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## REGULATORY ISSUES ARTICLE

# Cremation, Air Pollution, and Special Use Permitting: A Case Study

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**ABSTRACT**

Risks to health posed by emissions of hazardous air pollutants from crematories are emerging concerns. The presence of silver–mercury amalgams in bodies results in airborne emissions of mercury; and the combustion of essentially any material results in emissions of polychlorinated dibenzodioxins and furans (PCDD/Fs; "dioxins"). These and other trace emissions from crematories are not regulated at the U.S. federal or (typically) state level, but neighborhood concerns may necessitate quantitative evaluations of potential local impacts, and local officials may need to rely on such evaluations in order to determine whether and under what conditions to grant (or deny) operating permits. Here we present a case study in which these and other issues were evaluated. Using air dispersion models and health risk assessment models, we predicted exposures that would be within health-based guidelines. Concerned citizens provided information that seemed to suggest otherwise. In the end, communication, education, and compromise led to a favorable result.

**Key Words:** cremation, mercury, dioxins, health risk assessment, permitting.

## INTRODUCTION

The siting of new crematories often involves consideration of impacts to ambient air from exhaust gases. Traditionally, the impacts of interest have been the potential for smoke and odors, but more recently, emissions of trace quantities of potentially toxic pollutants have also become concerns (Rahill 2008).

In terms of emission rate thresholds, crematories are not major sources of air pollution, so that oversight by environmental regulators at the Unite States federal

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and state level is minimal. At the local level, however, interest and oversight can be both intensive and extensive. This is especially true if the owners of a proposed facility are seeking a change in local zoning, a special use permit, or other approvals to be granted (or denied) at the level of the town, city, or county.

In what follows, we describe our analysis of impacts to ambient air and potential health-risks there from, due to emissions of trace pollutants from a proposed crematory. The crematory was proposed to be located next to a long-standing and well-regarded funeral home, located in a residential/mixed-use neighborhood in a small city in Virginia. Several neighbors expressed concerns about airborne emissions in general, and about polychlorinated dibenzodioxins and furans (PCDD/Fs; "dioxins") and Hg in particular. Our assignment was to determine whether these concerns were valid; and, if so, in what ways the proposed facility might be altered in order to render impacts acceptably small.



## METHODS

Our assessment proceeded in three steps. First, we estimated the amounts of PCDD/Fs and Hg that might be emitted from the proposed facility. To estimate emissions of PCDD/Fs, we obtained emission factors from the U.S. Environmental Protection Agency's (USEPA's) Webfire database system (http://cfpub.epa.gov/webfire/). These factors derive from testing in 1992 of a crematory in California. Per standard health-risk assessment practice, we multiplied each congener-specific emission factor by its "toxic equivalency factor," as established by the World Health Organization (WHO 2005), to generate a toxicologically equivalent effective emission rate of 2,3,7,8-tetrachlorodibenzo(*p*)dioxin (2,3,7,8-TCDD), the congener for which the largest amount of toxicity data are available. Assuming that non-detected congeners might be present just at their analytical limits of detection, we derived an emission factor of 0.735 $\mu$g 2,3,7,8-TCDD toxic equivalents (TEQs) per cremated body. For our analysis, we assumed that the proposed facility would cremate four bodies per day (d), yielding an estimated PCDD/F emission rate of approximately 3 $\mu$g 2,3,7,8-TCDD TEQs per day.

With regard to Hg, the amount emitted during cremation depends on the amount of Hg in the cremated body, which depends in turn primarily on the body's number and weight of silver-Hg amalgam dental restorations. Mercury emissions from crematories have been measured or modeled in various ways (reviewed in NESCAUM 2011; Mari and Domingo 2010; Rahill 2008; Tetra Tech 2007). Because the emissions datasets are few, highly variable, and may not be representative of the case at hand, we relied instead on a mass balance analysis by Cain and co-workers (2007), which yielded an average of 3 g of Hg emitted per cremated adult. Based on this estimate, combined with our assumption that the proposed facility would cremate four bodies per day, we estimated an Hg emission-rate of 12 g/d.

Second, we modeled the dispersion of the assumed emissions of PCDD/Fs and Hg into ambient air to determine levels of exposure to these chemicals. In particular, we used the USEPA air dispersion models ISCST3 and AERMOD (USEPA 1995b, 2004) to estimate the potential increases in PCDD/Fs and Hg in air at nearby residences and schools. We assumed regulatory default model options along with rural land use and flat terrain, according to USEPA (2005) guidelines. Mercury and PCDD/F

emissions were assumed to be released over a facility operating period from 8:00 a.m. to 9:00 p.m. (per the special use permit conditions). Stack parameters used as model inputs were determined from engineering drawings and technical specifications, and include an emission height of 26.75 ft, a stack exit diameter of 20 in, an effluent exit temperature of 1100°F, and an effluent flow rate of 2500 $ft^3$/min. Aerodynamic plume downwash was evaluated based on the dimensions of the existing funeral home and proposed crematory building. Five years of hourly meteorological data observations from the nearest airport were used to predict concentrations over grids of densely spaced receptor locations. Concentrations were modeled at ground level and at "flagpole" heights of 5, 10, and 15 m above ground, in order to evaluate plume impacts at neighboring, multi-story townhouses.

Third, we compared the predicted impacts with health-based guidelines, in order to determine whether these impacts would be acceptably small.



## RESULTS

With regard to PCDD/Fs, we estimated a worst-case impact to ambient air of 0.0008 pg/$m^3$ 2,3,7,8-TCDD TEQs at modeling locations throughout the residential areas to the east of the proposed crematory, and a worst-case increase of 0.0005 pg/$m^3$ at the nearest neighborhood school. To determine whether these dioxin impacts would be acceptably small, we first translated them into doses by assuming that a person would be at the point of maximum impact for 24 h/d, day in and day out; and, using "standard values," that he or she would weigh 70 kg and breathe 20 $m^3$ of air daily. Our resulting worst-case dose-estimates were thus 0.0002 pg/kg-d in the residential area and 0.0001 pg/kg-d at the school. For a child weighing 15 kg and breathing 10 $m^3$/d air, the corresponding dose-estimates were 0.0005 pg/kg-d and 0.0003 pg/kg-d.

To then determine whether these doses would be acceptable, we compared them with the "reference dose" (essentially, an acceptable daily intake) for 2,3,7,8-TCDD recently published by the USEPA (2012), which is 0.7 pg/kg-d 2,3,7,8-TCDD. Since our conservatively predicted incremental doses are thousands of times smaller than this acceptable limit, they would not be expected to harm health.

With regard to Hg, the maximum incremental concentration of Hg in the residential neighborhood was estimated to be 3 ng/$m^3$, and the predicted impact at the nearest school was estimated to be 2 ng/$m^3$. To evaluate whether these airborne concentrations of Hg are acceptably small, we compared them with exposure guidelines and limits that have been derived by various groups of regulatory toxicologists, whose tasks are to protect industrial workers and/or the general public, including infants. The occupational guidelines apply to exposures that may occur 8 h/d, throughout a working lifetime. Similarly, the guidelines for the general population represent long-term average concentrations (typically calculated as annual averages) expected to be safe over a lifetime. These values are provided in Table 1. Note that the predicted maximum incremental impact of Hg in ambient air (3 ng/$m^3$) is well within these long-term, health-based guidelines.

As just noted, the ambient air impacts of Hg that we predicted—and the guidelines against which we measured them—are long-term average concentrations. However, some states, including Virginia, also have guidelines for allowable "peak" exposures

**Table 1.** Benchmark concentrations of Hg in air.

| Type of exposure | Concentration ($ng/m^3$ Hg in air) | Regulatory/scientific agency |
|---|---|---|
| Health-based exposure limits/guidelines for workers | 100,000 | OSHA (2007) |
| | 50,000 | NIOSH (1992) |
| | 25,000 | ACGIH (2001) |
| Health-based exposure guidelines for the general population | 300 | USEPA (1995a) |
| | 200 | ATSDR (1999) |
| | 100 | Virginia DEQ (2012) |



that might occur over a worst-case hour. In particular, the hourly ambient air guideline for Hg set by regulators at the Virginia Department of Environmental Quality is 2,500 $ng/m^3$ Hg in air. For purposes of our analysis, we assume that this guideline would be enforced as are several federally enforceable standards, such that at least 99% of the hourly impacts at the maximally affected residence would have to be smaller than this guideline. To predict hourly impacts, we performed a probabilistic analysis that considered (i) the variability in the Hg content of human bodies, based on dental restoration counts from the National Health and Nutrition Examination Survey (NHANES) and various other factors (as estimated by Craft 2012) and (ii) hourly meteorological conditions that influence atmospheric dispersion and transport. Our analysis indicated that 99.99% of the predicted hourly impacts at the maximally affected residence would be smaller than the 1-h ambient air guideline-limit.

We would add that because moderate concentrations of Hg in air are not acutely toxic— but can, of course, be toxic given chronic over-exposures—compliance with long-term guidelines is more important than compliance with short-term limits. Indeed, toxicologists at USEPA and the Agency for Toxic Substances and Disease Registries (ATSDR) have set guidelines only for long-term, and not short-term, exposures to Hg. This is because Hg is not a respiratory irritant, and acutely toxic concentrations essentially cannot be reached in ambient air (Magos and Clarkson 2006).

We note also that dentists appear to be increasingly using non-Hg-amalgams to repair cavities (Figure 1), and the total number of restorations per person also appears to have been declining since at least 1980 (Eklund *et al.* 1997; Eklund 2010). Thus, all other things being equal, emission-rates of Hg from crematories are likely to decline over time (and to otherwise be smaller than assumed in our conservative analysis).

## DISCUSSION AND RESOLUTION

Community members concerned about new projects increasingly turn to the Web for information. However, as we all do or should know, not all such information is evidence-based, unambiguous, or otherwise reliable. Complicating matters is the fact that decision-makers, such as city council members, may not be completely

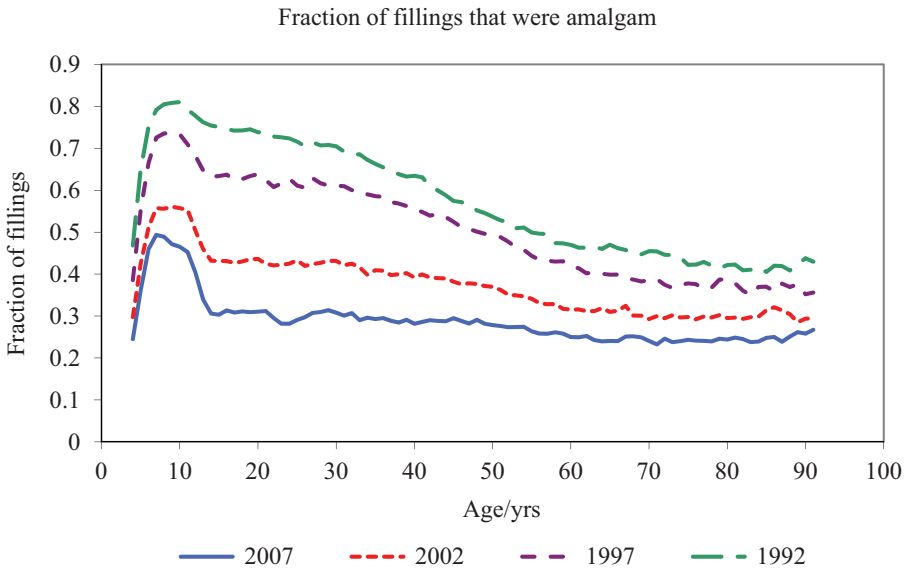


**Figure 1.** The fraction of new dental fillings that were amalgam, based on insurance claims of 1.25 to 1.84 million people in Michigan, USA (data from Eklund 2010). (Color figure available online.)

conversant with environmental sciences, toxicology, and other aspects of health risk assessment—and rarely have the funds to hire technical experts on whom they might rely.

In the case at hand, one concerned citizen found and submitted Figure 2 to the city council, a figure that apparently was adapted from the site No2Crematory.wordpress.com. The bar chart looks worrisome indeed, except that, the more you look, the less clear it is just what is being presented. In particular, in what way is <25 g the "EPA maximum 'safe' exposure level over 1 year"? No citation is provided, and we could not reproduce this value given any standard toxicologic approaches. Emissions of 25 pounds of Hg annually do distinguish a "major" source from a "non-major" source of pollution per USEPA's Clean Air Act regulations, but, of course, such distinction does not separate "safe" from "unsafe" facilities—and in any event, since 1200 g is 2.6 lbs, a crematorium would be classified as a "non-major" source. The concerned citizen could not have known this, and took the website's "information" as fact.

Another concerned citizen submitted to the city council a draft report from an air quality engineer with the Monterey Bay Unified Air Pollution Control District in California, entitled, *Crematory Toxic Emissions Inventories, Risk Assessments, and Risk Reduction Measures* (Craft 2012). The Executive Summary reads, in part:

> The information contained in this report shows that although many toxic substances are emitted from crematory operations, mercury is the most significant substance impacting people residing or working nearby. . . . Downwind mercury concentrations can be above the level the State of California has identified as having no acute adverse health effects.

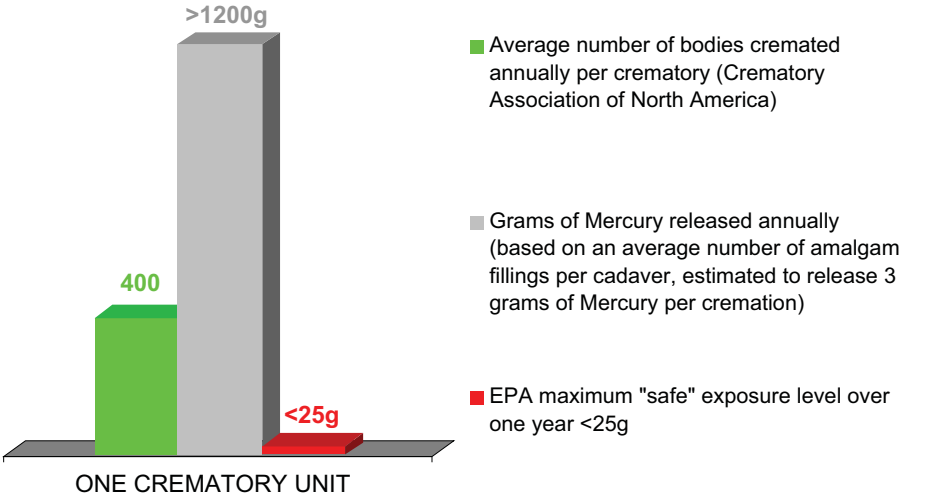


**Figure 2.** Erroneous bar chart, available at http://no2crematory.wordpress.com/faq/. (Color figure available online.)

On the face of it, this information is also worrisome. And, unfortunately, decision-makers often have little time to read beyond the Executive Summary. The body of the report indicates that the "downwind concentrations" alluded to are not measurements, but instead modeled estimates. These estimates were generated using "worst-case" estimates of Hg emission-rates, and a screening-level air dispersion model (SCREEN3)—and were reported at a (theoretical) location only 20 m away from the exhaust stack of the (theoretical) crematory. Moreover, the "level the State of California has identified as having no acute adverse health effects"—600 ng Hg/$m^3$ of air (OEHHA 2008)—is likely based on a misinterpretation of the mechanisms by which 1 h/d exposures to pregnant rats of mg/$m^3$-level concentrations of Hg vapor are toxic to their offspring (Danielsson *et al.* 1993).

Needless to say, discussing the technical details of issues such as these in public meetings is difficult at best, and made more difficult still by genuine fears and distrust. In the case at hand, the project's developer met with neighbors, agreed to limit operations in various ways, to plant large numbers of evergreen trees and address other aesthetic concerns, and to otherwise partner with the neighbors to mutual benefit. When all was said and done, by a vote of 4 to 3, the special use permit was granted by the city council.

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