

# **Summary of Research on Mercury Emissions from Municipal Landfills**

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## **Why are Mercury Emissions from Municipal Landfills a Potential Problem?**

Mercury is a potent neurotoxin that can affect the brain, liver and kidneys, and cause developmental disorders in children. Young children and developing fetuses are especially at risk.

Mercury is found in a variety of products, such as fluorescent and other lights, batteries, electrical switches and relays, barometers, and thermometers, much of which ends up in municipal landfills. The mercury contained in these products can evaporate into the air or leach into the groundwater from the landfills.

Researchers are just beginning to quantify and understand how much mercury is emitted to the atmosphere from landfills, and the data suggest that potentially important losses are occurring.

Mercury leaching from landfills into groundwater has been studied more than air emissions. Available data show that mercury in groundwater can exceed drinking water standards from older, unlined landfills, but is less likely to leach into groundwater from landfills that are lined and use leachate collection systems. Depending on how the leachate is treated, however, mercury collected in leachate systems may reenter the environment.

## **AIR EMISSIONS:**

### **How is Mercury Emitted to the Air from Landfills?**

Mercury comes in various forms. Metallic, or elemental mercury, is an inorganic form of mercury that is used in products, such as electrical switches, fluorescent bulbs, and thermometers. It is a liquid at room temperature, and like any liquid it evaporates into the air as a gas.

When products containing elemental mercury break in the waste stream, the mercury is released and begins to evaporate. Gaseous mercury can then be emitted at various stages of the solid waste disposal process, including:

- on the way to a landfill or other waste management facility (from collection containers, transport vehicles, and transfer stations);
- from the working face or active portion of the landfill, and during waste handling operations (i.e., transport, dumping, spreading, compacting and burial);
- from landfill gas vents (many municipal sites collect the methane gas produced at landfills and either burn it, harness it as an energy source, or vent it to the atmosphere);
- from the surface of covered, inactive portions of landfills.

## **Summary of Research on Mercury Emissions to Air**

Steven Lindberg and his colleagues at Oak Ridge National Laboratory (ORNL) have conducted the majority of research on mercury emissions from landfills, studying six municipal sites in Florida. More recently Lindberg teamed up with researchers from Minnesota and Washington State to study additional landfills in three other states (CA, DE, & MN). The results of these latter studies are not yet published (Lindberg et. al., in press; Southworth et. al., in press; Lindberg et. al. in review), but the author reports that their findings reinforce the results of the original Florida studies (Lindberg and Price, 1999; Lindberg et. al., 2002).

### **Key Findings:**

#### **1. Mercury losses occur through two main pathways, the working face and landfill gas vents**

The working face (WF) is where waste is trucked in from transfer stations, deposited, compacted and covered with fill material. The delivery and crushing activities can cause the release of the mercury from the products.

ORNL researchers measured mercury concentrations upwind and downwind of the working face at several Florida landfills, finding downwind mercury concentrations significantly elevated over upwind concentrations—often 30 to 40 times higher. Some measurements reached 100 nanograms per cubic meter ( $\text{ng}/\text{m}^3$ ) downwind, a level approaching the EPA Reference Concentration<sup>1</sup> (RfC) of  $300 \text{ ng}/\text{m}^3$  (Lindberg, 1999b).

The ORNL researchers also found that working face emissions correlated with delivery, dumping and crushing operations. Spiking one transfer truck with a number of fluorescent bulbs, the researchers were able to track the mercury lost to the atmosphere during routine WF activities. Using several models, the ORNL group estimated mercury flux, or flow, at the working face during delivery of MSW at levels more than 1,000 times greater than background soil mercury flux in Florida (Lindberg, 1999b).

ORNL researchers measured mercury inside the landfill gas vents at concentrations ranging from a few hundred to several thousand  $\text{ng}/\text{m}^3$ . The lower end is comparable to levels researchers detected in landfill gas at four Swiss municipal sites (Baccini, 1987). Although the higher end is equivalent to levels emitted by a coal-fired utility plant, the volume of gas emitted at a landfill is considerably lower. Consequently, the overall contribution of mercury to the atmosphere from municipal landfill gas is small in comparison to coal-fired power plants. However, there may be important contributions of mercury to the atmosphere in the immediate local area near the landfill.

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<sup>1</sup> The reference concentration is a screening tool used to help risk assessors determine where to focus their investigations into hazardous exposures; adverse health effects do not necessarily result from exposure at the reference concentration.

## **2. Landfills are a major source of the more toxic, organic mercury**

Once buried, some of the inorganic mercury in the landfill is converted by bacteria living there into a more toxic form, called organic or methylated mercury. Organic mercury can be released into the atmosphere from landfills in the same way that inorganic mercury is released.

Researchers have measured one organic mercury compound, dimethyl mercury, from gas destined for landfill venting at levels 1,000 times higher than what has been measured in open air (Lindberg, 2001).

Flaring, or burning landfill gas before emitting it to the atmosphere, destroys organic forms of mercury, but many landfills do not use flaring. Flaring does not destroy inorganic mercury.

Organic mercury is primarily a local pollution concern because it probably deposits quickly after being emitted. Once deposited, it can bio-concentrate up the food chain.

## **3. Mercury is also lost before it reaches the landfill**

Though more difficult to quantify, ORNL researchers estimate that the amount of mercury lost during collection, storage, compacting and transfer activities may be comparable to what's lost at the working face. They base this conclusion on amounts of mercury measured in dumpsters and open pits at transfer stations.

At one landfill, mercury was detected at concentrations greater than 10 times background levels in 20 of 200 dumpsters transported to the landfill. Mercury levels reached approximately 500 ng/m<sup>3</sup> in these dumpsters (Southworth et al, in press).

During routine truck unloading at a transfer station, Lindberg and his colleagues found mercury concentrations ranging from 30 to 90 ng/m<sup>3</sup>. Background levels averaged 10 ng/m<sup>3</sup> mercury during nonactive periods at a transfer station—suggesting prior mercury contamination. When fluorescent bulbs were intentionally added to the pit at the transfer station, mercury concentrations reached 500 ng/m<sup>3</sup> (Lindberg, 1999b). This level exceeds the EPA RfC, but is still lower than occupational health standards<sup>2</sup>.

Lindberg and other US EPA analysts estimate that nearly 100 percent of fluorescent bulbs break on route to the landfill, based on data from state environmental agencies and a study by Research Triangle Institute (US EPA, 1998, RTI, 1993).

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<sup>2</sup> The Occupational Safety and Health Administration (OSHA) sets a legally enforceable ceiling limit for workplace exposure at 100 micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ). The National Institute for Occupational Safety and Health (NIOSH) sets its recommended exposure limit (REL) for mercury vapor at 50  $\mu\text{g}/\text{m}^3$  as a time weighted average (TWA). The American Conference of Governmental Industrial Hygienists (ACGIH), recommends a threshold limit value (TLV) of 25  $\mu\text{g}/\text{m}^3$  mercury vapor as an average exposure for a normal 8-hour workday.

#### **4. Fluorescent bulbs are significant sources of mercury emissions**

Several researchers have found that a significant amount of mercury is released from broken fluorescent light bulbs disposed at solid waste facilities.

Fluorescent bulbs contain a small amount of mercury vapor and a larger amount of mercury in a phosphor powder or dust form. Researchers assume that the mercury vapor is immediately released when the bulb breaks, but they debate how much mercury is emitted from the powder (US EPA, 1998).

ORNL researchers estimate that as much as 20 to 30 percent of the total mercury in a bulb could volatilize over one week (Lindberg, 1999b), basing this estimate on measurements of the flow of mercury emitted from fluorescent bulbs in closed dumpsters over a week.

Researchers at the New Jersey Department of Environmental Protection have comparable findings. Simulating conditions at a solid waste disposal facility, they found that 17 to 40 percent of mercury was released from low mercury fluorescent bulbs over a two-week period following breakage, with higher temperatures contributing to higher releases of mercury (Aucott, 2003).

The US EPA in contrast estimates that broken fluorescent bulbs emit only 1.2 to 6.8 percent of the total mercury they contain—primarily the mercury vapor, based on studies by the Research Triangle Institute, the National Electrical Manufacturers Association, and Tetra Tech for the Electric Power Research Institute (US EPA, 1998).

#### **Factors Affecting Mercury Air Emissions at Landfills**

ORNL researchers have found that mercury emissions from landfills range widely, and report that there are no simple explanations for the disparities. Some of the factors affecting mercury emissions include:

- Age. Newer, operating landfills produce higher emissions than older, closed landfills. Lindberg speculates that although the older landfills likely contain more mercury wastes, the mercury from these wastes has either already been lost to the atmosphere or been stabilized by sulfur compounds in the landfill.
- Presence of hot spots. Hot spots are areas of the landfill associated with a relatively higher methane gas release and are identified by dead vegetation. Mercury is not more readily lost from hot spots, however, suggesting that the WF is the primary source of airborne Hg release in landfills.
- Active or passive venting of landfill gas. Landfill gas emissions are higher with active venting of landfill gases.
- Flaring. Flaring is the process of burning landfill gas before releasing it to the atmosphere. Flaring converts organic mercury to inorganic forms, but has no known effect on inorganic mercury.

## **GROUNDWATER EMISSIONS:**

### **How does mercury leach from landfills into the groundwater?**

When rain water infiltrates landfills it dissolves organic and inorganic material, forming a toxic leachate that collects at the base of the landfill. Like all metals, mercury dissolves easily in the acidic leachate. Until the late 1980s, landfills were not routinely lined and this leachate was allowed to seep slowly out of the landfill into the soil and groundwater.

Newer landfills are lined with clay and flexible synthetic membranes to prevent leachate from escaping and contaminating the groundwater. The leachate is instead drained through a collection of horizontal perforated pipes and collected by a sump for treatment. After treatment it is discharged to surface water or a sewer system.

However, even liners and leachate collection systems are not fool proof. Several researchers have documented that liners eventually leak (Line and Miklas, 1989) (Bonaparte and Gross, 1990), (Gross, 1990).

Furthermore, depending on how the leachate is treated, mercury may reenter the environment. Any mercury remaining in the leachate post-treatment could be discharged to a sewer system or surface water. Mercury discharged to a sewer system could then be retained in the sewage sludge—which is usually land-filled, incinerated, or applied to land as fertilizer. Lindberg and Price (1999) reported that leachate generated from LFG condensate contained highly elevated concentrations of methyl mercury at one Florida landfill.

### **Summary of Research on Mercury Emissions to Groundwater:**

Many investigations have documented mercury in the groundwater and soil of older, unlined municipal landfills, sometimes at levels exceeding federal guidelines (James, 1977), (North Carolina DEHNR, 1994), (Machado, in press) (ATSDR, no date), (Baccini, 1987). This groundwater contamination could lead to harmful exposure if the mercury reached surface waters or drinking water supplies.

The US EPA Office of Solid Waste summarized available groundwater data from municipal landfills in 1988. Out of 109 leachate samples, 7 percent contained mercury at levels above the safe drinking water limit of 0.002 milligrams per liter (mg/L). Eighty percent were below the detection limit, which varied for each analysis. The average concentration was 0.0008 mg/L.

In 1999 the US EPA Office of Solid Waste conducted a review of 39 Superfund sites on the National Priority List that involved mercury contamination. Ten of these were municipal landfills, 8 of which had mercury in soil or groundwater at levels exceeding federal guidelines (Dynamac Corporation, 1999).

A study of 6 landfills in Massachusetts found mercury in the leachate of lined landfills, but not in the groundwater (Massachusetts DEP, 1996).

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## **REFERENCES**

ATSDR, no date, Health Consultation, B.J. Landfill, Norcross, Gwinnett County, Georgia.

Aucott M, McLinden M, Winka M, 2003, Release of Mercury from Broken Fluorescent Bulbs, *Journal of the Air & Waste Management Association*, 53:143-151.

Bonaparte R. and Gross B.A., 1990, Field Behavior of Double-Liner Systems in Waste Containment Systems: Construction, Regulation, and Performance: ASCE Geotechnical Special Publication No. 26, November 1990, 52-83.

Dynamac Corporation, 1999, Summary Damage of Mercury Incidents from CERCLA RODs, personal communication to Kristina Meson, US EPA from Ronald Lamb, Dynamac Corporation.

Gross B.A., Bonaparte R., and J.P. Giroud, 1990, Evaluation of Flow from Landfill Leakage Detection Layers: Proceedings Fourth International Conference on Geotextiles, Volume 2, The Hague, June 1990, 481-486.

James, 1977. Metals in municipal landfill leachate and their health effects, *American Journal of Public Health*, 67(5):429-432.

Lindberg SE, Price JL, 1999a, "Airborne emissions of mercury from municipal landfill operations: A short-term measurement study in Florida," *J. Air & Waste Management Association*, 49:520-532.

Lindberg SE, Roy K, Owens J, "PaMSWaD, 1999b, (Pathways of mercury in solid waste disposal), ORNL sampling operations summary and preliminary data report for PaMSWaD-I," Brevard County Landfill, February 6.

Lindberg, S.E., D. Wallschlaeger, E. Prestbo, N. Bloom, J. Price, and D. Reinhart. 2001. Methylated mercury species in municipal waste landfill gas sampled in Florida. *Atmospheric Environment* 35: 4011-4015.

Lindberg, S. E., G. Southworth, E.M. Prestbo, D. Wallschläger, M. A. Bogle, J. Price. Gaseous methyl- and inorganic mercury in landfill gas from landfills in Florida, Minnesota, Delaware, And California, *Atmos. Envir.* (in review).

Lindberg, S., G. Southworth, M. Bogle, T. Blasing, H. Zhang, T. Kuiken, D. Wallschlaeger, J. Price, D. Reinhart, H. Sfeir, J. Owens, and K. Roy. Airborne emissions of mercury from municipal solid waste-I: New measurements from three landfills in Florida. JAWMA (in press)

Southworth, G.R.; Lindberg, S.E.; Bogle, M.A; Zhang, H., Kuiken, T.;Price, J.; Reinhart, D.; Sfeir H. Airborne emissions of mercury from municipal solid waste- II: potential losses of airborne mercury prior to landfill. JAWMA (in press).

Line, D.L., and Miklas, M.P., 1989, Detection and Location of Leaks in Geomembrane Liners Using an Electrical Method: Case Histories, 10th National Superfund Conference, November 27-29, 1989, Washington D.C.

Machado, W. et al, Mercury, zinc and copper accumulation in mangrove sediments surrounding a large landfill in southeast Brazil, Environmental Pollution, in press.

Massachusetts Department of Environmental Protection, 1996, Mercury in Massachusetts.

National Electrical Manufacturers Association, 2000, "Environmental impact analysis: Spent mercury-containing lamps."

Personal communication with Steven Lindberg, December 9, 2002.

Truesdale, Bealieu, Pierson, 1993. "Management of Used Fluorescent Lamps: Preliminary Risk Assessment, Research Triangle Institute.

US EPA, Office of Solid Waste, 1998, "Mercury emissions from the disposal of fluorescent lamps, Revised Model."