HealthHazard Evaluation Program®

Evaluation of Mercury and Noise Exposure at a Lightbulb Recycler

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Authors: **Melissa Charles, MS, CSP**

Dallas Shi, MD, PhD

Catherine Beaucham, PhD, CIH, REHS

Nick Somerville, MD, MPH

Analytical Support: Bureau Veritas North America, ARUP Laboratories

Desktop Publisher: Shawna Watts

Editor: Cheryl Hamilton

Industrial Hygiene Field Assistance: Micah Niemeier-Walsh

Logistics: Donnie Booher

Medical Field Assistance: Walter Alarcon, Sheldon Walker

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Disclaimer

The Health Hazard Evaluation Program investigates possible health hazards in the workplace under the authority of the Occupational Safety and Health Act of 1970 [29 USC 669a(6)]. The Health Hazard Evaluation Program also provides, upon request, technical assistance to federal, state, and local agencies to investigate occupational health hazards and to prevent occupational disease or injury. Regulations guiding the Program can be found in Title 42, Code of Federal Regulations, Part 85; Requests for Health Hazard Evaluations [42 CFR Part 85].

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Introduction

Request

Management at an electronics waste and lamp recycling facility requested a health hazard evaluation concerning employees' exposure to mercury, lead, and noise.

Workplace

The workplace was a single-story warehouse with added partitions to create a breakroom, hallway, restroom, personal protective equipment storage area, and office. The main office area had two stories, with the business office on the lower level and a conference room on the upper level. The stairway to the conference room went through the hallway. The warehouse was separated into the lamp room, retort (where the device to recover mercury was used), disassembly area, batteries and ballasts, and storage.

The disassembly area was typically used to disassemble mercury-containing items. However, because the retort was not working at the time of our visit, the disassembly area was unstaffed and housed a collection of mercury-containing steel and plastic drums. Just outside the lamp room was a dumpster containing broken glass.

At the time of our visit, 15 employees worked weekdays from 7 a.m. to 4 p.m. Lamp room employees placed mercury-containing lightbulbs of varying shapes, sizes, and compositions on a conveyor. The conveyor transported the bulbs to a work area where the bulbs were broken either manually or by a lamp crusher machine. A sorting machine separated the bulbs into glass, metal parts, and mercury-containing dusts. Battery and ballast employees placed tape over the battery electrodes to prepare them for shipping.

Although the retort was not in operation during our visit, retort employees used a forklift to transport mercury-containing dust stored in totes from the lamp room. The tote was deposited on top of the "shaker" machine that used vibration to separate fine glass from mercury-containing dust to be processed in the retort when it was operating. Retort employees also disassembled other mercury-containing devices.

To learn more about the workplace, go to Section A in the Supporting Technical Information

Our Approach

We visited the workplace on two occasions to learn more about the health concerns and observed work practices. We completed the following activities during our evaluation:

- Observed work processes, practices, and conditions.
- Measured employees' full-shift exposure to mercury in air over a 2-day period.

- Interviewed employees to learn about work history and practices, health and safety concerns, personal protective equipment use, training, and possible work-related health effects.
- Measured the amount of mercury in employees' urine.
- Measured employees' exposure to noise during two shifts.

To learn more about our methods, go to Section B in the Supporting Technical Information

Our Key Findings

Employee mercury exposures exceeded occupational exposure limits

- Of the 18 personal air samples we collected, 10 were above the limit set the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value.
- Of the 18 personal air samples, 7 were above limits NIOSH recommends during a normal workday.
- None of the air concentrations we measured were over the Occupational Safety and Health Administration (OSHA) permissible exposure limit. The OSHA permissible limits are legally enforceable limits.

Employees had elevated urine mercury levels and reported symptoms consistent with mercury exposure

- Of 14 employees, 5 had urine mercury levels above the limit set by professional guidelines.
- Of 15 employees, 10 reported having one or more health symptoms they thought were related to their work.
- Employees reported symptoms consistent with mercury exposure. These included a metallic or bitter taste in the mouth, difficulty thinking, changes in personality, and difficulty writing.

Workplace conditions and practices could be improved to reduce mercury exposures

- We observed mercury-containing dust piles throughout the facility that can increase employees' mercury exposures.
- We measured elevated concentrations of mercury in the air throughout the facility, including in nonproduction areas.
- We saw areas where engineering and administrative controls could be used to reduce the potential for exposures.
- We noted that three of the nine employees who wore a respirator were overdue for their annual fit test.

- We did not see a filter change-out schedule for respirators or a schedule for their maintenance and cleaning.

Some employees' noise exposures exceeded occupational noise exposure limits

- Of 18 full-shift personal noise exposure measurements, 10 were above the NIOSH recommended exposure limit. This means the noise levels were louder than NIOSH recommends during a normal workday. These included employees in the lamp room and in the retort division.
- Of 18 full-shift personal noise exposure measurements, 7 were above the OSHA action level. This is the level where an employer must take action. These included employees in the lamp room.
- None of the noise measurements we collected from the warehouse, battery sorting, or among retort managers were above occupational noise exposure limits.

To learn more about our results, go to Section B in the Supporting Technical Information

Our Recommendations

The Occupational Safety and Health Act requires employers to provide a safe workplace.

Potential Benefits of Improving Workplace Health and Safety:	
↑ Improved worker health and well-being	↑ Enhanced image and reputation
↑ Better workplace morale	↑ Superior products, processes, and services
↑ Easier employee recruiting and retention	↑ May increase overall cost savings

The recommendations below are based on the findings of our evaluation. For each recommendation, we list a series of actions you can take to address the issue at your workplace. The actions at the beginning of each list are preferable to the ones listed later. The list order is based on a well-accepted approach called the "hierarchy of controls." The hierarchy of controls groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or practical, administrative measures and personal protective equipment might be needed. Read more about the hierarchy of controls at https://www.cdc.gov/niosh/hierarchy-of-controls/about/index.html.

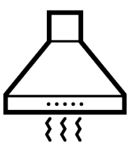
We encourage the company to use a health and safety committee to discuss our recommendations and develop an action plan. Both employee representatives and management representatives should be included on the committee. Helpful guidance can be found in *Recommended Practices for Safety and Health Programs* at https://www.osha.gov/safety-management.

Recommendation 1: Reduce exposures to mercury-containing dusts

Why? Breathing in mercury vapor for a short time (days or weeks) can seriously harm the lungs. Breathing in mercury vapor over a long period of time (months or years) can cause tremors, memory loss, mood changes, and mouth ulcers or sores. When lightbulbs are broken, phosphor dusts from inside the bulbs hold mercury. Later, mercury vapor can be released from the dust. These dusts can spread and can continue to emit mercury vapors.

We measured elevated levels of mercury vapors throughout the facility, even in nonproduction areas. Some employees' exposures were above occupational exposure limits. We recorded the highest values where lamp breaking was performed and near accumulated dust piles in the retort division. We also found high levels of urinary mercury in workers who worked in the lamp room and retort division.

How? At your workplace, we recommend these specific actions:



Install local exhaust ventilation and improve air flow in production areas.

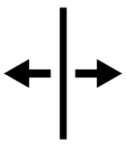
- Install local exhaust ventilation over the conveyer in the lamp room to reduce employee exposures to mercury vapors.
- Repair the lamp room heating, ventilation, and air-conditioning (HVAC) system to improve air circulation. Also keep the lamp room temperature cool. This can help reduce mercury exposures.
- Consult with a ventilation engineer to evaluate exhaust ventilation at the retort machine and install local exhaust ventilation at the lamp room conveyer.

Improve air flow in nonproduction areas.

- Consult with a ventilation engineer to assess your HVAC system. Have them find ways to improve air flow, specifically in the retort office, personal protective equipment storage, clean uniform storage, conference room, and break areas.
- Have the engineer assist with selecting the correct filter and making a change-out schedule.

Improve housekeeping procedures.

- Make a standardized housekeeping plan to regularly remove dust that collects in production areas.
- Stop using brooms for sweeping broken bulbs and mercury-containing dusts. A vacuum specifically designed for mercury cleanup will help prevent the spread of mercury throughout the facility.
- Clean tools at the end of each shift.
- Have specific cleaning supplies just for the production areas (lamp room, disassembly, and retort division). These cleaning supplies should never be used in the nonproduction areas or in the batteries and ballasts or shipping and receiving areas. This will help reduce the spread of mercury.



Separate clean and dirty functions in the workplace to prevent the spread of mercury-containing dusts into nonproduction areas.

- Consider having the workflow go in one direction where soiled equipment and clothing remain outside of the office and nonproduction areas.

Safely remove mercury-containing dusts from clothing and surfaces.

- Stop dry sweeping and using compressed air to remove mercury-containing dusts.
- Use a mercury-recovery vacuum instead of compressed air to remove dust from clothing before break periods, lunch, and at the end of the shift.
- Make sure office areas and break areas are cleaned daily with mercury wipes.

Standardize the use of personal protective equipment among employees who are exposed to mercury-containing dusts.

- Issue Tyvek suits that can be disposed of daily or provide clean coveralls or uniforms to all employees (temporary and fulltime) each day.
    - Tyvek or coveralls should be removed in a designated area at the end of each shift and before leaving the facility. Uniforms should be deposited in a receptacle for dirty uniforms to be laundered. Tyvek suits should be disposed of in a designated bin the locker room.
    - If using coverall or uniforms, consider using a laundry service for coveralls or uniforms to prevent employees from taking home mercury on their clothing.
- Revise the respiratory protection program in accordance with OSHA's respiratory protection standard [29 CFR 1910.134](). Make sure it includes filter change-out schedules,

employee training on respirator use, maintenance and care of respirators, and annual fit testing for those required to wear respirators.

- Train employees on the revised respiratory protection program elements. Make sure that respiratory protection is used and maintained according to the program.
- Have employees wear the correct protective gear at all times in the lamp room and retort division. This includes when the conveyor and retort are not in operation.
- Train all employees on the correct protective equipment to use. Also show them how to care for and maintain the equipment. Training should be given when they are first hired and when changes in processes or protective equipment point to retraining.
- Consult the following for more information about mercury and how to protect workers from mercury exposure: Mercury - Overview | OSHA; Mercury | NIOSH | CDC; Mercury | US EPA.

Recommendation 2: Reduce exposures to hazardous noise

Why? Noise-induced hearing loss can happen when you are exposed to loud noise for a long time. It is a permanent condition that gets worse when exposed to loud noise. Unlike some other types of hearing disorders, noise-induced hearing loss cannot be treated medically. Noise-exposed workers can develop substantial noise-induced hearing loss before the problem is noticed.

Noise monitoring results showed that noise exposures in the lamp room were above the NIOSH recommended noise exposure limit and OSHA action level. Noise exposures in the retort division were above the NIOSH recommended noise exposure limit.

How? At your workplace, we recommend these specific actions:

Improve the hearing loss prevention program.

- Include all employees with noise exposures above NIOSH's recommended limits in a hearing loss prevention program. Consult Hearing Loss Prevention Program | NIOSH Research Programs | CDC in the development of this program. Based on our noise monitoring results, the program would include production employees working in the lamp room and retort division.
    - All employees that are included in the hearing loss prevention program should have a baseline audiogram and annual audiometric testing thereafter.
    - Educate employees on noise exposures and hearing loss risks. Give them information related to hearing hazards and how to wear hearing protection properly. Explain to them which locations and job tasks require using hearing protection.

- Encourage employees to follow the instructions on the "hearing protection required" signs located at entrance to the lamp room and retort division.
- Instruct employees to report any symptoms right away that might be related to workplace noise exposure, such as trouble hearing clearly, or ringing or buzzing in the ears. Keep track of such reports. Encourage employees with possible work-related hearing concerns to get evaluated by a qualified healthcare professional.

Use engineering controls and equipment maintenance to reduce noise.

- Make sure equipment is properly maintained to prevent unnecessary movement, squeaks, or vibration. This can help reduce employees' noise exposures.
- Consider isolating or enclosing noisy equipment or processes to reduce noise levels in the shaker and retort division areas.
- Consult with a noise control engineer skilled in occupational noise reduction for ways to reduce noise in the shaker and retort division areas and to help determine where enclosures are feasible. The noise control engineer should be board certified by the Institute of Noise Control Engineers.

Continue to use hearing protection during work activities with high noise levels.

- Require employees use the correct hearing protection while working in the lamp room or retort division.
- Post signs to indicate when hearing protection is required.
- Reevaluate noise levels in the retort division once the retort is fully operational.

Recommendation 3: Periodically reevaluate workplace equipment and safety and health programs.

Why? To keep employees safe from mercury and other hazards, it's important to make sure equipment and safety measures are correctly working. Regularly checking and updating safety programs are an important part of keeping a workplace safe. Conducting thorough air monitoring can help confirm that the controls are working as expected to lower mercury levels.

How? At your workplace, we recommend these specific actions:

Create a comprehensive preventative maintenance program.

- Begin a preventive maintenance program that includes a thorough assessment of all equipment and engineering controls. This will help make sure equipment is in good working order and that engineering controls are working as designed.

Conduct comprehensive air monitoring around the facility.

- Conduct thorough air monitoring for mercury in the retort division once the equipment is restored to working order.
- Evaluate workplace mercury exposures on a regular schedule using air monitoring and/or biological monitoring, especially when processes or equipment changes.
- Add exposure controls, as needed, based on monitoring results.

Recommendation 4: Tell employees to report any new, persistent, or worsening health symptoms, especially those with a work-related pattern, to their healthcare providers.

Why? Recognizing work-related symptoms early can help identify possible job-related exposures and risk factors for disease. It can also help decide which interventions are most important to prevent work-related illness or disease in employees. A customized management plan for each employee (such as assigning them to a different work location) is sometimes required, depending upon medical findings and recommendations of the worker's healthcare provider.

How? At your workplace, we recommend these specific actions:

Report and track health symptoms associated with workplace exposures.

- Encourage employees to promptly report any symptoms they experience to a designated workplace health or safety officer to ensure timely monitoring and response.
- Record what was happening in the workplace when the symptoms occurred. Also note the corrective or follow-up actions performed to address the issues.
- Have employees with work-related health concerns report their exposure to mercury or other chemicals to their healthcare provider.

If needed, employees should seek care for work-related medical concerns from a healthcare provider knowledgeable in occupational medicine.

- If employees experience new, persistent, or worsening symptoms, have them report the symptoms to a medical provider.
- The American College of Occupational and Environmental Medicine (https://acoem.org/Find-a-Provider) and the Association of Occupational and Environmental Clinics (http://www.aoec.org/index.htm) maintain databases of providers to help locate someone in the area.
- Consider sharing a copy of this report with the healthcare provider.

Recommendation 5: Address other health and safety issues we identified during our evaluation

Why? A workplace can have multiple health hazards that cause worker illness or injury. Similar to those identified above, these hazards can potentially cause serious health symptoms, lower morale, and quality of life for your employees, and possibly increased costs to your business. We saw the following potential issues at your workplace:

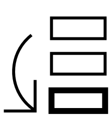
- Unsafe forklift operation in the warehouse area
- Uneven, damaged pallets

Although they were not the focus of our evaluation, these hazards could cause harm to your workers' health and safety and should be addressed.

How? At your workplace, we recommend these specific actions:

Make sure forklifts are operated safely within the facility.

- Use gas forklifts only outdoors or with the warehouse doors open to prevent the build-up of carbon monoxide gas.
- Keep forklift traffic areas clear to keep other workers safe during forklift operations.
- Clearly mark walkways next to where forklifts are being used to help other employees avoid forklift traffic.
- Install safety mirrors at blind corners so that forklift operators can see each other and pedestrians when traveling around corners. Consider convex or dome-style mirrors.



Ensure pallets are used safely.

- Throw out damaged or misshapen pallets. Stacking damaged or misaligned pallets can be unstable and dangerous.
- Stack pallets so they are evenly balanced and do not exceed manufacturer weight or height limitations.

Supporting Technical Information

Evaluation of Mercury and Noise Exposure at a Lightbulb Recycler

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Section A: Workplace Information

Building

The warehouse, constructed in 1956, was a single-story building with added partitions to create a breakroom, hallway, restroom, personal protective equipment (PPE) storage area, and an office. The main office area was constructed inside the warehouse in 1990. It had two stories, with the business office on the lower level and a conference room on the upper level.

Employee Information

There were 15 employees at the time of our second visit: 11 permanent and 4 temporary. These employees worked full time, Monday through Friday from 7 a.m. to 4 p.m., with occasional weekend shifts depending on production demands. Employees were not represented by a union.

History of Issue at Workplace

The facility was a Sustainable Electronics Recycling International R2 certified recycler. Facility operations included crushing mercury-containing lightbulbs in a lamp crusher and then processing the mercury in a retort to separate liquid mercury from mercury-containing dusts. The request concerned exposure to noise, mercury, and lead. After discussion with the requestor, we decided to focus our evaluation on mercury and noise exposures. This decision was based on learning the company had another facility that processed electronics containing lead (and other metals). They had a health hazard evaluation done at that facility in the past, and therefore did not want to include that location in the request at this time. At the time of our site visits, the retort and disassembly areas were not in operation.

Process Description

Lamp Room

The four temporary employees in the lamp room processed mercury-containing lightbulbs. Temporary workers wore personal clothing into the lamp room as they were not issued uniforms. Employees donned tight-fitting half-mask elastomeric respirators with mercury-vapor cartridges, safety glasses, cut-resistant gloves, ear plugs, steel-toed boots, long pants, and a long-sleeve uniform shirt prior to entering the room. The employees removed the light bulbs from external packaging and ensured that all the bulbs were separated from each other. The bulbs were placed on a conveyor belt that carried them to the "lamp crusher" at the bottom of an inclined conveyor (Figure A1).

Figure A1. Lamp room conveyor, lamp crusher, and sorting machine. Photo by NIOSH.

Employees broke the larger bulbs by cracking them against the sides of the conveyor. The inclined conveyor transported the broken bulbs up to a sorting machine that separated the components into metallic parts, mercury-containing dust, and glass. The broken glass was transported via conveyor to a dumpster outside of the facility for subsequent transport to an off-site landfill (Figure A2). Metallic components were separated into a box for shipping off-site to be processed. The mercury-containing dust was collected in a 55-gallon drum to be processed in the retort (Figure A3).

Figure A2. Dumpster filled with broken glass from the lamp room sorter. Photo by NIOSH.

Figure A3. A 55-gallon drum of mercury-containing dust and very fine glass. Photo by NIOSH.

Retort

The two employees assigned to the retort division donned respiratory protection, consisting of a half-mask elastomeric respirator with mercury-vapor cartridges. PPE was worn during work with the "shaker," in the disassembly area, and while the retort was operating. Additional PPE included steel-toed boots, safety glasses, palmar-coated cut-resistant gloves, and a company-issued long-sleeved uniform shirt. The employees used a forklift to retrieve the 55-gallon drum of mercury-containing dust and fine glass from the lamp room. They then transferred the mercury-containing dust from the drum to a large tote on top of the shaker table. When operating, the shaker used vibration to let the fine glass and mercury-containing dusts pass through a sieve into a large metal drum (Figure A4). The drum was equipped with a small window that allowed employees to monitor the size of the dusts that passed through the sieve. The retort employees then transported the collected mercury-containing dust into the retort room to be processed.

Figure A4. Shaker is designed to separate mercury-containing dusts from fine glass. Photo by NIOSH.

Although we were unable to observe the retort in operation, the process was described to us. The retort employee placed a metal tray full of mercury-containing dust (Figure A5) into the retort (Figure A6). The retort furnace heated the dust creating mercury vapor inside of the furnace, which was then rapidly cooled to condense the mercury vapor into liquid mercury. At the end of the 48-hour cycle, retort employees drained the liquid mercury (Figure A7) and removed the now mercury-free dust from the retort for disposal. The retort employees also disassembled mercury-containing devices and bulbs in the disassembly area (Figure A8).

Figure A5. Metal totes containing mercury dust. Photo by NIOSH.

Figure A6. Front of the retort where metal trays containing mercury dust are placed. Photo by NIOSH.

Figure A7. End of the retort where liquid mercury exits through ports into two buckets. Photo by NIOSH.

Figure A8. Removing the metal housing for mercury-containing lightbulbs in the disassembly area. Photo by NIOSH.

Batteries and Ballasts

Battery Sorting

In this area, one or two employees wearing eye protection, steel-toed boots, and leather gloves received 55-gallon drums full of mixed batteries. The types of batteries in the drums included nickel cadmium, lithium, lithium ion, and lead acid. Employees had already placed tape on the contact points of each battery. The taped batteries were sorted by battery type into separate drums for recycling or disposal. Occasionally when drums are opened, employees would notice an accumulation of battery acid in the bottom of the drum. When this occurred, one employee sprinkled a battery acid neutralizing powder into the bottom of the drum. Once the acid was neutralized, typically within a few minutes, the inert mixture was removed and placed into a separate bin for disposal.

Ballast Sorting

For this process, one employee, wearing eye protection, steel-toed boots, and leather gloves, received a palette of mixed ballasts. Some ballasts were received encased in a protective housing. For these ballasts, the employee first used hand tools to disassemble the protective housing. Once disassembled, the employee separated the polychlorinated biphenyl (PCB) ballasts from the non-PCB ballasts. PCB ballasts were placed in a 55-gallon drum for shipment and disposal. Non-PCB ballasts were placed in a gaylord box for shipment or disposal.

Section B: Methods, Results, and Discussion

Methods: Mercury Exposure Assessment

Full-Shift Air Sampling

We collected full-shift personal breathing zone samples and full-shift area samples for mercury over a 2-day period. The samples were collected using hopcalite solid sorbent tubes, 0.8 micron mixed cellulose ester cassette filters housed in 37-millimeter nylon cassettes, and air sampling pumps operating at a flowrate of 0.2 liters per minute (LPM). We analyzed each sample for mercury according to NIOSH Method 6009 [NIOSH 2023].

Jerome® Direct Reading Mercury Vapor Analyzer

We used a Jerome® J405 atomic fluorescence mercury vapor analyzer to measure mercury vapor concentrations in the air throughout the facility. The instrument measurement ranged 0.001–0.999 milligrams per cubic meter (mg/m^3). We collected 171 samples, with each sample taking about 1 minute to collect. We used these measurements to evaluate employees' potential exposures to mercury vapor in the air and to identify "hot spots" that contributed to elevated mercury levels in the facility.

We collected measurements in the production areas (lamp room, retort, shaker area, material storage, dismantling, glass roll-off [where crushed glass exits the lamp room], shipping and receiving, battery and ballast, and bulb storage) where employees wore respirators. We aimed to quickly evaluate if the selected respirators provided the appropriate level of protection. We evaluated nonproduction areas (including the breakroom, offices, clean clothes lockers, conference room, hallways, respirator storage, and restrooms) to evaluate whether these areas had unanticipated elevated mercury levels.

Results: Mercury Exposure Assessment

Full-Shift Air Sampling

Our measurement results showed that employees' full-shift time weighted average personal exposures to airborne mercury ranged 0.004–0.082 mg/m^3. We compared the personal air sample results with the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) of 0.1 mg/m^3, the National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) of 0.05 mg/m^3, and the American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Value (TLV®) of 0.025 mg/m^3.

Of the 18 personal air samples we collected, 10 were above the ACGIH TLV, 7 were above the NIOSH REL, and none were above the OSHA PEL. All eight personal exposure measurements taken in the lamp room were above the ACGIH TLV. Seven of the eight lamp room measurements were also above the NIOSH REL. In addition, the retort managers' exposures were above the ACGIH TLV, but less than the NIOSH REL.

Area sample results showed airborne mercury in the building entry (0.014 mg/m^3), breakroom (0.013 mg/m^3), and main office (0.007 mg/m^3). All these measurements were below the ACGIH TLV, NIOSH REL, and OSHA PEL. Table C1 shows the concentrations of mercury in personal air sampling conducted during the visit. Table C2 shows the concentrations of mercury in area samples in the breakroom, office, and building entrance.

Jerome® Direct Reading Mercury Vapor Analyzer

We found mercury vapor present in several locations throughout the facility. We took 171 direct reading measurements using the Jerome mercury vapor analyzer: 66 in production areas and 105 in nonproduction areas. The median mercury level in the production areas was 0.03 mg/m^3 (range: 0.001–0.106 mg/m^3) while the median in the nonproduction areas was 0.015 mg/m^3 (range: 0.001–0.074 mg/m^3). The highest level we measured in the facility was 0.106 mg/m^3, which was directly over the glass in the outdoor bulb collection bin in the crushed glass roll-off area.

The elevated concentrations resulted from accumulated mercury vapors on the glass, however, personnel entered this area infrequently. Consistent with personal air sampling results, the second highest concentrations of mercury vapors in the production areas were measured in the lamp room where concentrations ranged 0.002–0.091 mg/m^3. These measurements were taken near the conveyor belt where mercury-containing dusts were initially released from bulbs. Adding local exhaust ventilation (LEV) to the conveyor belt area could reduce worker exposures to mercury during this process.

In the retort division, the highest measurements were taken from piles of dust near the retort machine. This suggests improving housekeeping procedures to remove dust would be helpful in reducing worker exposures to mercury. Mercury vapor concentrations were measured throughout some of the nonproduction areas including in the breakroom, conference room, and retort office. We found measurable concentrations of mercury vapors in what should be uncontaminated areas, such as in the locker area, clean clothes lockers, and in respirator storage boxes. Table C3 shows the range of direct reading mercury measurement results by work area.

Methods: Employee Health Assessment

Confidential Medical Interviews

During our second visit in June 2023, we invited all 15 employees to participate in confidential semi-structured medical interviews. Interviews covered basic demographics, work history and practices, health and safety concerns, PPE use, training, and possible work-related health effects or direct exposure to mercury. All employees participated in an interview. If an employee's primary language was Spanish, a native Spanish speaker on our team conducted the interview.

Measurement of Urine Mercury Levels

During our second visit, we invited all 15 employees to participate in urine screening for mercury. We explained the objectives and methods of our evaluation, disseminated written information on mercury testing, and answered any questions employees had. After obtaining informed consent, we collected spot (random) urine samples to measure mercury levels. These urine samples were shipped on dry ice to Associated Regional and University Pathologists Laboratory (ARUP) in Salt Lake City, Utah.

Urine levels of mercury were measured by quantitative inductively coupled plasma mass spectrometry following published protocols [Caldwell et al. 2003]. Urine specimens were analyzed for creatinine (a protein used as a surrogate measure of kidney function) in a Clinical Laboratory Improvement Amendments (CLIA) certified laboratory. The laboratory results were reviewed and approved by a quality assurance officer to ensure that they conformed to acceptable quality standards. Mercury levels were then adjusted by urine creatinine level. Urine creatinine level was also used to judge if a specimen was excessively dilute or concentrated. The World Health Organization's guidelines for suitable urine creatinine levels are > 30 mg/dL and < 200 mg/dL [WHO 1980]. Urine mercury to creatinine ratio was compared with the ACGIH Biological Exposure Index (BEI®) of 20 micrograms per gram (µg/g) creatinine [ACGIH 2024].

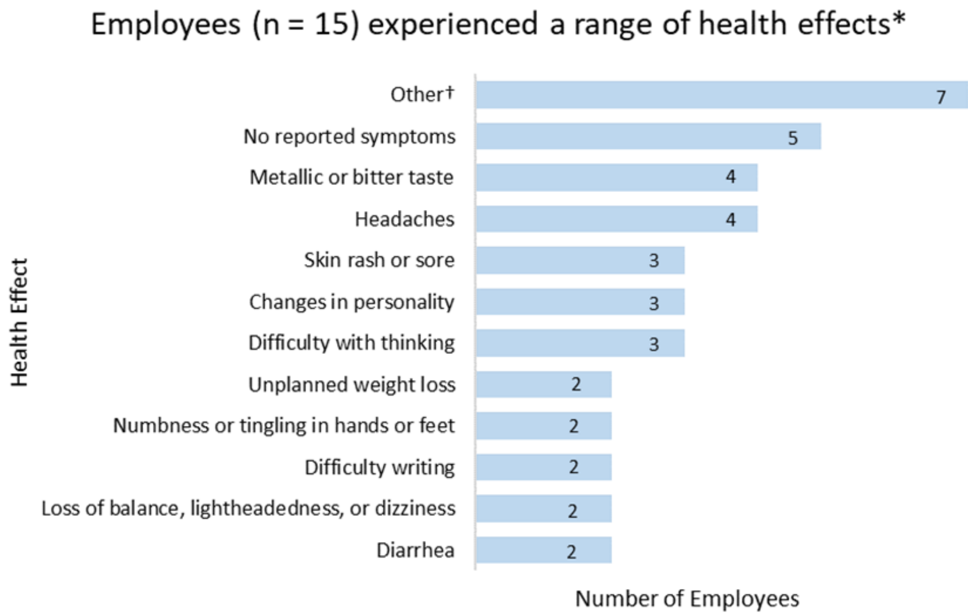
Results: Employee Health Assessment

Confidential Medical Interviews

During our visit, 15 employees participated in confidential medical interviews. Of the 15 employees, 13 (87%) were male and 2 (13%) were female. The median age was 42 years (range: 25–58 years). Because mercury levels in the body may be affected by whether a person smokes, consumes seafood, or has mercury amalgam dental fillings, we asked about these potential routes of exposures. Most participants never smoked or vaped (n = 9, 60%). Most ate seafood at 1–3 meals per month (n = 8, 53%) and three (20%) ate seafood at one meal per week (n = 3, 20%). Most (n = 13, 87%) did not have mercury amalgam fillings in their teeth. The remaining two (13%) employees did not know if they had mercury amalgam fillings. Characteristics of interviewed employees are shown in Table C4.

The 15 employees interviewed included 8 technicians, 3 managers or supervisors, 2 drivers, and 2 office workers. The eight technicians included retort, ballast, and battery technicians. Among all employees, the median job tenure was 15 months (range: 0–144 months). Most worked 40 hours per week (range: 40–55 hours). There was a consistent distribution of employees across work locations with most (n = 4, 27%) working primarily in the lamp room. Job characteristics of participants interviewed are in Table C4.

Most employees (n = 10, 66%) reported that they experienced symptoms they felt may be related to their work. The most common reported symptoms were having a metallic or bitter taste in their mouth (n = 4, 27%) and headaches (n = 4, 27%) (Figure B1). One in five employees (n = 3, 20%) reported skin rash or sores, changes in personality, or difficulty with thinking.



* Reported symptoms are not mutually exclusive. Participants could report multiple symptoms.
† Other includes difficulty with sleep, loss of muscle strength, changes in teeth/gums, skin irritation, hip pain, hearing loss, fatigue, tremors, and nose bleeds.

Figure B1. Self-reported work-related symptoms of interviewed employees (n = 15) that may be associated with mercury exposure.

All but one employee reported wearing some form of PPE at work. The employee who reported never wearing PPE stated they never needed to go into work areas where PPE was required. Among the 15 employees, almost all (n = 13, 87%) wore safety glasses and gloves (n = 13, 87%) (Table C5). Seven (47%) wore uniforms and five (33%) wore hearing protection. Ten of the 15 employees (67%) reported wearing a respirator at work: two reported wearing an N95® respirator, seven reported wearing an elastomeric half-mask respirator equipped with cartridges for mercury vapor, and one reported wearing both. All eight employees who wore an elastomeric half-mask respirator reported being medically cleared, fit tested, and trained to use the respirator. The remaining two who only wore N95 respirators were not trained, fit tested, or medically cleared. Three of the eight employees who wore an elastomeric half-mask respirator had worked at the site for more than 1 year. All three were overdue for their annual fit test with two employees reporting their last fit test was > 2 years ago.

Measurement of Urine Mercury Levels

Urine mercury concentrations and mercury to creatinine ratios are shown in Table C6 by primary work location. One sample was too dilute to interpret. Of the remaining 14 samples, the median urine mercury level was 23 micrograms per liter (µg/L) (range: 2.5–80 µg/L) and the median urine to creatinine mercury ratio was 51 µg/g (range: 1.3–64 µg/g). Of the 14 employees, 12 (86%) exhibited mercury levels in their urine that exceeded the reference range provided by the laboratory (range: 0.0–5.0 µg/L). Additionally, six employees (43%) had urine mercury-to-creatinine ratios surpassing both the laboratory's reference range for mercury-to-creatinine ratio of 0.0–20.0 µg/g and the ACGIH BEI of 20 µg/g [ACGIH 2024]. Workers who worked in the retort, shaker, or lamp rooms had the highest mercury levels and mercury to creatinine levels.

Methods: Ventilation Assessment

We assessed the ventilation systems at the facility. We observed the general ventilation units in the office and lamp room. We also examined the LEV systems in the lamp room, disassembly area, and retort division and evaluated air flow direction and pressurization between rooms. We also took face velocity measurements using a TSI VelociCalc Model 9535 hot wire anemometer with a Model 966 probe when possible.

Results: Ventilation Assessment

General Ventilation

The office area used forced air heat and a central air-conditioning unit with ducted air-returns. The air intake was on the north side of the building through an air handling unit located on the roof. The breakroom, retort manager's office, changing rooms, and PPE storage area did not have any supplied or exhausted air. However, the retort division had two exhaust fans roughly 2 feet in diameter, located in the wall. While the fans were not functioning at the time of our survey, they are typically used while the retort is running or when the work area becomes too hot. These fans exhausted directly into the parking lot.

Inside the lamp room were two broken ceiling mounted air-conditioning units that had not been repaired at the time of the site visit. The supply air intakes passed through two pleated filters with a minimum efficiency reporting value (MERV) of 8 (Figure B2). These filters were changed every 2 weeks when in operation. After passing through the cooling unit, the air was supplied above the lamp crusher and the feeding conveyor, near where employees placed the bulbs onto the conveyor. The intent of these air-conditioning units was to reduce the temperature in the lamp room to reduce the rate of mercury vapor volatilization.

Figure B2. Air intake through a pleated filter, air-conditioner, and supply ductwork for one of the two air conditioning units in the lamp room. Photo by NIOSH.

Local Exhaust Ventilation

Lamp Room

The local exhaust air intake in the lamp room was located inside the incline conveyor at the lamp crusher. Air first passed through a baghouse charcoal filter, and was then exhausted to the roof (Figure B3). There was no appreciable airflow or draw at the conveyor where the employees placed the bulbs (~12 feet per minute), but airflow velocity at gaps around the lamp crusher enclosure was faster (100–200 feet per minute). This system appeared to be designed to primarily exhaust the incline conveyor to reduce the escape of mercury dust and vapor while the bulbs are breaking inside the lamp crusher, not to reduce mercury concentrations where the employees place the bulbs on the conveyor. Employees typically worked about 6–8 feet from the incline conveyor but could also walk along the glass breaking conveyor and potentially work at the area where the glass breaking conveyor connected to the incline conveyor.

Figure B3. Baghouse and charcoal filter in the lamp room. Photo by NIOSH.

Dismantling/Disassembly

The LEV system in the dismantling/disassembly area consisted of two moveable hoods located over two disassembly stations (Figure B4). The hood exhausted through a baghouse, charcoal filter, and then was recirculated back into the room. We did not assess face velocity because the system was not in operation during our site visit. We did not review system maintenance or filter change-out schedules.

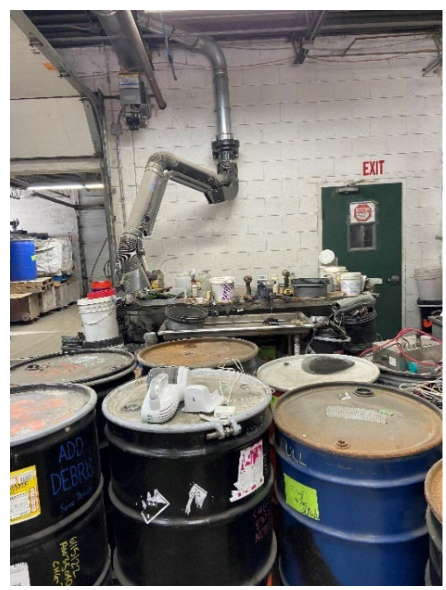


Figure B4. One of the moveable fume hoods in the disassembly area. Photo by NIOSH.

Retort

The front portion of the retort had a large overhead canopy hood and a slotted hood directly above the opening of the retort furnace (Figure B5). The ductwork to the overhead canopy hood connected to the LEV for the disassembly area while the slotted hood exhausted to the roof. We did not assess face velocity because the system was not in operation during our site visit.

Figure B5. Two overhead exhaust hoods over the cylindrical retort furnace. Photo by NIOSH.

Airflow and Pressurization

Air flow direction was from the production floor into the office area near the furnace, and from the employee entrance into disassembly/dismantling area. Airflow was neutral in the breakroom, changing room, and retort manager's office area.

On the production floor, the air flowed into the lamp room from all three doorways. The remainder of the warehouse had roll-up doors and natural air movement meaning air pressurization and air flow direction could change throughout the day depending on weather conditions and if the roll-up doors were open or closed.

Methods: Noise Exposure Assessment

Personal Noise Dosimetry

To evaluate employee noise exposures, we collected full-shift time-weighted average (TWA) personal noise exposure measurements. Using Larson Davis Spartan™ 730 integrating noise dosimeters, we collected full-shift samples from nine employees over a 2-day period (18 total full-shift measurements). We placed the dosimeter microphone on the top of the employee's shoulder at the midpoint between the neck and edge of the shoulder. We took noise dosimetry measurements using three different settings to compare with the NIOSH REL, the OSHA PEL, and the OSHA AL.

Sound Level Measurements

We used a Larson Davis Model 831 integrating sound level meter to collect instantaneous area sound level measurements in the lamp room and shaker areas. During measurements we positioned the instrument about 5 feet above the floor and within 3–6 feet of the employees or the primary noise source in the area.

Results: Noise Exposure Assessment

Personal Noise Dosimetry

A summary of personal noise dosimetry results is provided in Table C7. We compared employees' noise monitoring results with the noise exposure limits set by NIOSH and OSHA. These occupational noise exposure limits are meant to be the amount of noise that most employees can be exposed to without substantial risk of hearing loss. OSHA and NIOSH measure and calculate noise exposures in different ways, as described in Section D. For an 8-hour work shift, the NIOSH REL is 85 decibels, A-weighted (dBA). The OSHA AL is 85 dBA and the OSHA PEL is 90 dBA. Employers are required to keep noise exposures below the OSHA PEL; however, the NIOSH REL is more protective.

Results showed that all four employees who we monitored over two shifts in the lamp room had noise exposures at or above the NIOSH REL, and seven of the eight measurements were above the OSHA AL. The production worker we monitored over two shifts from the retort division was exposed to noise at or above the NIOSH REL. Noise exposures for the retort managers and for employees in the warehouse and battery sorting area were below NIOSH and OSHA noise exposure limits.

Sound Level Measurements

Sound level measurements in the lamp room ranged 73.6–90.6 dBA. The highest sound levels (greater than 85 dBA) in the lamp room were at the employee work stations on the conveyor line. Noise at the conveyor was primarily generated by the conveyor motor and glass breaking. Measurements at the shaker machine ranged 80.5–85.5 dBA.

Methods: Document Review and Observations of Work Processes, Practices, and Conditions

We reviewed the respiratory protection program and hearing conservation program for this facility. We observed the work processes, individual practices, PPE usage, and workplace conditions at the facility. The retort machine was not functioning at the time of our visit.

Results: Document Review and Observations of Work Processes, Practices, and Conditions

Document Review

The respiratory protection program document we reviewed was effective as of January 2019. This document provided detailed instructions regarding medical clearance, record keeping, fit testing, and training for the use of respiratory protection. The document specified that respirators should be washed with soap and water after each shift, sanitized before each use, and stored in a clear plastic bag. Employees were instructed to change the mercury-vapor cartridge of the respirator when scheduled to do so, but a timeline was not specified. They were also instructed to change the respirator cartridge if a strange odor or irritation occurred during use. For employees not required to use respiratory protection, a supplemental *Notice on Voluntary Use* document instructed employees to follow manufacturer instructions and to ensure the respirator chosen was appropriate to the hazard.

The hearing conservation program document outlined management and employee responsibilities, hearing protection device use and maintenance, and training and audiogram requirements. Management was required to conduct noise monitoring annually and whenever processes or equipment caused a change in noise exposures. Management was also responsible for annual hearing conservation training. Training on hearing conservation was to be conducted within a month of hire and annually thereafter. Audiograms were required within 1 month of hire to establish a baseline, then annually thereafter.

Observations of Work Processes, Practices, and Conditions

We observed inconsistent PPE use during our visits. In the lamp room, where respirators are always required, we observed employees removing their respirators and/or wearing their respirators improperly. One employee was wearing an N95 respirator with one of the straps cut off; this compromised the respirator's seal. We also observed personnel removing their hearing protection devices while the conveyor was in use and removing their respirators while in the lamp room.

We noted that some PPE was inappropriate for the task. Employees in the battery and ballast area wore flexible leather gloves with a rubber grip while handling batteries and ballasts. These gloves were not anti-corrosive and did not protect the wearer from contact with battery acids. In the lamp room, workers who performed lamp breaking near the conveyer frequently encountered sharp metal and broken glass. Although the employees wore cut-resistant hand protection, they did not wear arm protection to prevent injuries from sharp objects.

Some work practices contributed to increased mercury exposures. Mercury-containing dusts had accumulated on nearly every surface within the retort division and the inside the lamp room. At the time of our visits, there was no plan in place for the remediation of mercury-containing dusts. We observed employees using compressed air to remove accumulated dusts from their clothing and uniforms before lunch and at the conclusion of their shifts. This practice increases the likelihood of respiratory exposures to mercury-containing dusts. In the retort division, the retort trays were used with loose-fitting covers. These covers do not provide protection from mercury-containing dusts or vapors.

Discussion

The OSHA PEL for mercury vapor is 0.1 mg/m^3. Full-shift air sampling results showed that none of the employees were exposed to mercury vapor concentrations above the OSHA PEL. However, employees were exposed to mercury levels above the NIOSH REL of 0.05 mg/m^3 and the ACGIH TLV of 0.025 mg/m^3 in the lamp room and in the retort department, respectively.

When inhaled, mercury vapors are readily absorbed in the lungs and quickly distributed to all the organs of the body [Park and Zheng 2012]. Mild subclinical signs of mercury toxicity can be seen in workers at levels as low as 0.02 mg/m^3 [WHO 2017]. It is more protective to adhere to the most stringent guidelines to account for more sensitive worker populations. In addition, since the retort was not running at the time of our visit, additional monitoring should be conducted while the retort is in operation to further assess mercury exposures.

OSHA PELs are legally enforceable occupational exposure limits (OELs) for hazardous substances in the workplace. NIOSH RELs and ACGIH TLVs are not regulatory limits but are OELs. These guidelines are typically more protective and can provide protection for a broader range of employees, including those employees who may be more sensitive or prone to illness [WHO 2017].

Measurements taken with the Jerome mercury vapor analyzer showed elevated levels of mercury vapor throughout the facility. Similar to the breathing zone and area air sampling results, we found the highest mercury concentrations during production activities were in the lamp room and retort division. We also found elevated concentrations of mercury vapors in nonproduction areas. Measurements in the retort office showed mercury vapor levels as high as 0.04 mg/m^3. In the conference room, mercury vapor levels were as high as 0.03 mg/m^3. This suggests that mercury-containing dusts are transferred from production areas to office spaces via tools, clothing, or air movement. Notably, mercury was also found inside a respirator storage container, highlighting the importance of proper cleaning and maintenance of work areas, respirators, and other PPE to prevent secondary exposure. While these measurements from direct reading instruments cannot be directly compared with OELs, it is a useful tool in identifying areas where implementing robust housekeeping measures to reduce accumulation of mercury-containing dusts in production areas and ensuring uncontaminated PPE can significantly lower the risk of mercury exposure in both production and nonproduction areas.

When outdoor air supply and air movement is sufficient, air contaminants can be more readily diluted or removed. Stagnant air can cause air contaminants to accumulate in the air or fall out of the air onto surfaces such as workstations, floors, and chairs. We noted insufficient air movement in the main hallway, office areas, and break area, which coincided with elevated mercury vapor concentrations in all of these areas. Increased ventilation in these spaces can reduce mercury vapor exposures.

We found that urine mercury levels for workers in the retort and lamp rooms were especially high, which aligned with measurements from the Jerome mercury vapor analyzer and personal exposure monitoring results in those areas. The relationship between workplace location and elevated mercury urine levels underscores potential sources of exposure. Over time, these exposures can lead to various health effects, including neurological and renal toxicity. While the specific threshold at which mercury exposure induces symptoms remains unknown, the prevalence of self-reported symptoms among employees at this worksite is concerning. These symptoms, including memory deficits, headaches, and dizziness, are consistent with mercury exposure and underscores the importance of implementing preventive measures while enhancing awareness about potential health effects of mercury among employees. Proactive interventions, such as revising work practices, improving ventilation systems, and providing language-appropriate training on PPE use, should be prioritized. Regular health monitoring and medical evaluations can also be considered.

Employees noise exposures in the lamp room were above the NIOSH REL and OSHA AL, and employees in the retort division had noise exposures above the NIOSH REL. Sound level measurements revealed that the highest sound levels were at the conveyor line in the lamp room. Appropriate hearing protection should be worn by employees working in the lamp room and retort division at all times. Enlisting the assistance of a noise control specialist may be helpful in identifying potential noise reduction strategies, such as equipment enclosures or barriers, to help reduce noise exposures at the source. In addition, proper equipment maintenance can help prevent vibration, squeaks, or other sounds from contributing to employee noise exposures.

Limitations

This evaluation had a cross-sectional design, which means that information on exposures and health outcomes was collected at a single point in time. So we may not have seen all the production processes such as retort. Because the retort was not in operation at the time of our visit, we were unable to evaluate potential mercury or noise exposures during its operation. The retort remained inoperable for several months during our evaluation. We published this report to provide valuable health and safety information about employee exposures in a timely manner. The recommendations provided in this report can help reduce and prevent potentially harmful employee exposures. Further evaluation of mercury exposures should be conducted once the retort is in operation.

The design of this evaluation does not accurately capture changes in exposures or symptoms over time. ACGIH BEIs, including those for urine mercury, are recommended to be collected at the end of the shift and end of the work week [ACGIH 2024]. It is possible the spot urine samples we collected might be underestimating exposure levels. However, although the 24-hr urine specimen is regarded as superior, it is less convenient and can lead to collection problems [NCCLS 1997]. Thus, in most cases, a random urine specimen is adequate [Woods et al. 1996]. In addition, our assessment was designed to assess the presence of symptoms or adverse health outcomes that employees had experienced prior to or at the time of our visit. This evaluation is unable to capture symptoms or health effects that may occur following long-term, low-level exposure to mercury. Finally, the production process used at this facility was unique; findings from this evaluation may not be generalizable to other facilities.

Conclusions

Air sampling results indicate worker exposures to mercury and noise exceeded relevant OELs. We noted high urine mercury levels in employees who had high occupational exposure to mercury in air and found high occupational exposure to mercury even in nonproduction areas. Some employees also reported symptoms consistent with mercury exposure, suggesting exposures to mercury may have led to health effects. Some of these exposures could be preventable with improved ventilation, housekeeping practices, and health and safety programs. In addition, some workers were exposed to noise over the NIOSH REL in the lamp room and retort division areas. Equipment enclosures and preventative maintenance of equipment may help reduce hazardous noise exposures in these areas.

Attribution Statement

N95 is a certification mark of the U.S. Department of Health and Human Services (HHS) registered in the United States and several international jurisdictions.

Section C: Tables

Table C1. Personal air sampling results for mercury in June 2023

Job/Activity (Day 1)	Sample time (24-hr clock)	Concentration (mg/m^3)
Warehouse manager/operations	0717–1547	0.006
Warehouse technician	0722–1549	0.004
Retort manager/supervisor	0746–1548	0.035
Retort division employee	0729–1550	0.013
Battery sorter	0738–1549	0.011
Lamp room line employee 1	0733–1551	0.082
Lamp room line employee 2	0742–1552	0.039
Lamp room line employee 3	0745–1550	0.062
Lamp room line employee 4	0747–1551	0.070
Job/Activity (Day 2)	**Sample time (24-hr clock)**	**Concentration (mg/m^3)**
Warehouse manager/operations	0714–1600	0.007
Warehouse technician	0653–1550	0.029
Retort manager/supervisor	0710–1546	0.032
Retort division employee	0712–1548	0.011
Battery sorter	0704–1549	0.007
Lamp room line employee 1	0716–1552	0.068
Lamp room line employee 2	0714–1553	0.073
Lamp room line employee 3	0714–1552	0.074
Lamp room line employee 4	0712–1550	0.077
NIOSH REL		0.05 mg/m^3
OSHA PEL		0.1 mg/m^3
ACGIH TLV		0.025 mg/m^3

mg/m^3 = milligrams per cubic meter; PEL = Permissible exposure limit; REL = Recommended exposure limit; TLV = Threshold limit value

Table C2. Area air sampling results for mercury in June 2023

Location	Sample time	Concentration (mg/m³)
Building entrance	0754–1552	0.014
Breakroom	0704–1526	0.013
Main office	0702–1527	0.007
NIOSH REL		0.05 mg/m³
OSHA PEL		0.1 mg/m³
ACGIH TLV		0.025 mg/m³

Table C3. Jerome mercury vapor analyzer results by work area in June 2023

Production areas		Nonproduction areas	
Sample location	Concentration range (mg/m³)	Sample location	Concentration range (mg/m³)
Glass roll-off	**0.008–0.106**	**Respirator storage**	**0.007–0.074**
De-manufacturing	**0.092***	**Breakroom**	**0.011–0.049**
Lamp room	**0.002–0.091**	**Clean clothes lockers**	**0.010–0.048**
Material storage 1	**0.016–0.090**	**Retort office**	**0.017–0.040**
Retort	**0.011–0.067**	**Bathroom 1**	**0.022–0.033**
Bulb storage	0.001–0.018	**Conference room**	**0.013–0.030**
Shaker	0.001–0.011	Office 3	0.020*
Battery and ballast	< 0.001–0.001	Clean powder	0.015*
		Office 1	0.006–0.013
		Hallway	0.011–0.013
		Office 2	0.010–0.012
		Entrance	0.007–0.012
		Bathroom 2 (second floor)	0.010–0.011
		Material storage 2	0.010
		Outside	0.001–0.006

mg/m³ = milligrams per cubic meter

Results in **bold** indicate ranges where one or more measured concentrations were above the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) of 0.025 mg/m³. However, this comparison is for reference only. Jerome measurements, like all measurements from direct reading instruments, cannot be compared directly to OELs.

* Only one measurement was taken in this area.

Table C4. Characteristics of interviewed employees (n = 15)

Characteristics	No. (%)*
Age (median in years, range)	42 (25–58)
Sex	
Male	13 (87%)
Female	2 (13%)
Primary language	
English	11 (73%)
Spanish	4 (27%)
Smoking or vaping status	
Never	9 (60%)
Current	5 (33%)
Missing	1 (7%)
History of seafood ingestion†	
Never	2 (13%)
1–3 meals per month	8 (53%)
1 meal per week	3 (20%)
2–6 meals per week	2 (13%)
At least 1 meal per day	0 (0%)
Presence of mercury amalgam fillings	
No	13 (87%)
Do not know	2 (13%)
Job title	
Manager/supervisor	3 (20%)
Technician	8 (53%)
Driver	2 (13%)
Office worker	2 (13%)
Job tenure (median in months, range)	15 (0–144)
Hours per week (median, range)	40 (40–55)
Primary work location	
Office	3 (20%)
Retort/shaker area	2 (13%)
Truck/loading dock	3 (20%)
Lamp room	4 (27%)
Battery/ballast area	3 (20%)

* Not all percentages sum to 100% due to rounding.

† In the last 3 months.

Table C5. Personal protective equipment (PPE) use among interviewed employees (n = 15)

Self-reported PPE use	No. (%)
Safety glasses	13 (87%)
Gloves	13 (87%)
Respirators (fitted and unfitted)	10 (67%)
Elastomeric half-mask	7 (47%)
N95	2 (13%)
Both elastomeric half-mask and N95	1 (7%)
Uniform	7 (47%)
Hearing protection	5 (33%)
No PPE	1 (7%)

Table C6. Median urine mercury and mercury to creatinine levels by work location (n = 14)

Job/Activity	Median mercury level (range) µg/L	Laboratory reference category*	Median mercury to creatinine ratio (range) µg/g	Laboratory reference category*	ACGIH BEI category†
Office	11.4 (8.1–36.3)	High	8.6 (4.2–13.0)	Normal	Below
Retort/shaker/ lamp room	56.5 (20.9–80.0)	High	41.3 (16.1–64.0)	High	Above
Truck/loading dock	3.0 (2.5–27.4)	Normal	2.5 (1.3–10.8)	Normal	Below
Battery/ballast	24.8 (12–27.5)	High	25.5 (5.8–45.2)	High	Above
Total	23 (2.5–80)	High	51 (1.3–64)	High	Above

µg/L = micrograms per liter; µg/g = micrograms per gram

* The laboratory reference range for mercury in urine is 0.0–5.0 µg/L or 0.0–20.0 µg/g creatinine.

† The American Conference of Governmental Industrial Hygienists (ACGIH) Biological Exposure Index (BEI) for mercury in urine is 20 µg/g creatinine.

Table C7. Personal noise measurement results in June 2023

Job/Activity (Day 1)	NIOSH REL measurement criteria* (dBA)	OSHA AL measurement criteria* (dBA)	OSHA PEL measurement criteria† (dBA)
Warehouse manager/operations	80.9	74.3	68.6
Warehouse technician	81.7	74.4	69.7
Retort manager/supervisor	83.0	74.2	70.4
Retort division employee	86.3	83.4	77.0
Battery sorter	79.4	69.9	64.5
Lamp room line employee 1	95.1	86.0	82.3
Lamp room line employee 2	89.8	85.6	82.5
Lamp room line employee 3	89.8	85.7	82.2
Lamp room line employee 4	89.7	85.5	81.3
Job/Activity (Day 2)	**NIOSH REL measurement criteria***	**OSHA AL measurement criteria***	**OSHA PEL measurement criteria†**
Warehouse manager/operations	82.0	76.4	70.3
Warehouse technician	78.3	70.5	63.0
Retort manager/supervisor	77.3	70.3	59.0
Retort division employee	85.0	82.3	73.8
Battery sorter	75.7	67.1	58.0
Lamp room line employee 1	92.7	87.8	85.2
Lamp room line employee 2	89.3	84.0	79.1
Lamp room line employee 3	91.2	85.2	80.2
Lamp room line employee 4	95.7	86.7	83.6
Noise exposure limit (8-hour work shift)	85.0	85.0	90.0

REL = Recommended exposure limit; AL = Action level; PEL = Permissible exposure limit;
REL = Recommended exposure limit; dBA = A-weighted decibels

* The criteria for calculating the NIOSH REL and OSHA AL includes all noise exposures greater than or equal to 80 dBA.

† The criteria for calculating the OSHA PEL includes all noise exposures greater than or equal to 90 dBA.

Section D: Occupational Exposure Limits

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects.

However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a preexisting medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a TWA exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limits (STEL) or ceiling values. Unless otherwise noted, the STEL is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- OSHA, an agency of the U.S. Department of Labor, publishes PELs [29 CFR 1910 for general industry; 29 CFR 1926 for construction industry; and 29 CFR 1917 for maritime industry]. These legal limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH RELs are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2007]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, PPE, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Another set of OELs commonly used and cited in the United States includes the TLVs, which are recommended by the ACGIH. The ACGIH TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline “to assist in the control of health hazards” [ACGIH 2024].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at https://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index-2.jsp, contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA (Public Law 91-596) requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions.

Mercury

Mercury is a naturally occurring metal found in air, water, and soil. It exists in several forms including elemental, inorganic compounds, and organic compounds. The general population is primarily exposed to elemental mercury vapor from dental amalgam and to organic mercury from dietary sources such as fish. Occupational exposure to mercury can occur in dentistry, mining, and the manufacture and recycling of electrical equipment and medical instruments [Evans 1998].

Signs of mercury toxicity vary with the form of mercury and the route of exposure and can include gingivitis, mouth sores, and excessive salivation. These signs typically occur with urine levels greater than 300 µg/L [Magos and Clarkson 2006]. Neurologic effects can include personality changes, irritability, fatigue, tremor, ataxia, memory and concentration deficits, sleep disturbances, and a metallic taste. Mercury toxicity can also lead to kidney damage [Brodkin et al. 2007].

Since metallic mercury is volatile at ambient temperatures, most human exposure is by inhalation. In fact, inhalation exposure accounts for more than 95% of the absorbed mercury dose, whereas dermal exposure and ingestion contribute only 2.6% and 0.1% to this dose, respectively [ATSDR 2022]. Eighty percent of inhaled mercury is retained in the lungs, while the remainder is exhaled. Due to its high degree of lipophilicity (attraction to fat), 74% of inhaled mercury rapidly diffuses across the alveolar membranes into the blood [ATSDR 1992; Barregard et al. 1992; Cherian et al. 1978]. This lipophilicity also aids in its distribution to the many tissues and organs throughout the body; it can readily cross the blood-brain and placental barriers and has a high degree of affinity for red blood cells. Mercury absorbed into the blood and other tissues is quickly oxidized into divalent mercury via the hydrogen peroxide–catalase pathway and accumulates in the renal cortex of the kidney [ATSDR 2022; Doull et al. 2018]. After a substantial exposure, mercury reaches peak levels within the various tissue reservoirs within 24 hours, except in the brain where peak levels are not reached for 2–3 days [ATSDR 2022; Hursh et al. 1976]. In fact, more than 50% of the initially absorbed dose is deposited in the kidneys, with the brain, liver, spleen, bone marrow, muscles, and skin being minor reservoirs for absorbed mercury [Wallis and Barber 1982].

In air, OSHA currently enforces a PEL for mercury vapor of 0.1 mg/m^3 as an 8-hour TWA [CFR 1997]. Legally, the PEL is designated as a ceiling value, but a directive has been issued by OSHA stating that this designation is incorrect, and the value is, in fact, a time weighted average [OSHA 1996]. We are following the directive in this report. The NIOSH REL for mercury vapor is 0.05 mg/m^3 as a TWA exposure for up to 10 hours per day, 40 hours per week and a ceiling level of 0.1 mg/m^3, which should not be exceeded at any time. NIOSH and ACGIH have a skin notation, indicating that skin exposure (with vapors or direct skin contact) can be a significant contributor to overall worker exposure [ACGIH 2001; NIOSH 2007]. The ACGIH TLV for mercury is 0.025 mg/m^3 (TWA exposure, 8 hours per day, 40 hours per week).

Urine and blood are the recommended sources for measuring inorganic mercury in the body [Flomenbaum et al. 2006, pp. 1244–1250, 1334–1345]. The laboratory reference range for mercury in urine is 0.0–5.0 µg/L or 0.0–20.0 µg/g creatinine. The half-life of mercury in the urine is approximately 1–3 months [Jonsson et al. 1999; Roels et al. 1991]. Although many laboratories indicate that only urine levels above 150 µg/g of creatinine should be considered toxic, evidence suggests that early signs of mercury intoxication can be seen in workers excreting more than 50 µg/g of creatinine [Barregard et al. 1992; Echeverria et al. 1995]. ACGIH currently recommends that prior to shift inorganic mercury in workers' urine not exceed 20 µg/g of creatinine [ACGIH 2024].

Noise

Noise-induced hearing loss (NIHL) is an irreversible condition that progresses with noise exposure. NIHL is caused by damage to the nerve cells of the inner ear and, unlike some other types of hearing disorders, cannot be treated medically [AIHA 2022]. Approximately 25% of U.S. workers have been exposed to hazardous noise [Kerns et al. 2018] and more than 22 million U.S. workers are estimated to be exposed to workplace noise levels above 85 dBA [Tak et al. 2009]. NIOSH estimates that workers exposed to an average daily noise level of 85 dBA over a 40-year working lifetime have an 8% excess risk of material hearing impairment. This excess risk increases to 25% for an average daily noise exposure of 90 dBA [NIOSH 1998]. NIOSH defines material hearing impairment as an average of the Hearing threshold levels (HTLs) for both ears that exceeds 25 decibels (dB) at frequencies of 1 kilohertz (kHz), 2 kHz, 3 kHz, and 4 kHz.

Although hearing ability commonly declines with age, exposure to excessive noise can increase the rate of hearing loss. In most cases, NIHL develops slowly from repeated exposure to noise over time, but the progression of hearing loss is typically the greatest during the first several years of noise exposure [Rosler 1994]. NIHL can result from short duration exposures to high noise levels or even from a single exposure to an impulsive noise or a continuous noise, depending on the intensity of the noise and the individual's susceptibility to NIHL [AIHA 2022]. Noise exposed workers can develop substantial NIHL before it is clearly recognized. Even mild hearing losses can impair one's ability to understand speech and hear many important sounds. In addition, some people with NIHL also develop tinnitus. Tinnitus is a condition in which a person perceives hearing sound in one or both ears, but no external sound is present. Persons with tinnitus often describe hearing ringing, hissing, buzzing, whistling, clicking, or chirping like crickets. Tinnitus can be intermittent or continuous and the perceived volume can range from soft to loud. Currently, no cure for tinnitus exists.

Noise measurements are usually reported as dBA. A-weighting is used because it approximates the "equal loudness perception characteristics of human hearing for pure tones relative to a reference of 40 dB at a frequency of 1 kHz" and is considered to provide a better estimation of hearing loss risk than using unweighted or other weighting measurements [Murphy et al. 2022]. The dB unit is dimensionless, and it represents the logarithmic ratio of the measured sound pressure level to an arbitrary reference sound pressure of 20 micropascals, which is defined as the threshold of normal human hearing at a frequency of 1 kHz. Because the dB is logarithmic, an increase of 3 dB is a doubling of the sound energy, an increase of 10 dB is a 10-fold increase, and an increase of 20 dB is a 100-fold increase in sound energy. Noise exposures expressed in dB or dBA cannot be averaged using the arithmetic mean.

Workers exposed to noise should have baseline and yearly hearing tests (audiograms) to evaluate their hearing thresholds and determine whether their hearing has changed over time. Hearing testing should be done in a quiet location, such as an audiometric test booth, where background noise does not interfere with accurate measurement of hearing thresholds. In workplace hearing conservation programs, hearing thresholds must be measured at frequencies of 0.5 kHz, 1 kHz, 2 kHz, 3 kHz, 4 kHz, and 6 kHz. NIOSH also recommends testing be done at 8 kHz [NIOSH 1998].

The OSHA hearing conservation standard requires analysis of hearing changes from baseline hearing thresholds to determine if a standard threshold shift (STS) has occurred. OSHA defines an STS as a change in hearing threshold relative to the baseline hearing test of an average of 10 dB or more at 2 kHz, 3 kHz, and 4 kHz in either ear [29 CFR 1910.95]. If an STS occurs, the company must determine if the hearing loss also meets the requirements to be recorded on the OSHA Form 300 Log of Work-Related Injuries and Illnesses [29 CFR 1904.1]. In contrast to OSHA, NIOSH defines a significant threshold shift as an increase in the hearing threshold level of 15 dB or more, relative to the baseline audiogram, at any test frequency in either ear measured twice in succession [NIOSH 1998].

Hearing test results are often presented in an audiogram, which is a plot of an individual's hearing thresholds (*y*-axis) at each test frequency (*x*-axis). HTLs are plotted such that fainter sounds are shown at the top of the y-axis, and more intense sounds are plotted below. Typical audiograms show HTLs from −10 dB or 0 dB to about 100 dB. Lower frequencies are plotted on the left side of the audiogram, and higher frequencies are plotted on the right. NIHL often manifests itself as a "notch" at 3 kHz, 4 kHz, or 6 kHz, depending on the frequency spectrum of the workplace noise and the anatomy of the individual's ear [Mirza et al. 2018; Osguthorpe and Klein 1991; Schlauch and Carney 2011; Suter 2002]. A notch in an individual with normal hearing may indicate early onset of NIHL. A notch is defined as the frequency where the HTL is preceded by an improvement of at least 10 dB at the previous test frequency and followed by an improvement of at least 5 dB at the next test frequency.

NIOSH has an REL for noise of 85 dBA as an 8-hour TWA. For calculating exposure limits, NIOSH uses a 3-dB time/intensity trading relationship, or exchange rate. Using this criterion, an employee can be exposed to 88 dBA for no more than 4 hours, 91 dBA for 2 hours, 94 dBA for 1 hour, 97 dBA for 0.5 hours, etc. Exposure to impulsive noise should never exceed a peak level of 140 dBA. For extended work shifts, NIOSH adjusts the REL to 84.5 dBA for a 9-hour shift, 84.0 dBA for a 10-hour shift, 83.6 dBA for an 11-hour shift, and 83.2 dBA for a 12-hour work shift. When noise exposures exceed the REL, NIOSH recommends the using hearing protection and implementing a hearing loss prevention program [NIOSH 1998].

The OSHA noise standard specifies a PEL of 90 dBA and an AL of 85 dBA, both as 8-hour TWAs. OSHA uses a less conservative 5-dB exchange rate for calculating the PEL and AL. Using the OSHA criterion, an employee may be exposed to noise levels of 95 dBA for no more than 4 hours, 100 dBA for 2 hours, 105 dBA for 1 hour, 110 dBA for 0.5 hours, etc. Exposure to impulsive noise must not exceed 140 dB peak noise level. OSHA does not adjust the PEL for extended work shifts. However, the AL is adjusted to 84.1 dBA for a 9-hour shift, 83.4 dBA for a 10-hour shift, 82.7 dBA for an 11-hour shift, and 82.1 dBA for a 12-hour work shift. OSHA requires implementation of a hearing conservation program when noise exposures exceed the AL [29 CFR 1910.95].

An employee's daily noise dose, based on the duration and intensity of noise exposure, can be calculated according to the formula: Dose = 100 × (C1/T1 + C2/T2 + ... + Cn/Tn), where Cn indicates the total time of exposure at a specific noise level, and Tn indicates the reference exposure duration for which noise at that level becomes hazardous. A noise dose greater than 100% exceeds the noise exposure limit.

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