HealthHazard Evaluation Program

Exposure to Lead During Bullet Recycling

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November 2024

Centers for Disease Control and Prevention
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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].

Availability of Report

Copies of this report have been sent to the employer and employees at the facility. The state and local health departments and the Occupational Safety and Health Administration Regional Office have also received a copy.

Recommended Citation

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Introduction

Request

Management of a lead bullet recycling company requested a health hazard evaluation to evaluate lead exposure among employees processing lead-containing bullets. The request occurred after the New Jersey Department of Health identified a group of employees with high blood lead levels (BLL) (above 40 micrograms per deciliter [µg/dL]).

Workplace

The recycling facility was a single-story building with the entrance into an equipment storage area. Off the equipment storage area was a breakroom and two offices. A clean locker room led to the restroom and shower room then into an antechamber for putting on and taking off personal protective equipment (PPE). The antechamber contained lockers for respirator storage. The warehouse was divided into material storage and the furnace room. The facility had two shifts, however at the time of our second site visit, only one employee worked the first shift.

Employees received spent bullets and their copper jackets from firing ranges. The lead was melted in two furnaces. Employees removed the copper jackets and dross (removed contaminants) from the molten lead, then poured it into a mold. After the lead cooled, employees transported the 2,000-pound ingots (large lead block) to be weighed and sold.

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

Our Approach

We visited the facility on two occasions (March and December 2023). We completed the following activities during our evaluation:

- Observed work processes, practices, and conditions.
- Measured employees' lead exposure in air during two shifts.
- Measured the concentration of lead in air throughout the facility.
- Collected wipe samples for lead on surfaces outside of the warehouse.
- Interviewed employees to learn about work history, health and safety concerns, PPE use, training, and possible work-related health effects.
- Reviewed documents and employee BLL data.

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

Our Key Findings

Most employees were overexposed to lead in air

- Of the 11 personal air samples, 7 were above the Occupational Safety and Health Administration (OSHA) permissible exposure limit for lead of 0.05 milligrams per cubic meter (mg/m^3).
- Area air samples cannot be directly compared with occupational exposure limits (which are professional guidelines). But they can help identify areas where exposure levels may be of concern. Of the 13 area air samples for lead, 6 were above the OSHA permissible exposure limit for lead. Two additional samples were above the OSHA action level of 0.03 mg/m^3, which is the level where an employer must take corrective action.
- Some employees reported they did not always wear the loose-fitting hooded powered air purifying respirators (PAPRs) in the warehouse area and around the scales.

Lead was found on nonproduction surfaces and inside employees' protective gear

- Surface sampling showed lead was being tracked outside of production areas.
- Sampling showed lead inside employees' respirator facepieces. This may contribute to employee exposure.

Employee blood lead levels were elevated

- All employees' most recent blood lead levels were above 15 µg/dL. The median BLL among employees after at least 1 month of work was 34 µg/dL: the lowest was 8 µg/dL and the highest was 57 µg/dL. The California OSHA has suggested lowering the state's permissible exposure level to 10 µg/dL.
- Three (50%) of the employees were removed from lead exposure at work because their BLLs were more than 40 µg/dL.
- Employees returned to work when their BLLs came down to below 40 µg/dL. However, the American College of Occupational and Environmental Medicine and California OSHA recommend that employees not return to working around lead until their BLLs have returned to below 15 µg/dL.
- After returning to work, most employees had BLLs that began to rise again.

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
- Better workplace morale
- Easier employee recruiting and retention
- Enhanced image and reputation
- Superior products, processes, and services
- Increased 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/.

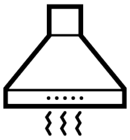
We encourage the company to use a health and safety committee to discuss our recommendations and develop an action plan. Both employee representatives and management representatives should be included on the committee. Helpful guidance can be found in *Recommended Practices for Safety and Health Programs*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

Recommendation 1: Reduce employees' exposure to lead in the air.

Why? Lead is harmful to all organ systems and has no health benefits. If you are exposed to too much lead, it can cause long-term health problems in multiple systems in the body. This includes problems with your brain and nerves, immune system, heart and blood vessels, kidneys, and reproductive system. Too much exposure may lead to general symptoms such as headaches, joint and muscle aches, weakness, and tiredness.

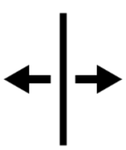
Four of six employees in this facility had full-shift personal air samples for lead over the OSHA permissible exposure limit. Although employees wore loose-fitting hooded PAPRs while working, we found all employees had at least one BLL above 15 µg/dL during their time with the company. Three employees were removed from work for BLLs above the company's medical removal level of 40 µg/dL.

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



Improve local exhaust ventilation over the melting pots/furnaces to better enclose the melting process.

- Discuss with a ventilation engineer familiar with lead melting and drossing on possible improvements to the local exhaust ventilation system. Consider installing the following:
    - Replace the elephant-trunk style duct with permanent metal ductwork. Be sure to consider fan speed for the system as a whole. Also consider duct size and entry angle for each additional component so the local exhaust ventilation system is not overburdened.
    - An enclosed dross pot connected via a dross chute to the main furnace and melting pot.
    - A local exhaust ventilation hood with a barrel specific style LEV hood for the barrel.
    - If not already installed, consider adding an impinger with a drain to the system to reduce the moisture and saturation of the baghouse and exhaust filters.
- Change the secondary exhaust air filters at the first indication from the local exhaust ventilation monitoring system that it is needed. This will prevent the local exhaust ventilation system from losing efficiency.
    - Consider checking the monitoring system at the beginning of each shift. If the percentage left on the filter is low, change the filters before starting operations.



Improve the separation between the furnace area and the rest of the warehouse

- Consider installing a more airtight barrier between the furnace area and the rest of the warehouse. This could help keep lead inside the furnace room. To offset the increased lead in the furnace room, improve the local exhaust and general ventilation systems in that area. A better barrier could lower the lead in the rest of the facility. This could possibly lessen the need to wear respirators in those areas as much. After making these changes, make sure to retest to confirm that lead levels were reduced.

Recommendation 2: Reduce employees' exposure to lead through improved medical surveillance, cleaning, training, and work practices.

Why? Lead on surfaces can be harmful to employees if they ingest it (eat or drink), breathe it in, or carry it outside the workplace on clothes, shoes, and skin. To keep this from happening, employees should be careful not to bring lead dust into their cars or homes. If employees don't remove lead dust before entering their cars or homes, they may continue being exposed to lead outside the workplace. They might also expose others to it. This can cause health problems for both employees and the people they come into contact with, such as their children.

We measured lead inside respirators and on multiple surfaces. The lead inside respirators suggests they are not being clean well enough. Although all employees were observed washing their hands, showering, and changing out of work clothes and boots before leaving the facility, take-home lead contamination remains a possibility if these actions are not strictly followed.

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

Adopt health-based medical removal and return to work limits for lead exposure.

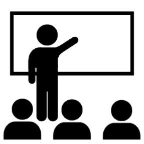
- Use health-based limits such as those recommended by the American College of Occupational and Environmental Medicine. Find these at [Workplace Lead Exposure | ACOEM].
- Obtain BLLs on lead-exposed employees with levels below 20 μg/dL every 2 months. Employees with levels consistently below 10 μg/dL can space out their testing to every 6 months.
- Obtain BLLs on lead-exposed workers with levels above 20 μg/dL every month.
    - If an employee has two consecutive BLLs of 20–29 μg/dL, or one BLL at or above 30 μg/dL, remove the employee from exposure to lead and test them monthly.
    - Allow them to return to lead exposure work after two consecutive BLLs are below 15 μg/dL.
- Evaluate lead controls again if an employee's BLLs cannot be kept below 10 μg/dL after initial improvements.

Improve respiratory protection equipment cleaning and storage.

- Thoroughly clean the hooded PAPR daily to prevent the buildup of lead dust inside the respirator facepiece. This includes cleaning the external components (hood, PAPR air tube, and battery pack) prior to storage.
    - Consult the PAPR manufacturer if unsure about the correct daily and weekly cleaning procedures.
- Store the clean PAPR inside a clean plastic bag inside individual employee lockers in the antechamber.
    - Store potentially contaminated components (e.g., battery pack, air tube) separate from the facepiece.

Reduce surface contamination and the potential for take-home lead.

- Provide employees with lead removing soap to use in the shower, in addition to the regular shampoo already provided. Use of lead removing soap could help decrease the amount of lead on exposed skin.
- Consider storing employees' clean work shoes in a separate bin from the employees' work boots.
- Consider replacing manually operated faucets in the sinks in the restroom with hands-free faucets to decrease the likelihood of getting lead on the handles.



Improve respiratory protection equipment training.

- Provide refresher training on proper respirator wear, including required use throughout the warehouse and whenever the furnaces are on and melting lead.
- Ensure annual training includes how to prevent take-home lead exposure and the importance of lead hygiene practices.

Consider buying colorimetric wipe test kits to periodically test the inside the respirators, employees' hands, and other high contact surfaces.

- Periodic tests will help identify potential sources of lead exposure and provide an indicator of the effectiveness of surface, hand, and respirator cleaning.

Recommendation 3: Reduce exposure to molten lead splashes.

Why? Splashing molten lead could cause thermal burns. Splashes can also contaminate uniforms with lead. We saw multiple uniforms with silver-colored splashes during both site visits. These likely happened when employees filled the ingot molds.

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

Reduce the "splashing" of the molten lead.

- Consider installing an automatic strainer. This way, employees do not have to be nearby while filling the mold.
- If that is not possible, consider looking into lowering the spigot closer to the mold or changing the nozzle to one that causes less splashing.

Supporting Technical Information

Exposure to Lead During Bullet Recycling

HHE Report No. 2023-0030-3407

November 2024

Section A: Workplace Information

Building

The single-story building was constructed in 1965. The building had a ducted forced-air general ventilation system, and the air intake for the office area was located on the roof. The warehouse, originally designed for stainless steel fabrication, was adapted for lead processing by adding two melting furnaces, a local exhaust ventilation (LEV) system to capture emissions from the melting furnaces, a "dirty" antechamber, a shower room, a clean locker room, and a breakroom (Figure A1).

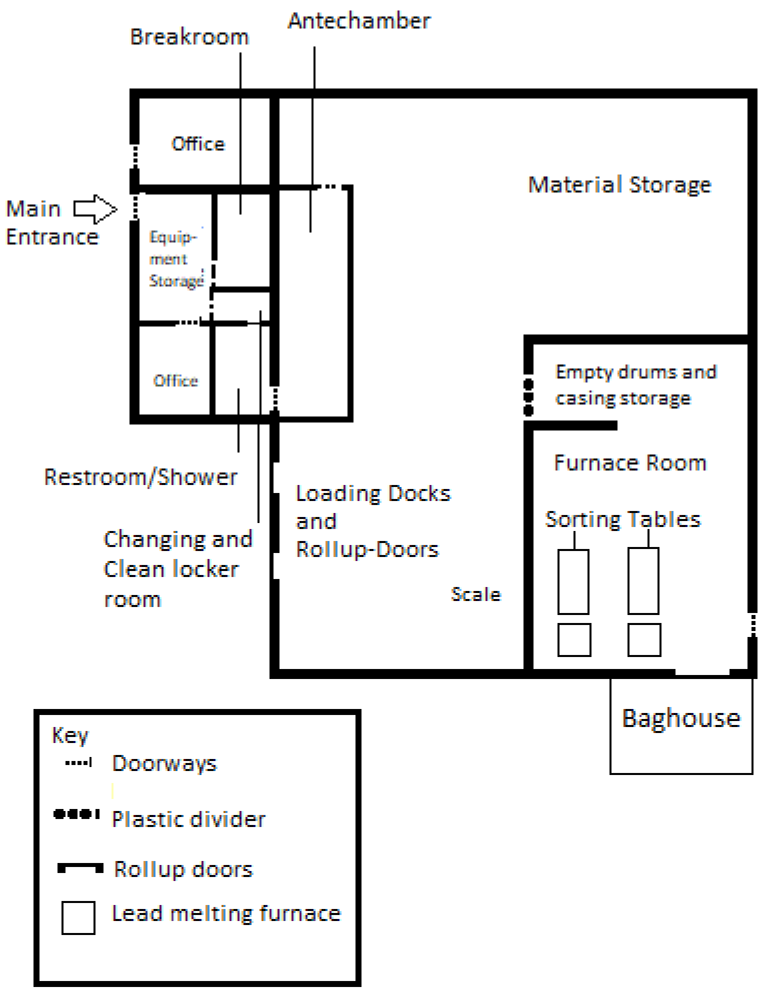


Figure A1. Facility layout. The warehouse includes material storage and the furnace room. Figure by NIOSH.

Employee Information

The facility had seven employees at the time of our evaluation. These employees worked full time, Monday through Friday. One employee worked 4:30 a.m. to 2:00 p.m. and turned the furnace heaters on. The rest of the employees typically worked 7:00 a.m. to 5:00 p.m. Employees typically worked 40 hours per week (excluding a 1-hour lunch break). Depending on production demands, more hours could be added. Employees had no union representation at the time of our visit.

History of Issue at Workplace

In early 2022, the New Jersey Department of Health identified a group of six employees at this metals recycling/smelting facility in New Jersey with an average blood lead level (BLL) of 42.1 micrograms per deciliter (µg/dL) (range: 14.5–57.2 µg/dL).

Process Description

The facility received bullet casings from firing ranges in large super sacs and processed them into lead ingots. The furnace heaters were turned on at the start of the first shift. While the furnaces heated up, employees worked in the material storage and scales area receiving and weighing raw material, including the copper jackets/bullet casings, and cleaned the facility. When the next shift of employees arrived, they placed the super sacs into the furnace room, which they opened and poured onto one of two sorting tables (Figure A2).

The employees used a specifically designed vacuum to remove the rubber components (Figure A3). The need for vacuuming depended on the source of the copper jackets and the quantity of rubber components in the raw material. Employees then pushed the copper jacket and lead bullet mixture into the furnace and left it for several hours to melt. A loose curtain was pulled across the doorway in front of the empty drum storage area while the lead furnaces were powered on and melting lead (Figure A4).

Figure A2. Pouring a super sac containing lead and copper jackets onto the sorting table. Photo by NIOSH.

Figure A3. Employees vacuuming rubber from the lead and copper components. Photo by NIOSH.

Figure A4. Loose curtain between the main warehouse and the lead melting area, pulled closed while the melting furnaces are powered on. Photo by NIOSH.

After the lead liquified, employees removed the copper jackets, which floated to the top. Employees then removed the dross (contaminants) from the liquid lead (Figure A5). An employee used a propane torch to liquify the lead inside a spigot. They then used a strainer to remove contaminants while the liquid molten lead was poured into a mold (Figure A6). The lead ingot and the barrel containing copper were left to cool and the heating cycle repeated. Forklifts were used to transport the raw material and final product around the warehouse. After the ingot cooled, employees used a forklift to remove the ingot from the mold; they then weighed and stored it (Figure A7).

Figure A5. Removing dross and copper jackets from the top of the liquid molten lead inside the furnace. Photo by NIOSH.

Figure A6. Pouring liquid molten lead into mold. Photo by NIOSH.

Figure A7. Lead ingots in the warehouse weighing approximately 2,000 pounds each. Photo by NIOSH.

Section B: Methods, Results, and Discussion

Methods: Employee Health Assessment

Confidential Interviews

In December 2023, we invited all seven current employees to participate in confidential semi-structured interviews. Interviews covered basic demographics, brief household demographics, work history and practices, health and safety concerns, personal protective equipment (PPE) use, training, and possible work-related health effects. If an employee's primary language was Spanish, a Spanish speaker on our team conducted the interview or a professional telephone interpreter assisted with the interview.

Review of Employee Blood Lead Levels

The company had an existing employee medical monitoring program for lead exposure and used an external occupational health clinic to provide testing for employees. Management provided our team with BLLs for all employees during 2019–2023. The frequency of BLL testing varied by individual employee. We reviewed all available BLLs.

Results: Employee Health Assessment

Confidential Interviews

We interviewed six of the seven current employees. All interviewed employees were male with a median age of 23 years (range: 19–47 years) and median job tenure of 2.2 years (range: 2 months–5 years). Two of the six (33%) reported smoking or vaping. A small number of employees reported having a symptom that could be related to lead exposure. All six interviewed employees reported wearing a loose-fitting powered air purifying respirators (PAPR) while working on the production floor or warehouse. However, a small number of employees also reported occasionally entering the warehouse without a respirator for short tasks, such as retrieving an item. All employees reported eating only in the breakroom or office. All six employees reported changing into worksite shoes and clothing at the beginning of their shift and changing back at the end of their shift. Five employees (83%) reported always showering at work at the end of their shift, and one (17%) reported usually showering at the end of their shift.

Review of Employee Blood Lead Levels

We reviewed the historic BLL results from November 2019 through November 2023 (Figure B1). During that time, 28 samples were collected to test BLLs among six employees (which included both current and former employees). The median BLL among employees after at least 1 month of work was 34 µg/dL (range: 8–57 µg/dL). Whenever an employee had a BLL greater than 40 µg/dL, they were removed from the production floor until they had two consecutive measurements below 40 µg/dL, taken one month apart. Three of the six employees (50%) were medically removed at least once during this period. One employee needed to be medically removed twice in two years.

In January 2022, facility management changed provided respiratory protection from tight-fitting elastomeric full-facepiece respirators to loose-fitting hooded PAPRs. The median BLL (29 µg/dL) in the period before the change (November 2019–December 2021) was lower than the median BLL

(38 µg/dL) after the change (January 2022–November 2023). Additional BLL measurements would be needed to evaluate this trend further.

Facility management completed the addition of an anteroom in mid-April 2023. The median BLL (35 µg/dL) was slightly higher before the completion of the anteroom than afterwards (29 µg/dL). Again, more BLL measurements are necessary to evaluate this trend further. In fact, the median BLL of the four current employees increased from May 2023 (25 µg/dL) to November 2023 (33 µg/dL). Three of the four employees had higher BLLs in November 2023 than in May 2023.

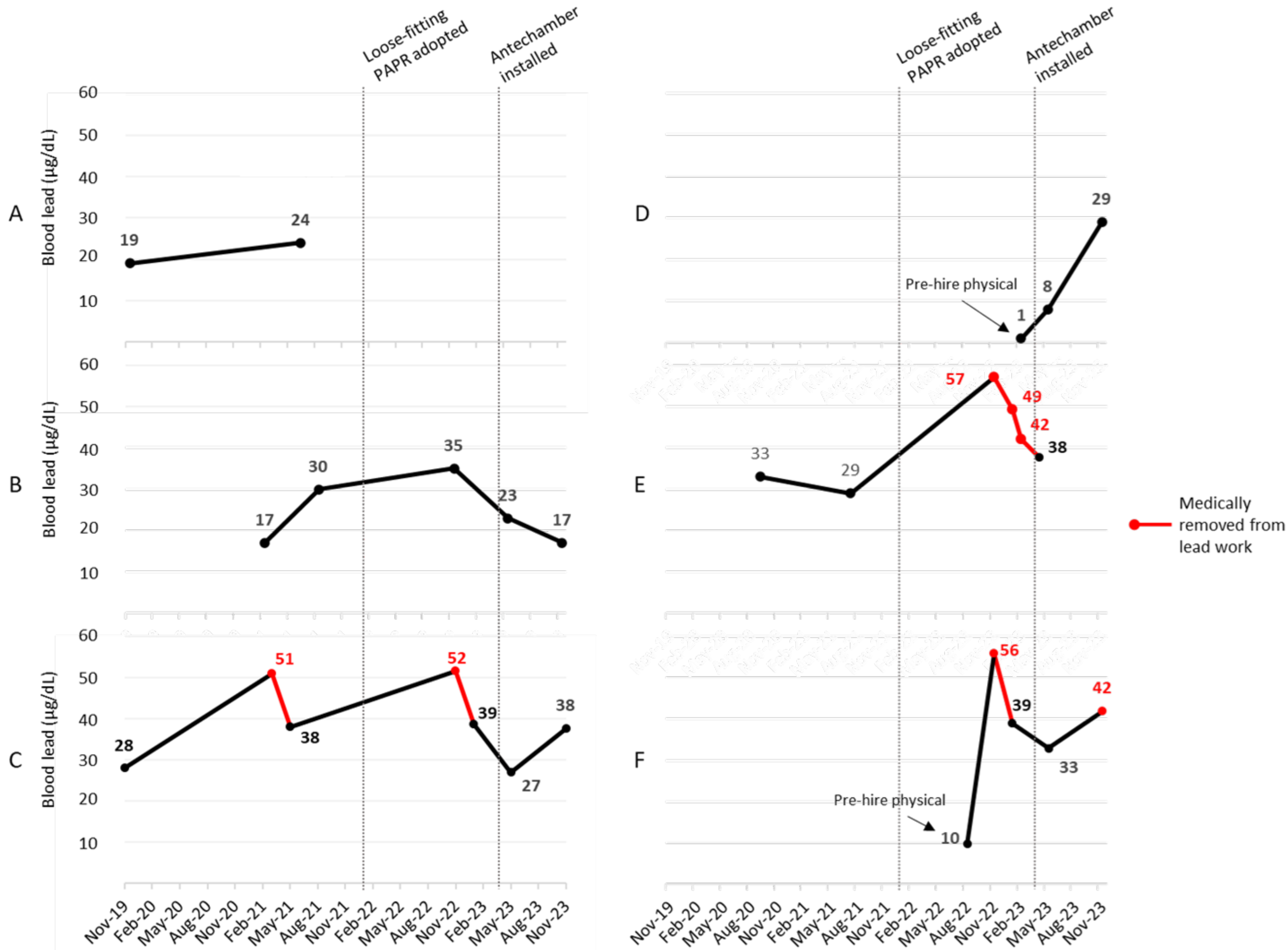


Figure B1. Blood lead levels (µg/dL) of six employees during November 2019-November 2023. Not all BLLs are from current employees.

Methods: Exposure Assessment

Personal Air Sampling

During the second site visit, we collected full-shift personal air samples for lead on five employees over 2 days and a sixth employee on 1 day. We collected one task-based sample while the employee changed the filters on the LEV system. We collected the samples on 0.8 micrometer (µm) mixed cellulose ester membrane filter at a nominal flow rate of 2 liters per minute. We analyzed the air samples for lead using National Institute for Occupational Safety and Health (NIOSH) Method 7303 [NIOSH 2024b]. The current OSHA permissible exposure limit (PEL), NIOSH recommended exposure limit (REL), and American Conference of Governmental Industrial Hygienists (ACGIH®) occupational exposure limit (OEL) are 0.05 milligram per cubic meter (mg/m^3) for lead in air. The OSHA action limit (AL) for lead is 0.03 mg/m^3.

Area Air Sampling

During the second site visit, we collected 13 full-shift area air samples for lead around the production warehouse to evaluate airborne lead concentrations throughout the facility. We collected a task-based area air sample in the furnace room while the furnaces were heating. We analyzed the samples for lead using NIOSH Method 7303 [NIOSH 2024b].

Surface Wipe Sampling

During the initial site visit, we performed qualitative lead wipe sampling on surfaces outside of the production warehouse area (in the administrative office area) to evaluate for the presence or absence of lead. During the second site visit, we collected 19 surface wipe samples for lead on a variety of surfaces outside of the production warehouse area. Before collecting each sample, we donned clean nitrile gloves and used a premoistened Ghost Wipe™ to collect the sample following NIOSH Method 9100 for quantification [NIOSH 2024b]. We used a 100-square centimeter (100 cm^2) disposable template to outline the surface areas that were sampled. For non-flat surfaces (e.g., door handles), we wiped an estimated area of 100 cm^2. Neither NIOSH nor OSHA has OELs for lead on surfaces. The OSHA lead standard requires that all surfaces be maintained as free as practicable of accumulations of lead CFR 1910.1025 [CFR 2024].

Results: Exposure Assessment

Personal Air Sampling

During our second site visit, the median air concentration for Day 1 of sampling was 0.15 mg/m^3 (range: 0.004–0.18 mg/m^3); for Day 2, it was 0.21 mg/m^3 (range: 0.005–0.36 mg/m^3) (Table C1). Of the 11 personal air samples, 7 were above the OSHA PEL and AL. Four employees were exposed to lead concentrations in air that were over the OSHA PEL; the two employees who were not overexposed worked most of the time in the office area, not on the facility floor. Sampling on Day 2 should not be considered representative of a typical workday because of a fire in the furnace area. In addition, the workday was shortened because of the fire (sample time ranged from 6 hours 27 minutes to 10 hours). The task-based sample taken while an employee changed the exhaust air filter on the baghouse resulted in a lead concentration of 0.04 mg/m^3 and was collected for 33 minutes.

Area Air Sampling

The area sampling results are presented in Table C2. Although this type of sample is not directly comparable with OELs, concentrations above the OELs can help identify potential areas of concern. The median air concentration for the full-shift area air sampling on Day 1 was 0.02 mg/m^3 (range: 0.0005–0.03 mg/m^3) while the median on Day 2 was 0.22 mg/m^3 (range: 0.004–0.39 mg/m^3). The difference in median concentration in the areas sampled between the days is possibly due to a combination of the fire and sampling additional production areas.

The area air samples collected in the antechamber on both days (0.03 mg/m^3 on Day 1 and 0.05 mg/m^3 on Day 2) were at or above the OSHA AL of 0.03 mg/m^3. In addition, two of the three samples collected in the furnace area were also above the AL on both days (0.03 mg/m^3 on Day 1 and 0.22 mg/m^3 on Day 2).

The task-based sample collected in the furnace room while the furnaces were heating was well below the AL (0.009 mg/m^3). The area air samples collected on Day 2 near the scale (0.33 mg/m^3), in the storage area (0.30 mg/m^3), inside the antechamber (0.05 mg/m^3), on the shelves outside of the antechamber in the warehouse (0.28 mg/m^3), and on top of the flammable cabinet in the warehouse (0.39 mg/m^3) were all at or above the OELs of 0.05 mg/m^3. The clean locker room (0.004 mg/m^3), breakroom (0.0005 mg/m^3 and 0.01 mg/m^3), and storage area in the warehouse on Day 1 (0.01 mg/m^3) were below the OELs.

Surface Wipe Sampling

The qualitative wipe sampling results during the first site visit revealed the presence of lead on the refrigerator handle in the breakroom, a bench in the changing area, and on the surface of the table in the main office.

The quantitative surface wipe sampling results from the second site visit are presented in Table C3. The range of concentrations for surface wipe sampling was 1–2,000 µg/100 cm^2. The highest lead level (2,000 µg/100 cm^2) was collected from inside the facepiece of an employee's respirator. Another respirator, which had not been worn recently, had a lead level of 110 µg/100 cm^2. Another sample with a high level was collected from the floor of the shower room (230 µg/100 cm^2). Other samples collected in the clean locker room (46 µg/100 cm^2 and 51 µg/100 cm^2) showed that some lead was being tracked out of the production area. Samples collected on doorknobs, in the shower room, and in the breakroom were relatively low (1–22 µg/100 cm^2), except for the breakroom refrigerator handle (46 µg/100 cm^2). The tablecloth on the picnic table in the equipment storage area (64 µg/100 cm^2) and samples collected from employee desks were higher (19–40 µg/100 cm^2) than the other nonproduction area samples.

Methods: Health and Safety Program and Previous Sampling Results, Workplace Observations, and Ventilation Assessment

We reviewed the employer's written Lead Compliance/Exposure Control Plan, Respiratory Protection Plan, and exposure monitoring records for lead and noise from September 2022 and January, May, and August of 2023. We documented the measures that the employer implemented to minimize employee exposure to lead. During our visits in March and December 2023, we observed work practices and procedures and noted changes in the facility between our visits.

We assessed the ventilation systems at the facility. We observed the general ventilation units in the office and examined the LEV system in the warehouse. We evaluated the direction of airflow between areas using smoke tubes and took face velocity measurements at the fume hoods where possible. While both doors were open, we took six measurements across the face of the openings of each stationary fume hood (top left, top middle, top right, lower left, lower middle, and lower right). While the doors were closed, we took three face velocity measurements (left, middle, right) for each stationary fume hood.

Results: Health and Safety Program and Previous Sampling Results, Workplace Observations, and Ventilation Assessment

Review of the Health and Safety Programs and Previous Sampling Results

The Lead Compliance/Exposure Control Plan included detailed job hazard analyses for each step of the work processes and identified the hazards and PPE selection for each step. One recurrent item was the concern regarding "splash from molten metals near the face of the operator." Molten metal splashes onto the torso or legs were not identified as a concern. In addition, the control plan described "Tyvek® suits" as an alternate to coveralls. Although Tyvek suits may prevent incidental contact with lead dust, they would not protect the wearer from thermal burns after exposure to molten lead splashes. The control plan described the requirement to always wear respiratory protection in the warehouse area and to utilize the buddy system when doffing PPE. We were informed that at times employees might enter the warehouse briefly without donning respiratory protection. We did not observe employees utilizing the buddy system as described in the control plan.

The biological monitoring plan included in the control plan required that employees' BLLs be measured once every 6 months. If the employee was found to have a BLL greater than or equal to 40 µg/100 g of blood, the frequency of testing increased to every 2 months and the employee was medically removed from working in the warehouse. Employees return to work once they have a BLL below 40 µg/100 g. Once the employee has two BLLs below 40 µg/100 g, the frequency of testing returns to every 6 months. If an employee had a BLL of greater than or equal to 60 µg/100 g, the frequency of testing increased to once per month.

The respiratory protection program included requirements for medical clearance, fit testing, and for daily and weekly respirator cleaning. Daily cleaning involved wiping accessible surfaces of the headpiece, harness, face shield, hose, filter assembly, and battery pack. The program also stated that "after cleaning, employees are to properly store their respirator." However, it did not describe what was considered proper storage other than "protected from damage, excessive moisture, and stored properly to prevent deformation." A description of keeping the respirator free from lead dust but storing it inside a plastic bag was not included. Weekly cleaning included washing all components in warm water with soap.

Figure B2 shows the air sample results from the facility collected by a contractor. In September 2022, seven of eight air samples (including three personal air samples) exceeded the OSHA PEL. Subsequent sampling in January, May, and August 2023 showed a decline in lead concentration in the air. In

January, four of eight air samples exceeded the PEL. In May, two of ten samples exceeded the PEL. In August, of 11 samples, 1 exceeded the PEL. Personal air samples of employees working around the lead smelters had lead levels consistently above the PEL. Area samples around the solder pots were also above the PEL. The area air sampling for January, May, and August 2023 showed that areas outside of the furnace area, including areas in the warehouse (scales, stockpile, shipping and receiving, and the anteroom) were below the PEL. However, the scales area was above the OSHA AL of 0.03 mg/m^3 in January and May, and the stockpile area was above the AL in May.

We reviewed full-shift noise sampling collected on two employees in August 2023. The time-weighted averages were 73.8 and 75.3 decibels (A-weighted), indicating that noise exposure was below the OSHA PEL of 90 dBA and the AL of 85 dBA.

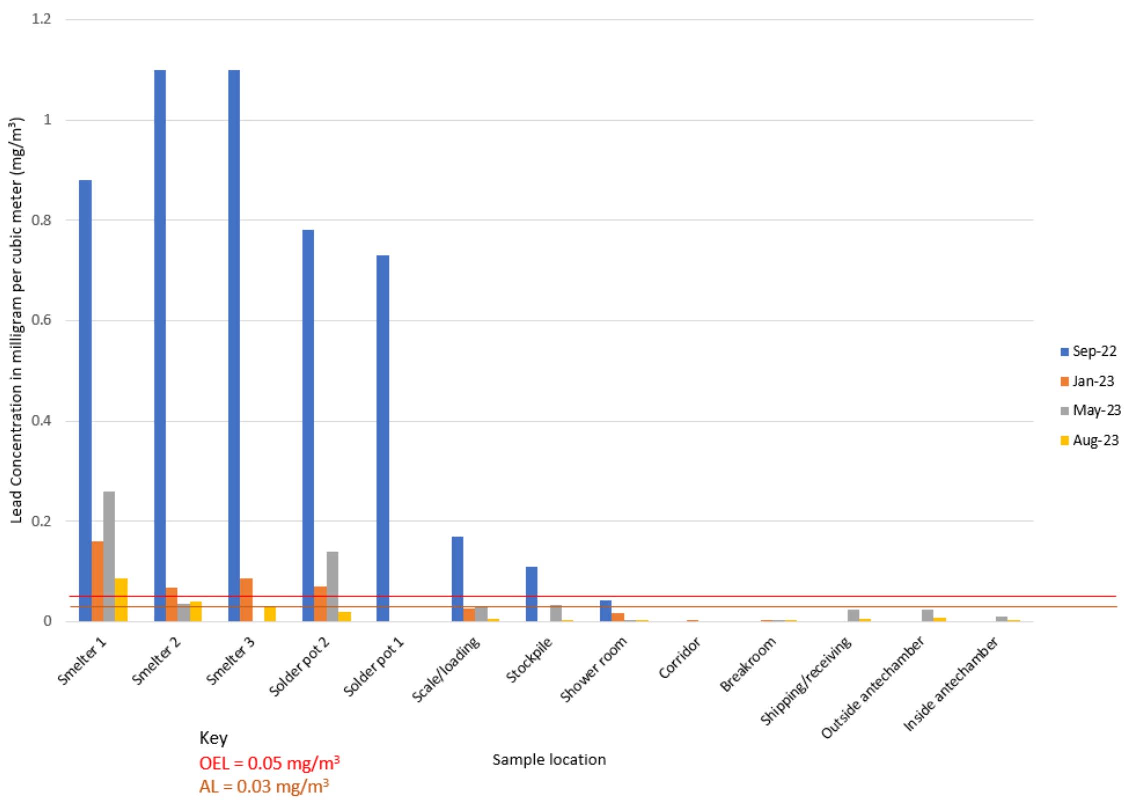


Figure B2. Historic air sampling for lead conducted by a consulting firm from 2022 and 2023. The shower room, corridor, breakroom, shipping and receiving, outside the antechamber, and inside the antechamber were below the OSHA PEL. The only locations below the OSHA AL of 0.03 mg/m^3 were the corridor, breakroom, shipping and receiving, and inside and outside of the antechamber.

Workplace Observations

During the first site visit, we observed uncovered 55-gallon drums with lead-containing materials that could potentially expose employees by dust escaping the barrels. In addition, we observed dried lead on uniforms that had been returned as clean from the uniform provider. Lastly, we observed that employee respirators were stored in a storage unit inside the processing floor. Between the first and the second site visit, the company installed an antechamber for PPE storage and covered the 55-gallon drums to prevent lead dust from being redistributed in the air. Management also reported that the newly cleaned uniforms no longer had visible lead contamination. We also observed an improvement in the general cleanliness of the warehouse.

During the second site visit, employees in this facility came in wearing street clothes and shoes. Upon arrival at work, they changed into company issued coveralls (Bulwark Flame Resistant) and clean work shoes in the clean locker room. When entering the warehouse, employees donned nitrile gloves and changed into work boots, leaving their clean work shoes in a bin in the antechamber. They then donned a 3M Versaflow TR-300 loose-fitting hooded PAPR with a motor and filter attached to a belt. The PAPR filters were "HE Particulate" filters (Model TR-3712N). This respirator has an assigned protection factor of 25. Employees entered the warehouse through the door in the antechamber. Once on the floor, the employees also donned heat-resistant gloves while working around the furnaces or melting pots.

During the straining process, we observed molten lead splash onto the employees' coveralls as liquid lead was poured from the furnace into the mold. We observed that more molten lead may have splashed if the employee held the strainer at the mouth of the spigot, and that one spigot seemed lower than the other.

After doffing the heat-resistant gloves in the furnace area, employees left the warehouse through the anteroom chamber. The next step in doffing PPE was to use the high-efficiency particulate air (HEPA) filtered vacuum cleaner to remove lead dust from their clothes. They then removed their PAPRs and placed them inside individual lockers in the antechamber, put their clean shoes back on (leaving their boots in the bin), and doffed their nitrile gloves. They then washed their hands with a grit and lead removing soap and proceeded to the clean locker room. At the end of the day, employees showered and changed back into their street clothes, leaving their uniforms onsite to be laundered by an external contractor. Tyvek® (Lakeland Micromax) suits were also available for employee use. However, these suits were not flame resistant like the coveralls.

General

The office area used forced air heat and a central air conditioning unit with ducted air returns. The air handling unit was located on the roof. There did not appear to be any re-entrainment of air from the ventilation exhaust into the office area, and air flowed from the office area into the warehouse (contaminated) areas. The warehouse had natural/open air ventilation (not supplied) and heating units in the warehouse area.

Local Exhaust Ventilation

Inside the lead melting area, there were two fixed fume hoods and one moveable "elephant trunk" style fume hood attached to a baghouse located immediately outside. The baghouse had 60 bag filters that were changed approximately every 6 months and two dust collection barrels. The baghouse exhaust had two 24 × 24 × 2 Minimum Efficiency Reporting Value (MERV) 8 pre-filters and two 24 × 24 × 11.5-inch HEPA filters. These filters were changed based on the pressure drop as indicated by the LEV system control panel, which occurred approximately every 2–3 weeks.

The air handling unit appeared to be in good working order, and there was not any visible emission from the air handling unit. There was a detectable plastic-like odor, which was likely due to melted rubber from the raw material. Although an impinger with drain (Donaldson®) was visible in the ventilation system drawings provided, no impinger was visible in the ductwork where indicated in the drawing.

The ductwork from the two stationary furnaces was made of metal and in good condition. We observed no visible damage, noticed no 90-degree entry angles, and saw an increase in duct diameter at every new entry; blast gates were also present to close off any unused ducts. The elephant trunk-style fume hood was made of corrugated plastic and attached in the middle between the two fixed hoods. Its entry at the main duct was wrapped over the top of the duct at an awkward angle and had multiple bends and elbows (Figure B3).

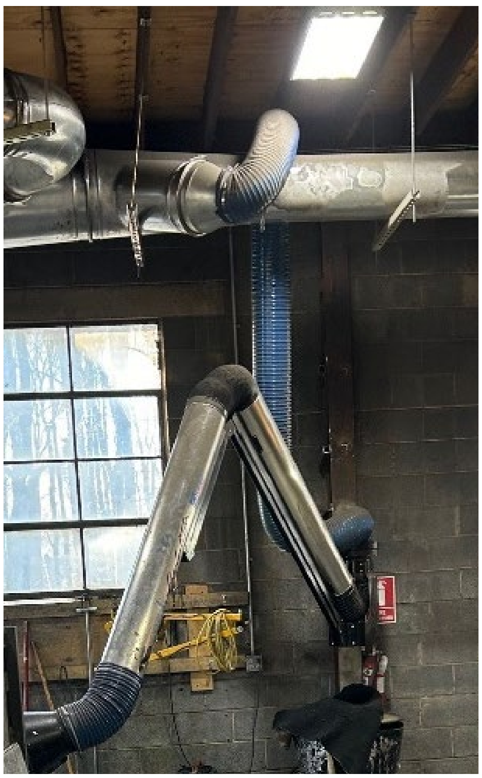


Figure B3. Movable flexible "elephant trunk" style LEV hood attached via corrugated plastic ductwork to the permanent hard metal duct. Photo by NIOSH.

Figure B4. Two stationary fume hoods over the lead melting furnace and one elephant trunk-style duct-hood. Photo by NIOSH.

The two pyramid-style fixed fume hoods semi-enclosed the two melting furnaces (Figure B4). Each hood had two hinged doors at the front of the hood so that employees could open the hood and remove copper metal jackets and other contaminants from the top of the molten lead. The doors were each approximately 18 inches tall and 29 inches wide, leaving the face of the fume hood at 24 inches × 58 inches when open. There was an approximate 6-inch gap between the surface of the lead furnace and the bottom of the fume hood enclosure, and three of the sides were semi-sealed with Plexiglas®.

Two barrels (one for copper jackets and one for dross) sat at the front of the melting furnaces and were sometimes covered with a fire blanket, metal lid, or left open to cool. If left open, the elephant trunk-style hood was placed near the barrel. The elephant trunk-style hood was moved to provide exhaust ventilation to the copper and dross barrels at both of the stationary hoods and sometimes for additional tasks such as removing debris from the rubber vacuums. The circular elephant trunk-style hood was approximately 12 inches in diameter at the face.

Face velocity measurements at the stationary fume hoods (with the doors closed) averaged 203 feet per minute (fpm) for Hood 1 and 195 fpm for Hood 2. Center line face velocity measurements at the elephant trunk-style moveable hood averaged 179 fpm at Hood 2 and 220 fpm at Hood 1. With the doors open, stationary Hood 1 averaged 82 fpm (55 fpm at the center measurement), and stationary Hood 2 averaged 102 fpm (87 fpm at the center measurement).

Using smoke to visualize airflow, we observed turbulent airflow around the elephant trunk-style hood and escaping smoke passing outside the edge of the stationary hood and not captured by the elephant trunk-style hood (Figure B5). This was most evident when both hood doors were open and the elephant trunk-style hood was located to the back of the barrel; however, this was also seen when it was located to the side of the copper barrel. The best smoke capture occurred when a fire blanket was placed over the top of the cooling copper barrel (Figure B6). The second-best capture was observed when a metal lid was placed over the barrel; this occurred both with hood doors open and closed (Figure B7).

Figure B5. Stationary fume hood with open doors plus elephant trunk-style hood over the barrel, emitting more smoke than when the barrel was covered with a fire blanket or the barrel was covered with a metal lid. Photo by NIOSH.

Figure B6. A fire blanket is used to cover the barrel containing cooling copper jackets to emit less smoke than the open barrel with the elephant trunk or the barrel with a metal lid. Photo by NIOSH.

Figure B7. A metal lid is used to cover a barrel containing cooling copper jackets. In this configuration, more smoke was emitted than with the barrel covered with a fire blanket but less than when the barrel was open with the elephant trunk-style hood. Photo by NIOSH.

During our second site visit, the LEV system monitor indicated that the exhaust filters needed to be changed. When removed, both the pre-filter and HEPA filters were visibly soiled and wet (Figures B8 and B9). Near the end of Day 1, after the filters were replaced and backpressure was reduced, face velocity airflow increased from an average of 85 fpm to 127 fpm with doors open at Hood 2; smoke capture also improved. However, some turbulence was still visible.

Figure B8. Dirty HEPA Filter. Photo by NIOSH.

Figure B9. Dirty pre-filter. Photo by NIOSH.

On Day 2 of the second site visit, at approximately 2:20 p.m., the arm of the elephant trunk-style ventilation hood caught fire. Something in the copper drum flared up and a spark or ember was pulled into the LEV. The plastic components of the LEV caught fire and rapidly disintegrated (Figure B10). The employees turned off the LEV, used fire extinguishers to put out the fire, removed a propane tank from the area, and then evacuated the area. The entire warehouse area was filled with smoke and remained smoky for the remainder of the day. The main ductwork of the LEV continued to smoke. Employees and management explained that a fire of this magnitude had never occurred before.

Figure B10. Ventilation ductwork after catching fire. Photo by NIOSH.

Discussion

The personal air samples show that all employees who worked in the warehouse are overexposed to lead. The area air samples showed that the lead furnaces are the primary sources of exposure while employees are actively melting, drossing, and working with the molten lead. Further enclosing the furnaces can help to control lead exposure at the source, thereby better protecting the employees.

Although not representative of a typical workday due to the fire in the furnace area, lead concentrations in the warehouse were also above the AL, suggesting that employees should continue to wear respiratory protection in all parts of the warehouse. Improving the separation between the furnace area and the rest of the warehouse could help to contain the lead. This may not only reduce lead concentrations in areas around the warehouse, such as the scales, material storage, and the shipping and receiving area, but could reduce the need for respiratory protection in those areas.

Our air sample results are further supported by the historical lead sampling data we reviewed. Although surface wipe sampling is not directly comparable with OELs, they are indicative of areas of potential spread and distribution of lead throughout the facility. Spread of lead into nonwork areas can result in an increased potential for lead ingestion. Employees are also more likely to unintentionally carry lead out of the facility into their vehicles or homes, referred to as take-home lead exposure. Our sample results indicate some lead is being tracked outside of the warehouse area, increasing the likelihood of take-home contamination. Improving housekeeping measures can help reduce this.

Half of employees undergoing routine BLL testing in November 2023 had levels above the American College of Occupational and Environmental Medicine (ACOEM) recommended medical removal limit of 30 µg/dL, and all were above 10 µg/dL [Holland and Cawthon 2016]. Lead exposure, including at levels < 10 µg/dL, can cause adverse health effects such as increased risk of hypertension and essential tremor [NTP 2012].

Of note, employees are medically removed from lead exposure at 40 µg/dL, which is lower than the required OSHA level, but not as low as other current health-based recommendations. Although the current federal OSHA medical removal level begins at 50 µg/dL, with return to work once two consecutive BLLs are measured below 40 µg/dL, multiple states, such as Michigan and California, have proposed lowering these levels significantly. In Michigan, if an employee is found to have a BLL of 15 µg/dL or higher, testing is required every 2 months [MIOSHA 2021]. These employees must be removed from work if they are found to have a BLL at or above 30 µg/dL, or if their average BLL is found to be at or above 20 µg/dL. California recently passed changes to their laws including lowering the medical removal threshold to one BLL test result above 30 µg/dL, or two consecutive BLL test results at or above 20 µg/dL, or the average of BLL test results in a 6-month period at or above 20 µg/dL [CalOSHA 2024].

Engineering controls are key to preventing lead fumes from escaping the furnace area and exposing employees. Improvements in the LEV system are the first line of defense for employee protection. Although flexible ductwork can be useful in many situations, especially as a temporary measure, its use in this facility is not recommended. Flexible ductwork is prone to have kinks and sharp turns like what is seen in Figure B11. This often occurs when excess duct is installed or is not removed. Another common problem with flexible ductwork is long, unsupported runs.

Figure B11. Flexible ductwork. Photo by NIOSH.

In addition, when used, the moveable elephant trunk-style hood should be placed directly above a hot process facing downward as to take advantage of the convective current created by the heat, not to the side of the process. Lastly, the corrugated design of the flexible duct also contributes to decreased airflow through the duct, increased friction inside the duct, and increased turbulence of the airflow inside the duct. All these factors could potentially cause the deposition of fine lead particles within the duct, further decreasing ventilation effectiveness and increasing fire risk.

A large amount of water vapor was introduced into ductwork with hot processes. In-line impingers, such as the Donaldson impinger with drain, are designed as the first line of removal for liquids to prevent them from saturating the dust collectors and exhaust filters. Adding the impinger back to the system (if missing) could help extend the working life of the exhaust system and reduce the filter changeout frequency.

After installing permanent metal ductwork, a barrel-specific local exhaust hood would offer better direct airflow into the LEV system than the "elephant trunk" style hood because it would more fully enclose the process. An example of this style of hood could potentially be used for the barrels containing copper jackets is shown in Figure B12 and is available through the OSHA Lead: Battery Manufacturing E-Tool [OSHA 2024]. Another example for enclosing the process more fully is shown in Figure B13. In this example, the employee would be able to keep the drossing tools inside the furnace LEV by adding a "dross chute" from the furnace into the dross pot. These recommended additions should help reduce the turbulent airflow caused by the "elephant trunk" style hood and would keep the process more fully contained, reducing the amount of escaping dusts and vapors.

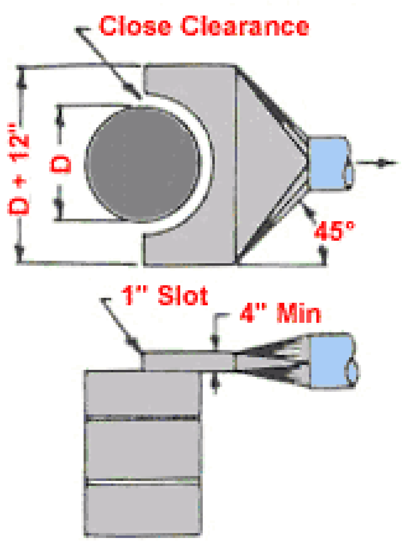


Figure B12. Barrel specific LEV [OSHA 2024].

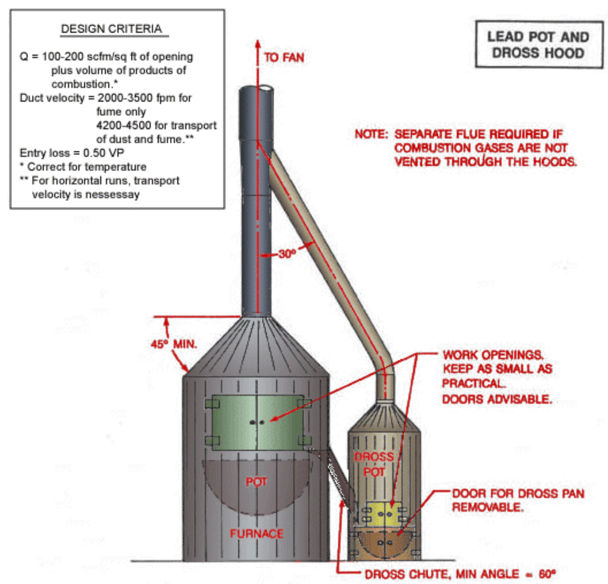


Figure B13. Enclosed lead pot and dross hood [OSHA 2024].

The assigned protection factor for the selected PAPR was 25, which is sufficient for the exposure levels seen in this facility. However, surface contamination inside the respirators was a likely contributor to elevated BLLs. Respirators should be cleaned on a regular basis. NIOSH recommends that users always follow the manufacturer's recommendations for cleaning [NIOSH 2018]. While wearing nitrile gloves, and at least daily, we recommend using a prepackaged respirator cleaning wipe to clean the outer surfaces of the motor/blower assembly and battery pack. Wipe the hose, hood, facepiece, and any other externally facing components. If contamination persists, the respirator (excluding the battery and filter) can be immersed in warm water (do not exceed 120°F) and a mild cleaning solution such as a neutral detergent. Lanolin, other oils, solvents, and harsh cleaning agents should never be used to clean the

PAPR. After cleaning the PAPRs, they should continue to be stored in the antechamber but be placed inside sealed, clean plastic bags to keep them free from falling particulate. Components that have not been cleaned daily (such as the filter) should be stored separately from the portion of the PAPR designed to cover the wearer's face and head. Respirators should be inspected for damage at least weekly.

This health hazard evaluation (HHE) was requested after the New Jersey Department of Health identified a group of employees at the same facility with high BLLs. As part of their heavy metal surveillance protocol, the health department conducted a follow-up discussion with the company, including consideration for take-home lead exposure among employees' families, and initiated prevention measures where appropriate. The health department discussed the NIOSH HHE program with the workplace, which then decided to request the HHE to obtain further recommendations on reducing lead exposure among employees. At the same time, the company began to strengthen lead protections, including those against take-home lead, such as mandating end-of-shift showering and requiring workplace-only shoes and clothing. At the time of our evaluation, nearly all employees reported adhering to these revised take-home lead protections. This evaluation highlights the importance of state public health surveillance systems in detecting lead exposures. It also emphasizes the importance of collaboration between state public health and the NIOSH HHE program to improve worker health and safety.

Limitations

Our evaluation had some limitations. This evaluation had a cross-sectional design and can only assess the timeframe in which we performed the evaluation. The industrial hygiene sampling during the second day was not representative of a typical workday due to a fire in the LEV system. The fire likely increased the amount of lead fumes in the air, thereby increasing concentrations. In addition, the use of fire extinguishers in the vicinity of the sampling pumps could impact the air samples.

Conclusions

The personal and area air sampling shows that all warehouse employees were overexposed to lead and that the highest concentration of lead was in the furnace area while actively processing molten lead. Surface wipe samples suggest that lead is being tracked outside of the warehouse. Historical records of employee BLLs suggest that medical removal from work or to job duties with lower exposure has been the predominant intervention in successfully reducing employee BLLs thus far, further indicating a need for improved controls. In addition, lead contamination inside the PAPR facepiece is a likely source of employee exposure. This suggests that controlling the lead exposure at the source and properly cleaning and storing PPE are critical to reducing lead exposure among employees.

Section C: Tables

Table C1. Personal lead air sampling results for six employees, December 2023

Employee	Day 1 Concentration (mg/m^3)	Day 2* Concentration (mg/m^3)	Sample time (minutes)
Employee 1	0.15	0.36	440 and 621
Employee 2	0.17	0.21	540 and 404
Employee 3	0.15	0.36	480 and 426
Employee 4	0.004	0.005	570 and 455
Employee 5	0.18	Not tested	568
Employee 6	0.006	0.02	525 and 387

* Sample results on Day 2 were not representative of a normal workday due to a fire in the facility.

Note: The OSHA PEL, NIOSH REL, ACGIH TLV are 0.05 milligram per cubic meter (mg/m^3).

Table C2. Area lead air sampling, December 2023

Location	Concentration (mg/m^3)	Sample time (minutes)
Day 1		
Warehouse storage area	0.01	539
Breakroom	0.0005	528
Inside antechamber	0.03	530
Furnace area	0.03	534
Day 2*		
Warehouse storage area	0.30	469
Breakroom	0.01	470
Inside antechamber	0.05	466
Furnace area while heating to temperature	0.009	154
Furnace area with active lead work	0.22	480
Scale	0.33	471
Outside of antechamber in warehouse	0.28	464
Flammable cabinet	0.39	467
Clean locker room	0.004	455

* Sample results on Day 2 were not representative of a normal workday due to a fire in the facility.

Milligram per cubic meter = mg/m^3

Table C3. Surface wipe sampling for lead, December 2023

Location	Level ($\mu g/100\ cm^2$)
Breakroom	
Breakroom on the bar near the wall	2.1
Breakroom table	1.0
Breakroom refrigerator handle	46
Entrance and office area	
Employee desk in the office area	19
Desk in the office, keyboard	40
Tablecloth on picnic table in the equipment storage area	64
Doorknob to equipment storage	19
Front door going to the outside	1.3
Clean locker room	
Clean locker room light switch	3.5
Doorknob inside the clean locker room	6.0
Inside clean locker in the locker room	46
Floor of the clean locker room	51
Shower room	
Shower room, inside doorknob leading to antechamber	7.8
Shower room, sink counter	5.9
Shower room, faucet handles	22
Doorknob to shower stall	17
Floor of the shower room	230
Antechamber	
Inside a rarely used respirator	110
Inside a respirator facepiece in a locker	2,000

Micrograms per 100-square centimeter = $\mu g/100\ cm^2$

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 time-weighted average (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 permissible exposure limits [29 CFR 1910 for general industry; 29 CFR 1926 for construction industry; and 29 CFR 1917 for maritime industry] called PELs. 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 threshold limit values (TLVs), which are recommended by 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.

Lead

Inorganic lead is a naturally occurring, soft metal that has been mined and used in industry since ancient times. It comes in many forms (e.g., lead acetate, lead chloride, lead chromate, lead nitrate, lead oxide, lead phosphate, and lead sulfate). Lead is considered toxic to all organ systems and serves no useful purpose in the body.

Occupational exposure to inorganic lead occurs via inhalation of lead-containing dust and fume and ingestion of lead particles from contact with lead-contaminated surfaces. Exposure may also occur through transfer of lead to the mouth from contaminated hands or cigarettes when careful attention to hygiene, particularly hand washing, is not practiced. In addition to the inhalation and ingestion routes of exposure, lead can be absorbed through the skin, particularly through damaged skin [Filon et al. 2006; Stauber et al. 1994; Sun et al. 2002].

Occupational Exposure Limits for Lead in Air

In the United States, employers in general industry are required by law to follow the OSHA lead standard [29 CFR 1910.1025]. This standard was established in 1978 and has not yet been updated to reflect the current scientific knowledge regarding the health effects of lead exposure. Under the OSHA standard, the PEL for airborne exposure to lead is 0.05 mg/m^3 of air for an 8-hour TWA, with an AL of 0.03 mg/m^3 (also an 8-hour TWA). In 2013, the California Department of Public Health (CDPH) recommended that California OSHA lower the PEL for lead to 0.5 to 2.1 µg/m^3 (0.0021 mg/m^3 as an 8-hour TWA [Billingsley 2013]. In March 2024, the California Occupational Safety and Health Standards Board adopted a more protective lead standard which will be enacted on January 1, 2025. This standard decreases the airborne 8-hour PEL to 10 µg/m^3 (0.01 mg/m^3), the 8-hour AL to 2 µg/m^3 (0.002 mg/m^3) and increases the frequency of BLL testing provided for workers when their BLL is at or above 10 µg/dL [CDPH 2024].

Other guidelines for lead exposure, which are not legally enforceable, are often followed in the United States. Like the OSHA lead standard, these guidelines have also not been updated. The NIOSH REL and ACGIH TLV for lead are 0.05 mg/m^3 as an 8-hour work shift [ACGIH 2024; NIOSH 2007].

Surface Exposure Limits for Lead

Neither NIOSH nor OSHA has established surface contamination limits for lead in the workplace. The U.S. Department of Housing and Urban Development (HUD) has guidance that limits lead on surfaces in public buildings and child-occupied housing to less than 10 micrograms of lead per square foot ($\mu g/ft^2$) [HUD 2017]. The U.S. Environmental Protection Agency (EPA) also updated their dust-lead hazard standards (DLHS) in 2021 to 10 $\mu g/ft^2$ for floors. In 2023, EPA proposed updating the DLHS to a 3 $\mu g/ft^2$ but that proposal has not been approved [EPA 2024].

OSHA requires in its substance-specific standard for lead that all surfaces be maintained as free as practicable of accumulations of lead [29 CFR 1910.1025(h)(1)]. An employer with workplace lead exposures must have regular and effective cleaning of surfaces to ensure they are as free as practicable from lead contamination. Because OSHA only states that surfaces should be as "free as practicable" of lead, safety and health professionals will routinely use the HUD and EPA guidelines as a quantitative measure of surface lead contamination.

Blood Lead Levels

In most cases, an individual's BLL is a good indication of recent exposure to lead because the half-life of lead (the time interval it takes for the quantity in the body to be reduced by half its initial value) is 1–2 months [CDC 2013; Lauwerys and Hoet 2001; Moline and Landrigan 2004]. Most lead in the body is stored in the bones, with a half-life of years to decades. Measuring bone lead, however, is primarily done only for research. Elevated zinc protoporphyrin levels have also been used as an indicator of chronic lead intoxication. However, other factors, such as iron deficiency, can cause an elevated zinc protoporphyrin level, so monitoring the BLL over time is more specific for evaluating chronic occupational lead exposure.

The OSHA lead standard mandates medical removal for an employee with a single BLL of $\geq$ 60 µg/dL, or three BLLs averaging $\geq$ 50 µg/dL, and permits return to work once the employee's BLL decreases to $<$ 40 µg/dL [29 CFR 1910.1025]. ACGIH recommends that employee BLLs be controlled to below 20 µg/dL, and also designates lead as an animal carcinogen [ACGIH 2024]. CDC recommends removal of pregnant women from lead-exposed work areas when BLLs are $\geq$ 10 µg/dL [CDC 2010]. In 2013, CDPH recommended that California OSHA keep BLLs below the range of 5–10 µg/dL [Billingsley 2013; CDPH 2021]. In 2015, NIOSH designated 5 µg/dL of whole blood, in a venous blood sample, as the reference BLL for adults [NIOSH 2024a].

Health Effects of Lead

The OSHA PEL, NIOSH REL, and ACGIH TLV may prevent overt symptoms of lead poisoning, but they do not protect workers from lead's contributions to conditions such as hypertension, renal dysfunction, or reproductive and cognitive effects [Brown-Williams et al. 2009; Holland and Cawthon 2016; Institute of Medicine 2013; Schwartz and Hu 2007; Schwartz and Stewart 2007]. Generally, acute lead poisoning with symptoms has been documented in persons having BLLs above 70 µg/dL. These BLLs are rare today in the United States, largely as a result of workplace controls put in place to comply with current OELs. When present, acute lead poisoning can cause a myriad of adverse health effects including abdominal pain, hemolytic anemia, and neuropathy. Lead poisoning has, in very rare cases, progressed to encephalopathy and coma [Moline and Landrigan 2004].

People with chronic lead poisoning, which is more likely at current OELs, may not have symptoms or they may have nonspecific symptoms that may not be recognized as being associated with lead exposure. These symptoms include headache, joint and muscle aches, weakness, fatigue, irritability, depression, constipation, anorexia, and abdominal discomfort [Moline and Landrigan 2004].

The National Toxicology Program (NTP) released a monograph on the health effects of low-level lead exposure [NTP 2012]. For adults, NTP concluded the following about the evidence regarding health effects of lead (Table D1).

Table D1. Evidence regarding health effects of lead in adults

Health area	NTP conclusion	Principal health effects	Blood lead evidence
Neurological	Sufficient	Increased incidence of essential tremor	Yes, < 10 μg/dL
	Limited	Psychiatric effects, decreased hearing, decreased cognitive function, increased incidence of amyotrophic lateral sclerosis	Yes, < 10 μg/dL
	Limited	Increased incidence of essential tremor	Yes, < 5 μg/dL
Immune	Inadequate		Unclear
Cardiovascular	Sufficient	Increased blood pressure and increased risk of hypertension	Yes, < 10 μg/dL
	Limited	Increased cardiovascular-related mortality and electrocardiography abnormalities	Yes, < 10 μg/dL
Renal	Sufficient	Decreased glomerular filtration rate	Yes, < 5 μg/dL
Reproductive	Sufficient	Women: reduced fetal growth	Yes, < 5 μg/dL
	Sufficient	Men: adverse changes in sperm parameters and increased time to pregnancy	Yes, ≥ 15–20 μg/dL
	Limited	Women: increase in spontaneous abortion and preterm birth	Yes, < 10 μg/dL
	Limited	Men: decreased fertility	Yes, ≥ 10 μg/dL
	Limited	Men: spontaneous abortion	Yes, ≥ 31 μg/dL
	Inadequate	Women and Men: stillbirth, endocrine effects, birth defects	Unclear

Various organizations have assessed the relationship between lead exposure and cancer. According to the Agency for Toxic Substances and Disease Registry (ATSDR) and NTP, inorganic lead compounds are reasonably anticipated to cause cancer in humans [ATSDR 2020; NTP 2021]. The International Agency for Research on Cancer (IARC) classifies inorganic lead as probably carcinogenic to humans [IARC 2006].

Medical Surveillance and Management

To prevent acute and chronic health effects, a panel of experts convened by the Association of Occupational and Environmental Clinics published guidelines for the management of adult lead exposure [Kosnett et al. 2007]. The panel recommended BLL testing for all lead-exposed employees, regardless of the airborne lead concentration. These recommendations do not apply to pregnant women, who should avoid exposures that would result in BLLs > 5 µg/dL. Removal from lead exposure should be considered if control measures over an extended period do not decrease BLLs to < 10 µg/dL, or an employee has a medical condition that would increase the risk of adverse health effects from lead exposure.

The health-based medical surveillance and management recommendations are summarized in Table D2. This table includes recommendations from an expert panel [Kosnett et al. 2007] and those from CDPH, ACOEM, and the Council of State and Territorial Epidemiologists (CSTE) to prevent acute and chronic health effects [CDPH 2009, 2021; CSTE 2009, 2013; Holland and Cawthon 2016; Kosnett et al. 2023].

Table D2. Health-based medical surveillance recommendations for lead-exposed employees

Category of exposure	Recommendations
All lead exposed workers	• Baseline or preplacement medical history and physical examination, baseline BLL, and serum creatinine
BLL < 5 µg/dL	• BLL monthly for first 3 months placement, or upon change in task to higher exposure, then BLL every 6 months; if BLL increases ≥ 5 µg/dL, evaluate exposure and protective measures, and increase monitoring if indicated
BLL 5–9 µg/dL	• Discuss health risks • Minimize exposure • Consider removal for pregnancy and certain medical conditions • BLL monthly for first 3 months placement or every 2 months for the first 6 months placement, or upon change in task to higher exposure, then BLL every 6 months; if BLL increases ≥ 5 µg/dL, evaluate exposure and protective measures, and increase monitoring if indicated
BLL 10–19 µg/dL	• Discuss health risks • Decrease exposure • Remove from exposure for pregnancy • Consider removal for certain medical conditions or BLL ≥ 10 µg/dL for extended period • BLL every 2 months; evaluate exposure, engineering controls, and work practices; consider removal. • Revert to BLL every 6 months after 3 BLLs < 10 µg/dL
BLL 20–29 µg/dL	• Remove from exposure for pregnancy • Remove from exposure if repeat BLL measured in 4 weeks remains ≥ 20 µg/dL • Annual lead medical exam recommended • Monthly BLL testing • Consider return to work after 2 BLLs < 15 µg/dL a month apart, then monitor as above
BLL 30–49 µg/dL	• Remove from exposure • Prompt medical evaluation • Monthly BLL testing • Consider return to work after 2 BLLs < 15 µg/dL a month apart, then monitor as above
BLL 50–79 µg/dL	• Remove from exposure • Prompt medical evaluation • Consider chelation with significant symptoms
BLL ≥ 80 µg/dL	• Remove from exposure • Urgent medical evaluation • Chelation may be indicated

Adapted from Kosnett et al. 2007, CSTE 2013 and 2015, and CDPH 2021.

Take-home Contamination

Occupational exposures to lead can result in exposures to household members, including children, from take-home contamination. Take-home contamination occurs when lead dust is transferred from the workplace on employees' skin, clothing, shoes, and other personal items to their vehicle and home [CDC 2009, 2012]. CDC considers a BLL in children of 5 µg/dL or higher as a reference level above which public health actions should be initiated and states that no safe BLL in children has been identified [CDC 2013].

The U.S. Congress passed the Workers' Family Protection Act in 1992 (29 U.S.C. 671a). The Act required NIOSH to study take-home contamination from workplace chemicals and substances, including lead. NIOSH found that take-home exposure is a widespread problem [NIOSH 1995]. Workplace measures effective in preventing take-home exposures were (1) reducing exposure in the workplace, (2) changing clothes before going home and leaving soiled clothing at work for laundering, (3) storing street clothes in areas separate from work clothes, (4) showering before leaving work, and (5) prohibiting removal of toxic substances or contaminated items from the workplace. NIOSH noted that preventing take-home exposure is critical because decontaminating homes and vehicles is not always effective. Normal house cleaning and laundry methods are inadequate, and decontamination can expose the people doing the cleaning and laundry.

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