to 20 - 50 % of that figure with the use of the selenium ampoule.

WITH ADDED Hg AND SELENIUM

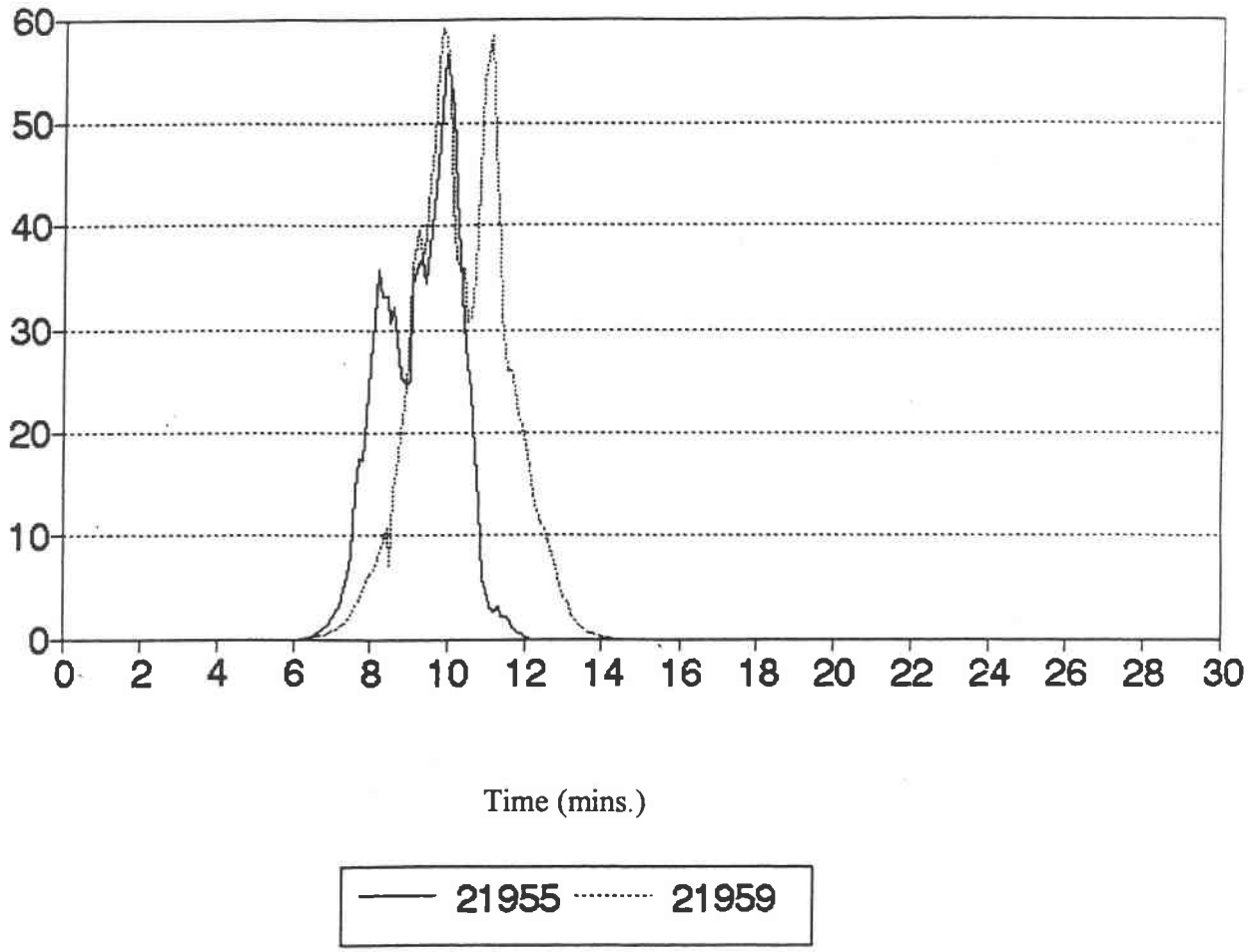

Fig. 8 Test with Hg-ampoule (20 g amalgam) and selenium ampoule

Conclusions and recommendations

Despite the rather brief series of tests, the investigation demonstrates relatively well how mercury emissions occur during "normal" cremations. The release of mercury starts about 8 - 12 mins. after the insertion of the coffin and lasts for about 10 mins. A certain delay can occur if the deceased has suffered from cancer. The maximum content registered in flue gases during "normal" cremation was 60 mg Hg/nm^3 . If measurements are taken over a longer period, higher amounts can be expected. The average age in the series of "normal" cremations was 64.7 years. Younger people often have more amalgam in their teeth.

The series of tests with selenium ampoules suggests that selenium reduces the amount of atomic mercury in flue gases. It should however be emphasized that it is not possible to state with any certainty the size of the reduction as in every case the dental history of the decreased was lacking. The maximum amount measured in flue gases during a cremation using a selenium ampoule was 11 mg Hg/nm^3 .

The investigation as a whole, however, shows that a reduction of at least 80 % of atomic mercury in flue gases can be expected with the use of selenium ampoules. Higher reductions can certainly be achieved if the selenium additive is optimized in terms of timing and position.

For a complete understanding of how mercury release occurs and how great the reduction capacity of a selenium ampoule is on the emission of mercury from crematoria, the following investigations are needed:

1) Measurements of a longer series of "normal" cremations.

2) Measurement of the occurrence of atomic mercury after the ejector fan to see if it is influenced in any way by an excess of 0_2 .

3) Analysis of the presence of HgSe in residual and airborne ash.

4) Attempts to optimize the use of the selenium ampoule.

5) Active control of selenium injection.

There is also reason to test the effectiveness of the selenium ampoule on other substances than mercury in flue gases from crematoria. As the cost of such tests should be quite limited there is no reason to invest more technically advanced and expensive solutions for flue gas cleaning before the effects of the selenium ampoule have been studied. The total environmental effect of the installation of flue gas cleaning at crematoria should be taken into account, i.e. the manufacture of equipment, the effects of separation at the crematorium and the final treatment of the separated ashes. It is also important to study the work environment for those involved with cremations and the handling of the residual waste.

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