Mercury Exposure Assessment

Testing a work practice for cleaning up broken fluorescent bulbs

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Abstract: *The U.S. Postal Service (USPS) Northeast Area (comprised of New England and upstate New York) conducted a negative exposure assessment for cleaning up broken fluorescent bulbs at the Boston Processing and Distribution Center in August 2004. This article summarizes the exposure assessment conducted and the results.*

APPROXIMATELY 620 MILLION fluorescent bulbs are discarded annually in the U.S., many of which are broken during disposal (Aucott, McLinden & Winka, 2003). Only about 20% of these bulbs are recycled. Fluorescent bulbs typically contain mercury in varied concentrations, based on size, manufacturer and age. When these bulbs are broken, the mercury is potentially released in both gaseous and particulate (oxidized mercury in the phosphor powder) states. Assuming that each bulb has 3 to 8 mg of mercury, these discarded bulbs account for approximately 2 to 4 tons of mercury waste per year.

Since much of this breakage is uncontrolled—meaning no engineering controls, acceptable work practices or use of PPE is in place—elevated levels of airborne mercury (a very persistent chemical in the environment) could be present in the vicinity of the breakage. Based on the conditions associated with that breakage, nearby facility occupants may be exposed to airborne levels of mercury that exceed recognized occupational exposure limits.

EPA (1997) has estimated that 6% of the mercury in broken bulbs is released into the air. Oak Ridge National Laboratory has estimated that concentration to be much higher—ranging from 20% to 80% of the mercury in broken bulbs, which may persist for at least a week (Lindberg, Roy & Owens, 1999).

In October 2000, a World Health Organization (WHO) report documented nominal background concentrations of mercury vapor in the range of 2 to 10 nanograms per cubic meter (ng/m^3) of air, or less than 0.00001 mg/m^3 in ambient air. While these ambient exposures are nominal, the occupational exposures in certain industrial settings can be significant. Even low-level occupational exposures can be significantly above ambient mercury levels.

Occupational Exposure Limits

OSHA's permissible exposure limit (PEL) for mercury of 0.1 mg/m^3 (100 µg/m^3). This PEL has been established as an 8-hour time-weighted average (TWA) value. [Although the OSHA standards (29 CFR 1910.1000, Table Z-2) indicate that the mercury PEL is 0.1 mg/m^3 as a "ceiling" concentration, OSHA clarifications/interpretations dated June 30, 1976, and Sept. 3, 1996, have indicated that the PEL is 0.1 mg/m^3 as an 8-hour TWA.] American Conference of Governmental Industrial Hygienists (ACGIH) and NIOSH recommend an 8-hour TWA exposure limit of 0.025 mg/m^3 and 0.05 mg/m^3 of air, respectively, for elemental mercury vapor.

Exposure Evaluation Justification

The potential release of mercury during the uncontrolled breakage of fluorescent bulbs presents opportunities to exceed OSHA's mercury PEL. Should bulbs break, additional mercury could be aerosolized during the cleanup of that debris if such activities are conducted in an uncontrolled manner

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Bulbs may break during the change-out process or because of improper storage, inadvertent contact or other means. Whenever breakage occurs, employees must clean up debris that might contain mercury.

or using an unsafe work practice. This exposure could occur for an extended period after the breakage because of the continuing volatilization of the elemental mercury and/or the disturbance of the particulate phase mercury during cleanup.

USPS maintenance and custodial personnel replace these bulbs often. Bulbs may break during the change-out process or because of improper storage, inadvertent contact or other means. Whenever breakage occurs, employees must clean up debris that might contain mercury.

At the time of this study, the USPS Northeast Area contracted with an environmental remediation firm to handle that process in order to preclude elevated or unknown exposures to employees. Since that service was costly, an exposure evaluation was conducted to determine whether there is a de minimus quantity of fluorescent bulbs, bulb types, mercury content and sizes for which cleanup could be safely handled by staff personnel. Currently, several states have developed or are considering regulations or guidance to provide universal waste exemptions for the cleanup of incidental quantities of broken bulbs. The results of this study support such regulatory exemptions from hazardous waste exposures.

While recycling lamps makes fiscal sense, the most important financial consideration in the overall selection of a fluorescent lamp is not the disposal cost but its long-term operating cost. This is based on the assumption that lamps are being recycled. If lamps are not recycled, then they must be disposed of as hazardous waste, which greatly increases the cost of cleanup and disposal.

In cases where bulbs are not recycled, the overall disposal cost overwhelms useful life operating cost as a decision variable. For example, a single broken bulb disposed of as hazardous waste costs an average of $500 per incident not including the $63 for its useful life operation. In contrast, a bulb that has been recycled costs only $1.45 excluding the useful life cost calculation (USPS Northeast Area, 2007).

Because of the potential for breakage and the costs associated with contracted cleanup, the USPS wanted to determine whether a certain level of cleanup could be performed by in-house resources. Doing so required that the health hazards associated with those potential exposures be evaluated in a controlled environment. If the results indicate that no adverse airborne exposure in excess of the published PEL exists, OSHA terms this process a negative exposure assessment. As such, if successful, the same work practices used during the assessment could be used to conduct future cleanups, assuming similar work conditions.

It is important to note that this assessment is valid for maintenance/custodial work activities performed using work practices identical to those described and involving fluorescent bulbs that contain no more mercury than those successfully demonstrated during the study. Any change of equipment, procedures, controls or personnel, or the addition of a new task that may result in more employees being exposed to mercury at or above the PEL, would necessitate additional exposure monitoring and interim protection measures including engineering controls, PPE and contracted remediation services.

Bulb Use Within One USPS Region

Data were gathered from facilities in one region of the USPS in December 2003 to determine the frequency and type of bulb breakages. Of 32 facilities assessed, 12 (38%) had bulb breakages involving approximately 58 bulbs. Of these incidents, 28% occurred during replacement, 41% during disturbance in storage and 31% when shipping containers were opened (USPS Northeast Area, 2003). Bulb breakage is not a common occurrence among USPS maintenance workers.

In the USPS Northeast Area in 2003, an estimated five bulb breakage incidents were recorded in each of the eight USPS districts. These incidents occurred primarily at nonplant sites (i.e., retail post offices). Each incident typically involved one or two bulbs. Approximately 2% of the fluorescent bulbs used in the USPS Maine District are 8-ft bulbs, with the remaining 98% being 4-ft bulbs, U-shaped bulbs or less than 4-ft bulbs. It also was estimated from this survey that 10,000 total bulbs were recycled annually in the Maine District.

Bulb use in USPS districts in Albany and Maine were judged to be representative of Northeast Area use. Bulbs were evaluated as to type, manufacturer, size, mercury content and availability in an attempt to replicate worst-case conditions for the exposure assessment test chamber studies. Vendors supplied the following 4-ft bulbs:

- Osram Sylvania F34CW/SS (15 mg of mercury);
- Philips F34CW/RS/EW/ALTO (3.5 mg of mercury);
- General Electric (GE) F34CW/RS/WM (15 mg of mercury).

Assuming that the USPS facilities were purchasing currently manufactured mercury bulbs, the Osram Sylvania and GE bulbs represented the highest potential mercury content that would be in use in USPS Northeast Area facilities. The Philips bulb, a low-mercury-concentration bulb, also was in use. Since the Osram Sylvania and GE bulbs had higher concentrations of mercury, it was decided to only conduct test chamber studies on those two makes. If successful negative exposure assessments were performed on these two types of bulbs (each containing an average of 15 mg of mercury), then the Philips bulbs (at an average of 3.5 mg of mercury) would be deemed to be successful based on its lower mercury concentration (assuming that the same work practices were used).

It was further determined that a typical bulb breakage scenario would rarely involve more than four 4-ft bulbs (only 8% of the survey incidents involved bulbs that were larger). Previous incident data indicated that the typical incident was one or two broken bulbs.

Using this information, the exposure assessment study was based on a maximum of four bulbs broken (92% of the survey), which would then, by default, take into account any breakages involving less than

Work Practice Summary: Handling Broken Fluorescent Lamp Spills

Application

This work practice is for personnel responding to incidents involving the breakage of up to and including four 4-ft fluorescent bulbs. *Adhere to these cleanup and safety procedures and use PPE required by the competent person. A respirator is not required if the work practice is followed.*

Required Tools & Equipment

Use safety cones and/or "restricted area" barrier tape; polyethylene, rubber or PVC gloves; safety glasses; Tyvek shoe covers; dust pan and small brush or squeegee; small pieces of cardboard with at least one straight edge; disposable mercury wipes; spray bottle (water); air-tight, sealable 6-mil plastic disposal bags or rigid plastic container; flashlight; duct tape. **Specialized equipment:** Use flowers of sulfur powder (not granulated) accompanied by an MSDS.

Prework Activities Checklist

- All employees engaged have completed initial and annual refresher training.
- Confirm that workers have the appropriate PPE including gloves, booties and safety glasses.
- If exposed to debris or vapors, wash exposed skin with soap and water.
- Assemble all required tools and equipment, including standard and specialized equipment.
- For individuals exposed to breakage, verify that shoes and clothing are not contaminated.

Work Area Preparation Checklist

- Clear bystanders from the area. Close doors where feasible.
- Wait 5 minutes before initiating this work practice.
- If practicable, turn off ventilating or air conditioning systems.

Conducting the Work Practice

- Dress appropriately: Remove jewelry and put on disposable booties, gloves and goggles.
- Contain breakage: Keep debris from cracks, floor drains or difficult to clean surfaces. Never use a vacuum cleaner for mercury. Never flush mercury down the drain.
- Remove mercury debris. Begin cleaning at the outer perimeter of the spill. For impervious surfaces use a dust pan, cardboard or squeegee to pick up glass. Use duct tape to pick up glass fragments. Avoid skin contact. Shine a flashlight to find glass fragments. For porous surfaces such as carpets, fold or roll it so the mercury debris is trapped inside, then place it in a plastic bag. Contact an environmental contractor for wall-to-wall carpeting.
- Sprinkle flowers of sulfur on the spill site to bind the mercury. Apply the powder from a standing position to cover hard-to-reach areas, such as cracks and crevices, to halt the release of vapors. Mist the powder using a spray bottle. Mercury will react with the powder to form an amalgam. Afterward, collect the amalgam with a moist paper towel and dispose of as a hazardous waste.
- Place debris and cleanup materials in a sealed container. Dispose of the cleanup tools and equipment. If bags are used, seal and use double bagging for additional protection. Consult an environmental professional for disposal instructions.

Post-Cleanup Activities

- Those exposed to mercury should wash skin using soap and water and thoroughly rinse.

four bulbs. This would encompass the majority of breakage scenarios reported in the study area and greatly minimize external cleanup costs, as well as expedite the response time for cleanup through an internal work practice with trained USPS staff.

Breakage Scenarios

A review of incident data regarding past bulb breakage showed that the most frequent causes of breakage (other than in shipment from the manufacturer) are either bulb changing (where the bulbs fall from fixtures at ceiling height) or bulbs falling to the floor when left unattended and leaning against a work surface.

It was assumed that the scenario which would result in the greatest spread of breakage debris would involve bulbs falling from a height (ceiling) rather than when leaning against a work surface. Therefore, the exposure assessments conducted during the test chamber studies involved dropping bulbs from a typical office ceiling height of 8 ft.

It was also assumed that the release of vapor and particulate phase mercury would be greatest when the breakage debris was spread widest. The research group decided to conduct the studies with the simultaneous breakage of four bulbs to simulate a worst-case scenario. It was agreed that this scenario would capture most incidents covered by these work practices.

Proposed Cleaning Protocol Work Practice

The proposed cleaning protocol (see Work Practice Summary sidebar above) for the broken fluorescent tubes follows draft guidance published by the Northeast Waste Management Officials Association (NEWMOA) in April 2003. Although the NEWMOA guidelines relate primarily to relatively large liquid mercury spills (up to and including 2 tablespoons), the basic cleaning techniques also can be applied to bulb breakage. In addition, all seven northeast state environmental regulators supported the draft guidelines.

The bulbs to be evaluated contained a maximum of 15 mg of mercury each, far less than the 2 tablespoon maximum quantity specified by NEWMOA.

Table 1

Mercury Exposure Monitoring Results

NEA[a]	Sample no.	Employee or location	Collection time (min)	Analyte	Results (μg/m³)[b]	8-hr TWA results[c] (μg/m³)	OSHA PEL[d] (μg/m³)
1	NEA-1T	Employee 1	31	Mercury	20	1.3	100
	NEA-1F						
1	NEA-2T	Employee 1	31	Mercury	19	1.2	100
	NEA-2F						
1	NEA-3T	Employee 2	32	Mercury	< 9	< 0.6	100
	NEA-3F						
2	NEA-4T	Employee 1	33	Mercury	24	1.7	100
	NEA-4F						
2	NEA-5T	Employee 1	33	Mercury	24	1.7	100
	NEA-5F						
2	NEA-6T	Employee 2	34	Mercury	< 9	< 0.6	100
	NEA-6F						
3	NEA-7T	Employee 1	39	Mercury	25	2.0	100
	NEA-7F						
3	NEA-8T	Employee 1	39	Mercury	26	2.1	100
	NEA-8F						
3	NEA-9T	Employee 2	42	Mercury	< 7	< 0.6	100
	NEA-9F						
4	NEA-10T	Employee 1	31	Mercury	28	1.8	100
	NEA-10F						
4	NEA-11T	Employee 1	31	Mercury	28	1.8	100
	NEA-11F						
4	NEA-12T	Employee 2	31	Mercury	< 10	< 0.6	100
	NEA-12F						
5	NEA-3T	Employee 1	32	Mercury	< 10	< 0.6	100
	NEA-13F						
5	NEA-14T	Employee 1	32	Mercury	30	2.0	100
	NEA-14F						
5	NEA-15T	Employee 2	36	Mercury	< 8	< 0.6	100
	NEA-15F						
Blank	NEA-16T	Blank	-	Mercury	< 6 μg	-	-
	NEA-16F						
Blank	NEA-17T	Blank	-	Mercury	< 3 μg	-	-
	NEA-17F						

Note. *Negative exposure assessments—Philips ALTO bulbs. F = filter; T = tube (all filter analytical results were below method detection limits). Results preceded by < are below the detectable limits of NIOSH Method 6009.*

[a]NEA = negative exposure assessment number. [b]μg/m³ = microgram per cubic meter. [c]8-hour TWA assumes no further mercury exposure for the balance of an 8-hour work shift. [d]PEL = permissible exposure limit of 100 μg/m³ is an 8-hour TWA.

Accordingly, the proposed USPS protocol for mercury spills related to fluorescent bulb breakage specifies that if a spill larger than four broken bulbs occurs on USPS property, an external licensed hazardous waste contractor must be hired to clean up the spill. The work practice specifies detailed cleaning procedures, equipment and supplies needed, and PPE to be used.

Study Results

Two types of exposure assessments were conducted at the Boston General Mail Facility. The initial studies were screening assessments conducted on two of the three types of bulbs identified. Since the Sylvania and GE bulbs both contained the same amount of mercury, and since postal facilities purchase more GE bulbs, the Sylvania bulbs were not used in the test chamber studies.

Based on the results of the screening studies, negative exposure assessments would be proposed for the bulb types shown not to exceed the OSHA PEL (8-hour TWA), as indicated by the use of Lumex RA-915 monitors. These monitors are portable real-time

Table 2

Statistical Analysis of Exposure Study Data

Experiment	Bulbs broken	Lumex TWA	NIOSH 6009 measured	NIOSH 6009 pred.	95% UCL (NIOSH pred.)	8-hr TWA	95% UCL for 8-hr TWA	95% UCL 8-hr TWA as % of OSHA PEL
Philips NEA #5	2 bulbs	15.44	17.5	19.08	26.75	1.23	1.73	1.7%
Philips NEA #1	2 bulbs	16.96	19.5	19.91	27.33	1.24	1.71	1.7%
Philips NEA #3	2 bulbs	21.96	25.5	22.62	29.64	1.77	2.32	2.3%
Philips NEA #2	2 bulbs	24.19	24	23.82	30.88	1.51	1.96	2.0%
Philips NEA #4	2 bulbs	33.87	28	29.07	37.69	1.79	2.32	2.3%
GE Screen #3	2 bulbs	3.23	-	12.53	23.48	0.56	1.05	1.1%
GE Screen #4	2 bulbs	24.91	-	24.21	31.31	1.82	2.35	2.3%
GE Screen #2	2+2 bulbs	43.15	-	34.10	45.57	2.17	2.90	2.9%
GE Screen #1	4 bulbs	48.50	-	37.00	50.41	5.09	6.93	6.9%
GE Screen #5	2 bulbs	79.58	-	53.85	79.89	3.65	5.41	5.4%

***Note.** Measurement units: microgram per cubic meter of air (µg/m^3). OSHA PEL = 100 µg/m^3. Statistical analysis of data was performed by B. Price & Associates as part of the overall exposure assessment. The data are not published elsewhere.*

detection devices that use the principle of cold vapor atomic absorption for the detection and quantification of mercury vapor. Lumex units were used during both phases of the study because of their high sensitivity to low mercury vapor emissions. It was determined that the screening tests would also help determine the spatial distribution of mercury in the chamber and the degradation of mercury concentration over time.

Three test chambers were constructed to allow at least three consecutive tests to be performed before chamber cleaning would be required. Each chamber was a self-contained unit under negative pressure with HEPA filtration. Each was approximately 12 ft long, 10 ft wide and 8 ft tall; these dimensions were selected to allow for any debris generated from bulb breakage to spread out in a debris field consistent with a normal breakage pattern and to allow enough room for personnel conducting the study to work.

Lumex units were placed at the approximate breathing zone of a cleanup worker, both standing (5 ft) and kneeling (30 in.) above the breakage. A third Lumex unit was used to determine the concentration of mercury several feet from the bulb breakage (in the corner of the chamber). This would allow a "degradation over distance" measure to be determined.

All Lumex measurements inside the room were taken continuously and were manually recorded by a technician every 30 seconds. For both cleanup workers, NIOSH method 6009 samples were taken on their left and right shoulders as a direct comparison for the OSHA PEL. Sampling pumps were calibrated to approximately 0.2 L/min and were allowed to run from the beginning of bulb breakage to the completion of cleanup activities. Sampling pumps were calibrated at the end of the sampling period as well. The following discussion describes the tests performed on each bulb type and the rationale for either continuing or discontinuing that protocol/series.

Initial Screening

On Aug. 7, 2004, the initial screening studies were performed using GE 4-ft bulbs (T-12, model number F34CW/RS/WM, 15 mg of mercury). Both low-range and high-range Lumex instruments were used in this phase. The low-range instruments had a maximum use range of approximately 28 µg/m^3, with a detection limit of 2 ng/m^3. The high sampling mode on the low-range units was not completely effective because in this mode samples are collected by passive diffusion rather than by active sampling. The high-range Lumex unit (active sampling as opposed to passive) was configured differently from the three low-range units and had a detection limit of 0.1 µg/m^3 (100 ng/m^3) mercury with a working range up to 100 µg/m^3. Note that 100 µg/m^3 or 0.1 mg/m^3 is the OSHA PEL (8-hour TWA) for airborne mercury vapor. (As noted, given the results of the screening studies involving the GE bulbs, no further studies were performed on any other manufacturer's bulbs with a similar mercury content.)

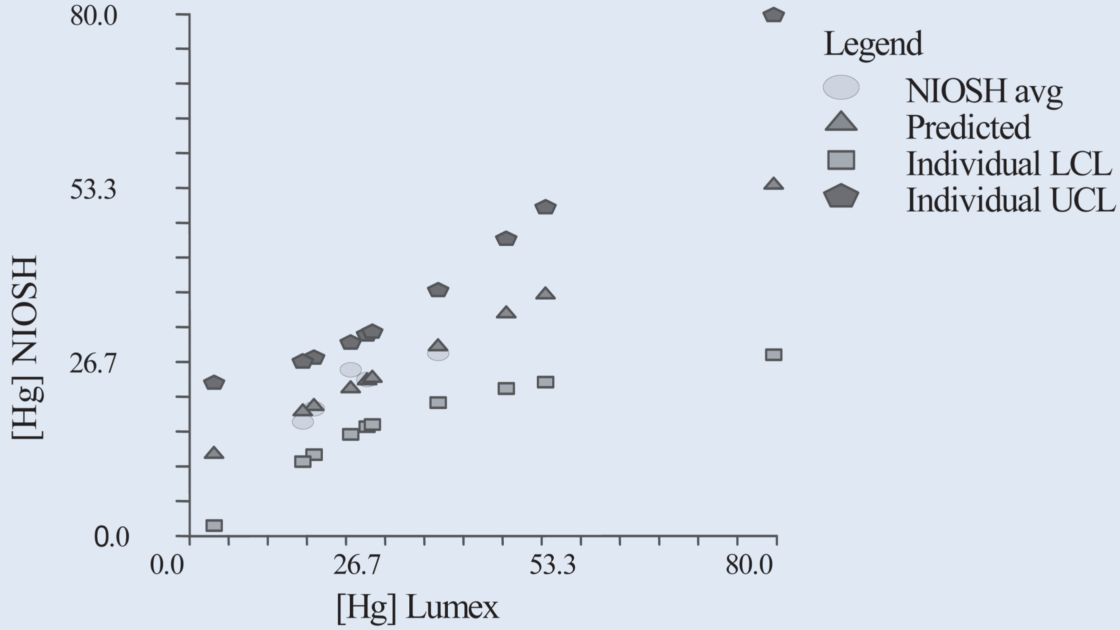
The Philips ALTO low-mercury bulbs were evaluated in the same manner, except that no prescreening "range finding" studies were performed. The USPS decided to conduct a series of screening studies involving the breakage of two ALTO bulbs, then to complete a series of negative exposure assessments under previously determined worst-case conditions using these bulbs. If the results were favorable, they could be extrapolated to a variety of bulb types, amounts and conditions to validate the cleanup work practices.

Philips ALTO Bulb: Screening Study

All three screening studies conducted during the breakage of two Philips ALTO bulbs (3.5 mg mercury each) indicated that the airborne mercury concentrations were well below the OSHA PEL. Consistent cleaning work practices were used during the screening studies and maximum bulb breakage and debris dispersion were attained. Mercury vapor dispersion trends were quantified during the work practice. Based on the screening study results, the group decided to conduct a series of full negative exposure assessments using similar conditions (bulb type, quantity, work practices). Similar screening with the Lumex monitor was performed in conjunc-

Figure 1

Measured Lumex & Predicted NIOSH 6009 Values



Note. *Measured Lumex and predicted NIOSH 6009 mercury values and their 95% confidence limits for the GE bulb studies. Statistical analysis of data was performed by B. Price & Associates as part of the overall exposure assessment. The data are not published elsewhere.*

tion with personal sampling using NIOSH Method 6009 so that a direct comparison to the OSHA PEL could be made and a valid negative exposure assessment could be documented.

Philips ALTO Bulb: Negative Exposure Assessment Study

The work practice evaluated resulted in an exposure assessment for the maintenance worker conducting that task. The actual mercury exposure was compared to the OSHA PEL to determine whether it had been exceeded or was likely for the work practice. According to the the analysis of the airborne samples collected during the course of the evaluation, PEL was not exceeded.

Therefore, the maintenance work practice performed, which was documented in detail as to procedures and equipment used, and the resultant mercury exposures that were determined serve as evidence of a negative exposure assessment for the work practice. This assessment satisfies OSHA's requirements and indicates that interim protection measures, such as respiratory protection, are not required for this work practice. Table 1 provides a summary of the NIOSH Method 6009 analytical results for the five negative exposure assessment test repetitions.

Data Interpretation/Statistical Analysis

Thirteen cleanup simulations were conducted using the GE and Philips bulb types. The five initial GE simulations involved from two to four of the higher-mercury-content bulbs, while the Philips simulations all involved two of the lower-mercury-content bulbs. A statistical analysis of the data was performed to determine the validity of the Lumex data versus the NIOSH Method 6009 data (the method used by OSHA to determine compliance with the mercury PEL). If a good correlation was found between the Lumex and NIOSH data, then extrapolations could be made to the initial GE data when NIOSH sampling had not been performed.

Ten of the simulations were chosen for the statistical analysis—the initial five GE bulb studies and the five Philips bulb studies using the NIOSH 6009 method and the Lumex analyzer. The three Philips screening studies were not used as they were well represented by the previously mentioned five Philips bulb negative exposure assessments.

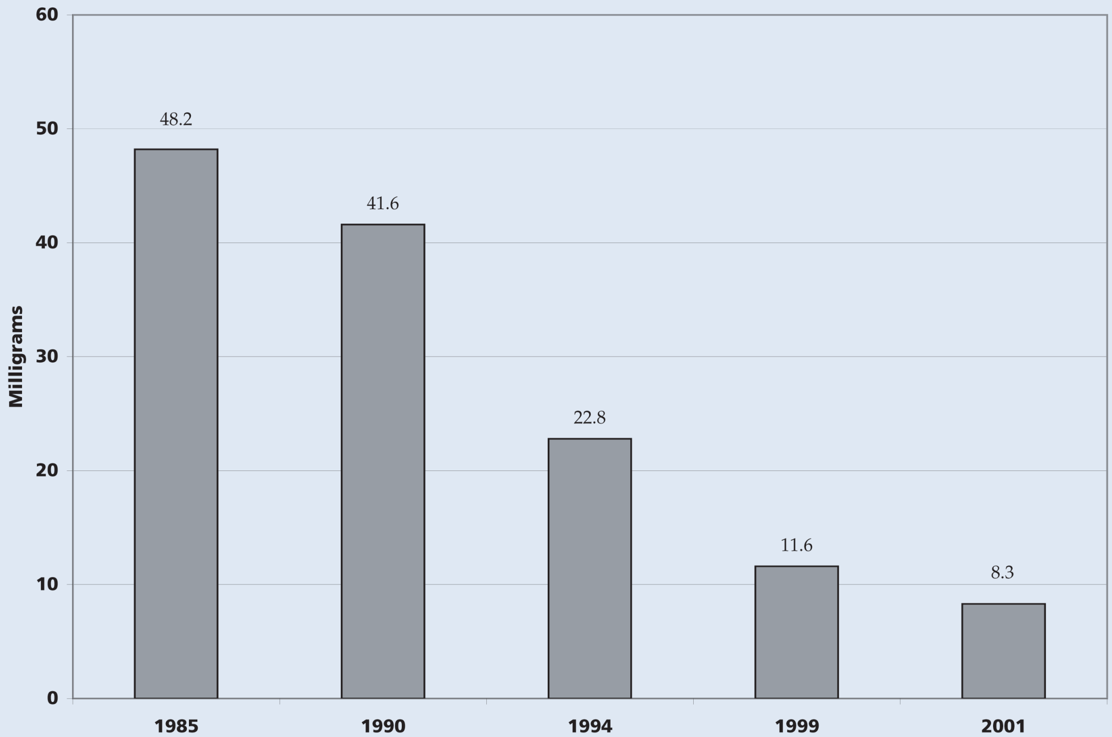
The paired Lumex and NIOSH 6009 data from the Philips studies were analyzed using regression analysis to estimate a straight-line relationship between NIOSH 6009 and Lumex measurements. The resulting relationship was applied to Lumex measurements from the simulations where NIOSH 6009 measurements were not obtained (GE studies) in order to estimate expected NIOSH 6009 measurements. Upper and lower confidence limits (95% confidence level) were then calculated for each NIOSH 6009 value.

Finally, the NIOSH 6009 values and their 95% upper confidence limits (95% UCL) were translated into 8-hour TWAs for comparison to the OSHA PEL. These TWAs were computed assuming one mercury cleanup per day. Table 2 shows the analysis results. Regression analysis was applied to the data in the first five rows of columns 3 and 4, and was used to calculate the predicted values in column 5; the regression analysis routine computed the corresponding confidence limits. The 8-hour TWA and 8-hour TWA confidence limits were then calculated assuming only one such exposure per 8-hour workday. Figure 1 depicts measured Lumex and predicted

Figure 2

Mercury Contained in 4-ft Lamp: Industry Average

Despite the limited amount of mercury in each lamp, manufacturers work to aggressively reduce mercury content to performance-threshold levels in major lamp types.



NIOSH 6009 mercury values and their 95% confidence limits for the GE bulb studies.

As shown in Table 2, column 7, the 8-hour TWAs for exposure to airborne mercury during cleanup of broken fluorescent bulbs are well below the OSHA 8-hour TWA PEL for mercury. In fact, the 8-hour TWAs also were well below the NIOSH- and ACGIH-recommended exposure limits. The 95% UCLs, which may be interpreted as upper bounds for exposure, are also a small fraction of the OSHA PEL. The largest 8-hour TWA exposure is less than 7% of the PEL (Table 2, last column).

Therefore, based on the data analysis and correlation between the two testing methods for the Philips bulb studies, a similar correlation was shown to be evident for the initial GE screening studies. Since the statistical analysis for the GE bulbs showed no potential for exceedance of the OSHA PEL for mercury (using up to four 15 mg mercury bulbs), these GE data would then be representative of valid negative exposure assessments for the work practices used.

Conclusion

Airborne mercury exposures when cleaning up four or fewer broken 4-ft fluorescent bulbs approached 10% of the mercury PEL. This study has shown that the following factors affect mercury exposure: number of bulbs broken, room size, temperature, work practices and engineering controls. Exposure to mercury vapors can be minimized by stepping away from the area where mercury lamps have broken to allow vapors to dissipate. This study also confirmed the importance of taking measured steps to control bulb breakage using appropriate PPE and cleanup equipment.

Future projects may address the issues of how many broken bulbs constitute a mercury exposure above OSHA's PEL; which low-mercury bulbs are the most energy efficient and long lasting; and strategies for increasing the national rate of bulb recycling among consumers and businesses. ■

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