Exposure to Lead during Work on and Near Lead-Sheathed Telecommunication Cables

HHE Report No. 2024-0046-3413

May 2025

Authors: **Jessica F. Li, MSPH, CIH**

Rachael Zacks, MD, MPH

Analytical Support: Bureau Veritas North America, Inc.

Desktop Publisher: Shawna Watts

Editor: Chery Hamilton

Medical Field Assistance: Nicholas Somerville

Industrial Hygiene Field Assistance: Karl Feldmann

Logistics: Ken Sparks, Joseph Hartwell

Keywords: North American Industry Classification System (NAICS) 517112 (Wireless Telecommunications Carriers [except Satellite]), Lead, Telecommmunications, Telecom, Lead Sheath, Lead-sheathed Cable, Massachusetts

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

Recommended Citation

NIOSH [2025]. Exposure to lead during work on and near lead-sheathed telecommunication cables. By Li JF, Zacks R. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2024-0046-3413, https://www.cdc.gov/niosh/hhe/reports/pdfs/2024-0046-3413.pdf.

Table of Contents

Main Report

Supporting Technical Information

Introduction

Request

A union representing workers at a telecommunications provider requested a health hazard evaluation (HHE) to evaluate lead exposure among workers conducting repair, maintenance, and installation of telecommunications cables.

Workplace

The local union represented telecommunications workers working across two states. The union identified three garages with a higher concern of possible lead exposure to focus on for the evaluation. At the beginning of a shift, workers gathered at their assigned garage and received important messages and assignments for the day. Workers drove their work vehicle with equipment to the field site. Some workers did not report to a garage before arriving to the field site, driving their work vehicle to and from their homes or a central office location. Workers then conducted their assignment of repairing, maintaining, or installing telecommunications cables in crews of at least two workers. Depending on the assignment, multiple crews may work together or near one another to complete the work.

The field sites vary and can be categorized based on where the telecommunication cables exist:

- Underground environments (also known as manholes): telecommunication manholes are typically located in urban environments. These manholes provide access points to telecommunication cables and equipment under streets or sidewalks. Manholes vary in size, which can affect the ability of a worker to move around in the manhole. Between manholes, telecommunication cables run through plastic or metal tubes called conduits.
- Central offices: facilities or buildings where telecommunication service providers house equipment and infrastructure necessary to manage, route, and switch communication signals. Central offices are a hub for handling local telecommunication services and have a large volume of telecommunications cables.
- Aerial environments: telecommunication cables are attached to utility poles and require workers to use a bucket truck to access and work on cables. These environments are open-air and can vary in height.
- Other locations may also exist where telecommunication cables are present and need repair. Examples include inside residences or in shallow trenches.

Wires within a cable are protected from the elements by several layers of material, one of which may be a layer of lead. In lead-sheathed telecommunication cable, the lead sheath protects the insulated conductors (wires) within. Some lead-sheathed cable remains in use. Some lead-sheathed cables have been removed and replaced by plastic-sheathed and fiber-optic cables, while some have been abandoned in place.

For repair work, workers cut open a lead-sheathed cable or a plastic covering to access the wires within a cable. For underground installation work, workers entered a series of manholes to prepare conduits for installation of new cable. At the end of the shift, workers cleaned up at the field site and returned either to the garage, directly back home, or to a central office. Assignments could vary in duration from several hours to several weeks, depending on the type of assignment.

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

Our Approach

We visited all three garages and field sites on two occasions to learn about work activities and potential exposures to lead from lead-sheathed cables in various work environments. We completed the following activities during our evaluation:

- Collected six personal air samples for lead during work on or near lead-sheathed cables in manholes. Participating employees were asked about their work that day, including tools and controls used.
- Collected nine hand wipe samples for lead from employees after their work at field sites.
- Collected 29 surface wipe samples for lead from tools, reusable personal protective equipment (PPE), company-owned vehicles, and common area surfaces in the garages.
- Collected three bulk samples of material from the bottom of dry manholes.
- Surveyed 71 employees about their work on or near lead-sheathed cables, their work history, training on lead exposure and health effects, blood lead level (BLL) testing, PPE use, and demographics.
- Reviewed records of BLLs provided by the union and management.
- Observed employees working in various environments, including in manholes, trenches, and aerial settings.
- Conducted walkthroughs of two central offices.

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

Our Key Findings

One personal air sample for lead was above the OSHA action level

- Of the four personal air samples collected on splice service technicians and two collected on outside plant technicians, one sample collected from a splice service technician was above the

Occupational Safety and Health Administration (OSHA) action level for lead of 30 micrograms per cubic meter (µg/m^3). The remaining air samples were below this action level.

- We observed some employees using KN95 masks instead of N95® filtering facepiece respirators for voluntary use during work in manholes.
- We observed that some workers were not sure when PPE was needed for working on or near lead-sheathed cable.
    - For working on and near lead-sheathed cable in underground environments, employees were required to wear disposable coveralls, foot protection (such as disposable booties), safety glasses, nitrile gloves (with additional gloves over nitrile gloves when needed), a hard hat, and a reflective vest. N95 filtering facepiece respirators were provided for voluntary use and strongly recommended when working on or disturbing lead-sheathed cable.

All sampled employees had lead on hands even after routine hand hygiene was performed

- Post-work handwipes were collected from 9 employees after work in a manhole was finished and after doffing PPE, after routine field hand hygiene was completed before returning to the garage or home, or after routine hand hygiene was completed at the garage before entering personal vehicles.
    - Levels of lead on hand wipes ranged from 1.3 to 83 micrograms per wipe, with the lowest amounts found on hands after routine hand hygiene at the garage.
    - The highest level of lead on hands (83 micrograms) was found on an employee immediately after doffing PPE. The employee had not yet performed any field hand hygiene.
- Routine field hand hygiene before leaving the worksite or before eating consisted of using wet wipes.
    - Between the first and second site visit, the company acquired and was in the process of introducing the use of lead removal wipes instead of wet wipes.
    - Due to worksite constraints, workers may not have many opportunities to leave the worksite once work has started, limiting the ability to use soap and water for hand hygiene prior to breaks or eating.
    - Soap and water were not always available to employees for hand hygiene at worksites.

Lead was found on surfaces in vehicles, on equipment and tools, and in some common areas in the garages

- Lead found on surfaces may contribute to lead exposure through accidental ingestion during hand-to-mouth activities (for example, eating or smoking) and increase the potential for take-home lead exposure.

Some employees had BLLs above health-based reference levels recommended by public health agencies

- Twenty-one percent (9/42) of reviewed BLL test results provided by the union and 12% (14/120) of BLL test results provided by management were greater than the Council of State and Territorial Epidemiologists (CSTE) blood reference level of 3.5 micrograms per deciliter (µg/dL).
- Seventeen percent (7/42) of reviewed BLL test results from the union and 9% (11/120) of reviewed BLL test results from management were at or above the NIOSH adult blood reference level of 5 µg/dL.

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	↑ 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 is a way of determining which actions will best control exposures. In most cases, the preferred approach is to eliminate hazards or to replace the hazard with something less hazardous (i.e., substitution). Installing engineering controls to isolate people from the hazard is the next step in the hierarchy. Until such controls are in place, or if they are not effective or practical, administrative controls 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 employees' exposure to lead in air

Why? Lead is harmful to all organ systems and has no health benefits. Lead exposure can increase the risk for long-term health problems in multiple body systems. These include problems with the brain and nerves, immune system, heart and blood vessels, kidneys, and reproductive system. Other possible health effects include non-specific symptoms such as headaches, joint and muscle aches, weakness, and tiredness.

The main ways that lead can get into the body are by breathing it in (inhalation) or by swallowing lead that gets into the mouth (ingestion). Lead particulate can be released into the air during work tasks such as cutting, dry carding (using a wire brush to prepare cable for bonding or soldering), cable pulling, and repairing or removing lead-sheathed cables. Physically disturbing environments that have lead particulate remaining from historical activities can also release lead into the air. The now-prohibited practice of lead wiping could release lead fumes into the air because it required heating lead until it melted.

The employee with an exposure above the OSHA action level cut lead sheath with cable cutters, removed debris from around the cable to be spliced, used a hammer and a wrench, and prepared the cable for splicing.

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

Follow the OSHA lead standard requirements after an air sampling result above the action level

- Conduct additional exposure monitoring as described when monitoring shows the possibility of any employee exposure at or above the action level. Additional exposure monitoring includes conducting air sampling at least every 6 months until two consecutive samples, collected at least 7 days apart, fall below the OSHA action level.
- Implement feasible engineering and administrative controls to reduce exposure. If controls are insufficient, provide respirators to employees.
    - Examples may include use of portable dust collection systems or additional use of amended water throughout the course of work in dry manholes.
- Institute a medical surveillance program for employees exposed above the action level for more than 30 days per year. Medical surveillance includes BLL testing and medical examination.
- Provide lead hazard training annually.

When possible, identify if work assignments in manholes and other environments employees will enter have or previously had lead-sheathed cable

- Employees can use drawings of cable locations, institutional knowledge from supervisors, and safety coaches to identify if lead-sheathed cable may be present.
- Supervisors and safety coaches should work with crews to reinforce proper use of required PPE.

Continue requiring and providing training on work practices to prevent exposure to lead in air

- Work practices that prevent lead particulate from entering the air or employees from breathing in lead particulate include the following:
    - Aim blower hoses away from the bottom of the manhole and other surfaces that may have settled lead dust.
    - Continue the practice of spraying amended water when working in environments that had or have had lead-sheathed cable, especially if the environment is dry.
    - Continue applying encapsulating compounds when working on or disturbing lead-sheathed cable, as required by the company.
    - Avoid the use of reciprocating and power tools when possible.
    - When possible, position the head away from and above work on lead sheath to minimize exposure to generated particulate as much as possible.

Train workers to recognize when PPE for working on or near lead-sheathed cable is required

- Encourage the use of safety coaches for employees who are inexperienced with using PPE in these environments.
- Emphasize the environments where PPE is required as described in current trainings.

Train workers on appropriate use of N95 filtering facepiece respirators

- Provide visual aids to help employees identify the differences and use cases for N95 filtering facepiece respirators and KN95 masks.
- Continue providing Appendix D of the OSHA Respiratory Protection standard when providing N95 filtering facepiece respirators for voluntary use.
- Inform employees that facial hair will decrease the performance of N95 filtering facepiece respirators.

Recommendation 2: Reduce employees' exposure to lead on hands and surfaces

Why? Lead on surfaces can be harmful to employees if they accidentally ingest it, 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 accidentally expose others to lead. This can increase the risk of health problems for both employees and people who may be more at risk to the health effects of lead, such as children or pregnant women.

We measured lead on multiple surfaces. Although some employees used wet wipes to clean up after work at field sites and reported washing their hands or changing out of work clothes and boots before leaving the facility, post-work practices among employees varied. Take-home lead contamination remains a possibility if proper hygiene and post-work practices are not strictly followed.

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

Continue implementing the replacement of wet wipes with lead removal wipes at field sites

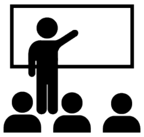
- Continue to encourage employees to use lead removal wipes to clean hands before eating or drinking, using the restroom, after conducting work and handling tools, before using cell phones, and before entering vehicles.

Provide workers with lead removal soap at garages

- Workers have access to soap and water at garages. Since lead was found on employee hands after hand hygiene at garages, washing hands with regular soap and water may not be adequate to remove lead from hands.
- Increase training for thorough hand hygiene practices. Resources for proper handwashing can be found on the CDC website.

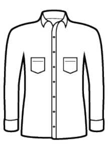
Conduct thorough cleanings of vehicles, tools, and other surfaces that may have lead using lead removal wipes. Schedule regular cleanings of company vehicles and tools that may be used on lead-sheathed cables.

- One option would be to conduct cleaning when other regularly scheduled maintenance or check-ups take place.
- Use lead removal wipes to clean vehicle surfaces and tools.



Train workers to reduce the potential for take-home lead exposure

- Include guidance to employees of the benefits of removing contaminated clothing and footwear before entering personal vehicles or their homes.
- Consider providing a location in a clean area for employees to store footwear and change clothing at the garage.
- Consider providing time for employees to shower at garages after working on or near lead-sheathed cables.
- Provide workers with information on take-home lead.
  - NIOSH has developed Leave Lead at Work to communicate why it is important and ways to prevent take-home lead exposure.
  - OSHA has developed a QuickCard titled If You Work Around Lead, Don't Take It Home!



If employees wear tops with loose hoods, require the use of coveralls with hoods.

- We observed that dirt from the manhole, which may or may not contain lead, could collect on hoods and other parts of clothing not covered by coveralls.
- Alternatively, consider prohibiting the wearing of tops with hoods if a coverall hood cannot be worn.

Discuss barriers to wearing nitrile gloves while conducting splicing work.

- Conduct work while wearing nitrile gloves as much as possible.
  - If nitrile gloves cannot be worn during splicing work, consider enhancing hand hygiene during and after work.

Recommendation 3: Reduce employees' exposure to lead through improved medical surveillance

Why? BLL test results provided by management and the union showed that multiple employees had BLLs above health reference levels, increasing the risk of health effects. In addition, the majority of the employees who responded to the questionnaire reported that they had not participated in management's voluntary BLL testing program and had never had their BLLs tested outside of work since working in telecommunications, suggesting that there are many employees with unknown BLL status.

Medical surveillance is an important tool that can be used to supplement other administrative controls to reduce lead exposure among employees. Medical surveillance can help determine which employees have lead levels above reference ranges and are at greater risk of health effects, which work practices are protective against lead exposure, and which job tasks may be of higher risk or require more health and safety interventions.

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

For new workers, conduct initial BLL testing before any work that may expose them to lead

- Encourage new employees to receive voluntary testing prior to beginning work duties.

Conduct annual voluntary BLL testing for current employees and intermittent testing after suspected lead exposure events

- Encourage employees to receive annual voluntary testing regardless of work tasks in previous months.
- Provide opportunities for spot testing after an employee identifies high-risk work tasks that may have resulted in lead exposure.
- Continue to investigate any work tasks that are associated with BLLs above population-based reference levels.

Consider 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 (ACOEM) to advise workers on BLL results. Find these at Workplace Lead Exposure | ACOEM.
- Examples of some of the health-based recommendations from ACOEM are described below:
    - 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.
    - Remember that health-based limits for women who are attempting to conceive, pregnant women, or lactating women should be < 5 µg/dL.

Supporting Technical Information

Exposure to Lead during Work on and Near Lead-Sheathed Telecommunication Cables

HHE Report No. 2024-0046-3413

May 2025

Section A: Workplace Information

Employee Information

At the time of our evaluation, management provided a roster with 1,531 active employees across two states. The three garages included in our site visits included 117 employees, the majority of whom were male (97%) with a median age of 54 years (range: 37 to 64 years). Employees worked an average of 40 hours per week over either five 8-hour shifts or four 10-hour shifts, Monday through Friday. Alternative work schedules and overtime were available. The employees were represented by a union.

Among the 117 employees, 70% (n = 82) had the job title of splice service technician (SST), with the remaining having the title of outside plant technician (OPT).

- SSTs have expertise in cable splicing and work collaboratively to install, splice, test, repair, and maintain lead, fiber-optic, and copper cables. SSTs' job tasks include connecting, disconnecting, testing, repairing, maintaining, installing and rearranging equipment, inside wiring, and wires located on poles, underground, or in building terminals. SSTs may climb ladders and poles and enter manholes to complete their work.
- OPTs, also known as linemen, build and maintain external network infrastructure by placing, rearranging, and removing outside plant (physical infrastructure and equipment in a telecommunications network located outside of buildings and facilities) in various outdoor environments, including aerial, underground, submarine, buried, block and house cables, poles, and other hardware or fixtures. OPT tasks may involve climbing poles, digging and entering trenches, entering manholes to connect or install wires and cables to terminals, and attaching or detaching various kinds of hardware to wires, cables, buildings or poles. Job tasks may also include construction work such as digging holes and placing poles using designated equipment. OPTs are generally involved when there is gross removal or pulling of telecommunication cables.

SSTs and OPTs work together to ensure that telecommunication cables and equipment are installed, connected, and tested to ensure they function properly.

History of Issue at Workplace

Request basis: From the late 1800s to the mid-1900s, telecommunication companies used lead sheath to cover and protect telecommunications cables from the elements. These lead-sheathed cables were hung on poles, buried underground in manholes, and placed underwater and in other environments. After the change to plastic-sheathed cables in the mid-20th century, some of these lead-sheathed cables have been removed and replaced. However, an unknown number of lead-sheathed telecommunications cables continue to be actively used or remain abandoned in place after being replaced by plastic-sheathed cables. As lead-sheathed telecommunications cables continue to age, lead oxides can form a white powdery substance. Various groups have expressed concerns that the degradation of these lead-sheathed cables could release lead, which could enter the water and soil in the surrounding environment, potentially affecting communities nearby.

In response to these concerns, the U.S. Environmental Protection Agency (EPA) sampled soil for lead in an area near some telecommunications cables in Pennsylvania and New Jersey in August 2023. At both sites, surface soil samples directly below the lead-sheathed cables and surface soil samples from the opposite side of the road had lead concentrations above an EPA screening level of 400 parts per million at the time [EPA 2024a]. All samples tested were primarily from areas covered with grass, a natural barrier that helps prevent soil dust from being easily kicked up into the air. Most of these samples were also collected in locations away from where children gather for long periods of time. EPA's initial scientific review of the data indicated that there are no threats to the health of people nearby that would warrant an immediate EPA response action. The EPA continued its work by establishing a national working group to consider next steps to ensure public safety [CRS 2023, EPA 2023a,b].

A union representing telecommunication workers was concerned about potential occupational exposure to lead during work in and around lead-sheathed cables. Union representatives shared that some employees had concerns about potential hazards from the use of a lead encapsulating compound and its efficacy in controlling exposure to lead. After observations and discussion with the union requestor and management, we focused on evaluating exposures to workers during routine repair, maintenance, and installation work in telecommunication manholes due to the smaller space and potential concentration of lead-sheathed cables in these environments that workers may encounter or disturb.

Previous issues: Past industrial hygiene sampling conducted by the company of employees in another locality removing or "pulling" large sections of lead-sheathed cables had found overexposures to lead in air. Currently, removal and replacement of these lead-sheathed cables is not done as extensively as in the past, but still occurs occasionally as needed. Major lead projects, defined as removing more than 25 feet of lead cable, involves more administrative controls under the supervision of environmental health and safety management because of the potential for higher lead exposure; they are outside of the scope of this evaluation. Lead projects also occur less often than routine work on lead-sheathed cable and in environments where lead-sheathed cable is present.

Routine Maintenance, Repair, and Installation Work in Manholes

Work involving maintenance and repair of lead-sheathed and plastic-sheathed cables and installation of plastic-sheathed or fiberoptic cables in manholes where lead-sheathed cable is or was present is described here. This description does not include the planned pulling of lead-sheathed cables from conduit in manholes or large-scale removal of lead-sheathed cables greater than 25 linear feet ("lead projects").

Step 1

After setting up around the manhole, workers open the manhole cover. To ensure safety for entry, workers use a 4-gas meter to evaluate the air in the manhole for oxygen, carbon monoxide, hydrogen sulfide, and lower explosive limit. According to management representatives, telecommunications manholes do not meet the definition of a confined space by the Occupational Safety and Health Administration (OSHA) [OSHA 2007]. A blower is placed in the manhole to purge the air in the manhole for 15 to 20 minutes. If a manhole contains enough water that it interferes with work, workers use a pump to remove water from the manhole.

Step 2

Cable diagrams of telecommunications lines may provide clues to the composition of the sheathing of the cable to be worked on. If a lead-sheathed cable is suspected to be present in the manhole, company policy requires that workers don personal protective equipment (PPE) for working near and with lead, which includes disposable Tyvek® coveralls, foot protection (e.g., disposable booties, rubber boots), and nitrile gloves. N95® filtering facepiece respirators are provided for voluntary use when working on or disturbing lead-sheathed cable.

With the blower still ventilating the manhole, a worker enters the manhole using a ladder to assess the cables and equipment. If the worker discovers upon entry that there is lead that was not suspected or identified in the diagrams and drawings, the worker leaves the manhole to don the appropriate PPE. If lead-sheathed cable is present in the manhole, workers are instructed to spray amended water (soap and water solution) onto surfaces. If lead-sheathed cable will be worked on or potentially disturbed, workers are instructed to paint the sheath with a lead encapsulating compound. After lead encapsulating compound is applied, workers can then cut open any sheaths if work is to be done on the wires inside a cable.

Step 3

The worker enters and exits the manhole(s) as needed to complete the work. Another worker (helper) stands at the manhole entrance to retrieve tools, coordinate tasks with the worker in the manhole, and act as a safety measure. Workers may work the whole shift in this configuration, or they may switch positions. If any lead sheaths are removed during work, workers are instructed to place these pieces into thick disposable plastic bags for disposal in the hazardous waste bins at the garage.

Step 4

When the task is finished, workers close any opened sheaths. Workers are instructed to clean work tools used on lead sheath by rinsing them with regular soap and water (discarding the dirty soap and water in a bag) and wiping them down with a disposable towel at the field site. For tools dedicated for lead work, tools may also be sealed in a plastic bag and labeled before being placed on work vehicles. If these tools are to be used on areas without lead, the tools must be thoroughly cleaned with soap and water.

When workers leave the manholes and put tools used on lead materials away, they doff PPE, close the field site, and wipe their hands with wet wipes before they return to their work vehicles. Some workers return to their garage and others to their home or to a central office at the end of their shift. Workers who worked out of a garage were instructed to thoroughly wash hands with soap and water before entering their personal vehicles.

Section B: Methods, Results, and Discussion

Methods: Exposure Assessment

Document Review

We reviewed the following documents provided by company management:

- Job hazard analyses for
    - Working with lead-sheathed cables during removal of aerial strand, dated November 2014
    - Working with lead-sheathed cables in manholes, dated November 2014
    - Lead scrapping operations, dated November 2014
    - Cutting conduit during construction activities, dated April 2017
- Past air sampling for lead conducted by contractors, dated November 2012 through May 2018
- Internal webpages containing procedures for working underground
    - Removing cable, dated September 2018
        - Overview
        - Lead in the workplace
        - Setting up for cable removal
    - Placing and removing underground cable – work orders for underground work, undated

Personal Air Sampling & Post-work Questionnaire

During the second site visit, we collected full-shift personal air samples for lead on 6 workers for one shift each during work on or near lead-sheathed cables, beginning when employees first entered the manholes and ending when the employees exited the manhole for the last time during the shift. We collected the samples on an internal capsule sampler (cellulose acetate dome with inlet opening) attached to a 0.8 micrometer (µm) mixed cellulose ester membrane filter at a nominal flow rate of 4 liters per minute following procedures in National Institute for Occupational Safety and Health (NIOSH) Method 7306. We analyzed the air samples for lead using a modified NIOSH Method 7303 [NIOSH 2025]. We compared results to the current OSHA permissible exposure limit (PEL), NIOSH recommended exposure limit (REL), and the American Conference of Governmental Industrial Hygienists (ACGIH®) threshold limit value (TLV®) of 50 micrograms per cubic meter (µg/m^3) for lead in air. We also compared results to the OSHA action level (AL) for lead of 30 µg/m^3 for lead in air.

During the second site visit, for workers who entered manholes for a full shift of work and participated in air sampling, we administered a confidential post-work questionnaire to understand work activities, work tasks, and controls used. Results were evaluated qualitatively in combination with observations we made from above the telecommunication manhole, in lieu of being able to enter the manhole to make observations directly.

Hand Wipe Sampling

During the second site visit, we collected hand wipe samples on the palm sides of hands from nine employees in the crews we observed conducting work in manholes. To document potential for exposure throughout the work process, we collected these samples at various points in their post-work routine:

- After doffing PPE, before any hand hygiene
- Before entering a work vehicle to return to a garage or home, with routine hand hygiene completed
- While in a work vehicle before returning to a garage, with routine hand hygiene completed
- After returning to a garage and before returning home, with routine hand hygiene completed

One industrial hygienist collected all hand wipe samples. Before collecting each sample, the industrial hygienist donned clean nitrile gloves. Then they used a premoistened Ghost Wipe™ to wipe the palm side of the worker's hand three times total, following NIOSH Method 9100. We quantitatively analyzed the hand wipe samples for lead using a modified NIOSH Method 7303 [NIOSH 2025]. Neither NIOSH nor OSHA has occupational exposure limits (OELs) for lead on hands.

Surface Wipe Sampling

During the first site visit, we performed qualitative and quantitative surface wipe sampling on garage surfaces, in work vehicles, and on tools and equipment used on lead-related tasks. During the second site visit, we performed quantitative surface wipe sampling in work vehicles and on reusable PPE. One industrial hygienist collected all surface wipe samples. Before collecting each sample, the industrial hygienist donned clean nitrile gloves. Then they used a premoistened Ghost Wipe™ to collect the sample following NIOSH Method 9100 for quantification and analyzed using a modified NIOSH Method 7303 [NIOSH 2025]. For non-flat surfaces, we wiped the whole item or an estimated area of 100 square centimeters (cm^2). For flat surfaces, we used a disposable 100 cm^2 template to outline the surface areas that were sampled. Neither NIOSH nor OSHA has OELs for lead on surfaces. The OSHA lead standard (CFR 1910.1025) requires that all surfaces be maintained as free as practicable of accumulations of lead [OSHA 2020]. Refer to Surface Exposure Limits for Lead in Section D for more information on surface limits established by the U.S. Department of Housing and Urban Development (HUD) and the U.S. EPA. While these levels are not directly applicable to the worksites sampled, they are useful benchmarks to understand these results.

Bulk Analysis

During the second site visit, we asked the worker entering and working in three dry manholes to collect sediment from the bottom of the manhole for analysis of lead concentration. The samples were digested according to EPA Method 3050B and analyzed according to EPA Method 6010D for lead concentration [EPA 2020]. Neither NIOSH nor OSHA has OELs for lead in soil.

Observations

During both site visits, we observed work in an aerial environment, in manhole environments, and in a trench. When we were able to, we observed work tasks, practices, and use of controls. We also toured two central offices to understand this setting, but we did not observe work in the central offices.

Questionnaire

During the second site visit in January 2025, we visited three garages and invited all employees present on the day of our visit to participate in an anonymous paper questionnaire. The questionnaire covered basic demographics (e.g., age), work characteristics (e.g., year and month when employment began, job title and department), frequency of lead-related work (e.g., lead projects or work directly on lead), frequency of work in environments that may have lead present, perceptions of lead training, employee use of PPE, employee hygiene and post-work practices, perceptions of lead encapsulating compound training and use, and BLL testing. Data from paper questionnaires were manually entered into REDCap for data management. Data cleaning and analysis was conducted in R version 4.4.0 and analyzed using RStudio version 2024.04.2. Analysis included data cleaning and descriptive statistics, including counts and proportions for each question.

Current company administrative systems did not keep records of work environments or types of routine work, so to understand the frequency of exposure we used the employee questionnaires to provide estimates of frequencies of lead work and frequencies of non-lead work in different environments that could affect lead exposure.

Results: Exposure Assessment

Document Review

Detailed job hazard analyses were provided for four tasks that may be conducted by employees. The most relevant job hazard analysis to this request was "working with lead-sheathed cables in manholes," which described work performed in manhole environments where lead-sheathed cable existed, and the control measures used to prevent and reduce lead exposure. This analysis described this similar exposure group to include all the various tasks that may occur while technicians work inside and outside the manhole, including handling sections of lead-sheathed cabling. The analysis indicated that exposure varied by individual work practices, work environment, the amount of lead-sheathed cable present, environmental conditions including moisture within the manhole, and the intensity and duration of work.

The job category associated with the highest potential for exposure to lead was "Cutting conduit during construction activities," which included employees performing cutting and removal of telecommunication conduits associated with municipal roadway or infrastructure projects. The main source of exposure to lead during this activity is from cutting conduit that may contain lead particulates or lead-sheathed cables. The frequency of this activity was variable and dependent on the number of projects that required relocation of communication conduit.

The other two job hazard analyses were reviewed but not described here. A similar exposure group described in these job hazard analysis documents was "work performed in cable vaults." However, a job hazard analysis for this similar exposure group was not provided.

The company provided personal and area sampling results for lead collected in a different region during November 2012–May 2018. In total, over 200 personal air sampling results for lead were included in provided documents. The descriptions of work sampled included cutting and transporting/removing or stockpiling cable in manhole and central office settings with and without use of lead encapsulating compound; pulling and cutting cables (scrapping) in manhole, central office, and aerial settings; removing debris; cutting and removing cast iron pipes and cable; and removing lead-containing splice cases. The encapsulating compound used in most past sampling results was not the same compound currently being provided to employees.

From these past air sampling results, the highest recorded personal exposures to lead in air were from cutting and transporting cable in central office locations (i.e., an activity considered to be a major lead project) with a median 8-hour time-weighted average (TWA) result of 65 µg/m^3 and range of < 4.2–9,400 µg/m^3 (n = 23). The narrative descriptions accompanying these samples did not include lead encapsulating compound use. One past personal air sampling result for cutting and transporting or removing cable from a manhole (i.e., an activity similar to those included in the present evaluation) had a maximum 8-hour TWA result of 30.09 µg/m^3. The remainder of personal air sampling results were under the lowest applicable OELs.

The internal webpage describing placing and removing of underground cable describes how supervisors and workers can determine from drawings beforehand if the manhole they are entering may contain lead-sheathed cable.

Personal Air Sampling and Post-work Questionnaire

Results of personal air sampling for six employees for lead are shown in Table C1. TWA exposure concentrations for SSTs were 6.9–55 µg/m^3 with 8-hour TWA exposures of 2.7–32 µg/m^3. An SST conducting a cable transfer had a personal air sample result for lead of 55 µg/m^3 over a sample time after entering the manhole of 282 minutes (4.7 hours). This equates to an 8-hour TWA exposure of 32 µg/m^3 to lead, assuming no exposure to lead in air during the remainder of their shift. This result exceeded the OSHA action level of 30 µg/m^3. On the post-work questionnaire, this employee reported that while air sampling was being conducted, they cut lead sheath using cable cutters. They also reported that they used the lead encapsulating compound and amended water during their shift. This employee reported wearing the required full PPE ensemble for working on or near lead sheath. They did not report voluntarily wearing an N95 respirator during their shift.

TWA exposure concentrations for OPTs were not detected and 0.75 µg/m^3, with 8-hour TWA exposures of not detected and 0.27 µg/m^3, respectively. We collected personal air samples on two OPTs preparing for the installation of fiber-optic cable by pulling mule tape through conduits between manholes). This activity consisted of locating old mule tape (if present) and using this old mule tape to pull new mule tape through the conduit. Locating old mule tape could require entering the manhole for various durations. If the tape was easily located without entering, entering the manhole was not needed. If old mule tape did not already exist in a conduit, a conduit duct rodder was used to pull mule tape through the conduit between manholes, with an OPT entering briefly to set up this process. This new mule tape was later used to pull fiber-optic cable into conduits. The higher of the two OPT air sampling results did not include the first entrance by that employee into a manhole. Generally, the 8-hour TWA exposure range to lead in air was lower for OPTs (not detected–0.27 μg/m³) than the range of 8-hour TWA exposure range for SSTs (2.7–32 μg/m³). The OPTs did not use amended water or lead encapsulating compound since they were not working on or disturbing lead-sheathed cable, although lead-sheathed cable was visible in multiple manholes. The OPTs we observed reported spending less time in manholes (1 hour and 5 hours) with sample times of 73 and 169 minutes than the SSTs (4 hours and 8.5 hours) with sample times of 188–282 minutes for the tasks we observed.

Hand Wipe Sampling

Results of post-work hand wipe sampling are shown in Table C2. Lead was found on all nine hand wipe samples collected on workers in the crews we observed. The highest amount (83 μg) was found on an SST's hands after exiting from the manhole and doffing of PPE before hand hygiene, followed by on an SST's hands after work and recommended field hand hygiene of using wet wipes to wipe hands before entering their work vehicle (45 μg). The remainder of the hand wipe samples were collected either in the worker's truck before returning to the garage (6.6 μg–13 μg) or at the garage after routine hand hygiene as the worker prepared to enter their personal vehicles to leave (1.3 μg–11 μg). We asked workers to perform hand hygiene practices as they normally would.

Surface Wipe Sampling

Results for 29 surface wipe samples collected during both site visits can be found in Table C3. Higher levels for surface wipes were found on tools used directly on lead sheath and used in routine work in manhole environments, a chipping knife (140 μg), the handle of a hammer used for lead work (32 μg), and the bottom of a ladder (30 μg). Lead was found on seven steering wheels of work trucks (0.71–48 μg). These surface wipes were not collected with a 100 cm² template. Lower levels were found on other surfaces in vehicles, on helmets and headlamps, and in common areas in the garage.

Bulk Analysis

We collected three samples for bulk analysis, two from manholes where a cable transfer was in process and one from a dry manhole during preparation for fiber-optic cable installation. The highest concentration of lead detected in the collected sediment was 30,000 milligrams per kilogram (mg/kg) or parts per million (ppm) in soil detected in the "downhill" manhole where an employee cut lead cable using cable cutters. The other two samples found 170 ppm and 530 ppm in the "uphill" manhole during cable transfer and during the preparation for fiber-optic cable installation, respectively. The bulk sample from the downhill manhole was collected at the end of the shift.

Observations

For the employee whose personal air sample was above the action level, we observed them remove debris from the manhole at the beginning of their shift and use tools including a hammer and a wrench. The space was crowded by multiple cables and the employee struggled to move them around to gain access to a specific one for service. We observed that SSTs and OPTs spent varying amounts of time in different environments (for example, manhole with visible lead cables, manhole without visible lead cables) and doing different types of routine work tasks (for example, working directly on lead cables, working with non-lead cables). The two central offices we toured were clean and kept at ambient temperatures and conditions. Likely most of the lead exposure in central offices would be from directly working on and around lead-sheathed cables at central offices.

Questionnaire

We received 72 employee questionnaires, with 71 of the questionnaires having at least one question filled out. If we assume the management roster provided from June 2024 was equivalent to the employee population at the time of the questionnaire in January 2025, then the response rate was 61% (71/117). All employees present at work during our visit turned in a questionnaire. We were not able to capture employees who were not present in person during our visit.

Among employees responding to the questionnaire, 98% were male and had a median age of 52 years (range: 21 to 63 years) and a median job tenure of 27 years (range: < 1 year to > 30 years). Seventy respondents provided information for job title, with 57% (40/70) selecting SST and 43% (30/70) selecting OPT. Respondents represented the installation & maintenance, construction, and pro-active maintenance departments (Table C4).

We summarized the frequency of work in different environments and types of work by job title in Figures B1, B2, and B3.

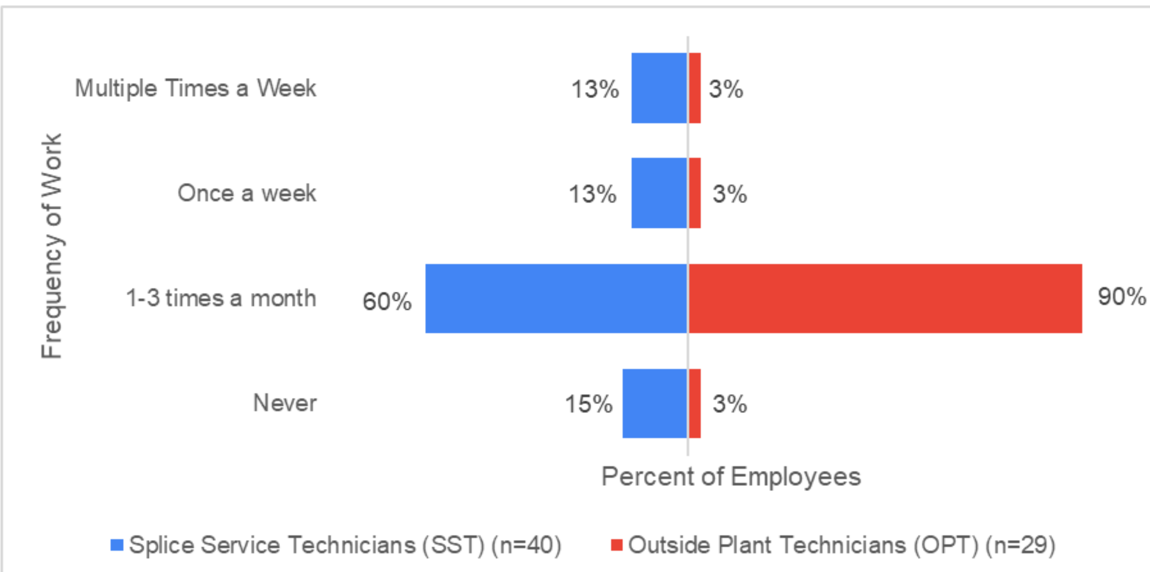


Figure B1. Frequency of underground manhole work by job title (n = 69)*

*Employees that answered the question were included in the analysis. Due to rounding, percentages do not sum to 100%.

In a typical month, 60% of SSTs and 90% of OPTs reported working in a manhole environment 1–3 times a month (Figure B1). Similarly, in a typical month, 61% of SSTs and 90% of OPTs worked 1–3 times a month in manholes where lead cables were visible in the environment, but they were not working directly on lead (Figure B2). SSTs reported working a median of 3.5 hours (range: 0.5 to 8 hours) in a manhole during a typical 8-hour shift and OPTs reported working a median of 3 hours (range: 0.5 to 5 hours).

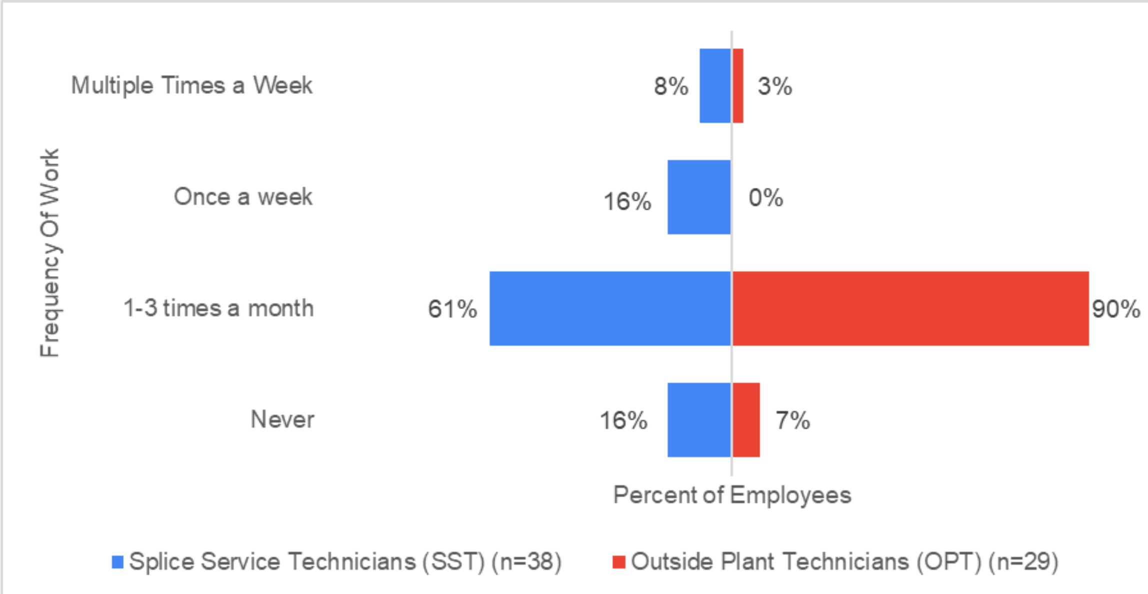


Figure B2. Frequency of non-lead work in a manhole where lead is visible in a typical month by job title (n = 67)*

*Employees that answered the question were included in the analysis. Due to rounding, percentages do not sum to 100%.

Figure B3 shows that 56% of SSTs and 64% of OPTs never work directly on lead cable or lead sheath in a typical month.

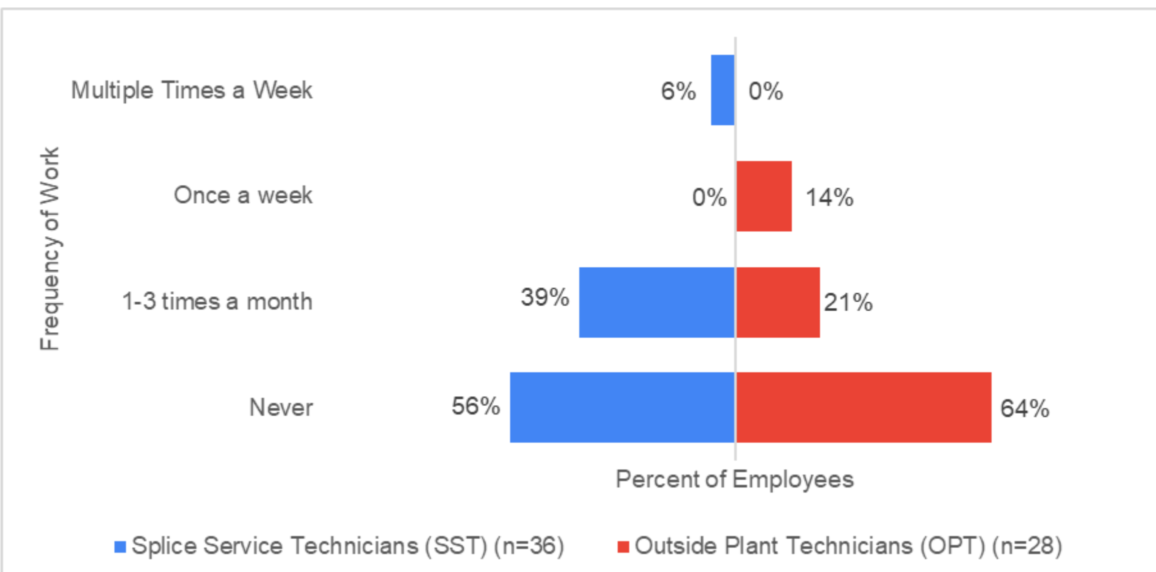


Figure B3. Frequency of work directly on a lead cable or lead sheath in a typical month (n = 64)*

*Employees that answered the question were included in the analysis. Figure B3 includes 36 SSTs and 28 OPTs. Due to rounding, percentages do not sum to 100%.

Lastly, the frequency of lead project work in the past 5 years varied based on job title. Seventy percent (21/30) of OPTs and 28% (11/40) of SSTs reported ever participating in lead projects in the past 5 years.

Overall, employees in both job titles reported exposure to manhole environments, work in manholes with lead visible but not working directly on lead, work on lead, and work on lead projects.

Methods: Work Practices

Personal Protective Equipment (PPE) and Hygiene

Document Review

We reviewed the following documents provided by company management:

- Training documents for managers and employees, including
  - Video training: Lead awareness and exposure control, undated
  - Lead Awareness & Exposure, undated
  - Internal webpages containing procedures for working underground
    - Setting up for safety, dated September 2018
  - Lead sheathing safety program, dated March 2021
  - Lead residue management procedures when working with lead-sheathed cable, dated 2011
  - Employee job aid: lead work practices, undated
  - Respiratory protection program, dated May 2019
  - Hazard communication program, dated July 2021
- Safety data sheets (SDSs) for compounds used while working on lead-sheathed cable
- Previously reviewed documents from Exposure Assessment Document Review section

The following documents were provided by management but not incorporated in the review below:

- Working with lead sheathed cable, undated
- Voluntary use of N-95 dust mask respirators: guidance on proper use, dated 2011
- Working on or around lead sheathed cables – required work practices and controls, dated 2011

Questionnaire and Post-work Questionnaire

The methods for the questionnaire are described in the previous section under "Methods: Exposure Assessment: Questionnaire." Regarding work practices, we focused on questionnaire questions that related to employee PPE use. Specifically, we asked when employees wear full lead protection, with full lead protection defined as Tyvek coveralls, booties or other foot protection, safety glasses, gloves, hard hat, reflective vest, and voluntary use of an N95 respirator.

Methods for the post-work questionnaire are described in a previous section under "Exposure Assessment: Personal Air Sampling & Post-work Questionnaire." The same methods were applied here but focused on questions related to employee PPE use.

Observations

During both site visits, we observed PPE worn and hygiene practices in an aerial environment, in manhole environments, and in a trench. When available, we observed PPE donning and doffing and hygiene practices during various work tasks and practices, and use of controls.

Results: Work Practices

Personal Protective Equipment (PPE) and Hygiene

Document Review

The Lead Awareness & Exposure Training and other associated documents described above indicated that employees are to wear full lead protection (Tyvek coveralls, booties or other foot protection, safety glasses, gloves, hard hat, reflective vest) when working in manholes or controlled environmental vaults (CEVs) that were known to contain lead-sheathed cable or when working on, handling, or disturbing lead-sheathed cable. N95 filtering facepiece respirators are provided for voluntary use and strongly recommended when working on or disturbing lead-sheathed cable. In instances when it was not known if lead-sheathed cable was or is present in manholes and it was discovered upon entry, employees are to exit and put on PPE before continuing work. Training documents included instructions or hands-on demonstrations for donning and doffing procedures.

From trainings, it was unclear when or if PPE should be doffed and donned again when entering and exiting manholes repeatedly. According to policies and training materials, company management provided workers with N95 filtering facepiece respirators for voluntary use when working on or disturbing lead-sheathed cable. It was also unclear how and how often reusable PPE, such as hard hats and reflective vests, were to be cleaned.

Provided documents prohibit eating, drinking, and smoking at field sites and placing items in the mouth. Training instructs employees in the field to use wet wipes to wash hands and face after doffing PPE and before leaving the work area or entering work vehicles. Once employees return to the garage or home, they are instructed to wash their hands and face again. It is unclear if showers are recommended after work or how employees should thoroughly wash hands. There is limited information on recommendations to reduce take-home lead and preventing lead from leaving field sites.

Questionnaire & Post-work Questionnaire

When asked on the questionnaire when they wear full lead protection, 65% (43/66) of employees who work on or near lead responded they wore full lead protection when working directly on a lead cable, 47% (31/66) when working on a lead project, and 38% (25/66) when working in a manhole where lead is visible in the environment, but they are not working directly on lead.

In the post-work questionnaire, employees reported wearing a combination of nitrile, latex, and leather gloves. All employees entering manholes who completed the post-work questionnaire reported not voluntarily wearing N95 respirators during their work.

The most common questionnaire responses of employees about hygiene and post-work practices after getting off a work shift where the employee worked directly on lead were to go home in the same clothes they wore to work (66%, [41/62]), go home in the same shoes that they wore to work (53%, [33/62]), and wash their hands in the garage prior to going home (65%, [40/62]). The most common post-work practices were consistent across both types of work (when working directly on lead and when working in a manhole where lead was visible, but they were not working directly on lead) (Table C5).

Observations

During the first site visit, we observed that some employees were unsure of when full lead protection was required when working in manholes.

During the second site visit, all employees who entered manholes wore full lead protection without voluntary N95 respirators. We observed one employee's Tyvek coveralls were ripped at the end of the shift after wearing the coveralls for most of their shift. At times, we observed technicians taking off nitrile gloves to better locate specific wires. We observed an employee repeatedly entering manholes don PPE including Tyvek coveralls to enter the first manhole. We observed the employee kept the coveralls on while entering and sitting in their work vehicle. We also observed some workers wearing clothing with attached hoods that sat outside of Tyvek coveralls and that dirt and debris from the manhole could collect on these hoods. We observed one employee don a KN95 mask when working near lead-sheathed cable in a manhole. When we asked a different crew of employees to see their respirators, employees showed us KN95 masks provided by the company and did not have N95 filtering facepiece respirators in their vehicles.

We observed workers using wet wipes before entering their vehicles and before consuming food. We also observed workers eating while not working in manholes at the job site without hand washing. We observed that based on the location, hand washing facilities with soap and water may not be readily available in the field. We also observed that due to work constraints during work in busy roadways with police management of traffic, it was difficult to pause to allow for restroom or eating breaks away from the field site. At the beginning of the second site visit, the company had begun ordering and implementing the use of lead removal wipes to replace wet wipes for hand hygiene for workers at field sites.

Methods: Employee Training

Document Review

We reviewed the documents provided by company management on training that were reviewed in previous Document Review sections in Exposure Assessment and Work Practices: Personal Protective Equipment.

Questionnaire

The methods for the questionnaire are described in the previous section under Methods: Exposure Assessment: Questionnaire. The same methods were applied here but we focused on questions from the questionnaire related to perceptions of general lead training and perceptions of the lead encapsulating compound and training.

Observations

During both site visits, we observed work in an aerial environment, in manhole environments, and in a trench. When we were able to, we observed work tasks, practices, and use of controls.

Results: Employee Training

Document Review

Workers who may work on or around lead-sheathed cable are required to take lead awareness training. The training materials we reviewed included a presentation entitled "Lead Awareness & Exposure," which covered hazards, work practices and controls to prevent exposure, training requirements, exposure routes and factors, acute and chronic health effects, and BLL testing. During the time of the site visits, this training was only required once and was ongoing for new employees and employees who had not yet received the training.

According to the lead encapsulating compound SDS, there are components in the lead encapsulating compound that are "toxic to aquatic life." The presence of these components ranged from less than 1% to up to 5%, the most abundant of which is texanol ester alcohol. The SDS hazard statement describes that this product may cause an allergic skin reaction and skin sensitization and to avoid breathing in any "dust/fume/mist/vapors/spray." The company and the manufacturer of the lead encapsulating compound provided personal air sampling results collected in May 2018 for propylene glycol during application of the lead encapsulating compound on lead and while scaling lead-sheathed cable inside a manhole. Results showed levels of propylene glycol under the reporting limit, and lead results with concentrations < 18 $\mu g/m^3$ for the entirety of the task (88–90 minutes) and < 37 and < 38 $\mu g/m^3$ during the scaling (106–108 minutes).

Another concern reported by the union requestor was that the SDS for the lead encapsulating compound was not readily accessible to employees. Between the first and second site visit, the company created an inventory system of SDSs that could be accessed using a QR code on a company-provided device. This system allowed for SDSs to be updated as needed and easy access for employees.

Questionnaire

Seventy percent (50/71) of employees who responded to the questionnaire were able to provide an estimated year for their last lead training (2022–2025). Only two individuals stated they had never taken any lead training, including one which had started working within the last 3 months.

Similarly, when asked if they had completed lead encapsulating compound training, 76% (52/68) of employees who responded to the question stated they had completed lead encapsulating compound training. Most employees who responded to the question had no concerns about using lead encapsulating compound (81%, [51/63]).

Of the 12 employees who reported concerns with lead encapsulating compound on the questionnaire, the most common concerns were "concerns that the lead encapsulating compound is toxic to the environment" and "concern that the lead encapsulating compound could have negative health effects on workers," reported by 8 employees each.

Observations

The company had promoted several tenured employees who were SSTs and/or OPTs to the role of "safety coach." We observed safety coaches providing assistance and instruction to employees during both site visits. Safety coaches worked full-time observing workers and providing guidance or help on health and safety concerns that arise during work. They served as a way for employees to have an experienced observer help to ensure that they are following appropriate safety and health procedures when working, or help retrieving additional supplies when needed.

Methods: Blood Lead Level (BLL) Testing

Document Review

We reviewed the following documents provided by company management:

- Voluntary BLL Testing Program Appointment Request Form
- OSHA's Form 300 Log of Injuries and Illnesses for Massachusetts and Rhode Island, from January 1, 2022, through December 31, 2023
- Email communications to employees about voluntary BLL testing, dated July 2023
- Employee roster dated June 24, 2024
- Employee BLL test results
    - We received lists of test results of employee BLLs from the union and from management. Data from the union included 3 lab testing reports provided voluntarily to the union by individual employees and a list of 39 BLL results that were given to the union by management after the union requested employee BLL results from January 1, 2020 to March 20, 2024. We combined both union data sources to calculate the total number of tests reported, the median and range of BLL test results, the number of tests above the Council of State and Territorial Epidemiologists' (CSTE) adult blood lead reference value of 3.5 μg/dL [CSTE 2022] and the number of tests above the CDC's Adult Blood Lead Epidemiology and Surveillance (ABLES) definition for an elevated BLL (5 μg/dL) [NIOSH 2024a]. Data was organized by year as changes in lead health and safety practices at the workplace were implemented at various points over the last 3 years.
    - Data from management included 120 BLLs from employees that had voluntarily participated in the company's voluntary BLL testing program and had their BLL drawn and tested through the company's occupational medicine contractor. Company management provided a list of deidentified BLL results during January 1, 2022–May 16, 2024. We summarized the management data with the same methodology as the data provided by the union, described above. The only methodology change was that for test results reported as less than a value (e.g. < 0, < 1.0, < 1, or < 3 μg/dL) we converted those to zero for calculation purposes. In the data provided by the union, there were no values in a less than format.

Questionnaires

The methods for the questionnaire are described in the previous section under Methods: Exposure Assessment: Questionnaire. The same methods were applied here but we focused on questions from the questionnaire related to employee perceptions on BLL testing, employee recollection of BLL testing done outside of work, and employee reported participation in the management voluntary BLL testing program.

Results: Blood Lead Level (BLL) Testing

Document Review

Currently, the company has a voluntary BLL testing program. To request a BLL test, an employee logs onto a company portal and fills out a form with their name, their supervisor's name, work location, and an open comment to describe what recent lead activity they completed. Management in Environmental Health and Safety (EHS) review requests twice a week. If an employee has worked on lead in the past 3 months, they are scheduled for a test with an occupational medicine contractor. The employees are given up to 4 hours of paid time off to get the test completed. Results are sent to the employee and the EHS office after review by an occupational medicine healthcare provider. Internal company culture indicates that EHS speak to managers if a test result is greater than 20 µg/dL to identify root causes of exposure similar to an accident investigation for a "near miss" event. Otherwise, there are no administrative interventions or policies unless a level reaches the OSHA medical surveillance consultation or removal limits (40 µg/dL and 60 µg/dL, respectively).

Among 42 BLL results provided by the union, 21% were above 3.5 µg/dL and 17% were at or greater than 5 µg/dL (Table C6). The median BLL was 1.8 µg/dL with a range of 0 to 35 µg/dL. Among 120 BLL results provided by management, 12% were above 3.5 µg/dL and 9% were at or above 5 µg/dL. The median BLL was 1 µg/dL with a range of 0 to 33 µg/dL.

None of the BLLs reviewed were above 60 µg/dL, the OSHA medical removal limit for general industry, or above 40 µg/dL, the OSHA limit for annual medical examination or consultation [OSHA 2020].

Review of OSHA Logs from the past two years (2022–2024) did not reveal any injuries or illnesses related to lead exposure.

Questionnaires

On the employee questionnaire, only 7% (5/70) of employees indicated they had participated in the voluntary BLL monitoring program and only 9% (6/70) indicated they had ever had BLL testing done outside of work since working in telecommunications. Additionally, 86% (60/70) of respondents indicated "yes" or "maybe" to being willing to have BLLs drawn every year if it was free and available at work.

Discussion

Evaluation of Lead Exposure

Overall, the HHE found that telecommunication workers conducting repair, maintenance, and installation of telecommunications cables are exposed to lead. One of the key findings in support of this conclusion was an elevated 8-hour TWA personal air sampling result of an SST who conducted a cable transfer in a manhole above the OSHA action level of 30 µg/m^3. This air sample was measured on the first day of conducting a higher risk task (i.e., cutting lead-sheathed cable), in a higher risk environment (i.e., a manhole environment with lead cables present) and despite the employee reporting following administrative controls of using lead encapsulating compound and amended water. Additionally, the SST's TWA exposure over the duration of air sampling while he was working in the manhole (282 minutes) was 55 $\mu g/m^3$, meaning that there was a potential for this worker's exposure to exceed the OSHA PEL of 50 $\mu g/m^3$ if the same tasks were conducted for 8 hours or more.

Other personal air samples collected from other SSTs on day 2 of the cable transfer were for approximately half of a typical shift, suggesting their results are likely an underestimate of the actual 8-hour TWA exposure. These findings suggest the possibility that other employees working in manholes may be exposed to lead in air above OSHA action levels, as questionnaire data reported that many workers operate in manhole environments and work directly on lead cables on a regular basis (Figures B1–B3).

There are multiple factors that can influence exposure to lead in air such as the work environment; nature, extent and duration of work; and individual work practices. In our evaluation, we found the highest bulk analysis soil lead level in the manhole associated with the SST who had the elevated personal air sampling result, suggesting that higher levels of lead in the dirt in manhole environments could contribute to higher levels of exposure to lead in air. We acknowledge the bulk analysis results may be influenced by sampling bias as the sample was collected by the employee at the end of work in the manhole, but other studies have found lead on surfaces associated with elevated exposure to lead in air [NIOSH 2023; Virji et al. 2009a; Virji et al. 2009b].

The presence of surface lead in work environments was further supported by hand wipe samples. All hand wipe samples collected from both OPTs and SSTs found detectable amounts of lead. The highest result was collected from an employee after exiting the manhole and doffing PPE, before any hand hygiene. This lead dust could have been transferred onto the worker's hands during work tasks in the manhole or from tools or equipment stored on the trucks. We observed some SSTs removing nitrile gloves when doing splicing work, suggesting that work requiring fine motor skills may be difficult to accomplish while wearing nitrile gloves, and employees' hands may have a higher likelihood of interacting with lead in the environment. The hand wipe samples suggest that working in manhole environments where lead is or was present can contribute to detectable levels of lead on hands.

The lead in the manholes and on hands can also be transferred to company vehicles and reusable tools and PPE. Various surfaces in work vehicles had detectable levels of lead present. Lead training materials instruct employees to clean tools that have been used on lead-sheathed cables with wet wipes or amended water at the field site followed by a more thorough cleaning with soap and water. The time of and location of this thorough cleaning with soap and water is unclear from provided training materials. Cleaning of tools with wet wipes was observed during our visit. We did not observe any vehicle cleaning. It is unclear when or how often vehicles are cleaned based on reviewed documentation and site observations. Lead removal wipes have been recommended in previous HHEs as more effective alternatives forcleaning surfaces and hands when soap and water are not readily available [NIOSH 2019, 2023].

Lead transferred from the work environment to an employee's body, clothing, footwear, or personal items can be deposited in personal cars and homes. This process is referred to as "take-home lead." Cleaning up lead dust is difficult and expensive, and other populations such as children may be at increased susceptibility to health effects from lead exposure, so it is better to prevent take-home lead than invest in post-exposure remediation. The most common post-work practices employees reported on the questionnaire after working on lead-sheathed cable or in environments where lead is present were to go home in the same clothes they wore to work and to go home in the same shoes they wore to work. No employees reported showering at the garage, despite showers being available, and only a few reported changing out of work clothes or work shoes prior to going home. These post-work practices may contribute to lead exposure from work being transferred to personal employee environments. Management can emphasize communicating the importance of adapting alternative post-work practices with a NIOSH developed factsheet called Leave Lead at Work that shares information and details on how to prevent taking lead home and the importance of occupational controls in preventing transfer of lead from the work environment.

The compilation of exposure assessment data suggests that management may need to take additional steps as dictated by the OSHA lead standard to evaluate if additional occupational controls are required while maintaining a more regular hygiene schedule to reduce lead dust accumulation in the work environment. Additionally, our recommendations provide early interventions to reduce lead exposure among workers and address deficiencies noted in the exposure assessment evaluation.

Evaluation of Current Company Occupational Controls

Currently, the administrative and PPE controls in place to prevent lead exposure in the workplace are not sufficient to prevent lead exposure. Many of the current management administrative controls are important and should remain. These include standardized general lead training, trainings on practices to prevent exposure, trainings for lead encapsulating compound use, increased access to lead encapsulating compound SDSs, access to PPE, and updated use of lead removal wipes.

Lead encapsulating compounds are typically used in housing to provide a barrier to contain lead paint. In homes, they are not recommended on all surfaces, especially on friction and impact surfaces [HUD 2012]. This workplace had invested in a novel lead encapsulating compound for use during lead work and was regularly training employees on its use. The union requested we evaluate the components of the lead encapsulating compound due to a concern that since the encapsulating compound was disturbed with tools after it was applied to the lead cables, it may not actually prevent lead from being dispersed into the air. Most lead encapsulating compounds are designed to prevent particulate from being released from the surface of the object by creating a seal on the surface. In theory, painting an item with a lead encapsulating compound would prevent any lead particulate that has formed on the surface of the sheath from being aerosolized. However, cutting a lead sheath could disturb the encapsulated surface and could release particulate generated by cutting into the air. We reviewed manufacturer provided air sampling results for propylene glycol during encapsulating compound application to a lead-sheathed cable and for lead during scaling of that cable to evaluate if the product worked as an effective lead encapsulating compound. Based on these results and review of the SDS, the way and the amount that is used for encapsulating lead-sheathed cable likely is not posing a risk of harm to worker health, especially if nitrile gloves are worn to protect skin during application and N95 filtering facepiece respirators are recommended to be worn after application during activities that disturb the painted lead-sheathed cable.

The manufacturer did not provide evidence that the use of lead encapsulating compound prevented release of lead into the air when lead sheath is cut. Normally, a wet method (such as applying amended water) would be more effective than applying a lead encapsulating compound in reducing dust when a lead-sheathed cable needs to be cut by keeping the surface wet; however, this is not an option in this workplace as the wires inside the lead-sheathed cable are insulated with paper which must be kept dry. Other methods to control dust exposure could be an engineering control that captures particulate generated during cutting or other tasks that generate particulate, such as a high-efficiency particulate (HEPA) vacuum or local exhaust ventilation.

Document review and questionnaire data support that current trainings have been taken by most employees and training covers key topics for lead prevention including PPE to wear in different work environments, health effects of lead exposure, and how to use lead encapsulating compounds. Although the type of PPE to wear in environments with lead was described in training materials, observations during site visits made it clear that employees are often confused on what PPE is necessary when working in a manhole with lead nearby, but they are not working directly on lead cables. Further air sampling in these environments could help to discern what PPE is needed in such an environment.

Other administrative policies may be less useful in reducing lead exposure and provide an opportunity for improvement. For example, during site observations it was noted that at some garages, lead tools are required to be kept in a separate, locked room. This practice varied by garage, and it is unclear how effective this practice is to reduce employee exposure to lead. For some job tasks, employees are instructed to rotate after 4 hours of work; while reducing exposure to the individual by reducing exposure time, job rotation is not an ideal method to reduce exposure overall.

It may be more beneficial to focus on alternative administrative controls that could reduce health effects of lead exposure such as an enhanced medical surveillance program.

Enhanced Medical Surveillance

Review of BLL test results from the company's voluntary BLL testing program and a compilation of test results from the union found some employees already have known BLLs above health reference values. These test results represent a small minority of current employees as the questionnaire found that most employees have not had any BLL testing. Despite the underutilization of the voluntary program or outside BLL testing, employees are generally willing to participate in a more regular BLL testing program if the program is provided at work.

BLLs are a good indication of recent exposure to lead because the half-life of lead in blood (the time interval it takes for lead in the bloodstream to be reduced by half its initial value) is 1–2 months [Lauwerys and Hoet 2001; Moline and Landrigan 2004]. BLLs above reference values are generally due to a recent exposure to lead through inhalation or ingestion of lead particles, a health condition that causes increased bone turnover or bone breakdown which can release stored lead into the bloodstream (for example, hyperthyroidism or bone cancer), or both processes happening simultaneously [Goldman et al. 1994].

Enhancing the voluntary BLL program into a medical surveillance program that includes pre-placement, annual, and periodic post-lead work BLLs as recommended in this report can help distinguish if employee BLLs above reference values are due to exposures at work. For example, if a newly hired employee has a BLL above the reference level before participating in any work tasks, then it is likely the lead exposure is occurring outside of work and no further management investigation is necessary. For a current employee, an annual level can provide information on whether current administrative policies and procedures are protective. Importantly, continuing intermittent BLL measurements after work tasks with suspected high lead exposure can inform management if current environmental health and safety practices for that task are effective.

If the program identifies BLLs above reference values, increased access to communication about health effects will be an important part of the program. Tables D1 and D2 in Section D provide details on BLLs that correspond to specific health effects and guidance on health-based BLL recommendations for work. Additionally, CDC's Blood Lead Level Guidance offers a summary of the range of BLL reference values and related recommended actions used by various public health agencies [NIOSH 2024b].

Limitations

Our evaluation had several limitations. This evaluation had a cross-sectional design and sampling activities only assessed the timeframe and specific activities observed during the evaluation. The nature of telecommunications employees' work is variable in environment, duration, and task, with the observed work only being a subset of the work that these telecommunication workers do. Additionally, we were only able to evaluate a small number of employees within a larger worker population. For tasks within manholes, we were not able to directly observe work tasks and relied on employee self-report of work practices and controls. Therefore, the results of this evaluation may not be representative of all work scenarios experienced by this worker population.

For personal air sampling calculations, we assumed no exposure for the remainder of the shift because workers were no longer working in a manhole environment. Additional exposure to lead in air could have occurred during the remainder of the shift but is not as likely as in the manhole environment. An alternative to this approach would be to conduct air sampling until employees enter personal vehicles for workers that return to a garage or arrive at home for workers who do not return to a garage. The results for SSTs may not be generalizable to all tasks that SSTs may do because we were only able to evaluate the task of a cable transfer in a specific location.

We took hand wipes at various times after an employee ended work in a manhole, so hand wipe sample results were not comparable with each other.

Lastly, when reviewing the BLL test result lists provided by management there was not enough information to be able to discern if there were multiple tests from one individual or if the test results from the management list were the same as the BLL test results provided by the union. There is the possibility that a couple of the results from the management list were retests from the same individual, although discussions with management suggested that it was very rare that an employee was tested more than once. Additionally, since we were unable to match the union provided list to the management list, we treated them as separate data sources.

Conclusions

There is evidence that workers are exposed to lead in air when conducting work in manholes, especially if direct work on lead occurs or the work is in an environment where lead dust is present from current or past activities. Additionally, there is potential for workers to be exposed to lead through accidental ingestion of lead dust found on hands, common work surfaces, and work environments. Consistent use of occupational controls including administrative controls (including regular cleaning of surfaces, use of amended water and lead encapsulating compounds, regular training on work processes, continuation of recommended work practices to reduce lead exposure, and an enhanced medical surveillance program) and consistent and proper PPE use of can prevent or reduce exposure to lead at work and decrease the likelihood of take-home lead.

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, January 2025

Job title	Sample time (minutes)	Air concentration (µg/m^3)	8-hour TWA concentration (µg/m^3)
Splice Service Technician	282	55	32
Splice Service Technician	244	14	7.3
Splice Service Technician	201	14	5.7
Splice Service Technician	188	6.9	2.7
Outside Plant Technician	169	0.75*	0.27
Outside Plant Technician	73	ND	ND
	NIOSH Recommended Exposure Limit (REL)		50
	ACGIH Threshold Limit Value (TLV)		50
	OSHA Permissible Exposure Limit (PEL)		50
	OSHA Action Level		30

ND = not detected. This result was below the minimum detectable concentration of 0.7 micrograms per cubic meter (µg/m^3)

* This result was between the minimum detectable concentration of 0.3 µg/m^3 and the minimum quantifiable concentration of 0.9 µg/m^3, meaning there is more uncertainty.

Table C2. Post-work hand wipe sample results

Job title	When and where sample taken	Result (µg per wipe)
Splice Service Technician	After doffing of PPE at field site	83
Splice Service Technician	After routine field hand hygiene (wet wipes)	45
Splice Service Technician	After routine hand hygiene at garage	4.8
Splice Service Technician	After routine hand hygiene at garage	13
Outside Plant Technician	In truck, before returning to garage	13
Outside Plant Technician	In truck, before returning to garage	11
Outside Plant Technician	In truck, before returning to garage	6.6
Outside Plant Technician	After routine hand hygiene at garage	11
Outside Plant Technician	After routine hand hygiene at garage	1.3

µg = microgram

PPE = personal protective equipment

The limit of detection for lead was 0.2 µg per wipe. The limit of quantitation was 0.52 µg per wipe.

Table C3. Lead surface wipe results

Date collected	Location	Item	Result (µg per wipe)	Surface area sampled
9/17/2024	Garage 1	Tabletop - Meeting room	0.49	100 cm^2
9/17/2024	Garage 1	Tabletop - Meeting room	0.27	100 cm^2
9/17/2024	Garage 1	Walkie talkie for use underground	4.2	item
9/17/2024	Vehicle 1	Truck steering wheel	8	item
9/17/2024	Vehicle 1	ACT intercom system	1.3	item
9/17/2024	Vehicle 1	Overhead switches	0.8	item
9/17/2024	Vehicle 2	Truck steering wheel	0.71	item
9/17/2024	Vehicle 2	ACT intercom system	1.5	item
9/17/2024	Vehicle 2	Overhead switches	0.46	item
9/18/2024	Garage 2	Tabletop - Meeting room	ND	100 cm^2
9/18/2024	Garage 2	Truck handle, storage compartment	ND	item
9/18/2024	Garage 2	Doorknob from garage into conference room	0.55	item
9/18/2024	Garage 2	Latch of proact cage	8	item
9/18/2024	Garage 2	Tool handle, hammer used for lead work	32	Approx 100 cm^2
9/18/2024	Vehicle 3	Truck steering wheel	26	item
9/18/2024	Vehicle 3	Truck grab handle to enter	4.6	item
9/18/2024	Worksite	Bottom of ladder	30	100 cm^2
9/18/2024	Worksite	Tool handle, chipping knife	140	Approx 100 cm^2
9/19/2024	Garage 3	Handle of storage compartment	0.46	item
1/14/2025	SST Truck 1	Truck steering wheel	31	item
1/14/2025	SST Truck 1	Truck grab handle to enter	9.4	item
1/14/2025	SST Truck 2	Truck steering wheel	48	item
1/14/2025	SST Truck 2	Truck grab handle to enter	3.4	item
1/14/2025	Worksite	Hard hat	11	100 cm^2
1/14/2025	Worksite	Headlight	17	item
1/15/2025	OPT Truck 1	Truck steering wheel	8	item
1/15/2025	OPT Truck 1	Transmission panel	3	100 cm^2
1/15/2025	OPT Truck 2	Truck steering wheel	6	item
1/15/2025	OPT Truck 2	Transmission panel	1	100 cm^2

µg = microgram

cm^2 = square centimeter

ND = not detected

Item = the entire item was wiped for the surface wipe sample

Approx 100 cm^2 = an area of approximately 100 cm^2 was wiped for the surface wipe sample.

The limit of detection for lead was 0.2 µg per wipe. The limit of quantitation was 0.52 µg per wipe.

Table C4. Demographic and work characteristics of questionnaire respondents by job title (n = 70)*

	Job title	
	Splice Service Technician (n = 40)	Outside Plant Technician (n = 30)
Median age (range)†	54 (48–63)	46 (21–62)
Median years worked on the job (range)‡	28 (1–37)	24 (1–33)
Department, n (%)		
Installation & Maintenance (I&M)	16 (40)	0 (0)
Construction	22 (55)	29 (97)
Pro-Active Maintenance (ProAct)	0 (0)	0 (0)
Multiple (ProAct & Construction)	2 (5)	0 (0)
Other§	0 (0)	1 (3)

* 1 employee did not provide their job title.

† 9 Splice Service Technicians and 8 Outside Plant Technicians did not report age.

‡ 5 Splice Service Technicians and 7 Outside Plant Technicians did not report the year they started work.

§ 1 Outside Plant Technician indicated department as other.

Table C5. Employee-reported post-work practices after completing a work shift (n = 71)

	Reported work type	
	Worked directly on lead cable, lead sheath or lead project (n = 62)*	Worked in manhole where lead was visible in the environment, but did not work directly on lead (n = 67)†
Employee behaviors at the end of shift	No. (%)	No. (%)
Went home in the same clothes they wore to work	41 (66)	49 (73)
Washed their hands at the garage prior to going home	40 (65)	43 (64)
Went home in the same shoes that they wore to work	33 (53)	41 (61)
Showered at home immediately after work	26 (42)	25 (37)
Removed work shoes prior to entering their home	22 (35)	20 (30)
Changed out of work shoes at the garage prior to going home	6 (10)	6 (9)
Changed out of work clothes into new clothes at the garage prior to going home	3 (5)	2 (3)
Showered at the garage prior to going home	0 (0)	0 (0)
Other	4 (6)	3 (4)

* 9 employees indicated they never work on lead and were excluded.

† 4 employees indicated they never work in an environment near lead.

Table C6. Employee blood lead level (BLL) tests by data source

Union (January 1, 2020 – March 20, 2024)*				
Year	Number of BLL tests	Number of BLL tests > 3.5 µg/dL (%)	Number of BLL tests ≥ 5 µg/dL (%)	Median BLL µg/dL (range)
2023	23	6 (26)	5 (22)	1.8 (0–33)
2024	17	3 (18)	2 (12)	1.8 (0–35)
Unknown	2	0 (0)	0 (0)	2.5 (2–3)
Total	42	9 (21)	7 (17)	1.8 (0–35)
Management (January 1, 2022 – May 16, 2024)†				
2022	8	1 (13)	1 (13)	0 (0–7)
2023	79	10 (13)	8 (10)	1 (0–33)
2024	33	3 (9)	2 (6)	1.3 (0–30)
Total	120	14 (12)	11 (9)	1 (0–33)

* Although the union requested test results from January 1, 2020 – March 20, 2024, the results provided by management only included tests from the years of 2023 and 2024. It is not known if the discrepancy is because there were no tests conducted in 2020, 2021 or 2022 or if the results were just not available at the time of the union request.

† 14 test results were reported as < 0, < 1.0, < 1 or < 3 µg/dL. These results were converted to 0 to calculate the median. This methodology introduces a possible underestimation of the median values for results provided by management.

Section D: Occupational Exposure Limits

NIOSH investigators refer to mandatory (legally enforceable) and recommended occupational exposure limits (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 Permissible Exposure Limits (PELs). These legal limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH Recommended Exposure Limits (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 the American Conference of Governmental Industrial Hygienists (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 2025].

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 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 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 50 $\mu g/m^3$ of air for an 8-hour TWA, with an AL of 30 $\mu g/m^3$ (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 $\mu g/m^3$ (0.0021 mg/m^3 as an 8-hour TWA) [Billingsley 2013]. In February 2024, the California Occupational Safety and Health Standards Board adopted a more protective lead standard enacted on January 1, 2025. This standard decreases the airborne 8-hour PEL to 10 $\mu g/m^3$ (0.01 mg/m^3), the 8-hour AL to 2 $\mu g/m^3$ (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 (µg/ft^2) [HUD 2017]. The U.S. Environmental Protection Agency (EPA) also updated their dust-lead hazard standards (DLHS) in 2021 to 10 µg/ft^2 for floors. In 2024, EPA replaced DLHS with dust-lead reportable level (DLRL), reducing the level of lead in dust that is considered hazardous from previous DLHS to any reportable level as analyzed by a laboratory recognized by EPA's National Lead Laboratory Accreditation Program [EPA 2024b]. This was done to recognize that there is no level of lead in blood that has been found to be safe for children.

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 [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 (ZPP) level, so monitoring the BLL over time is more specific than ZPP levels for evaluating chronic occupational lead exposure.

The OSHA lead standard mandates medical removal for an employee with a single BLL of ≥ 60 µg/dL, or three BLLs averaging ≥ 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 2025]. The American College of Occupational and Environmental Medicine (ACOEM) recommends that workers BLLs should be maintained <10 µg/dL [Kosnett et al. 2023]. CDC recommends removal of pregnant women from lead-exposed work areas when BLLs are ≥ 10 µg/dL [CDC 2010]. In 2013, the California Department of Public Health (CDPH) recommended that California OSHA keep BLLs below the range of 5–10 µg/dL [Billingsley 2013; CDPH 2021]. The Council of State and Territorial Epidemiologists (CSTE) recommended lowering the blood lead level reference value for adults to 3.5 µg/dL from 5 µg/dL in 2022 [CSTE 2022]. In 2015, NIOSH designated 5 µg/dL of whole blood, in a venous blood sample, as the reference BLL for adults with any level greater than or equal to 5 µg/dL considered above the reference value [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 because 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 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 exposure to lead can result in exposure 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 exposures 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.

Section E: References

Cleaning and Other Topics

Filon FL, Boeniger M, Maina G, Adami G Spinelli P, Damian A [2006]. Skin absorption of inorganic lead (PbO) and the effect of skin cleansers. J Occup Envion Med *48*(7):692–699, https://journals.lww.com/joem/abstract/2006/07000/skin_absorption_of_inorganic_lead__pbo__and_the.12.aspx.

HUD [2012]. Guidelines for the evaluation and control of lead-based paint hazards in housing. Washington, DC: U.S. Housing and Urban Development, https://www.hud.gov/sites/documents/second_edition_2012.pdf.

HUD [2017]. Revised dust-lead action levels for risk assessment and clearance; clearance of porch floors. Washington, DC: U.S. Housing and Urban Development, https://www.hud.gov/sites/documents/leaddustclearance.pdf.

NIOSH [2023]. Leave lead at work. By Couch J, Rinsky J, Grimes R, Carlson K, Reynolds L, Burnett G, Tsai R. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2024-101 (revised 10/23), https://doi.org/10.26616/NIOSHPUB2024101revised102023.

NIOSH [2024]. Protect your family and household from work-related lead. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, https://www.cdc.gov/niosh/lead/prevention/household-lead.html.

Health Effects of Lead

ATSDR [2020]. Toxicological profile for lead. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Agency for Toxic Substances and Disease Registry, https://www.atsdr.cdc.gov/ToxProfiles/tp13.pdf.

Goldman RH, White R, Kales SN, Hu H [1994]. Lead poisoning from mobilization of bone stores during thyrotoxicosis. Am J Ind Med *25*(3):417–424, https://doi.org/10.1002/ajim.4700250309.

IARC [2006]. IARC monographs on the evaluation of carcinogenic risks to humans. Inorganic and organic lead compounds. Summary of data reported and evaluation. Vol. 87. Lyon, France: World Health Organization, International Agency for Research on Cancer, http://monographs.iarc.fr/ENG/Monographs/vol87/.

Institute of Medicine [2013]. Potential health risks to DOD firing-range personnel from recurrent lead exposure. Washington, DC: National Academies Press, https://www.ncbi.nlm.nih.gov/books/NBK206966/pdf/Bookshelf_NBK206966.pdf.

Moline JM, Landrigan PJ [2004]. Lead. In: Rosenstock L, Cullen MR, Brodkin CA, Redlich CA, eds. Textbook of clinical occupational and environmental medicine. 2nd ed. Philadelphia, PA: Elsevier Saunders.

NTP [2012]. NTP Monograph: health effects of low-level lead. Research Triangle Park, NC: U.S. Department of Health and Human Services, National Institutes of Health, National Institute of Environmental Health Sciences, National Toxicology Program, https://ntp.niehs.nih.gov/ntp/ohat/lead/final/monographhealtheffectslowlevellead_newissn_508.pdf.

NTP [2021]. Lead and lead compounds. In: Report on carcinogens. 15th ed. Research Triangle Park, NC: U.S. Department of Health and Human Services, National Institutes of Health, National Institute of Environmental Health Sciences, National Toxicology Program, https://ntp.niehs.nih.gov/ntp/roc/content/profiles/lead.pdf.

Schwartz BS, Stewart WF [2007]. Lead and cognitive function in adults: a question and answers approach to a review of the evidence for cause, treatment, and prevention. Int Rev Psychiatry *19*(6):671–692, https://doi.org/10.1080/09540260701797936.

Lead Exposure

Brown-Williams H, Lichterman J, Kosnett M [2009]. Indecent exposure: lead puts workers and families at risk. Health Research for Action (University of California, Berkeley). Perspectives *4*(1):1–9, https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjGgIXfkb6KAxUzQjABHatED7QQFnoECBQQAQ&url=https%3A%2F%2Fwww.migrantclinician.org%2Ffile%2F240648%2Fdownload&usg=AOvVaw0iPTJNjztUbvtW8XXm7RCC&opi=89978449.

CDC [2009]. Childhood lead poisoning associated with lead dust contamination of family vehicles and child safety seats—Maine, 2008. MMWR *58*(32):890–893, https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5832a2.htm.

CDC [2013]. Blood lead levels in children aged 1–5 years—United States, 1999–2010. MMWR *62*(13):245–248, https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6213a3.htm.

CRS [2023]. Legacy lead-sheathed telecommunications cables: status and issues for Congress. Washington, DC: Congressional Research Service (CRS) In Focus IF12559, https://www.congress.gov/crs-product/IF12559.

EPA [2023a]. California and Coal Center lead. Philadelphia, PA: Environmental Protection Agency, https://response.epa.gov/CalandCoal.

EPA [2023b]. West Orange lead sampling. New York, NY: Environmental Protection Agency, https://response.epa.gov/leadcablesNJ.

EPA [2024a]. Updated soil lead guidance for CERCLA sites and RCRA corrective action facilities. Washington, DC: Environmental Protection Agency, https://www.epa.gov/superfund/updated-soil-lead-guidance-cercla-sites-and-rcra-corrective-action-facilities.

EPA [2024b]. Health standards and clearance levels for lead in paint, dust, and soil (TSCA sections 402 and 403). Washington, DC: Environmental Protection Agency, https://www.epa.gov/lead/hazard-standards-and-clearance-levels-lead-paint-dust-and-soil-tsca-sections-402-and-403.

NIOSH [1995]. Report to Congress on the workers' home contamination study conducted under the Workers' Family Protection Act (29 U.S.C. 671a). Cincinnati, OH: U.S. Department of Health and

Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 95-123, https://www.cdc.gov/niosh/docs/95-123/.

NIOSH [2019]. Exposure to lead during residential water line replacement activities. By Methner MM, de Perio MA. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2019-0192-3377, https://www.cdc.gov/niosh/hhe/reports/pdfs/2019-0192-3377.pdf.

NIOSH [2023]. Exposure to lead during bullet recycling. By Somerville N, Beaucham C. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2023-0030-3407, https://www.cdc.gov/niosh/hhe/reports/pdfs/2023-0030-3407.pdf.

Schwartz BS, Hu H [2006]. Adult lead exposure: time for change. Environ Health Perspect *115*(3):451–454, https://doi.org/10.1289/ehp.9782.

Stauber JL, Florence TM, Gulson B, Dale LS [1994]. Percutaneous absorption of inorganic lead compounds. Sci Total Environ *145*(1–2):55–70, https://doi.org/10.1016/0048-9697(94)90297-6.

Sun CC, Wong TT, Hwang YH, Chao KY, Jee SH, Wang JD [2002]. Percutaneous absorption of inorganic lead compounds. Am Ind Hyg Assoc J *63*(5):641–646, https://doi.org/10.1080/15428110208984751.

Virji MA, Woskie SR, Pepper LD [2009a]. Skin and surface lead contamination, hygiene programs, and work practices of bridge surface preparation and painting contractors. J Occup Environ Hyg *6*(2):131–142, https://doi.org/10.1080/15459620802656636.

Virji MA, Woskie SR, Pepper LD [2009b]. Task-based lead exposures and work site characteristics of bridge surface preparation and painting contractors. J Occup Environ Hyg *6*(2):99–112, https://doi.org/10.1080/15459620802615772.

Medical Guidelines and Blood Lead Monitoring

CDC [2021]. Guidelines for the identification and management of lead exposure in pregnant and lactating women. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, https://stacks.cdc.gov/view/cdc/147837.

CDPH [2009]. Medical guidelines for the lead-exposed worker. Sacramento, CA: California Department of Public Health, Occupational Lead Poisoning Prevention Program, https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/OHB/OLPPP/CDPH%20Document%20Library/medgdln.pdf#search=Medical%20guidelines%20for%20the%20lead%2Dexposed%20worker.

CDPH [2021]. Health-based guidelines for blood lead levels in adults. Sacramento, CA: California Department of Public Health, Occupational Lead Poisoning Prevention Program, https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/OHB/OLPPP/CDPH%20Document%20Library/BLL_Adult_Mgmt_Guidelines_Revised_Jan_10_2022.pdf#search=Health%2Dbased%20guidelines%20for%20blood%20lead%20levels%20in%20adults.

CDPH [2024]. March 2024 occupational health watch. California occupational safety and health standards board approves the nation's strongest occupational lead standards. Sacramento, CA: California Department of Public Health, Occupational Health Branch, https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/OHB/Pages/March2024.aspx.

CSTE [2021]. Management guidelines for blood levels in adults. Atlanta, GA: Council of State and Territorial Epidemiologists, https://cdn.ymaws.com/www.cste.org/resource/resmgr/occupationalhealth/publications/ManagementGuidelinesforAdult.pdf.

CSTE [2022]. Public health reporting and national notification of lead in blood. Atlanta, GA: Council of State and Territorial Epidemiologists, https://cdn.ymaws.com/www.cste.org/resource/resmgr/ps/ps2022/22-EH-01_Lead_in_Blood.pdf.

Holland MG, Cawthon D [2016]. ACOEM position statement: workplace lead exposure. J Occup Environ Med *58*(12):e371–e374, https://doi.org/10.1097/jom.0000000000000928.

Kosnett MJ, Berenji M, Burton A, Durand-Moreau Q, Esty E, Fischman M, Hudson TW, Nabeel I, Papanek PJ, Sokas R [2023]. ACOEM position statement: workplace health and safety necessitates an update to occupational lead standard provisions for medical removal protection, medical surveillance triggers, and the action level and permissible exposure level for lead in workplace air: ACOEM response to OSHA. J Occup Environ Med *65*(3):e170–e176, https://doi.org/10.1097/JOM.0000000000002774.

Kosnett MJ, Wedeen RP, Rothenberg SJ, Hipkins KL, Materna BL, Schwartz BS, Hu H, Woolf A [2007]. Recommendations for medical management of adult blood lead exposure. Environ Health Perspect *115*(3):463–471, https://doi.org/10.1289/ehp.9784.

Lauwerys RR, Hoet P [2001]. Industrial chemical exposure: guidelines for biological monitoring. 3rd ed. Boca Raton, FL: CRC Press, https://doi.org/10.1201/9781482293838.

NIOSH [2024a]. Elevated blood lead levels charts. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, https://wwwn.cdc.gov/NIOSH-WHC/chart/ables-ab/exposure?T=ZS&OU=L03&V=C&D=SINGLE&Y=2023&chk_codes=False.

NIOSH [2024b]. Blood lead level guidance. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, https://www.cdc.gov/niosh/lead/bll-reference/index.html.

Methods

EPA [2020]. Selected analytical methods for environmental remediation and recovery (SAM) 2017. Capisano R, Hall K, Griggs J, Willison S, Reimer S, Mash H, Magnuson M, Boczek L, Rhodes E, eds. Washington, DC: U.S. Environmental Protection Agency, EPA Publication No. 600R17356, https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=339252&Lab=NHSRC.

NIOSH [2025]. NIOSH manual of analytical methods (NMAM). 5th ed. O'Connor PF, Ashley K, eds. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2014-151, http://www.cdc.gov/niosh/nmam.

OSHA [2025]. OSHA sampling and analytical methods. Salt Lake City, UT: U.S. Department of Labor, Occupational Safety and Health Administration, http://www.osha.gov/dts/sltc/methods/index.html.

Occupational Exposure Limits and Regulation

ACGIH [2001]. Documentation of the threshold limit values and biological exposure indices. Includes 2002–2019 supplements. 7th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists, ISBN: 978-1-882417-43-8.

ACGIH [2025]. TLVs and BEIs: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists, https://www.acgih.org/tlv-bei-guidelines/policies-procedures-presentations/.

Billingsley KJ [2013]. Letter from K.J. Billingsley, California Department of Public Health, to Juliann Sum, Division of Occupational Safety and Health (Cal/OSHA), California Department of Industrial Relations, September 30.

CalOSHA [2024]. §1532.1. Lead. California code of regulations, construction safety orders, https://www.dir.ca.gov/title8/1532_1.html.

CFR [2025]. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register, https://www.ecfr.gov/.

MIOSHA [2021]. General industry standard: part 310, lead in general industry. Michigan Department of Labor and Economic Opportunity. Lansing, MI: Michigan Occupational Safety and Health Administration, MIOSHA-STD-1207, https://www.michigan.gov/leo/-/media/Project/Websites/leo/Documents/MIOSHA/Standards/General_Industry/GI_310/GI_310___04-13-2021.pdf?rev=71b5f6a30756480798cb63a6d83abf68&hash=0D69C4B2F8F66C496C0FB714417B465C.

NIOSH [2007]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-149, http://www.cdc.gov/niosh/npg/.

OSHA [1978]. 29 CFR 1910.1025. Lead. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration, https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1025.

OSHA [2007]. Interpretation of coverage for the telecommunications industry with regard to the new Permit-Required Confined Spaces standard. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration, https://www.osha.gov/laws-regs/standardinterpretations/1993-05-19.

Public Health Reporting and Surveillance

CSTE [2009]. Public health reporting and national notification for elevated blood lead levels. CSTE position statement 09-OH-02. Atlanta, GA: Council of State and Territorial Epidemiologists, https://cdn.ymaws.com/www.cste.org/resource/resmgr/PS/09-OH-02.pdf.

CSTE [2015]. Public health reporting and national notification for elevated blood lead levels. CSTE position state 15-EH-01. Atlanta, GA: Council of State and Territorial Epidemiologists, https://cdn.ymaws.com/www.cste.org/resource/resmgr/PS1/15-EH-01_revised_12.4.15.pdf.

Promoting productive workplaces through safety and health research

HHE Report No. 2024-0046-3413