Elemental Mercury Emission In The Indoor Environment Due To Broken Compact Fluorescent Light (CFL) Bulbs

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Paper control number 553

Introduction

Compact fluorescent light (CFL) bulbs require elemental mercury for operation. Each bulb contains a few milligrams of mercury, a value that has been decreasing over time due to new technologies and methodologies, driven primarily by environmental and consumer concerns. If a CFL breaks, some of the mercury is immediately released as elemental mercury vapor while the remainder is available for emission over time to air via the bulb debris and contaminated indoor surfaces until properly remediated. Remediation is an important step in maintaining indoor air quality as mercury may emit from surfaces for an extended time if not properly cleaned.

In a study designed to investigate the impact of various breakage and cleanup scenarios, the Maine Department of Environmental Protection (2008) observed: initial transient air concentrations following breakage as high as 50 µg/m^3 under one scenario near the CFL breakage; that concentrations varied greatly in time and space; that remediation of carpets was challenging; and that vacuuming contaminated the vacuum and temporarily increased mercury concentrations in the room air. We consider these data, and others like them, to provide a starting point for identifying research needs relating to the assessment of potential mercury exposure and remediation.

Figure 1a: CFLs that qualify for Energy Star use 75% less energy and last ten times longer than standard incandescent bulbs.

Figure 1b: When the glass tubing of a CFL breaks, elemental mercury is released, necessitating proper cleanup and disposal to minimize indoor mercury emissions and concentrations in air.

Why is mercury necessary for CFL use?

CFL bulbs, just as fluorescent bulbs, require mercury for operation as part of their design. When in use, the vapor state elemental mercury generates ultra violet light. This UV light then interacts with the phosphor lining the inner walls of the glass tubing to generate visible light.

EPA recommend steps for CFL debris cleanup

Before cleanup (1) Have people and pets leave the room. (2) Air out the room for 5-10 minutes by opening a window or door to the outdoor environment. (3)Shut off the central forced air heating/air-conditioning system, if you have one. (4) Collect materials needed to clean up broken bulb.

During cleanup (1) Be thorough in collecting broken glass and visible powder. (2) Place cleanup materials in a sealable container.

After cleanup (1) Promptly place all bulb debris and cleanup materials outdoors in a trash container or protected area until materials can be disposed of properly. Avoid leaving any bulb fragments or cleanup materials indoors. (2) If practical, continue to air out the room where the bulb was broken and leave the heating/air conditioning system shut off for several hours.

Mercury emissions from broken fluorescent bulbs

Published research on mercury emissions from lighting

Aucott et al. (2003) generated mercury emission rate equations for fluorescent lamps (FLs) broken in a barrel at three ambient air temperatures in an effort to quantify mercury emissions in time. Equation 1 is their published mercury release rate as a function of time at 30 °C.

$$\text{Mercury Emission Rate} = 0.10 \times t^{-0.70}\ (\text{mg} \times \text{h}^{-1}) \qquad (1)$$

Example scenario of indoor mercury concentrations in air

Elemental mercury is emitted when a CFL is broken. This includes both an instantaneous release of the vapor state elemental mercury present in the bulb prior to breakage, and a time-dependant emission of elemental mercury from the bulb components, such as the phosphor, the glass, etc. and any indoor surfaces contaminated with mercury.

To achieve an estimate of indoor mercury concentrations when a bulb is broken, an example scenario was created for a simple single room at 0.5 ACH which is within the range of average ventilation rates for residential properties. Equation 1 is used as input in the U.S. EPA indoor zonal model IAQX (Guo, 2000) for this example to estimate potential indoor concentrations due to emissions in the absence of cleanup. Model output is presented in Figure 2. Note: While the Aucott emission equation is relevant for spent FLs, it provides perspective for mercury emissions from other lighting products. The authors do not assume a similarity between CFLs and FLs emission rates.

California Reference Level for mercury

While the U.S. EPA does not have a one-hour acute reference level for elemental mercury vapor inhalation, the State of California does (CA.GOV, 2008). This is published as a concentration in air of 0.6 µg/m^3 and is shown on Figure 2 for comparison with modeled concentrations.

This example transient case shows the potential for exceedance of the one-hour acute reference value developed by the State of California. This analysis does not take into consideration effectiveness of remediation, proximity to the emission source and the potential impact on long term background concentrations in buildings.

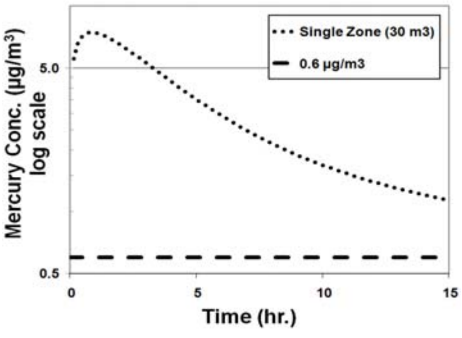

Figure 2: Modelled potential indoor air mercury concentrations following CFL breakage in a single room, compared to the one hour Acute CA-REL (CA.GOV, 2008).

Broken CFL Bulb Cleanup

The U.S EPA, as part of its public outreach program, provides cleanup guidance when a CFL is broken in the indoor environment. As part of this guidance, it is recommended that the debris be cleaned up following 5 to 10 minutes of increased ventilation and some initial steps. Figure 3 shows indoor model results that include the emission rate of Equation 1, but with source removal occurring at 15 minutes to provide a visual of the impact of proper cleanup on indoor mercury concentrations following FL breakage. This is conducted using (a) the average residential building ventilation rate of 0.5 ACH and (b) simulating an open window for additional ventilation at 2 ACH.

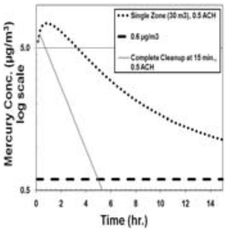

Figure 3a: Using the Aucott emission rate in an example room with 30 m^3, 0.5 ACH, and full cleanup within 15 minutes, the indoor elemental mercury concentrations in air fall below the California one hour reference value within about five hours.

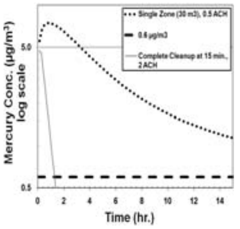

Figure 3b: Using the Aucott emission rate in an example room with 30 m^3, 2 ACH to represent addition ventilation through an open window, and full cleanup within 15 minutes, the indoor elemental mercury concentrations in air fall below the California one hour reference value in less than two hours.

Discussion

Presented here are modeled indoor elemental mercury vapor concentrations based on an empirical model of mercury emissions found in the published literature for fluorescent lamps. These example transient cases show the potential to exceed the one-hour acute reference value developed by the State of California and do not attempt to quantify actual effectiveness of remediation, proximity to the emission source (localized concentrations) and the potential impact on long term background concentrations in buildings.

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