Compact Fluorescent Bulbs and Mercury Pollution

Using Material Flow Analysis to Prioritize Concerns

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Replacing incandescent bulbs with compact fluorescent light bulbs (CFLs) saves energy. This saving, coupled with the longer life of CFLs in most applications, could be expected to lead to rapid acceptance of the bulbs. However, use of CFLs in the United States, while growing, and higher in some regions such as California and the Northwest, is still relatively low. Various reasons exist for the poor acceptance of CFLs so far, including higher initial cost, unsuitability for certain uses (e.g., dimmable fixtures), and, in some cases, undesirable light quality. One concern that has been expressed is that the bulbs contain mercury. Mercury's toxic properties are well known, and its use in products and release to the environment during these products' life cycles has contributed to widespread mercury pollution.

A material flow analysis, carried out with the use of data available in New Jersey, has been instructive in placing mercury aspects of CFLs in perspective with other uses and releases of mercury.

Because of certain useful properties, mercury and mercury compounds have been intentionally added to products for years, including pharmaceuticals, agricultural chemicals, dry-cell batteries, and paints. Although these uses have been essentially phased out, other uses continue, including chlor-alkalai production, switches and electrical apparatus, dental amalgam, and, as discussed here, fluorescent light bulbs. Mercury also is present in coal, with a typical concentration in the vicinity of 0.1 parts per million (ppm). And, as a naturally occurring element, it is generally present at measurable levels in soils and organic material.

In the case of CFLs, the quantity of mercury contained and likely to be released to the environment over varying time scales corresponding to stages in the product's life cycle should be compared with the benefits of the bulbs in terms of energy savings and also in terms of lowered mercury releases from electricity production. A paper by Eckelman and colleagues (2008), based on a spatially differentiated analysis, indicates that the reduction of mercury pollution by end-of-life treatment of CFLs could be significant.

A material flow analysis (MFA), carried out with the use of data available in New Jersey, has been instructive in placing mercury aspects of CFLs in perspective with other uses and releases of mercury. In this MFA, we used several of the data and assumptions as specified by Eckelman and colleagues (2008). Such an analysis suggests that, for the United States as a whole, widespread use of CFLs would add a relatively small quantity to the mercury pollution burden, and this quantity would be more than offset by reduced mercury emissions from electric power production. (Not

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explored by this analysis is the possibility that there may be other mercury-related issues associated with CFLs, such as exposures to mercury vapor if bulbs are broken in poorly ventilated environments where humans or pets are present for extended periods.)

The first step in this analysis was an assessment of the overall flow of mercury to disposal facilities. A new method, based on the concentration of mercury in municipal solid waste (MSW) incinerator ash, was used. Residual ash and solid waste data were obtained from the monthly summary reports submitted to the New Jersey Department of Environmental Protection (NJDEP) from two MSW incinerators in New Jersey. Total MSW incinerated, percent ash moisture, total ash residue, and total concentrations of mercury in the ash were tabulated on a monthly basis for the period 1995–2007 for one incinerator, and from 2004–2007 for the other. Also submitted to NJDEP as part of air pollution permits for these facilities are quarterly stack test data showing mercury content in the exhaust gas. Mean monthly total content of mercury of the ash was determined and compared with the total amount of waste incinerated. The quantity of mercury in the exhaust gas was added to the quantity of mercury in the ash to arrive at the total amount of mercury in the incinerated waste. The estimated mean concentration and 95% confidence limits for mercury concentration of the MSW processed by the two incinerators was 2.6 ± 0.2 ppm and 0.9 ± 0.2 ppm (Aucott et al. 2009).

The incinerator with the higher concentration of mercury in its MSW receives about six times as much MSW as the other incinerator, and it receives a higher proportion of industrial waste. Based on these two facilities' data, a national average MSW mercury content is likely to be in the general range of 1 to 2.5 ppm. About 250 million (short) tons of MSW are generated yearly in the United States, and about 170 million tons of this are either landfilled or incinerated. Modern incinerators can be expected to capture 95% or more of the mercury in incinerated waste through the use of activated carbon in their emission control systems. This captured mercury, bound to carbon, is transferred to the ash, which goes to landfills. Assuming a mean concentration of 1.5 ppm, these 170 million tons of MSW disposed would represent 250 tons of mercury sent to landfills in the United States each year. Interestingly, this quantity is similar to the amount of mercury used in products in the United States in recent years,[1] and much less than the quantity used in products earlier, which was in the range of 1,500 to 2,000 tons annually from the 1950s through the 1980s.

The fate of mercury deposited in landfills must be considered. Although no data exist on performance of landfills for periods greater than 50 years, available data indicate that releases of heavy metals from landfills are low (Aucott 2008). Based on review of landfill vent stack test data and measurements of leachate concentrations, the New Jersey Mercury Task Force estimated that landfills in New Jersey emit in the range of 10 kilograms (kg) mercury per year to the air (NJDEP 2002). Apportioning this quantity to the entire United States suggests a yearly mercury air emission from landfills in the range of 0.3 tons. Landfills also can be expected to emit mercury in the form of leachate. Data suggest that the mean concentration of mercury in landfill leachate is in the range of 7 micrograms per liter (μg/l).[2] Using this value and assumptions about quantities of landfill leachate suggests that the yearly U.S. emission of mercury to the environment in the form of landfill leachate is in the range of 2 tons.

These estimated emissions from landfills should be compared with the estimated 125 tons of mercury estimated to be released to the air yearly by industrial and other sources in the United States. The USEPA estimates that approximately 50 tons of this total comes from coal combustion. It should be noted that mercury released from landfills is coming from the entire pool of mercury deposited in those landfills, which, because mercury has been used in products since at least the beginning of the 20th century, is likely to be on the order of 50 or more times the current yearly input of mercury to these disposal sites.

How much could CFLs contribute to the flux of mercury to landfills, and to the overall emission of mercury to the environment? CFLs are reported to contain an average of 5 milligrams (mg) of mercury. A new voluntary standard adopted by the National Electrical Manufacturers Association (NEMA) in 2007 limits the mercury content

of CFLs to 5 mg (Eckelman et al. 2008), and many bulbs are reported to already contain less. The United States passed the Energy Independence and Security Act of 2007, which establishes a lighting efficiency standard sufficiently high that it is likely to phase out most incandescent bulbs by 2014. Eventually, with the assumption that most of the several billion incandescent bulbs currently in use are replaced by CFLs, and that the lifetime of CFLs is in fact significantly longer than that of incandescent bulbs, 300 million or more CFLs might be sold per year in the United States, and this many might eventually be discarded yearly as well. At 5 mg each, 300 million bulbs would add 1.5 tons, about 0.6 percent, to the total amount of mercury deposited in landfills each year. Their relative contribution to the total pool of mercury in landfills, and hence to the emissions of mercury from these landfills, would be much lower however, since, as discussed above, the total quantity of mercury in landfills is likely to be much more than the current annual deposition. Even if it is mostly fresh inputs of mercury that contribute to emissions from landfills, CFLs would contribute less than 1% of an emission that totals only 2 to 3 tons per year.

What about breakage of CFLs while in use, or while in the disposal stream? Broken CFLs, if they behave similarly to broken fluorescent tubes, can be expected to release perhaps as much as 40% of the mercury they contain in a two-week period, at the end of which period they would very likely be entombed in a landfill (Aucott et al. 2003). A small amount of mercury can be expected to escape from emission controls at incinerators and be released to the air from incinerated bulbs. Altogether, discarded bulbs might release as much as 0.75 tons to the air, about 0.6 percent of the yearly air emission in the United States. If at some point it proves feasible to recycle a significant percentage of discarded CFLs and so recapture the mercury they contain, the quantity released would be smaller still.

In addition, saving energy reduces emissions of carbon dioxide, a major greenhouse gas. Reductions of emissions of such gases are important, perhaps essential, for future well-being. And, by saving energy, CFLs should contribute to lower emissions of mercury by power plants. It is estimated that residential buildings account for about one third of the nation's electricity use, and that lighting accounts for about 10% of residential energy use. Residential lighting thus represents about 3% of the nation's electricity use. Approximately 50% of U.S. electricity is produced by coal combustion, which, as noted above, emits about 50 tons of mercury per year. At 3% of the total electricity use, residential lighting thus would be responsible for about 1.5 tons of the mercury released by coal combustion. CFLs use about one fourth of the electricity used by an incandescent bulb of similar brightness. So, if they universally replaced incandescent lighting, they might cut this 1.5 ton release to less than 0.5 tons, a reduction of greater than 1 ton of emissions per year.[3] This is more mercury than these bulbs would release to the environment, even if it is assumed that a large portion of them break before they are sequestered in a landfill or recycled.

Based on this materials-accounting analysis, CFLs, even if used much more widely than presently, are not likely to contribute significantly to the anthropogenic releases of total mercury in the environment. If these bulbs are widely adopted, their net effect could be a modest lowering of such releases.

Notes

1. Editor's note: For analysis of mercury in products in the United States, see the article by Cain and colleagues (2007).
2. Based on data from SWANA (2004) as interpreted by the USEPA.
3. This estimated reduction in mercury emissions assumes that reductions in electricity demand are accompanied by proportionate reductions in coal-fired electricity production. The mix of power sources used to generate electricity depends many factors, however, which vary temporally and geographically. A more detailed examination of the degree to which coal combustion would be reduced as electricity needed for lighting was reduced is beyond the scope of this analysis.

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