Mercury Vapor Emission from Broken Compact Fluorescent Lamps and Cleanup procedures

Raj Singhvi
USEPA/ERT, Edison, NJ, 08820
Singhvi.Raj@epa.gov; 732-321-6761

A. Taneja
Department of Chemistry, St. John's College,
Dr. B R Ambedkar University, Agra, India

J. Patel, D. Kalnicky, C. Gasser
Lockheed Martin/SERAS, Edison, NJ, 08837

INTRODUCTION

- Compact fluorescent lamps (CFLs) replacing incandescent lamps
- Concern: use of CFLs may adversely affect human health
- Potential for mercury (Hg) release if CFL is broken
- Relevant to policy efforts to phase out incandescent lamps
- Need comprehensive information database for policymakers
- CFL mercury content approximately 2 to 5 milligrams
- NEMA proposed reduction in max from 5 to 4 mg (NEMA, 2010)
- Green Seal Standard (Green Seal, 2009); encapsulated dosing methods to minimize worker exposure during CFL manufacture
- Cleanup/disposal methods for the general public not standardized
- More data needed to standardize guidance

MATERIALS

Chamber: 24” x 18” x 24” (width x length x height) acrylic chamber two compartments (Fig 1), each 24” x 18” x 12 “, effective compartment volume 2.53 ft^3 (0.0716 m^3)

CFL samples: Five popular different spiral CFLs selected based on mercury content

Real-time Mercury Vapor Measurement: Mercury Tracker 3000 Analyzer; portable instrument; Hg concentration in $\mu g/m^3$

Figure 1. Acrylic chamber used for mercury vapor emission studies

EXPERIMENTAL DESIGN

All measurements performed at 72 +/- 2^{o}F.

<u>Mercury Loss From Broken CFLs on Plastic.</u>

- Used one compartment of the acrylic chamber
- CFL in middle of piece of vinyl sheet in cardboard tray in chamber; CFL smashed into small pieces (Fig 2)
- Hg vapor monitored with Mercury Tracker 3000; air flow from the chamber 1.5 L/min (exchange rate of 1.25/hour)
- Hg vapor measurements logged every 15-sec for 24-hours
- Experiment repeated two additional times (triplicate)
- Four other types of CFLs measured in the same fashion

EXPERIMENTAL DESIGN, cont'd…

All measurements performed at 72 +/- 2^{o}F.

Mercury Loss From Beads

- Metallic mercury weighed in plastic dish, placed in chamber, Hg vapor monitored using Tracker 3000
- Used various weights (comparable to mercury content in CFLs) of single beads or two beads of Hg

Mercury Loss From Broken CFLs on Carpet

- Performed for each of the five different types of CFLs
- Same compartment of the acrylic chamber
- Same conditions as for broken CFLs on plastic

CLEANUP

- Cleanup procedures performed between individual experiments to remove CFL debris

- Adequate to start the next experiment when the Hg vapor concentration was less than 0.1 $\mu g/m^3$

Figure 2. Broken CFL (on plastic) in the chamber

CFL BROKEN ON PLASTIC

- Table 1: Percent Hg loss for five CFL bulb types on plastic
- Fig 3: Plots of emission data (average of triplicate runs for each bulb type)
- Average 24-hr Hg loss from broken CFLs 0.6% to 22%
- Hg loss not directly related to Hg content or how Hg is incorporated in the bulb (metallic or amalgam)
- Location of the Hg in the bulb, how bulb is broken, ambient temperature may affect emission after breakage

Table 1. 24-Hour Mercury Loss from CFLs Broken on Plastic

CFL Bulb Type	Hg content (mg)[a]	Average Concentration (µg/m³)[b]	Total Hg Emitted (µg)	% Hg Loss
B-23W	2.57	7.4	15.9	0.6
G-15W	2.42	200	432	18
N-14W	2.18	217	471	22
P-13W	4.75	213	461	9.7
S-13W	1.22	12.4	26.8	2.2

[a] CFL average mercury content (Singhvi, et al., 2011)
[b] Average of three measurements for each bulb type
B, G, N, P – Mercury in bulb as metallic mercury
S – Mercury in bulb as an amalgam

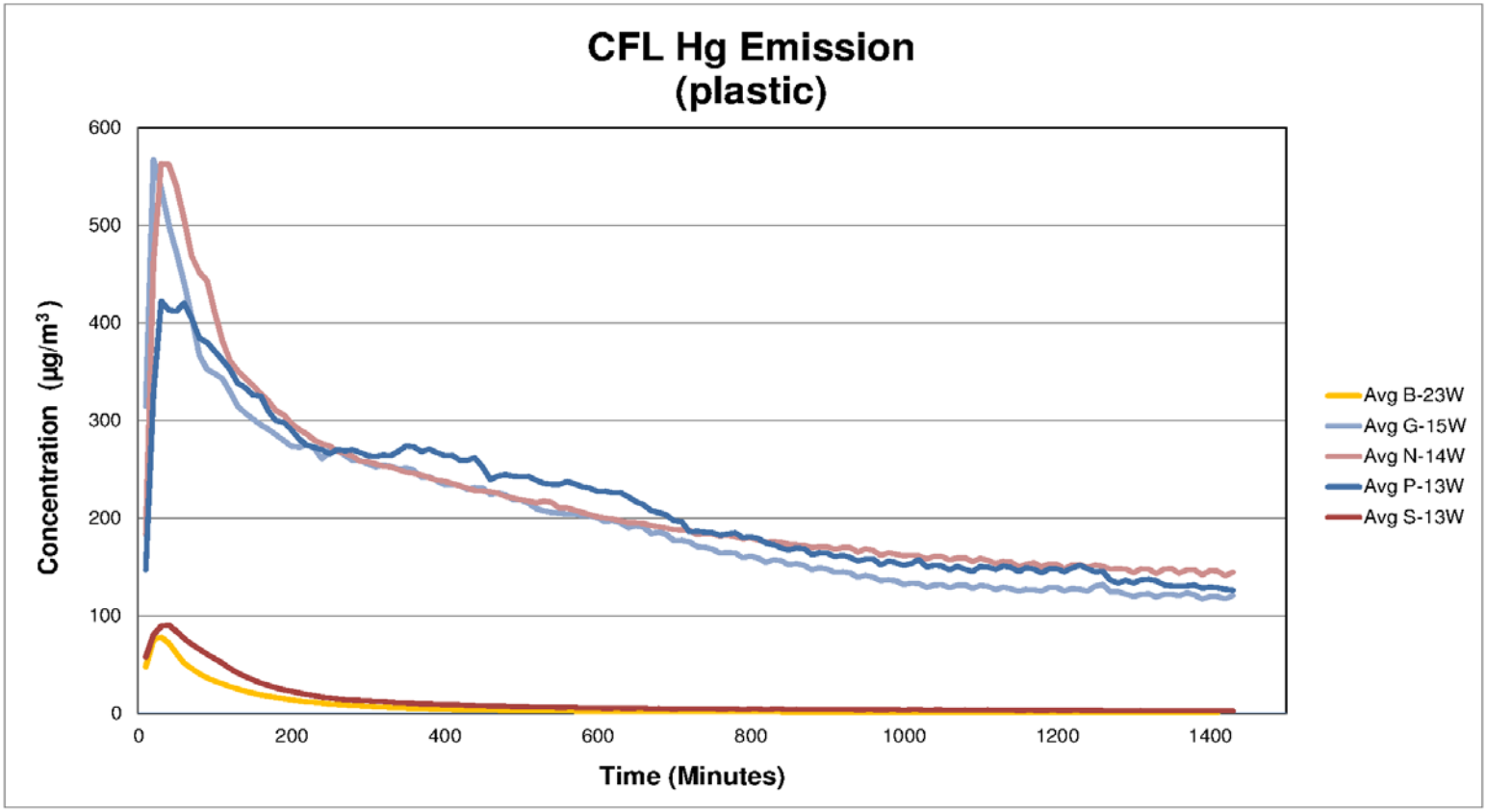


Figure 3. Mercury concentration vs. time for CFLs broken on plastic.

PROJECTED HG CONC FROM CFLs BROKEN ON PLASTIC

- Table 2: Hg concentrations projected for breakage of CFL bulbs in a 12’ x 9.33’ x 8’ room (25.4 m^3) at air exchange rate of 1.25

- Projected concentrations for the B-23W and S-13W bulb types are below the ATSDR minimum risk level of 0.2 $\mu g/m^3$ (ATSDR, 2000)

- Values for the G-15W, N-14W, and P-13W bulb types are above the ATSDR risk level

Table 2. Projected Mercury Concentration for CFLs Broken on Plastic in a Room[a]

CFL Bulb Type	Hg content (mg)	Projected Avg. Conc. for 1.25 Exchanges/hour (µg/m^3)[b]
B-23W	2.57	0.021
G-15W	2.42	0.58
N-14W	2.18	0.62
P-13W	4.75	0.61
S-13W	1.22	0.035

[a] Room dimensions: 12’ x 9.33’ x 8’ (25.4 m^3), 24-hour average values

[b] Predicted based on measured average concentration (Table 1) scaled to room volume using a previously developed model (Singhvi, et al., 2005)

B, G, N, P – Mercury in bulb as metallic mercury

S – Mercury in bulb as an amalgam

MERCURY LOSS FROM BEADS

- Table 3 and Fig 4: Mercury loss from beads with different weights
- Projected 24-hour Hg loss (0.4% to 0.9%) much lower than that for CFLs with comparable Hg content
- Hg may emit at a higher rate from a broken CFL compared to a bead with the same weight of Hg
- Reason not clear; may be due to larger surface area or the presence of mercury vapor in the CFLs

Table 3. Mercury Loss for Beads

Bead weight (mg)	Run Time (hours)	Average Concentration (µg/m³)[b]	Total Hg Emitted (µg)	% Hg Loss (24 hours)[a]
2.90	5.6	11.8	5.93	0.9
3.10	4.6	11.8	4.89	0.8
3.72	6	6.4	3.47	0.4
2.95[b]	6	8.8	4.76	0.6
2.12[b]	6	9.0	4.87	0.9

[a] Projected percent mercury loss for 24-hours

[b] Total weight for two beads

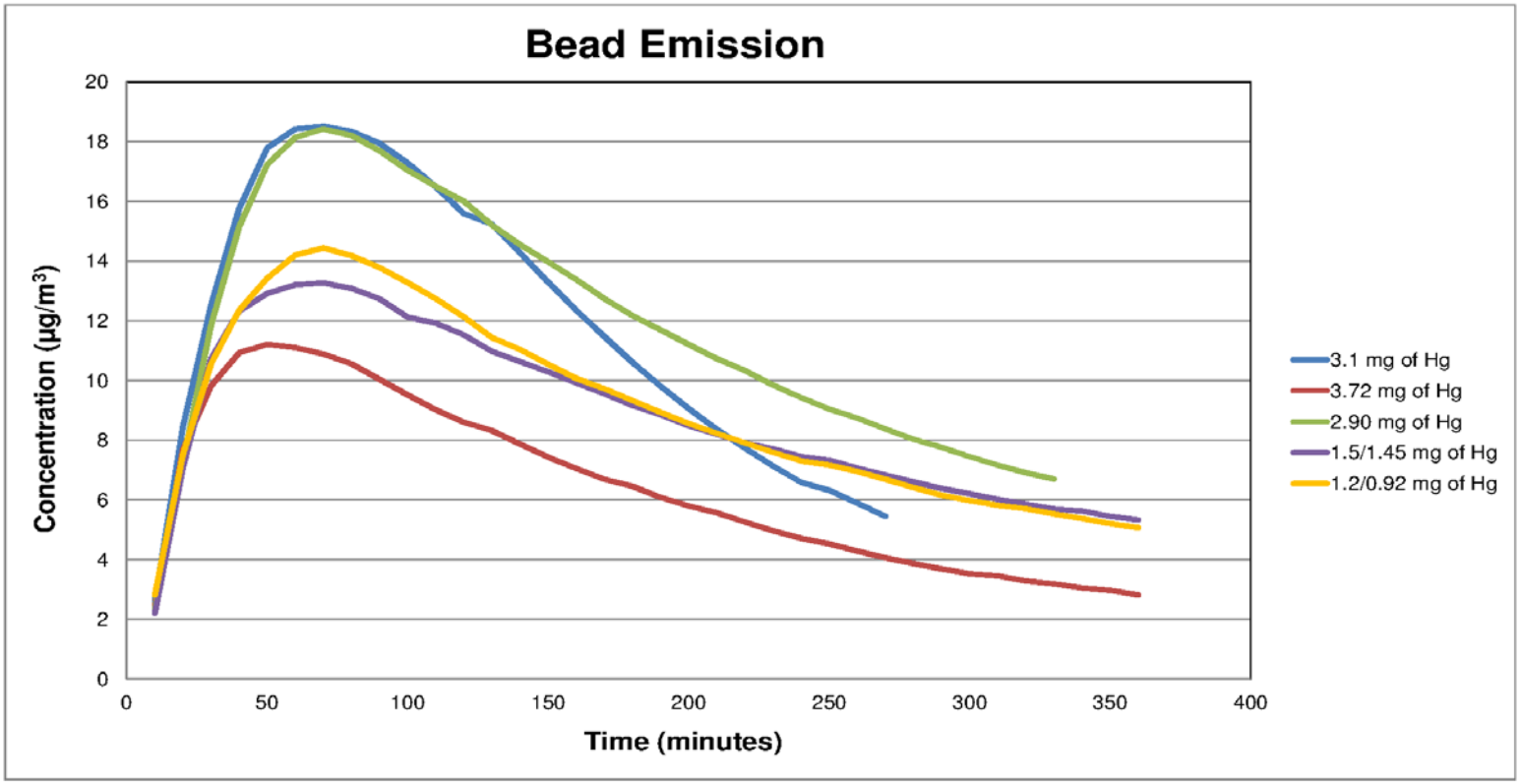


Figure 4. Mercury concentration vs. Time for different bead weights.

CFL BROKEN ON CARPET

- Table 4: Percent Hg loss for five CFL bulb types on carpet

- Fig 5: Plots of the emission data

- Avg. 24-hour Hg loss from broken CFLs 2.6% to 28%; not directly related to the Hg content or how Hg is incorporated in the bulb (metallic or amalgam)

- Avg. emission and mercury loss higher for breakage of CFLs on carpet compared to plastic except for the N-14W CFL bulb type

Table 4. 24-Hour Mercury Loss from CFLs Broken on Carpet

CFL Bulb Type	Hg content (mg)[a]	Average Concentration (µg/m³)	Total Hg Emitted (µg)	% Hg Loss
B-23W	2.57	31.1	67.8	2.6
G-15W	2.42	309	677	28
N-14W	2.18	201	431	20
P-13W	4.75	245	529	11
S-13W	1.22	21.2	45.8	3.8

[a] CFL average mercury content (Singhvi, et al., 2011)
B, G, N, P – Mercury in bulb as metallic mercury
S – Mercury in bulb as an amalgam

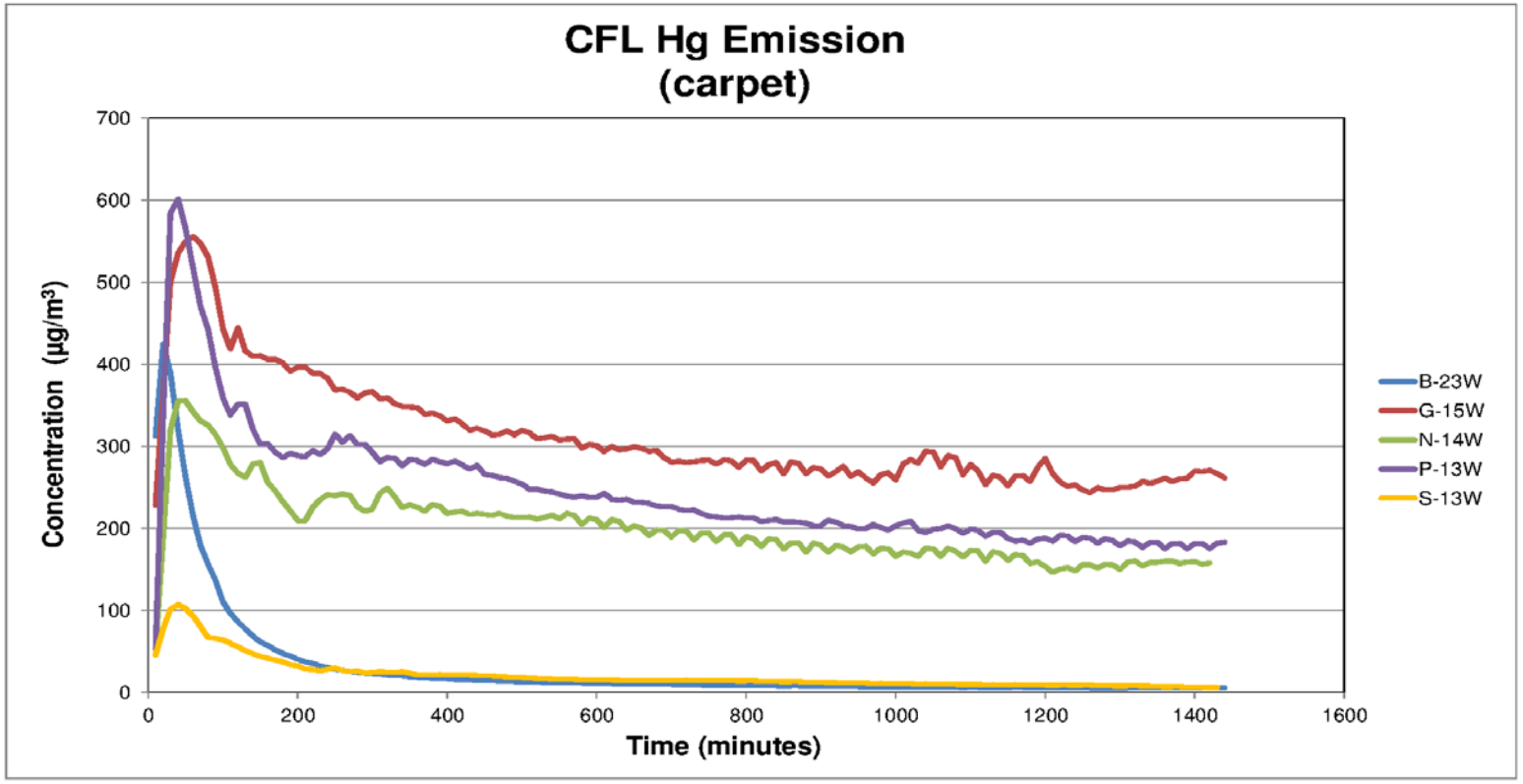
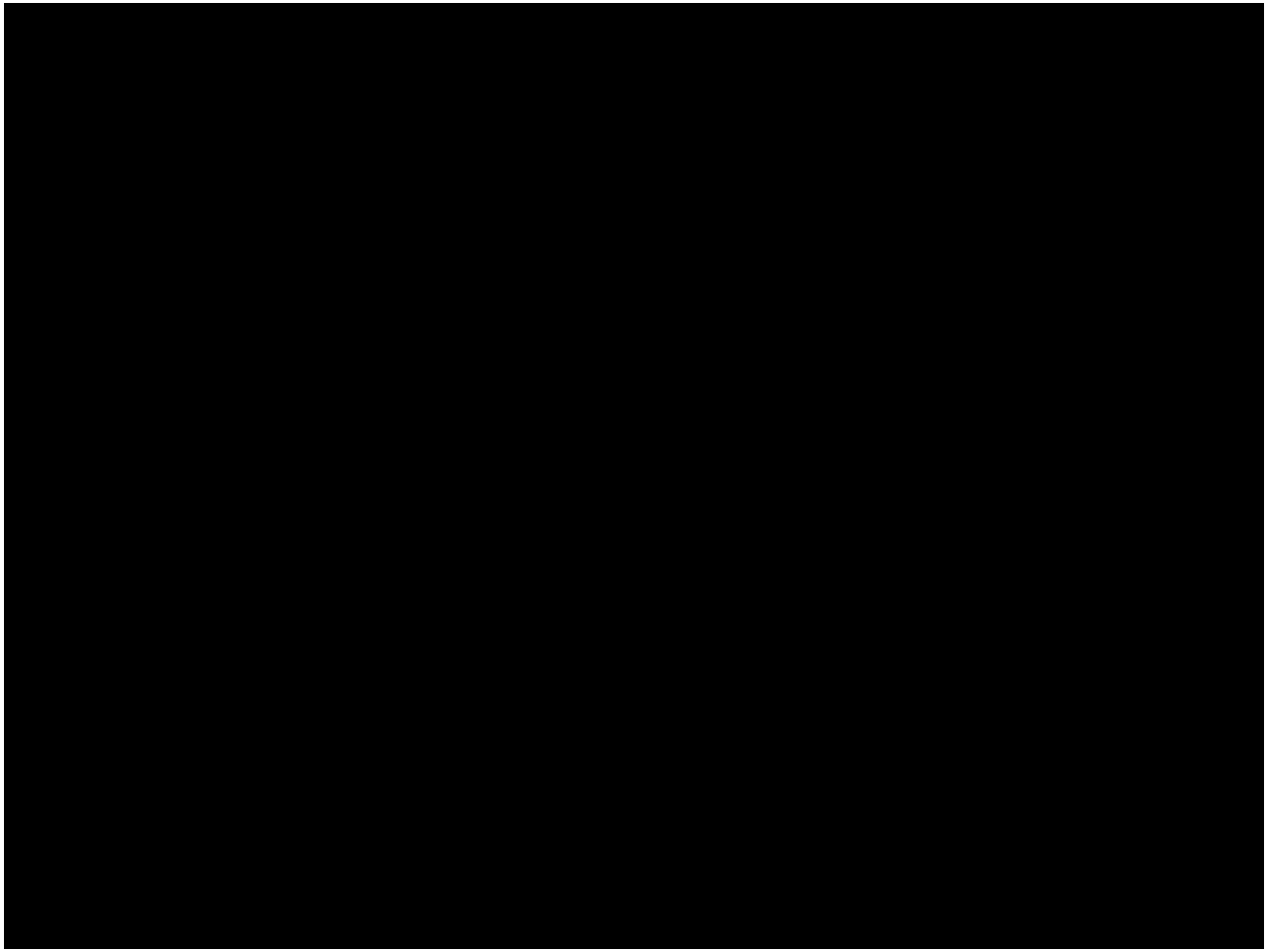


Figure 5. Mercury concentration vs. Time for CFLs broken on carpet.

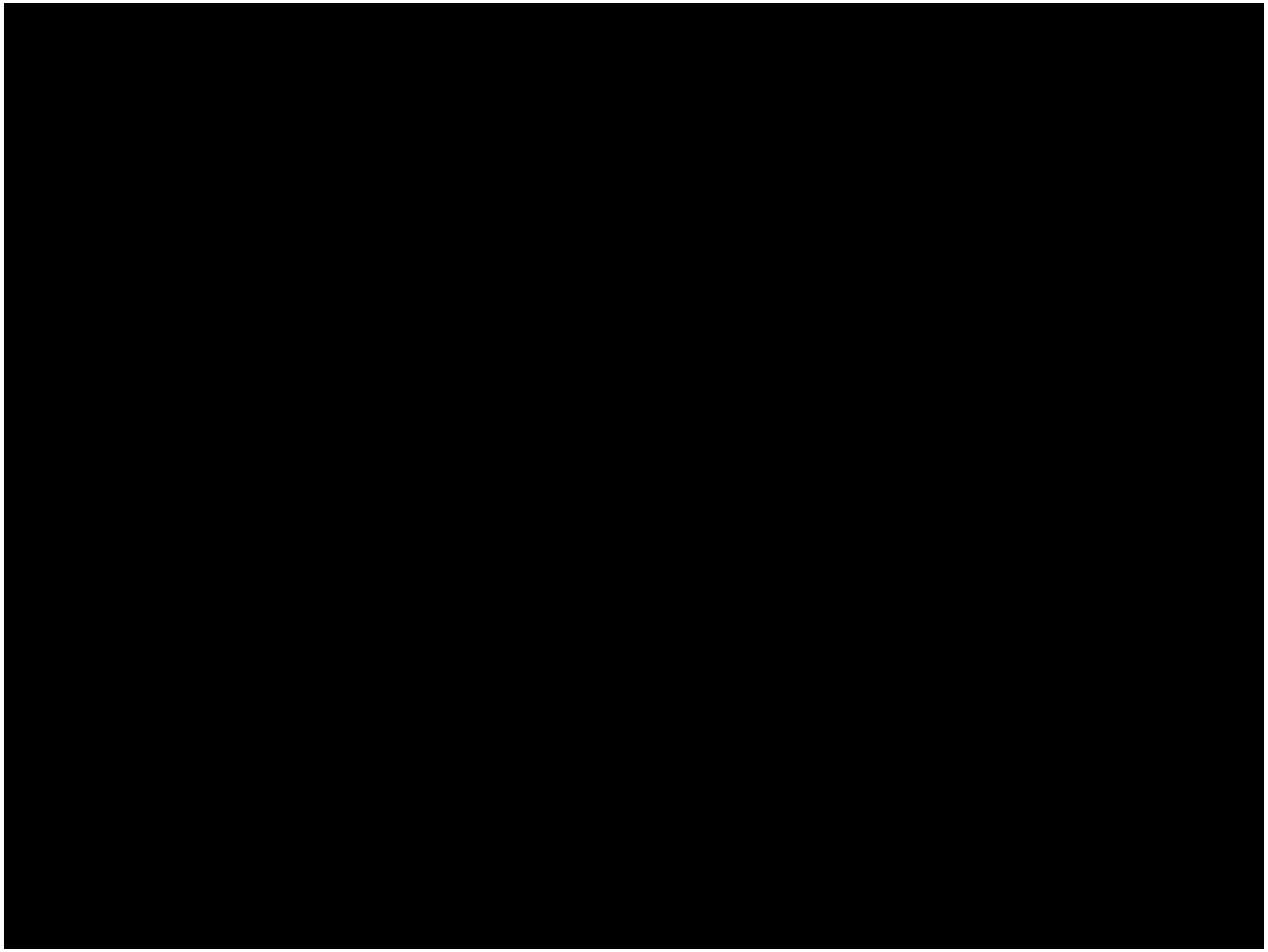
Clean up Procedures

- Open the window where CFL is broken immediately
- Wear kitchen rubber gloves to collect broken pieces of bulb using two card board pieces in garbage bag and/or a glass container
- On the carpet use lint remover, duct tape, pizza dough or chapatti dough (in India) can also be used to remove the small Phosphor particles / mercury left on the carpet
- On tiles use clorox wipes to clean the floor
- Collect all the material in the garbage bag and double bag it, if glass container is not used
- Leave the bag or container out side the home. Dispose the waste material as per local laws
- Wash your hands with soap and lot of water
- A vacuum is not recommended for removing the debris as air movement may cause further distribution of mercury and contaminate the vacuum cleaner
- See now two video clips for clean up.

Broken CFL on Carpet- Clean up Video



Broken CFL on Tiles- Clean up Video



CONCLUSIONS

- CFL Hg vapor emissions may be significantly greater than from beads of liquid mercury with comparable weights

- Avg. 24-hour Hg loss for CFLs broken on plastic 0.6% to 22%; not directly related to the mercury content or how mercury is incorporated in the bulb (metallic or amalgam)

- Avg. 24-hour Hg loss from CFLs broken on carpet 2.6% to 28%

- Reason for increased emission and mercury loss from CFL breakage on carpet compared to plastic is not clear and will be investigated in future work

CONCLUSIONS, cont'd…

- 24-hour Hg loss for liquid mercury beads much lower than for CFLs with comparable mercury content; location and form of the mercury in the bulb, how the bulb is broken, ambient temperature may affect emission after breakage

- Projections for a 12' x 9.33' x 8' room (25.4 m^3); CFL breakage may produce 24-hour mercury concentrations above the ATSDR minimum risk level of 0.2 $\mu g/m^3$ (ATSDR, 2000)

- If appropriate procedures are implemented for cleanup, it is unlikely that breakage of a CFL will have any health effect.

ACKNOWLEDGEMENT

The authors wish to acknowledge the assistance of the following: Dennis Miller and Donna Getty of Lockheed Martin/SERAS; and Jeff Heimerman, David P. Wright, and Harry R. Compton of USEPA for management support. The authors are also thankful to Deborah Killeen of Lockheed Martin; and Ellie McCann, of USEPA, for their expertise in reviewing the manuscript.

DISCLAIMER

Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

REFERENCES

ATSDR (Agency for Toxic Substances and Disease Registry), 2000. Minimal Risk Levels (MRLs) for Hazardous Substances. Available at *http://www.atsdr.cdc.gov/mrls.html*.

NEMA (National Electrical Manufacturers Association), 2010. *Limits on Mercury Content in Self-ballasted Compact Fluorescent Lamps*, Standard Publication LL 8-2010.

Singhvi, R., Y. Mehra, J. Patel, D. Miller, and D. Kalnicky, 2005. Ritualistic Use of Mercury - simulation: A Preliminary Investigation of Metallic Mercury Vapor Fate and Transport in a Trailer. *OSWER 9285.4-08, EPA/540/04/006.*

Singhvi, Raj; Taneja, Ajay; Patel, Jay R.; Kansal, Vinod; Gasser, Charles J.; and Kalnicky, Dennis J., 2011. " Determination of Total Metallic Mercury in Compact Fluorescent Lamps (CFLs)", Environmental Forensics 12:2, 143-148.