Testimony of Alexis Cain[1]
Before the Domestic Policy Subcommittee of the Oversight and Government Reform Committee
Estimating Mercury Releases Resulting from Use of Dental Amalgam

Wednesday, May 26, 2010

I appreciate the opportunity to speak to the subcommittee today about lifecycle releases of mercury resulting from the use of dental amalgam. In 2007, I, along with colleagues from Barr Engineering, the Wisconsin Department of Natural Resources, and Dane County Wisconsin's Recycling Division, published an article in the *Journal of Industrial Ecology* on the lifecycle environmental releases resulting from the use of a variety of mercury-containing products, including dental amalgam, along with lamps, bulk mercury, switches and relays, and measurement and control devices.[2] This paper was based on a mass balance model developed by Barr Engineering with funding provided by the Minnesota Pollution Control Agency and the U.S. Environmental Protection Agency. This model estimated the lifecycle flow of mercury in products from production through use and disposal, using "distribution factors" to estimate how much mercury would enter various disposal pathways, and using "release factors" to estimate how much mercury would be released to air, land and water at each of these stages.

Mercury Releases from the Dental Amalgam Lifecycle

We estimated, based on the mercury flow model, that use of dental amalgam was responsible for 4.5 metric tons of mercury releases to the atmosphere in 2005. For context, the Environmental Protection Agency estimates that total mercury emissions from all sources totaled approximately 100 metric tons in 2005. Based on our estimates, dental amalgam is certainly not the largest source of mercury to the atmosphere, but it is nonetheless a significant source accounting for roughly four to five percent of total emissions. Emissions from human cremation, as the result of the presence of dental amalgam fillings in corpses, accounted for approximately half of these emissions. It is likely that these emissions will increase over the next decade, given that the number of cremations is projected to increase and that there is a trend towards increased retention of teeth (and therefore of fillings) until the end of life as the result of improved dental care. Other significant air emissions pathways included volatilization of mercury within the dental office (approximately 0.7 metric tons) and disposal of sewage sludge, both from incineration (approximately 0.5 metric tons) and land application (approximately 0.3 metric tons). Additional emissions are caused by other pathways such as exhalation of mercury-containing breath from people who have amalgam fillings and releases from dental waste incinerated as the result of improper disposal.

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[1] Environmental Scientist, U.S. Environmental Protection Agency, Region 5, Office of Air and Radiation, testifying as a private citizen.

[2] Cain, A., Disch, S., Twarski, C., Reindl, J.& Case, C.R. (2007). Substance flow analysis of mercury intentionally used in products in the United States. *Journal of Industrial Ecology, 11*(3).

There is considerable uncertainty around all of these estimates, particularly the estimates of air releases from land-applied sewage sludge[3] and from volatilization of mercury in the dental office.[4]

We also estimated that dental amalgam was responsible for 0.4 metric tons of mercury releases to water in 2005. These results are consistent with a study by the National Association of Clean Water Agencies that found that dental offices create the largest identifiable mercury inputs to sanitary sewers.[5] It is also consistent with a study, published in *Air Water and Soil Pollution* in 2005, which found that dental offices discharge 5.9 metric tons of mercury annually to sanitary sewers, of which 0.4 tons is released to water, with the remainder ending up in sewage sludge.[6] It is likely that these releases have been reduced since 2005, as more dental offices have installed separators and as use of amalgam has decreased. We estimated, using the model, that implementation of best practices, including amalgam separators, at all dental offices would reduce water discharges by 0.3 metric tons and air emissions by 0.9 metric tons (through reducing the mercury content of sewage sludge).[7]

Finally, we estimated that dental amalgam was responsible for 28 metric tons of mercury disposal to land in 2005. The disposition of most of this mercury followed three pathways: burial of corpses with dental amalgam fillings, landfilling of mercury-containing wastes, and land application of sewage sludge.

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[3] The Mercury Flow Model assumes 10 percent volatilization of mercury from land-applied sewage sludge. To a large extent, the appropriate factor depends on the time period of interest. We would expect most of the mercury in land-applied sewage sludge to volatilized on a very long time scale (centuries), but a much smaller amount to volatilize within a year of application. Carpi, A., Lindberg, S.E. (1997) "The Sunlight Mediated Emission of Elemental Mercury from Soil Amended with Municipal Sewage Sludge," Environmental Science and Technology 31(7): 2085-2091.

[4] The Mercury Flow Model estimates for air emissions from dental offices are based on studies of mercury vapor concentrations in air exhausted by dental office vacuum units. Rubin, Paul G., Yu, Ming-Ho. Mercury Vapor in Amalgam Waste Discharged from Dental Office Vacuum Units. July/August 1996. *Archives of Environmental Health* 51: 335-337. More recent research has found similar mercury vapor concentrations. M.E. Stone, M.E. Cohen and B.A. Debban. 2007. Mercury vapor levels in exhaust air from dental vacuum systems, *Dental Materials* 23: 527–532. However, estimates of air flow from dental office vacuum systems are highly uncertain.

[5] Association of Metropolitan Sewerage Agencies. 2002. *Evaluation of the Effectiveness of Publicly Owned Treatment Works (POTW) Mercury Pollution Prevention/Minimization Programs.* Washington, DC: National Association of Clean Water Agencies.

[6] Vandeven JA, Mcginnis SK. 2005. An Assessment of Mercury in the Form of Amalgam in Dental Wastewater in the United States. *Water Air and Soil Pollution* 164: 349-366.

[7] A study of the impact of separator installation on mercury concentrations of influent, effluent, and sludge by the National Association of Clean Water Agencies supports the hypothesis that dental amalgam separator installation is associated with reduced mercury concentrations in influent and sludge at wastewater treatment plants. However, the study did not find a decrease in mercury concentrations in effluent associated with separator installation. According to NACWA, "This result could be due, in part, to the limited number of amalgam separator installations occurring at the POTWs with generally lower effluent mercury concentrations at the study's outset." National Association of Clean Water Agencies. January 2008. *An Examination of Mercury Levels at Clean Water Agencies. 2003-2006.*

Modeled versus Measured Releases

You may wonder what the value of this type of modeling is. Why use a model to estimate releases instead of measuring these releases directly? I think that there are several reasons that this type of exercise can be useful. First, a model can provide estimates, however rough, of sources that are difficult to measure directly, such as releases from land application of sewage sludge. Second, a model can generate estimates of releases caused by particular products. Direct measurement can give us an estimate of mercury emissions from incinerators, for instance, but a model can estimate how much of these emissions result from various products going into the waste stream. Third, a model allows us to predict the impact of various management options, for instance, to estimate the potential decline in mercury releases resulting from installation of amalgam separators at all dental offices. Fourth, when a model's results differ significantly from measured results, it could mean that the model is incorrect, or it could indicate problems with the measurements.

Mercury Emissions from Crematories

In the case of mercury releases from human cremation, EPA estimates that total nationwide emissions were 0.3 tons in 2005,[8] based on extrapolating from emissions measurements. The substance flow analysis estimates that these emissions are more than 2 tons per year. As a general rule, there are good reasons to prioritize measured results over an output from a model when developing an emissions inventory. However, I believe that, in this case, there are several reasons while the model may produce more reliable results than a small number of emissions tests. EPA's estimates are based on a small number of emissions tests at a single facility. Facilities can vary in their emissions rates based on differing technologies employed, and we would expect releases per cremation to vary greatly depending on whether the particular corpse being cremated at the time the measurements were being made had no dental amalgam fillings, a few fillings, or many fillings. Therefore, extrapolation from small number of tests could generate a misleading result.

The substance flow model estimates mercury inputs into crematories by utilizing data on the number of dental amalgam fillings an average person has at the end of life, the amount of mercury per filling, and the percentage of corpses that are cremated.[9] The primary uncertainty in this calculation is the number of dental amalgam fillings at the end of life. Based on the factors, we estimated roughly three metric tons of mercury input into crematoria. We then estimated that 75 percent of mercury input to crematories was emitted to the air, with 25 percent in ashes. I now believe, based on reviewing the information in an attached paper by John Reindl, that this

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[8] Conversation with Anne Pope, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, May 17, 2010.

[9] Approximately 800,000 cremations, with each corpse having 12 fillings, and each filling having 0.3 grams mercury = 2.9 metric tons mercury input to crematory. Assuming 75% of mercury input is emitted to air, 2.2 metric tons are emitted.

estimate was conservative, and that well above 75 percent of mercury inputs are released to the air.

The hypothesis that emissions inventories may understate the significance of mercury emissions from crematories is supported by evidence from emissions testing in Europe, where there has been more testing done than in the United States. John Reindl has reviewed this evidence (see attached) and found that there is a wide range of estimates, but that the most credible estimates are in a range of 2 to 4 grams per cremation. This estimate is based in part on emissions tests, in part based on studies that look at the number of fillings present in corpses that get cremated. The National Emissions Inventory for the United Kingdom uses an emissions factor of 3 grams per cremation, while Norway and Sweden each use a emissions factor of 5 grams per cremation. EPA's emissions inventory implies emissions of 0.4 grams/cremation, far lower than the likely range suggested by European evidence. The lifecycle flow model implies emissions of 2.7 grams/cremation.

Given all of the uncertainties, I certainly do not claim that the mercury flow model has produced a correct estimate of mercury emissions from human cremation. However, I believe that the evidence is strong that EPA's estimate understates emissions from this source category. I believe that an evaluation of all of the available evidence, or the development of new evidence through additional stack testing or studies of mercury inputs to crematoria, would lead to an increase in EPA's estimate of mercury emissions from cremation.