Summary of References on Mercury Emissions from Crematoria

Summary

Based on a review of the current literature and email contacts from the US and several European countries, the release of mercury from cremations in Wisconsin is estimated to vary from 9 grams a year to nearly 61,000 grams a year. None of the references have a mass balance of mercury from the bodies cremated and the resultant mercury in the ash or deposited on the walls of the crematoria. The US data provides the lowest estimates, but no primary articles on this subject were found; instead, only secondary references are given and the primary data appear not to have been released.

Number of cremations in Dane County and Wisconsin

In a phone conversation with the Dane County Coroner's office, it was stated that there were about 1,000 cremations in Dane County last year and that the number of cremations is increasing about 10% a year, with about a third of all funerals by cremation. It was also noted that there are 5 crematoria in Dane County.

On the web page http://www.cremation.org/stats.shtml, a map gives the estimated percentage of cremations for Wisconsin in 2000 at 27% of all deaths, with the data from the Cremation Association of North America (CANA).

On the CANA web page, at http://www.cremationassociation.org/docs/state99.pdf, a table gives Wisconsin's 1999 deaths at 45,413, and a 1999 cremation rate at 24.96%, with the estimated rate for 2000 at 26.71% and for 2010 at 52.47%.

On the web page http://www.dhfs.state.wi.us/deaths/pdf/00deaths.pdf, the State of Wisconsin Department of Health and Family Services puts total Wisconsin deaths in 2000 at 46,405, with the cremation rate at 27%, an increase from 15% in the past decade. For Dane County, 3,100 deaths were reported.

Mercury use in Dentistry

Data were obtained from a variety of sources, including the US Bureau of Mines, the US Geological Survey and EPA for the use of mercury in dentistry from 1941 through 2000. In 1941, mercury use was about 0.15 grams per person per year. That number increased to just over 0.50 grams per person per year in the 1970's and has since decreased to about 0.15 grams.

In a Power Point presentation of the city of Palo Alto, CA, it notes that a small filling typically has 0.37 grams of mercury, calculated at one amalgam

unit with 0.55 gram mercury, minus 0.14 gram waste during the filling process, minus 0.04 grams in trimmings. A large filling starts with two amalgam units, but the final amount of mercury in the filling is not stated, although it is implied to be 0.74 grams.

In 1997, a US study was published with the results of a 1992-3 study of fillings in 1,166 male US Air Force Veterans, of which 1,105 had teeth. The results are in the following table:

The authors note that other studies had found that the people in this study probably had better dental care than the population as a whole and had both more restored dental surfaces and fewer missing teeth than the population as a whole.

In a Swedish report from 1996, it is reported that the average filling weighs one gram, of which 50% is mercury. In a study of people with an average age of approximately 44, there was an average of 11-12 fillings per person.

Mercury in Body Tissues, Bones

According to a study done by the US Centers for Disease Control and Prevention (the 1999 National Health and Nutrition Examination Survey (NHANES 1999)), the geometric mean for mercury in the blood of women aged 16 to 49 as 1.2 ppb, with a 90th percentile reading of 6.2 ppb. For hair samples, the geometric mean was not calculated, but the 90th percentile level as 1.4 ppm.

I do not know the relationship of mercury levels in either blood or hair to levels in other body tissues. According to a web page of the World Health Organization, 80-90% of ingested methylmercury becomes combined with red blood cells. This implies that only 10-20% would combine with other body tissue. Several articles have discussed the half life of mercury in the body, and more details will be sought on this subject.

As an indication of mercury levels from body tissues as part of cremations, if the average weight of a cremation is estimated at 80 kilograms (176 pounds), the data from blood and hair samples would provide a range of 9.6 x 10-5 to 1.2 x 10-1 grams of mercury in body tissues per cremation. The high end is viewed as extremely conservative as it represents the 90th percentile, not the mean level of mercury in hair.

Longevity of fillings

In a US Geological Survey report published in 2000, it was noted that the average life of a mercury amalgam filing is reported to be from 5 to 8 years, while in a 1995 article in a Swiss dental medicine journal, the average life was stated to be 10 years. In a 1991 article in Consumer Reports, however, the life of mercury fillings was given as 10-20 years.

If these data are correct, they imply at least two things: (1) the amount of mercury fillings in cremations depends on the amount of fillings obtained in the last decade or so of life, and (2) changes in dental filling practices will affect the amount of mercury found in cremations relatively rapidly. For example, cessation of the use of mercury fillings would decrease the amount of mercury in cremations by about 50% within five to ten years and virtually eliminate it in 10 to 20 years, all other things equal

Mercury from Fillings in Cremations

In a Swiss study published in 1990, it was found from an examination of deceased people (average age of 66) that molar fillings average 1.22 grams of amalgam each and pre-molar fillings averaged 0.79 grams of amalgam each. It was estimated in this study that amalgams have between 40 and 43% mercury.

In a 1993 Swedish report on mercury flows in Gothenburg, an accounting was done for cremations in 1984 and 1991, with a forecast for 2000.

The study notes that the amount of mercury in fillings per cremation changed from 1984 and 1991 from 3.6 to 4.6 grams, while the forecast is for 5.9 grams in 2000. This is due in part to a change in the age distribution of the deceased, but more due to an increased retention of teeth by older people and hence a greater presence of mercury fillings in the cremations. For example, from 1984 to 1991, the percent of cremations and amount of mercury per cremation changed as follows in Gothenburg;

Mercury from Dental Fillings in Cremations in Gothenburg, Sweden

Two articles from a Swiss dental medicine magazine were also found.

The first Swiss article is from a 1990 journal of dental medicine. A study was done of the amount of mercury found in 130 cremations in Zurich, with each body examined by visual techniques and x-rays. Based on a study of the amount of mercury in extracted teeth (62 molars and 72 pre-molars), it was assumed for the cremations that each molar filling had 1.20 grams of amalgam, while each pre-molar filling had 0.79 grams of amalgam. The authors assumed that 40% of the amalgam was mercury, although noted that a more recent study had found that 43% of the amalgam was mercury.

The average age of the deceased was 77.4 years, and it was found that 32% of the deceased had no natural teeth, with a 95% confidence interval of + 8.3%. For those with teeth (average age was 60.9 years), there were 2.49 grams of mercury in the fillings, with a 95% confidence interval of +0.37 grams.

The second article is from 1995 and builds on the first article. The amount of

mercury in 28 cremations was studied and given by age, but it is not clear the these are representative of the Swiss population as a whole or instead more likely is what was available as part of the study to determine mercury emissions from crematoria. These data were analyzed statistically by this reviewer. The results are as follows:

Mercury from Dental Fillings in Test Cremations in Zurich, Switzerland
Air emissions from cremations

Data on mercury air emissions from cremations was found from the US, the UK, Norway, Sweden and Switzerland. The range of data is very large, from 0.94 x 10-3 gram/body in a US report to 5.6 grams in other reports. In no case was a mass balance performed, with measurements of mercury deposited on the walls of the crematoria or the amount of mercury in the cremated ash. While one study found a relationship to account for almost 77% of the mercury from the cremation of three cases of mercury amalgam added to a coffin without a corpse, other reports account for less than 1% of the mercury available in the fillings.

For the US, the data on mercury emissions from crematoria is extremely limited. Two different EPA reports on the Internet from 1997 provide two drastically different conclusions, both based apparently on the same study. In one study, a value of 1.5 x 10-3 kg (1.5 grams) of mercury per cremation is reported, from a 1992 test done in California of a propane fired crematorium. The EPA report does not provide data on the age of the deceased, or the number and size of the fillings and the mercury estimated to be contained in the fillings. The reference for this data is a report of California Air Resources Board (CARB), 1992. *Evaluation Test on Two Propane-Fired Crematories at Camellia Memorial Lawn Cemetery. Test Report No. C-90-004. October 29, 1992*. This study has not been obtained by this reviewer.

In the second EPA report, the amount of mercury 0.94 x 10 —6 kg/body (0.94 x 10-3 gram/body). The test results were obtained from a confidential test report to the California Air Resource Board. The reference give for this report is FIRE, 1995. *FIRE Version 5.0*, EPA-454/R-95-012, U. S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, August 1995.

In 1999, EPA and the Cremation Association of North America did a series of tests of emissions from cremations. The tests were done from June 11 through June 17, 1999 at The Woodlawn Cemetery, The Bronx, New York. The data are both reported on the Internet, and, according to an email note from a staff person with the state of Maine, in an industry trade magazine, *The Cremationist of North America* (Vol 35, No. 4, 1999). Nine cremations were done, 3 each at the operating temperatures of 1400û F (810û C), 1600û F (920û C) and 1800û F (1030û C). It does not appear that

information was gathered on the input of mercury in each cremation, nor that any data on the composition of the ash were taken. The article on the Internet says that mercury averaged 0.23 grams/hour of operation, but there are no data on mercury emissions varying with temperatures., since it was assumed that mercury emissions would not change with temperature. According to the writer from Maine, this level of emission appears to be in the range of 1 gram or so per cremation. This would imply that each cremation lasts over 4 hours, much longer than what is reported in European information.

From an email note from the state official in Maine, a report titled *The Northeast States and Eastern Canadian Provinces Mercury Study,* February, 1998 is said to suggest a range of emission values from 0.8 to 5.6 grams of mercury per cremation, or an average rate of 2.9 grams of mercury per cremation. A copy of this report has not been obtained by this reviewer. However, a chapter of this report was found on the Internet, and in this chapter, the suggested emission levels from crematoria based on a review of data by EPA from Germany, Switzerland and the United Kingdom is said to be about 1 gram per cremation.

In another Canadian publication, a January 1998 document known as the *Emission Inventory Guidebook*, the role of crematoria for a variety of air emissions is summarized, with a review of data from 12 countries. It concludes that for most materials, crematoria are a minor source of emissions. The exception is heavy metals, including mercury, for which cremations are said to be responsible for up to 21% of the emissions, as in Sweden.

The guidebook notes that the majority of the mercury comes from dental fillings, which it lists as being between 5 and 10 grams per corpse. However, it lists the emissions from the EPA study as 9.344 x 10-7 kg per body, or 9.344 x 10-4 grams/body, less than 0.02% of the mercury contained in the fillings.

In a February, 2001 newspaper article in a UK newspaper, it was report that the 440,000 cremations done annually in Great Britain resulted in an emission of 1,300 kg of mercury to the air, or about 2.95 grams of mercury per cremation.

In Norway, a researcher reported in a February 2001 email that it is estimated that between 2 and 4 grams of mercury are emitted to the air per cremation, but that it is dependent on the age of the deceased. He has measured one such cremation and found an emission level of 0.80 mg Hg/ Nm_ gas over a cremation of 2 hours. The gas volume was some 3,500 Nm_ gas/hr.(one furnace), so the total volume was 5.6 grams. In a different email, this same researcher reported for another cremation the same concentration of mercury, but a 1.5 hour duration and a gas volume of 3,880 Nm_/hour.

A staff person at the Norwegian equivalent of the EPA also wrote an email, noting that an inventory of mercury emissions in Norway puts the emissions per cremation at 4.9 grams. The report is available on the Internet at http://www.ssb.no/milgiftn/.

In a draft fact sheet on crematoria from early 2001 being prepared for the Swedish Environmental Protection Agency, an average emission of 5 grams of mercury is assumed. The reference for this assumption is not listed, although the bibliography for the fact sheet has several references to a number of Swedish reports on mercury emissions from crematoria. The fact sheet notes that in Sweden, cremations account for just under 32% of the mercury emissions to the atmosphere.

Two Swiss articles were reviewed. In the first, a study was made of mercury and other substances in the area surround several crematoria in Zurich. It was found that there were measurably higher levels of mercury in the soil than in background soil, especially within 100 meters of the crematoria. The level of mercury in the soil in the future is of concern, since the number of cremations is expected to increase faster than the decrease in the amount of mercury used for dental purposes. Three scenarios where done of mercury emissions from crematoria over the next 50 years, using assumptions of 2, 3 and 5 grams of emission per cremation.

The second Swiss article was published in 1995 in a Swiss journal of dental medicine. In this study, the amount of mercury was estimated in 54 bodies before cremation using a modification of the technique in the article described above, by classifying the filings in various size categories as well as type of tooth. The bodies were cremated without the level of mercury known to the people doing the cremations or testing the stack for emissions and the exhaust gases were measured for mercury levels. Data on the deceased include their age in 20 year intervals and the amount of mercury in their fillings and the results are provided for each cremation and analyzed by output vs input and by furnace temperature.

A total of 60 cremations were done, divided into a group of 54 cremations of corpses, approximately half with mercury fillings and half without, and 6 "blind" tests where the coffins were empty but a specific amount of mercury amalgam was added in three of these coffins.

There was a correlation of 0.85 between input quantities of mercury and output quantities when all data were included and 0.93 when several "outliers" where excluded. However, the output averaged only about 56% of the input for the 54 cremations of actual bodies and approximately 77% in the three tests that a known amount of mercury amalgam was added to the blind test coffins. There was also mercury in the emissions of corpses that had no fillings. In a series of cremations of corpses with no fillings, the level of mercury emissions in the exhaust steadily declined with each subsequent

cremation. It was concluded that during those cremations with mercury fillings , some of the mercury was deposited on the walls of the crematory rather than being exhausted to the air. The wall-deposited mercury was then emitted during subsequent cremations, including cremations that had no mercury. An analysis was also done of mercury emissions from the cremation those corpses without mercury fillings with respect to exhaust temperatures. A positive relationship was found, with more mercury emitted with higher temperatures, and a correlation of 0.56. There was no correlation found for mercury emissions and age for those corpses that had no fillings.

Actual output data were not provided in a numerical form, but instead are represented in a bar graph. Similarly, the level of mercury emissions per Nm_ was not provided, although it was stated that in 82% of the cremations of people with fillings, emission levels exceeded 0.2 mg/Nm3. In addition, this level was exceeded for 12% of the cremations of bodies with no fillings.

It was recognized that mercury could come from other sources, such as mercury in body tissues or other devices, such as the batteries of pacemakers. However, these sources of mercury were not calculated or estimated.

Mercury in Crematoria Ash

In an email from Dr. Thomas Thomassen of Miltec in August 2002, he reported that he took 4 samples of ash from cremations and found that the mercury levels were less than 1 microgram/kilogram of ash. He noted that this low level was to be expected, given the high temperatures produced during cremation.

Mercury Deposits on Crematoria Chimneys

In an email from Dr. Thomas Thomassen of Miltec in Norway on September 12, 2002, he reported that he chipped off part of the brick material from a crematorium and found that the sample had 0.9 grams of mercury per kilogram of matter. He noted that it was easy to obtain a chipped sample, as the concrete was rotten due to exposure to acid mists from the cremations. In followup tests, again near the top of the chimney, data were obtained on the surface dust, the cement between the bricks, and in samples that included pieces of the brick:

	mg Hg/kg sample
Surface dust on the bricks (black)	168
Cement between bricks (rotten)	20
Brick (solid chunk)	2.3

Dr. Thomassen believes that the level of mercury would be higher in lower levels of the chimney.

Regulation of Mercury Emissions from Crematoria

At the present time, no national mercury emission standards for crematoria were found in the four European countries checked, although several countries are working on such standards. No standards are known to exist in the US. Under Section 129 of the Clean Air Act, the US EPA is required to set standards for a variety of air sources. Originally, the standards for crematoria were to be developed by November 2000, but in a Federal Register notice at that time, EPA set a new schedule to release its standards by November 15, 2005.

In Germany, two states (Sachsen and Brandenburg) had local standards, with Sachsen's at 0.2 mg/Nm_, while Brandenberg's standard was 0.05 mg/ Nm_. However, both of these standards were superseded by national regulations for crematoria as given in 27. BImSchV (the Federal Emission Regulation for crematoria, promulgated March, 1997), which contains no mercury standards. In addition, the German Association of Engineers published guidelines for crematoria (VDI 3891, promulgated August, 1992), but it also has no standard for mercury. However, in a February 2001 email from the German firm IFZW, it is expected that there will soon be an amendment of the 27th BImSchV with a limit for mercury of 0.05 mg/Nm_.

Norway's Pollution Control Authority (SFT) has developed air and water regulations for crematoria, which went into effect on January 1, 2003 for new crematoria and 2007 for existing crematoria. The regulations will result in a 95% reduction in mercury emissions from the largest crematoria, according to an SFT news release issued on January 15, 2003. For air, the requirement is 0.05 mg/Nm_, while for water, it is 2.0 µg/liter. The contacts at SFT are Signe Nåmdal at signe.namdal@sft.no and Bente Sleire at bente.sleire@sft.no.

In early July, 2001, two Norwegian environmental groups came out with a statement that it preferable to remove the teeth of the deceased before cremation rather than rely on control equipment. One Norwegian newspaper ran a poll on this through the Internet, and of 221 respondents, 40% said that they thought it was right to remove the teeth for environmental concerns, while 53% said it was not right to extract the teeth (7% had no opinion).

Denmark was checked for regulations, and an email message from the Danish equivalent of the EPA said that they do not have any mercury-related regulations, although they do have other crematoria regulations.

For Sweden, an article in the March 18, 2002 edition of the Norwegian newspaper *Aftenposten* noted that there were no emissions standards for

mercury from crematoria. Instead, the Swedish Naturvårdsverket has published guidelines, and that since 1995, some 20 crematoria have been built in Sweden with control equipment. The article quotes staff at the Swedish agency as saying that standards have not been developed due to the difficulties in measuring mercury emissions. According to one staff person, some measurements show that control equipment provides for clean emissions, but other measurements only result in a third of all mercury being trapped by the filters, and that either the measurements are in error or there is another path for the mercury. A new freeze-dry technology is being explored that would not involve any combustion and therefore could result in virtually no emissions of mercury to the air.

Control Technology for Mercury Emissions

There are undoubtedly many systems available for the control of mercury from crematoria. Selenium as a control media was mentioned in several articles reviewed. During this preliminary search, three, other types of control systems were found, one from Germany, one from Norway and one from Switzerland.

The German organization known as IFZW says that its equipment can reduce mercury emissions from crematoria to a level of below 0.05 mg/Nm_.

In Norway, the Miltec firm (http://www.miltec-mercury.com) has control equipment for mercury and has installed this equipment on a crematorium. Trial runs in the spring of 2001 resulted in a 94% reduction in mercury emission to the environment.

In Switzerland, the firm of SEU Schenkel AG has developed an adsorption process for dioxins, furans and mercury. A system was installed on a crematorium in Basel in 1999 and a paper describing the firm's system is on the Internet at http://www.seuag.com/scripte/Summary.pdf. The unit is said to be 99.9% effective in removing mercury, with the resultant effluent below 0.05 mg/Nm3.

In Sweden, as noted above, some 20 crematoria have been fitted since 1995 with air pollution control equipment for mercury. However, results are ambiguous due either to measurement problems or that there are other paths to which the mercury is going. A newspaper article in March 2002 notes the development of a liquid nitrogen freeze-dry process that is said to have no mercury emissions to the air.

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