Human Health Risks from Mercury in Concrete and Wallboard Containing Coal Combustion Products

Technical Brief – *Coal Combustion Products–Environmental Issues*

Overall Summary

This technical brief presents an overview of a risk assessment conducted to evaluate potential human health risks from mercury in concrete and wallboard manufactured using coal combustion products. Using many assumptions that tend to overestimate exposure and toxicity, this risk assessment indicated that the mercury in coal fly ash concrete and flue gas desulfurization gypsum wallboard (both in use and after disposal in landfill) does not pose a health concern. Specifically, the calculated risks from gaseous mercury were well below the United States Environmental Protection Agency's risk target of 1 (hazard quotients ranged from 0.00003 to 0.0015), demonstrating negligible risk from mercury from use and disposal of concrete and wallboard containing coal combustion products. Additionally, the estimated mercury exposures from concrete and wallboard containing coal combustion products were at or below levels commonly encountered in indoor and outdoor environments.

Introduction

The process of burning coal to generate electricity creates several distinct coal combustion products (CCPs), including coal fly ash (CFA) and flue gas desulfurization (FGD) gypsum. CCPs can either be stored in landfills or surface impoundments, or recycled for a variety of beneficial uses. In 2007, about 41% (approximately 51 million tons) of the total CCPs generated nationwide by coal-burning power plants were beneficially recycled. Not only does the beneficial use of CCPs conserve natural resources and reduce the need for landfills and ponds, but CCPs have also been found to improve the quality and performance of many final products.

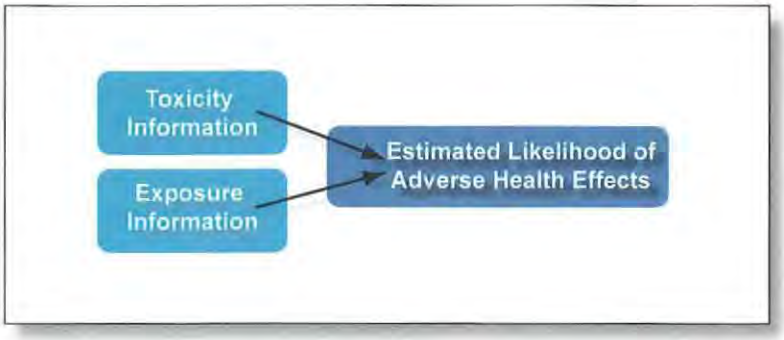

Figure 1: Risk Assessment Basics

Two of the most widespread beneficial uses of CCPs are the use of CFA in concrete and the use of FGD gypsum in wallboard. The American Coal Ash Association estimated that about 14 million short tons of CFA were used in concrete and grout products in the United States in 2007. Approximately 9 million short tons of FGD gypsum were used in wallboard products in 2007.

Coal and its combustion products contain trace amounts of mercury. In an effort to reduce mercury emissions from coal burning, power plants are beginning to implement technologies that capture mercury, which can lead to an increase in the concentration of mercury in fly ash and FGD gypsum. Because the mercury in CCPs can potentially volatilize or leach, it is important to examine potential health impacts from mercury associated with the use of CCPs in wallboard and concrete.

The Role of Risk Assessment

Risk assessment is a tool that can be used to examine whether the use of CFA in concrete or FGD gypsum in wallboard will present a human health concern. In general, the aim of a risk assessment is to determine the likelihood of adverse health effects in an individual or population by estimating potential chemical exposures and relating these exposures to information on chemical toxicity (Figure 1). Conducting a risk assessment is important because the mere presence of a chemical in the environment or a product does not mean that people will be exposed in a manner or at a level sufficient to cause a health problem.

It is important to note that in order to ensure adequate health protection, risk assessments by design tend to use toxicity and exposure assumptions that overestimate risks.

To investigate potential health concerns from exposure to mercury from CFA and FGD gypsum in building materials, EPRI sponsored a risk assessment that examined four exposure scenarios:

1. CFA concrete use in a classroom

2. FGD gypsum wallboard use in a classroom

3. FGD gypsum wallboard use in a residence

4. CFA concrete and FGD gypsum wallboard disposed of in a construction and demolition (C&D) landfill

The results of this risk assessment are summarized here; complete details and supporting references are provided in the final report prepared for EPRI.[1]

Risk assessments should consider all potential pathways of exposure. For mercury in concrete and wallboard, volatilization of mercury (while in use or in a landfill) would be expected to be the major pathway of exposure for an individual. For individuals spending time in a house or classroom, their exposure from dermal contact or incidental ingestion of these materials is unlikely to be significant; concrete and wallboard usually have a protective coating, such as paint, epoxy, or wallpaper, which would effectively limit any direct contact with mercury in these materials.

In landfill settings, as water from rain or other sources seeps through a landfill, it can come into contact with disposed concrete or wallboard containing CCPs, potentially leaching mercury and mixing with groundwater, which may be used for drinking water. Numerous research and field studies by EPRI and others have been conducted on the leaching of mercury from CFA and FGD. These studies collectively show that the leaching of mercury from CCPs is negligible, typically in the part per trillion range (which is well below the maximum contaminant level of 2 part per billion established by US EPA). US EPA has estimated long-term release of mercury from CCPs and found that mercury in leachate ranged from less than 0.02 to 5% of the total amount of mercury in the CCPs. Given that the mercury concentration in leachate is less than the drinking water limit, the exposure to mercury from CCPs from consumption of drinking water is expected to be negligible.

Mercury Toxicity Information and Its Use in Risk Assessment

At high exposures, gaseous mercury can cause adverse health effects. Studies have shown that workers exposed to high concentrations of gaseous mercury (25,000 ng/m^3) can experience a variety of neurological disorders such as hand tremor, memory problems, and irritability; there is also evidence of slight dysfunction of the autonomic nervous system.

Based on available toxicology information, US EPA develops reference concentrations (RfCs) for use in risk assessments. An RfC represents a chemical air concentration that, over a lifetime of exposure (24 hours a day, 7 days a week), is unlikely to cause any adverse health effects (see side box). When developing RfCs, US EPA uses several conservative assumptions to ensure the RfC will protect the whole population against adverse health effects, even potentially susceptible members of the population, such as children and the elderly. Based on the worker studies described above in which health effects were observed at 25,000 ng/m^3, US EPA has applied several safety factors to develop an RfC of 300 ng/m^3 for elemental mercury (the type of mercury that can volatilize from concrete and wallboard).

Exposure Information and Its Use in Risk Assessment

An essential element of a risk assessment is the exposure assessment. The purpose of an exposure assessment is to ask *what, how, where, who, and when* to estimate *how much* of a chemical to which an individual or population might be exposed.

The answers to these questions for this risk assessment are presented in Table 1.

US EPA defines an RFC as:
"An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime."

Estimating Air Concentrations

Mercury Emissions from Concrete and Wallboard

A critical component of this exposure assessment is understanding how much mercury volatilizes from products and the resulting indoor or outdoor air concentrations that an individual might breathe.

For this risk assessment, information on mercury volatilization from concrete was obtained from a laboratory study that measured mercury gas from CFA concrete during the curing process, when mercury emissions would be expected to be the highest. The study demonstrated that mercury volatilizing from CFA concrete diminished over time, and estimated that by 12 weeks the CFA concrete had the same mercury emission rate as conventional concrete (*that is.,* concrete made with ordinary portland cement). The resulting emission rate was 2.8 ng/m^2-hour.[2]

Information on mercury volatilization from wallboard was obtained from a laboratory study that measured mercury emissions from newly manufactured wallboard. The average emission

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
What?	Mercury vapor from CFA concrete used for walls and flooring	Mercury vapor from FGD gypsum wallboard used for walls and ceiling	Mercury vapor from FGD gypsum wallboard used for walls and ceiling	Mercury vapor from CFA concrete and FGD gypsum wallboard in a C&D landfill
How?	Indoor air inhalation	Indoor air inhalation	Indoor air inhalation	Indoor and outdoor air inhalation
Where?	In a classroom	In a classroom	In a residence	Outside a residence
Who?	Children and adults	Children and adults	Children and adults	Children and adults
When?	During school hours- 200 days/year, 5 days/week, 6.7 hours/day, for 16 years	During school hours- 200 days/year, 5 days/week, 6.7 hours/day, for 16 years	During time at home- 350 days/year, 7 days/week, 16 hours/day for 30 years	During time at home- 350 days/year, 7 days/week, 16 hours/day for 30 years

Table 1: Exposure Assessment Information

rate of the wallboard samples was 0.25 ng/ m^2-hour.[3]

Estimating Indoor Air Mercury Concentrations

Once information on how much mercury is expected to volatilize from concrete and wallboard is known, one can estimate the air concentration of mercury in a room (such as in a classroom or in a house) using assumptions regarding:

- How fast the air turns over in a classroom or house (the air exchange rate)
- The volume of a room or house
- The surface area of floors and walls for concrete use, and walls and ceiling for wallboard use

This information is then used in a well-accepted indoor air mass balance model to estimate the concentration of mercury in a room attributable to the concrete or wallboard.

Estimating Outdoor Air Mercury Concentrations

To quantify exposure from wallboard and concrete disposed in a C&D landfill, it was necessary to use an air model to estimate outdoor air concentrations. The air model used in this risk assessment, US EPA's SCREEN3 model, predicts the 1-hour maximum mercury air concentration at the location with the highest exposure under worst-case weather conditions (that is, weather conditions that would be expected to produce the highest chemical exposures). To estimate the exposure from a landfill using this equation, it is necessary to have information on:

- The amount of mercury expected to volatilize from landfill materials
- Landfill size (length and width)
- The total weight of materials disposed in the landfill
- How much of the landfill is filled with concrete *and* wallboard vs. other materials

Calculating a Time-Adjusted Exposure

In accordance with US EPA guidance, an individual's risk is then calculated for a time-adjusted exposure by considering:

- How many hours a day an individual is exposed (exposure time)
- How many days a year an individual is exposed (exposure frequency)
- How many years an individual is exposed (exposure duration)

The time-adjusted exposures calculated for the scenarios evaluated in this risk assessment are presented in Table 2 in the Risk Results section that follows.

Risk Results

In the final stage of the risk assessment, the time-adjusted exposures were used to determine whether the mercury volatilizing from wallboard and concrete will be a health risk. This is accomplished by calculating a hazard quotient. As shown in the equation below, a hazard quotient is equal to the time-adjusted exposure concentration divided by the US EPA RfC (300 ng/m^3 for volatile mercury). In accordance with US EPA guidance, if the hazard quotient is less than or equal to 1, the exposure is not expected to pose a health risk.

$$\text{Hazard Quotient}^* = \frac{\text{Time - Adjusted Exposure } (ng/m^3)}{\text{RfC } (ng/m^3)}$$

*A Hazard Quotient of < 1 Indicates No Health Risk

Table 2 and Figure 2 present mercury inhalation risks from CFA concrete and FGD gypsum wallboard (expressed as a hazard quotient). The hazard quotients range from 0.00003 to 0.0015. Because these values are considerably lower than 1, potential mercury exposures from CFA concrete and FGD gypsum wallboard are not expected to be a health concern. Another way to interpret these results is that the time-adjusted mercury exposures are 650 to 33,300 times <u>lower</u> than the RfC (which represents a concentration considered safe to breath over a lifetime) and 54,000 to almost 3,000,000 times <u>lower</u> than the concentration at which adverse health effects have been observed in workers (at 25,000 ng/m^3).

While most of the assumptions in this risk assessment reflect typical exposure conditions, several conservative assumptions were used, including that an individual would be exposed at the 1-hour maximum modeled concentration in the location with the highest predicted mercury concentration over the entire exposure period. A separate risk assessment using less typical and more high-end exposures was also performed (details not included here). Even using the high-end assumptions, estimated exposures did not pose a health risk (hazard quotients ranged from 0.00021 to 0.015) and were at or below background.

Background Exposures to Mercury

Additional perspective on the potential risks of mercury exposure from the use of CCP building materials can be gained by comparing modeled mercury concentrations for the various scenarios to background levels of mercury.

Mercury is a naturally occurring metal found in the environment mainly as elemental mercury or inorganic mercury compounds in water, soil, and air. Typical background mercury concentrations range from 10 to 20 ng/m^3 in urban outdoor air.

Scenario	Modeled Exposure (ng/m^3)	Time-Adjusted Exposure (ng/m^3)	Hazard Quotient
Concrete			
•Classroom	0.8	0.122	0.0004
Wallboard			
•Classroom	0.06	0.009	0.00003
•Residence	0.72	0.46	0.0015
C&D Landfill			
•Nearby Residence	0.47	0.3	0.001

Table 2: Risk Results

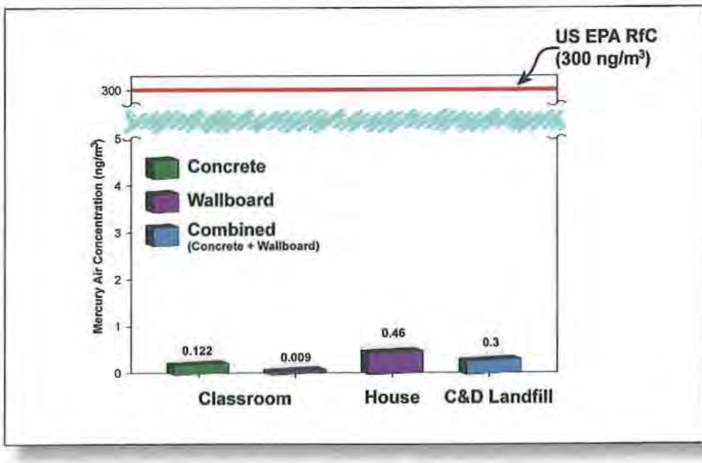

Figure 2: Time-Adjusted Mercury Exposures Compared to US EPA's RfC

Mercury can also be found in common household items (*for example,* thermometers, fluorescent light bulbs, electrical switches, barometers, gas regulators, and batteries). The mercury in these devices is normally housed in a glass or metal container and does not generally pose a risk unless the item is damaged or broken. However, mercury vapors may be released into indoor air from spills, such as those from broken thermometers or damaged electrical switches. Because spilled mercury is difficult to remove from clothing, furniture, carpet, floors, and walls, these sources of exposure can remain for months or years. Despite the relatively high levels reported in such spills, associated adverse health effects have rarely been noted. Due to the many different sources of mercury in indoor settings, indoor mercury air concentrations are typically higher than outdoor background concentrations of mercury. For example, in a study of indoor residences and office buildings in New York City, Carpi and Chen found that indoor mercury concentrations ranged from 4 to 523 ng/m^3.[4]

Figure 3 graphically displays how the modeled mercury air concentrations for each scenario compares to background levels of mercury in urban outdoor air. All of the mercury concentrations estimated in this risk assessment are within the range of or below background levels typically measured in both indoor settings and outdoor air.

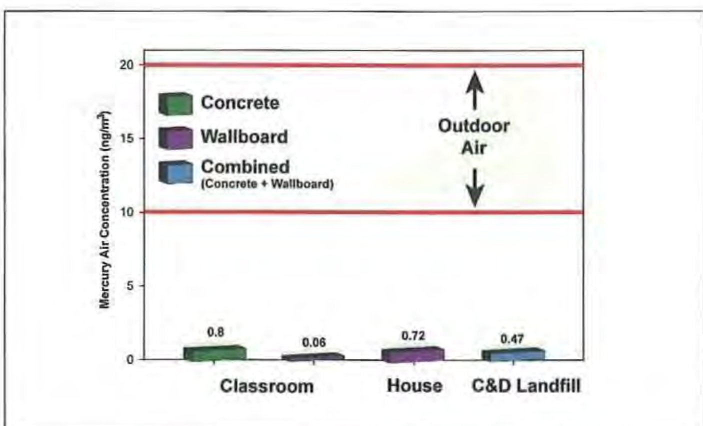

Figure 3: Estimated Indoor and Outdoor Concentrations Compared to Outdoor Background

Conclusions

Using many assumptions that tend to overestimate exposure and toxicity, this risk assessment shows that the mercury in CFA-concrete and FGD gypsum wallboard (both in use and after disposal in a landfill) does not pose a health concern. Moreover, the estimated mercury exposures from concrete and wallboard containing CCPs are at or below levels commonly encountered in indoor and outdoor environments.

References

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4. Carpi, A; Chen, YF. 2001. *Gaseous elemental mercury as an indoor air pollutant.* Environ. Sci. Technol. 35:4170-4173.

Copies of this Technical Brief may be obtained by eligible organizations and individuals by contacting the EPRI Customer Assistance Center at 800.313.3774, or email askepri@epri.com

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