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Evaluation Program

Evaluation of Fire Debris Cleanup Employees' Exposure to Silica, Asbestos, Metals, and Polyaromatic Hydrocarbons

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Authors: Catherine Beaucham, MPH, CIH, RS/REHS

Judith Eisenberg, MD, MS

Analytical Support: Bureau Veritas North America, Inc.

Desktop Publisher: Jennifer Tyrawski

Editor: Cheryl Hamilton

Industrial Hygiene Field Assistance: Donnie Booher, Pita Gomez, Adrienne Eastlake

Logistics: Kevin Moore

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Introduction

Request

In March 2018, an employer representative with a government agency for the state of California requested a health hazard evaluation concerning exposures to asbestos, heavy metals, respirable crystalline silica (respirable particles are 10 micrometers or less in diameter), and polyaromatic hydrocarbons during cleanup of structural debris and burn ash after wildfires spread into areas where homes and business were located. Union representatives from the Operating Engineers Local 3 and the Construction and General Laborer's Local 185 also submitted requests. Management representatives from three of the most frequently contracted construction companies for fire debris cleanup also submitted health hazard evaluation requests. Because all of these evaluation requests concerned employees' exposures during fire debris cleanup, they were consolidated into one overall health hazard evaluation response. This response was conducted at worksites managed by the company (one of the three mentioned above) that won the contract for the Carr Fire cleanup.

Background

The Carr Fire was the sixth most destructive wildfire in California history. The fire burned in Shasta and Trinity counties in Northern California over approximately 2 months (July and August) in 2018. The Carr Fire burned 229,651 acres and destroyed 1,079 residences, 22 commercial buildings, and 503 outbuildings before it was fully contained. When structures are destroyed, hazardous materials may be left behind and must be cleaned up to limit the impact to the public and the surrounding environment.

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

Our Approach

In August 2018, we met with employee and employer representatives to get a better understanding of the processes and the challenges associated with fire debris cleanup work. We also reviewed environmental sampling records from previous exposure assessments during wildfire debris cleanup work. In September 2018, we returned to California for a site visit during fire debris cleanup. During the site visit, we did the following:

- Observed work practices.
- Measured employees' exposures to respirable crystalline silica, asbestos, metals, and polyaromatic hydrocarbons in air.
- Measured metals and polyaromatic hydrocarbons on skin.
- Interviewed employees about their work and their health.

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

Our Key Findings

Some employees were overexposed to respirable crystalline silica

- Skid steer operators had the highest average exposure to silica (quartz) and two operators had exposure levels over occupational exposure limits.
- Laborers and excavator operators were not overexposed to respirable crystalline silica.
- We observed several instances where employees working inside the lot footprint did not use dust suppression with water (Figure 1).

Figure 1. Two employees working inside the lot footprint with no dust suppression, surrounded by dust that may contain silica. Photo by NIOSH.

Employees were not overexposed to asbestos, metals, or polyaromatic hydrocarbons in air

- Asbestos was not detected in any of the air samples.
- All metals were at least 10 times lower than their lowest applicable exposure limit.
- Naphthalene was detected at levels well below occupational exposure limits in all of the air samples. The average concentration was 0.6 micrograms per cubic meter (range: 0.17 to 2.8 micrograms per cubic meter).

Employees had metals and polyaromatic hydrocarbons on their skin

- We sampled 15 employees' hands at lunch and all had metals including lead on them.
- We detected phenanthrene in one preshift neck wipe sample and four postshift neck wipe samples.
- We detected fluoranthene in one preshift and one postshift handwipe sample.

Some employees did not wear personal protective equipment correctly

- We observed some employees not wearing respirators at all and others not wearing them correctly. Examples of incorrect wear included: wearing them over the chin instead of covering the nose and mouth, and wearing respirators when not clean-shaven.
- We observed inconsistent use and enforcement of personal protective equipment use across task forces.
- We observed that the types of personal protective equipment available and the decontamination procedures used appeared to vary across task forces.

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.

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

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

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/shpguidelines/index.html.

Recommendation 1: Reduce employee exposures to respirable crystalline silica and educate employees on silica and silicosis.

Why? Occupational exposure to respirable crystalline silica has been associated with silicosis, lung cancer, pulmonary tuberculosis disease, and other airway diseases. The Occupational Safety and Health Administration (OSHA) permissible exposure limit and National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit for respirable crystalline silica exposure is 50 micrograms per cubic meter, with OSHA also defining a 25 micrograms per cubic meter action level. The American Conference of Governmental Industrial Hygienists threshold limit value for quartz is 25 micrograms per cubic meter. We found two exposures above the American Conference of Governmental Industrial Hygienists threshold limit value and OSHA action level. One of these exposures was also above the OSHA permissible exposure limit and NIOSH recommended exposure limit.

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

Ensure that water spray is consistently used to reduce dust.

Improve silica hazard education.

- OSHA requires employers to ensure that each employee with potential silica exposure above the OSHA action level can do the following:
    - Demonstrate knowledge and understanding of the health hazards associated with exposure to silica.
    - Identify specific tasks in the workplace that could result in exposure to silica.
    - Identify specific measures the employer has implemented to protect employees from exposure to silica.
    - Understand the purpose of the medical surveillance program.
- The OSHA hazard communication standard also requires training for silica regardless of airborne exposure level.
- Training may include existing silica-related NIOSH documents:
    - *Silicosis-Working with Cement Roofing Tiles: A Silica Hazard*
        - Designed for roofers and exposures from dry cutting cement tiles, the document may be useful for general construction because it directly addresses silica exposure as a result of mechanically breaking cement materials, which often occurs during fire debris cleanup.

        - Available in English and Spanish: (https://www.cdc.gov/niosh/docs/2006-110/) (https://www.cdc.gov/spanish/niosh/docs/2006-110_sp/).
    - *Silicosis: Learn the Facts!*
        - Designed for the construction and abrasive blasting industries, the document describes silica exposures, the effects of silicosis, and methods to protect against silicosis.
        - Available in English and Spanish: (https://www.cdc.gov/niosh/docs/2004-108/default.html) (https://www.cdc.gov/spanish/niosh/docs/2004-108_sp/).

Develop a medical surveillance program for workers exposed to silica—see Section D for more information.

- Construction companies whose employees are likely to be exposed to respirable crystalline silica above the OSHA action level for ≥ 30 days per year must have a medical surveillance program.
- Medical surveillance for silica-exposed workers should include the following:
    - Preplacement, annual, and exit medical examinations focused on the respiratory system.
    - Medical history including an extensive work history, history of preexisting respiratory conditions (like asthma), and a smoking history.
    - Spirometry prior to first fire debris cleanup and annually as long as engaging in work with potential exposures to respirable crystalline silica and/or asbestos.
- Employees should be encouraged to inform their primary care provider of their workplace exposure to silica.
    - Provide employees with copies of any air sampling results documenting silica exposure and medical surveillance results obtained through the medical surveillance program.
    - Incorporate documentation of respirable crystalline silica exposure into employees' medical records to ensure that this information is available for their healthcare provider to allow for the most complete medical care.

Recommendation 2: Reduce the amount of lead and other metals on the employees' hands and work clothes.

Why? Exposure to lead and other metals on hands can lead to ingestion of those contaminants by transfer from the hands to the mouth when proper handwashing is not practiced. Although no occupational exposure limits exist for the permissible amount of lead on the skin, OSHA requires work areas such as eating areas or break area to be as free as practicable from lead contamination. In addition, occupational lead exposure can result in exposures of household members, including children, from take-home contamination. We found lead and other metals on the hands of fire debris cleanup employees at lunch and before they went home for the day.

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

Add handwashing facilities and lead-removal handwipes at the decontamination tent.

Require employees to wash their hands after leaving the lot footprint, and before eating, drinking, or smoking.

Require employees to change shoes prior to going home to avoid tracking dust containing lead and other heavy metals at home.

Recommendation 3: Require consistent use and enforcement of personal protective equipment and decontamination procedures among all contractors and subcontractors.

Why? Lack of or improper personal protective equipment use when necessary exposes employees to hazards. We observed inconsistent use and enforcement of personal protective equipment use across task forces. We also observed that the types of personal protective equipment available and the decontamination procedures varied across task forces. In addition, we found that some employees used latex gloves, which can cause allergic sensitization.

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

Enforce consistent personal protective equipment use across all task forces and by all task force leads.

- Improve communication and consistency of personal protective equipment selection and use among all contractors, subcontractors, and task forces.
    - Standard operating procedures, job hazard analyses, and required personal protective equipment should be documented, disseminated, explained, and reinforced equally for all subcontractors and task forces.
- Provide periodic refresher training on the specific hazards and personal protective equipment that employees must use during fire debris cleanup work.
- Collaborate with the unions, contractors, and subcontractors to develop standardized training materials for fire debris cleanup workers.
- Take immediate corrective action when improper use of personal protective equipment is noted on the job site.

Provide only nitrile gloves to employees.

- Use only nitrile gloves when tight-fitting chemical resistant gloves are required. Do not use latex gloves.
- Remove latex gloves from the decontamination tent area due to potential for latex sensitization.

Ensure methods used to decontaminate footwear on exiting the lot footprint are adequate and followed.

- We observed that the boot covers that laborers used disintegrated during the shift. Therefore, laborers should not wear boot covers and instead should use a boot wash on exiting the footprint.

Ensure all task forces comply with the respiratory protection standard.

- Ensure that all employees are fit-tested, trained, and medically cleared to wear a respirator.
- Emphasize the proper use, training, cleaning, maintenance, and storage of respirators.
    - Include the requirement to be clean-shaven, when to wear the respirator, filter change-out schedule, and how to properly store and clean the respirator.

Recommendation 4: Measure employees' full-shift noise exposures to determine if exposures are above the NIOSH recommended exposure limit.

Why? Although we did not include noise dosimetry or audiometry during our assessment, noise from construction equipment could expose operators and laborers to noise levels above NIOSH's recommended exposure limit of 85 decibels as an 8-hour time weighted average. We observed that not all employees wore hearing protection when in the lot footprint.

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

Ensure all employees who are exposed to hazardous levels of noise are properly protected.

- Include any overexposed employees in a hearing conservation program.
    - The program should include initial and annual audiometric exams, providing hearing protection, training on hearing loss and use of hearing protection, and include periodic noise exposure assessments.
- For additional information on noise and guidance on developing a hearing loss prevention program, refer to the NIOSH document Occupational Noise Exposures at https://www.cdc.gov/niosh/docs/98-126/default.html.

Supporting Technical Information

Evaluation of Fire Debris Cleanup Employees' Exposure to Silica, Asbestos, Metals, and Polyaromatic Hydrocarbons

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Section A: Workplace Information

Background Information

The national trend in wildfires since 1998 shows that, although the total number of fires is decreasing, each fire is burning more land. In 2017 alone, over 10 million acres of land were ravaged by wildfires, and the 2018 fire season in California reached historic levels [NIFC 2017, 2018]. When wildland fires extend into residential areas, after the fire has been extinguished, construction crews must be brought in to clean up the debris that has been left behind. Remnants of burned residential structures may contain respirable crystalline silica (RCS) (typically quartz) from demolished concrete used in foundations, walls, and roofing tiles or naturally occurring in the rocks and soil. Cristobalite (another form of RCS) is typically found in igneous rocks, which are formed as a result of previous volcanic activity. Depending on the age of the building, asbestos can also be present. Home electronics and melted vehicles can leave behind various metals such as lead, cadmium, and aluminum. Additionally, potentially carcinogenic substances found in soot (burn ash) called polyaromatic hydrocarbons (PAHs), also known as polycyclic aromatic hydrocarbons, may also be exposure hazards.

After a wildfire has been contained and the burned area declared safe to enter, the state agency responsible for overseeing and managing contractors and consultants involved in wildfire debris cleanup and removal begins a stepwise process to initiate cleanup and eventual reoccupation of the area. The agency starts this process with an initial site hazard assessment that includes identifying sites that potentially contain asbestos and a visual inspection for presence of explosive hazards such as propane cylinders, etc. The initial hazard assessment can be contracted to another company depending on the number and type (i.e., residential or industrial) of damaged lots. Afterward, the agency creates a contract for the fire debris cleanup. The contract specifies how the contractor must address the identified on-site hazards (i.e., asbestos abatement, propane cylinder removal), what environmental sampling should be done during the cleanup, and how removed debris will be transferred to the final disposal sites. Due to environmental regulations, only specific sites are certified by the state as acceptable for receiving wildfire debris. The agency then collects bids from construction companies and selects a primary contractor.

Depending on the size of area to be cleaned and the available resources of the primary contractor, other construction companies may be subcontracted to ensure completion of the cleanup by the date specified in the contract. In this evaluation, we refer to the primary contractor as Company A. The agency also contracted an engineering services company (Company B) that subsequently subcontracted a portion of their tasks to two additional companies (which we refer to collectively as Company C). Company A also selected three subcontractors to carry out the debris removal (Companies D, E, and F).

After the home owner indicates that they wish to have the fire debris removed by the state by signing a right of entry form, debris removal is done in phases. The first phase, completed by the California Department of Toxic Substances Control (or other dedicated agency), is household hazardous waste removal. In the second phase, the California Department of Resources Recycling and Recovery assesses and documents the site. This phase includes evaluating soil samples to establish cleanup goals for the project and removing asbestos-containing material. The third phase is debris removal, done by the subcontractor. After the lot has been certified by the state that it has been cleared of hazards and that all debris has been removed in accordance with state regulations, the lot occupants can return to rebuild. An additional state requirement is to collect personal and environmental samples during debris cleanup to ensure that potential exposures are controlled. See Section E for additional information on the hazardous exposures from fire debris cleanup activities and how the state of California approaches fire debris cleanup activities.

The task force leader, who supervised on-site operations, kept track of departing loads. Typically, task force leads were not represented by a union and were employed by Company B or C. The construction employees (from Companies D, E, and F) in this evaluation were represented by two separate unions, the Operating Engineers Local 3 and the Construction and General Laborer's Unions. The Operating Engineers union represented employees who operated the heavy equipment, such as front-end loaders and backhoes. Heavy equipment was needed to move large pieces of remaining structures (i.e., lift out chimney stacks, pull down partially standing walls, break up concrete foundations, remove fallen trees, etc.) and potentially contaminated dirt. These vehicles were also used to load debris into the removal trucks that would take the debris to a predetermined site for disposal.

After removal of all the debris, heavy equipment was used to level the lot. The Laborers' Union represented those employees who manually removed debris, handled the water sprays for dust suppression inside the lot footprint during debris removal, identified hazards in the lot, covered trucks that were loaded with debris with a tarp before it departed for the debris disposal site, and removed items such as metal screws and nails from the lot upon completion of the debris cleanup. Some laborers also operated skid steers. The Laborers' union in California is divided into regions, and each region has several local chapters. Due to the extensive areas impacted by the Carr Fire, the laborers in this evaluation were represented by six different local chapters (local Chapters 185, 203, 261, 294, 324, and 1130) from many regions in California and several other states.

A typical lot footprint for fire debris cleanup is depicted in Figure 2. The footprint usually consisted of a residence, such as a house and any outlying structures like pools, sheds, or guest houses. The lot footprint size range depended on the size of the house and the location of the outlying structures. The perimeter of the lot footprint was set to encompass all burned structures within the footprint and was demarcated by using caution tape. The driveway was typically used to park, load, and tarp trucks that carried fire debris to be disposed.

All employees were required to wear personal protective equipment (PPE), including respirators, Tyvek® suits, boots or boot covers, hearing protection (sometimes), and gloves (work gloves and/or nitrile) when they entered the lot footprint. All required PPE were to be donned before passing though the decontamination area at the front of the lot. All employees were also required to leave the lot footprint through the decontamination area. Also located in the decontamination area was a decontamination table. They first removed their boot covers (if they had them on) or walked through a boot wash. Afterwards, they remove their Tyvek suits and disposed of them in the trashcan. Next, employees removed their respirators, and then removed their tight-fitting chemical resistant gloves last. The task force lead and/or an environmental sampling technician typically remained at the table in the decontamination tent.

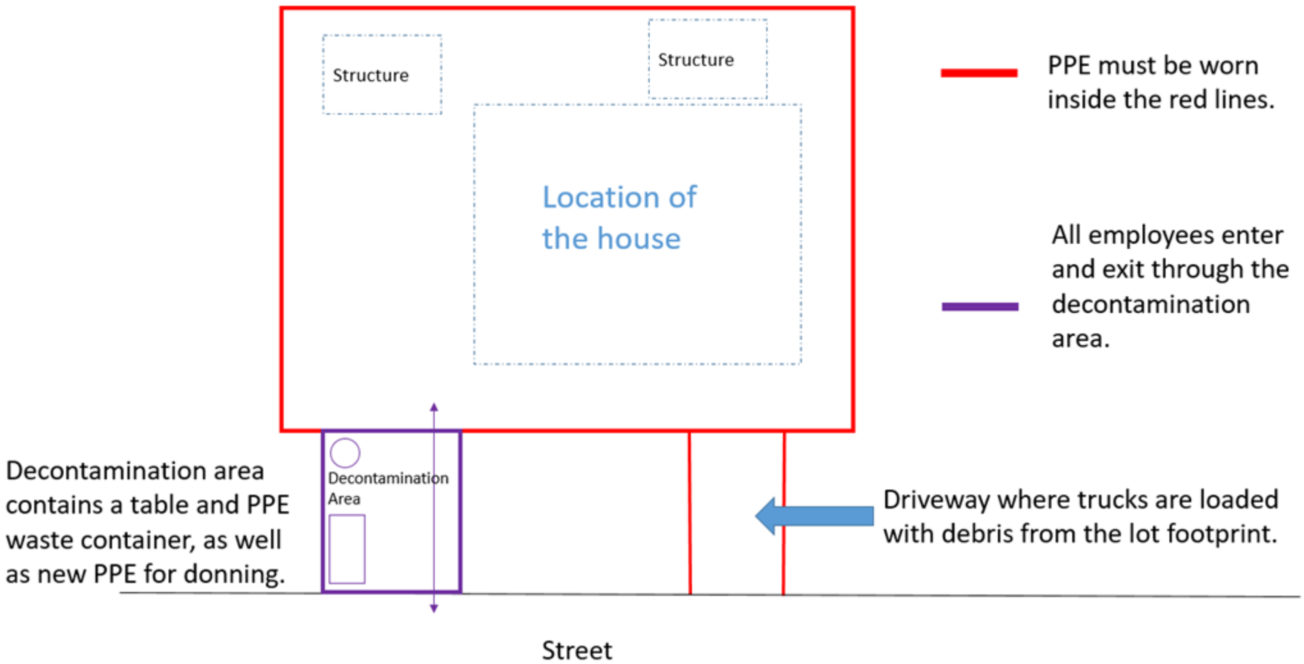

Figure 2. Typical lot footprint for fire debris cleanup activities.

Section B: Methods, Results, and Discussion

Our objective was to evaluate fire debris cleanup employees' exposure to RCS and asbestos in air, and metals and PAH in air and on the skin. During the Carr Fire cleanup, 35 different "task forces," each typically consisting of one task force lead, one equipment operator, and two laborers, were located on damaged lots throughout Shasta County. On Days 1, 2, and 3 of our evaluation we evaluated four or five task forces for RCS and PAH. On Days 4 and 5 of our evaluation we evaluated three or four task forces for metals and asbestos. We selected the lots that met the following criteria: (1) for RCS and PAH sampling, we specified lots that were on Days 1, 2, and 3 of their cleanup operations and (2) for the asbestos samples, we specified lots that had previously been identified as needing an asbestos abatement. NIOSH invited all of the employees who were participating in exposure monitoring to also complete a confidential medical interview. We also interviewed task force leads and other personnel who were conducting environmental monitoring if they were working around the lot footprint.

Methods: Respirable Crystalline Silica

Silica can occur in one of three crystalline forms: quartz, cristobalite, and tridymite. We sampled for all 3 crystalline forms. We collected samples for RCS using NIOSH Manual of Analytical Method 7500 [NIOSH 2019]. We collected 42 personal silica air samples for 17 different employees over 3 days. We also collected area air samples for RCS at three of the decontamination tables.

Results: Respirable Crystalline Silica

We detected RCS in 33 (73%) of 45 samples. Results for the RCS quartz samples are displayed in Table C1. The mean air concentration for all personal RCS quartz air samples was 13.2 micrograms per cubic meter ($\mu g/m^3$) and ranged from 2.4–76 $\mu g/m^3$. Of the seven skid steer operators sampled, two had air RCS concentrations above the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) and OSHA action level (AL) of 25 $\mu g/m^3$. One of these two was also exposed above the NIOSH recommended exposure limit (REL) and OSHA permissible exposure limit (PEL) of 50 $\mu g/m^3$ [OSHA 2019a].

We also detected RCS cristobalite in 3 (6%) of 45 samples, but at a concentration well below occupational exposure limits (OELs). The cristobalite concentrations ranged 2.9–3.4 $\mu g/m^3$, which were between the minimum detectable concentration (MDC) of 2.6 $\mu g/m^3$ and minimum quantifiable concentration (MQC) of 9.4 $\mu g/m^3$. This indicates more uncertainty associated with these results. Area air sample results for RCS ranged from not detected to 2.7 $\mu g/m^3$.

Methods: Asbestos Fibers

We collected samples for asbestos and other fibers using NIOSH Method 7400 and phase contrast microscopy (PCM). We collected 21 personal air samples (4 skid steer operators, 10 laborers, and 7 excavator operators) for 17 different employees over 2 days. We also collected area air samples at all five decontamination tables. We further analyzed the fiber samples that had 0.01 fibers per cubic meter (f/cc) or more using NIOSH Method 7402, transmission electron microscopy, to identify whether the fibers were asbestos. The OSHA PEL for asbestos fibers is 0.01 f/cc.

Results: Asbestos Fibers

Air sampling results for fiber concentrations in the 21 personal air samples are displayed in Table C2. All air sample results were below OELs. Laborers had the highest mean concentration of fibers (0.090 f/cc), followed by skid steer operators (0.03 f/cc), and last by excavator operators (0.007 f/cc). The fiber concentrations across these jobs ranged from 0.004–0.15 f/cc. The fiber concentration of the area samples ranged from 0.002–0.007 f/cc. Thirteen air samples were above 0.01 f/cc; however, transmission electron microscopy revealed that none of these fibers were asbestos. The primary type of fibers found in the samples were organic fibers. We also detected iron, aluminum silicate, calcium silicate, and hornblende fibers; none of which have OELs.

Methods: Metals in Air and on Skin

We collected and analyzed samples for metals and metalloids in air using NIOSH Method 7303 and on the skin using NIOSH Method 9102. We collected 20 air samples on 17 employees over 2 days. We took these samples on the same 17 employees on whom we also collected asbestos fiber samples. We did not analyze one of the air samples we took because the sample media had fallen off and could have been contaminated. We collected handwipe samples before the shift began, at lunch, and after the shift was over just before the employee went home. If the employee chose to wash his or her hands, we collected the handwipe samples afterwards.

Results: Metals in Air and on Skin

Metals in Air

The sources of metals exposure can include electronics, cars, refrigerators, stoves, etc. (Figure 3). When these items are burnt by the fire, these metals, such as lead, cadmium, and aluminum, can melt and contaminate the ground below them and be found in the debris and dust in the lot footprint. Employees could potentially inhale the metals while cleaning up this dirt and debris. No air samples exceeded any OELs for any metals or metalloids, and all samples were at least an order of magnitude below applicable OELs. Results are shown in Table C3.

Figure 3. Cars and trucks that had been burnt in the fire. Photo by NIOSH.

Metals on Skin

Employees could also ingest these metals if they are on their hands before eating or smoking. Results of handwipe samples for metals and metalloids are displayed in Table C4. We found metals on employees' hands before their shift started, at lunch, and after their shift was over before leaving the worksite. We observed slightly higher levels for most metals at the end of the work shift compared to the before shift samples, however this difference was not statistically significant. We also observed that some employees did not wash their hands before eating lunch or leaving the worksite at the end of the day. Although there were sinks located at the portable restrooms, many were not very convenient to all of the lots, which could have made washing hands a lunch difficult.

Methods: Polyaromatic Hydrocarbons in Air and on Skin

We took 49 full-shift personal air samples for PAHs on the same 17 employees on which we collected RCS and asbestos air samples. We did not analyze one of the samples because the air sampling pump had stopped working. We analyzed the PAHs in air according to NIOSH Method 5506. We collected dermal skin wipes on the hand and the back of the neck before and after a shift. We also collected an additional handwipe after a shift on the second day of sampling. We analyzed the PAHs in wipes by NIOSH Method 5506, modified for the wipe material.

Results: Polyaromatic Hydrocarbons in Air and on Skin

Polyaromatic Hydrocarbons in Air

Table C5 shows the personal air sampling results for naphthalene and phenanthrene. All air samples were well below the lowest OEL for naphthalene. No OELs exist for phenanthrene. However, all but 15 samples were below the MDC, and all were below the MQC. We detected acenaphthene in one sample. However, the air sampling pump had failed during sample collection, so we could not calculate the concentration. We also analyzed the samples for anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i,)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorine, indeno(1,2,3-cd)pyrene, and pyrene. We did not detect any of these in any sample.

Polyaromatic Hydrocarbons on Skin

We detected phenanthrene in one preshift neck wipe sample (0.2 micrograms per sample [μg/sample]), 3 postshift handwipe samples (0.3–0.4 μg/sample), and 1 postshift neck wipe sample (0.2 μg/sample). We detected fluoranthene in one preshift handwipe sample (0.2 μg/sample) and in one postshift handwipe sample (0.6 μg/sample). We also collected hand and neck wipe samples for acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i,)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluorine, indeno(1,2,3-cd)pyrene, and pyrene. None of these were detected in any sample.

Methods: Confidential Medical Interviews

We invited all 40 employees from the selected task forces to participate in confidential medical interviews in either English or Spanish. The interview covered work history, work practices and tasks based on their reported job title, union affiliation, prior wildfire debris cleanup experience, hazard training, PPE use, and pertinent medical history. The medical history questions focused on diagnoses and symptoms associated with exposure to lead, asbestos, and RCS.

Results: Confidential Medical Interviews

We interviewed all 40 of the employees during the September site visit. Table C6 shows the number of employees we interviewed from each company. We did not interview any employees from the agency or Company A because none were working in or around the lot footprints that we evaluated. We interviewed employees from Company B (n = 3) and subcontractors for Company B (n = 2) who were responsible for on-site supervision (known as task force leaders) and/or environmental sampling. These employees worked outside of the lot footprint. We also interviewed 35 employees from three subcontracted construction companies (Companies D, E, and F). These employees worked inside the lot footprint as laborers or equipment operators. All employees we interviewed reported being represented by their respective unions.

Interview Results

For the five participants who worked outside the lot footprint, the median age was 35 years (range: 31–40 years), three were male, and the median years working in construction was 1.5 years (range: 0.1–25 years). Four of these participants (all of the task force leaders) reported that they had prior fire debris cleanup work experience, and that they started working fire debris cleanup within the previous 2 years.

We aggregated the remainder of the interview results based on employees' on-site roles as operators or laborers because of the small employee numbers from individual companies and the job tasks being similar no matter which company the employee worked for. Details of the interview responses for the operators and laborers can be found in Table C7. All of the laborers and all but one of the operators were male, and the majority of both groups of employees had previous experience working fire debris cleanups.

Of the 14 interviewed operators, 11 indicated that that were concerned about "other" exposures including unknown chemicals, toxic gases, live power lines, and sharp objects. Seven operators indicated being concerned about smoke, ash, and dust. Three operators were concerned about exposure to asbestos and metals other than lead. The 21 laborers reported that they were primarily concerned about exposure to asbestos (n = 10), silica (n = 8), and lead (n = 6). Some additional concerns included vehicle accidents, dust, ash, vapors, explosions, toxic substances from plastics, dead animals, and odors. The majority of both groups reported that their employer did not provide lead-removal handwipes (n = 8 operators; n = 10 laborers). All participants reported having received "adequate information and/or training regarding potential health hazards likely to be encountered during fire debris cleanup" from their employer.

The 14 operators reported that their most common tasks were operating a closed cab excavator (n = 13), a skid steer/bobcat (n = 9), open cab excavator (n = 4), and front-end loader (n = 4). Other operator tasks included operating a grading/paving vehicle (n = 2) and operating a street sweeper (n = 1). For the laborers, all 21 participants reported they did raking/shoveling ash or debris, raking/shoveling soil, operating water hoses, and securing debris loads with tarps once loaded onto removal trucks. The most common tasks reported by the laborers were manual handling and removal of metal debris (n = 17), manual removal of concrete debris (n = 15), and flagger operations or traffic control (n = 13).

The PPE reportedly used by both employee groups is detailed in Table C8. Both groups of employees we interviewed seemed to be confused regarding the differences between a dust mask, disposable respirator, and a half-mask elastomeric respirator. In addition, some employees were uncertain regarding the composition of their gloves. Both groups reported that when hearing protection was used, earplugs were used more frequently than earmuffs. Only five interviewed employees reported that they always wore earplugs, and only one employee reported always wearing earmuffs. Three employees reported never using either earplugs or earmuffs.

Since working on their first fire debris cleanup, none of the laborers or operators reported the following:

- Receiving a diagnosis of asbestosis, silicosis, asthma, emphysema/chronic obstructive pulmonary disease (COPD), cancer, lead poisoning/toxicity, or anemia by a healthcare provider.
- Experiencing difficulty breathing or shortness of breath, chest tightness, wheezing, dry or nonproductive cough, unusual fatigue, or severe, unexplained abdominal pain they felt may be work-related.
- Having any current health problems they thought were work-related.

Methods: Observations of Work Practices, Processes, and Conditions

We observed work processes, practices, and conditions in the lot footprint. We observed employee use of PPE and dust suppression methods including water spray from a large tanker and from a hand-held hose spray from a portable water tanker.

Results: Observation of Work Practices, Processes, and Conditions

We observed that the activities of the excavator and skid steer generated fairly large dust clouds, especially when felling chimneys (excavator), breaking concrete (excavator), and piling up debris (skid steer). The dust clouds were more noticeable when the dust suppression methods were either not in use or when the water spray was not able to reach the location where the activities were occurring (Figure 4). Although laborers were sometimes in the dust clouds generated by the heavy equipment, the only visible dust cloud generated by laborers occurred when they cut concrete without a water spray. This happened just once for about 2 minutes before employees realized that they needed to have dust suppression.

Figure 4. An employee standing inside the lot footprint was not wearing the required respirator and protective suit. In addition, no dust suppression spray was being applied. Photo by NIOSH.

Figure 5. Employee utilizing a boot wash. Photo by NIOSH.

One of the primary activities done by laborers was dust suppression using a handheld hose attached to a "water buffalo," which is a tank holding about 100 gallons of water that could be transported from lot to lot on the back of a small trailer. In some neighborhoods, we observed a large tanker truck full of water. This truck drove through the neighborhood and wet all of the damaged structures throughout the area using a large hose with a directional spray attachment. This was to ensure that all lots were wet for dust suppression even if they were not being worked on. This tanker truck was also used when felling a chimney near the back of the lot footprint. The laborer's handheld spray could not reach the top of the chimney, so they would not fell the chimney until dust suppression was made available.

At times, we observed homeowners or construction companies that had been hired directly by the homeowner working in lots in the vicinity of those that we were sampling. These companies did not always adhere to the same safety protocols and dust suppression protocols.

We observed that adherence to the required PPE varied between the task forces. Some task force leads began each shift with a reminder of the required PPE and reminded employees throughout the day if observed without the correct PPE. Other task force leads were not as strict about the rules. We observed several employees with full beards under their respirators and some respirators worn incorrectly (i.e., on the chin instead of covering the nose and mouth). Although the required glove type was nitrile, we observed the use of latex gloves at some of the lot footprints.

Decontamination procedures varied across task forces, especially as it pertained to footwear. Some task forces required reusable rubber boots in the footprint, which required using a boot wash when exiting the lot footprint (Figure 5). However, some task forces did not enforce the use of the boot wash and we observed employees exiting the lot footprint without washing their boots. Some task forces required disposable boot covers while working in the footprint, which required that the boot covers be removed when exiting the lot footprint. Many times the boot covers disintegrated while working in the lot and, therefore, there was nothing to remove. If the boot covers disintegrate and the boot is not washed, contamination from inside the lot footprint can be tracked outside of the footprint.

Discussion

Our personal air sampling results showed that some of the skid steer operators were overexposed to RCS. During fire debris cleanup, the skid steers generated substantial visible dust clouds while moving debris into piles for removal by excavators. The skid steers were equipped with rollover cages; however, these cages were not enclosed, leaving the operator exposed to dust. We found the highest exposure on the first day of fire debris cleanup. It is likely that more dust is generated on the first day and then decreases as the burnt debris is removed.

We observed that the other skid steer operator who was overexposed to RCS worked on a lot where dust suppression methods did not fully cover the worksite. This likely contributed to more dust being generated, possibly leading to the higher RCS concentration. Other factors that could influence RCS exposures include wind speed and direction and silica concentration in dust. In contrast to skid steer operators, we found that excavator operators and laborers were not overexposed to RCS. Excavator operators were enclosed in cabs, which limited their exposures, even though substantial dust was generated by the excavators. Laborer RCS exposures were likely mitigated by the type of work (i.e., hand picking debris and holding the water suppression hose) and by the distance maintained from the skid steers and excavators.

A previous study of RCS exposure in the construction industry demonstrated that exposure control methods could reduce silica exposures significantly [Rappaport et al. 2003]. These researchers found that with consistent use, wet dust suppression reduced laborers' silica exposures approximately threefold and the use of enclosed ventilated cabs in construction vehicles reduced operating engineers' exposures approximately sixfold. Our finding of RCS exposures above the ACGIH TLV and OSHA AL of 25 $\mu g/m^3$ indicate the need for periodic monitoring to assess the need for or effectiveness of control measures.

Although silica has been a known occupational hazard for centuries, silicosis remains a largely underestimated disease. Silicosis is an irreversible, progressive, but preventable lung disease caused by the inhalation of RCS particles. A silicosis diagnosis requires a history of exposure to RCS and chest imaging or lung biopsy findings consistent with this condition.

Silicosis is often underdiagnosed. This may be because the employee is unaware of their workplace exposure to RCS or does not relay the exposure history to their healthcare provider not knowing its importance. This breakdown in communication may result in silicosis symptoms being misdiagnosed as COPD or other nonspecific lung disorders.

Although no employees reported being diagnosed with silicosis or described symptoms that could be consistent with silicosis, the establishment of a medical surveillance program is an important cornerstone to ensure an early and accurate diagnosis of silicosis in employees with potential overexposures to RCS. Employee hazard training should also emphasize the importance of informing their healthcare providers of their work history. This is especially important when documented RCS exposures occurred in that workplace, no matter how much time has passed, because of the potential long latency period for chronic silicosis.

Three subcontractors indicated that they had a silicosis medical surveillance program. However, the records provided to us by their occupational medicine clinic did not contain the elements needed to make the diagnosis of silicosis. These elements should include clinic visit notes documenting reported symptoms, physical examination findings, pulmonary function testing, chest imaging studies (i.e., chest X-rays or CT), or pulmonologist referral for lung biopsy. Details on the components of a medical surveillance program for silica can be found in Section D.

Even though none of our air sampling results indicated overexposures to metals, we detected metals on the hands of employees before the shift started, prior to lunch, and prior to going home at the end of their shift. This is a concern because of the potential for hand-to-mouth transfer of metals such as lead that can readily be absorbed into the body after ingestion. The presence of metals on hands before the start of the shift could indicate that soap and water alone are not effective in completely removing these metals, which is consistent with NIOSH research [Esswein et al. 2011]. Our interviews revealed the need for more frequent handwashing.

Employees reported that they had received adequate training; our interviews revealed that employees were doing tasks such as dry sweeping, which is known to reaerosolize dusts containing lead. Although no employee reported being diagnosed with lead poisoning or toxicity since working their first fire debris cleanup, we do not know what their actual blood lead levels (BLLs) were because the medical records we reviewed did not contain BLL test results. Taking lead home to family members is an additional concern if work boots and other potentially contaminated clothing is not left at the worksite. Since employees reported wearing their work boots home at the end of their workday, and this may expose others in the home to lead from the workplace.

Employees need to be familiar with the hazards that they may encounter when cleaning up fire debris and the methods used to reduce those hazards (i.e., dust suppression via water spray), including the required PPE. Based on our interviews and observations, many employees were uncertain about the specific types of required PPE (e.g., type of respirator, use of Tyvek coverall). We observed incorrect use of respirators, which can lead to employees inhaling air contaminants because air bypasses the respirator filters. In addition, we observed employees working at some lots had been provided the wrong type of gloves (i.e., latex gloves instead of nitrile), which could lead to latex sensitization. We also observed variability of PPE enforcement depending on the lot, specific task force, task force leads, and other factors. This variability demonstrates the importance that all task force leads undergo refresher training for on-site hazards, PPE requirements, and proper use of the required PPE. It is important that rules be consistently reinforced across all subcontractors, lots, and task forces.

Although we did not include noise dosimetry or audiometry during our assessment, noise from construction equipment could potentially expose operators and laborers to noise levels above the NIOSH REL of 85 decibels as an 8-hour time-weighted average (TWA) [NIOSH 1998]. Most (36 of 40) employees indicated that they only “sometimes” wore hearing protection inside the lot footprint during fire debris cleanup. This could increase their risk of hearing loss, particularly from noise exposure to construction equipment or powered tools. In addition, noise exposures combined with exposures to ototoxic (damage to the ear) agents, such as lead and carbon monoxide from equipment exhaust, can increase hearing loss risk [OSHA 2019b]. An accurate assessment of the sound levels produced by the heavy equipment and employees' noise exposures during use or working near this equipment would determine which employees would need to be included in a hearing loss prevention program. This information can also help determine what level of hearing protection is needed.

Limitations

Our evaluation was subject to some limitations. First, the exposure monitoring results taken over two or three days might not be representative of every type of fire debris cleanup operation. Cleanup operations occurring in housing developments with a different predominant type of building structure, industrial/manufacturing locations, and geographic areas containing natural deposits of heavy metals and/or asbestos may result in exposures to additional hazards or to similar hazards found during this evaluation but at varying concentrations. In addition, dust suppression varied greatly between neighborhoods and lot footprints, which could impact the quantity of airborne dust. Lastly, although the construction employees were reportedly enrolled in a silicosis surveillance program, none of the employee medical records documented annual physical examinations, spirometry, or chest imaging studies, therefore we were unable to review these documents during our evaluation.

Conclusions

Many of the fire debris cleanup employees we evaluated were exposed to RCS. Two of the skid steer operators were exposed to concentrations above the ACGIH TLV and the OSHA AL. Employees were not overexposed to asbestos, metals, and PAHs in air. Employees' hands had detectable amounts of metals on them; most of the skin wipes had nondetectable amounts of PAHs. Respirators were required at all times within the lot footprint, but they were not worn consistently and some instances of improper use were not corrected by the task force leader. Improving dust suppression and employee education, as well as consistently and properly wearing PPE, will likely help reduce employee exposures. The employee silicosis surveillance program should include a chest X-ray or CT scan along with documented RCS exposure to ensure a diagnosis of silicosis can be made in the future.

Section C: Tables

Table C1. Full-shift personal air sample results for quartz in µg/m^3

Job title	Number of samples	Mean concentration (range)
Skid steer operators	7	25.7 (3.5–76*)
Laborers	20	10.5 (ND–17)
Excavator operators	12	4.5 (ND–5.0)
NIOSH REL		50 µg/m^3
ACGIH TLV		25 µg/m^3
OSHA AL		25 µg/m^3
OSHA PEL		50 µg/m^3

ND = Not detected above the MDC of 2.6 µg/m^3.

* Two samples were above 25 µg/m^3 and one was above 50 µg/m^3.

Table C2. Full-shift personal air sample results for fibers* in f/cc

Job title	Number of samples	Mean concentration (range)
Skid steer operators	4	0.03 (0.004–0.096)
Laborers	10	0.09 (0.003–0.15)
Excavator operators	7	0.007 (0.002–0.019)

* Fibers are defined as particles having a length-to-width aspect ratio equal to or greater than 3:1.

Table C3. Full-shift personal air sample results for metals and metalloids (n = 20)

What we sampled, MQC:	% Detected	Air concentration, µg/m³			
		Mean	Minimum	Maximum	Lowest OEL
Aluminum, MQC = 2.7	95	14	> 0.75	46	10,000 NIOSH
Arsenic, MQC = 1.0	40	[0.44]	> 0.28	[0.70]	10 ACGIH
Barium, MQC = 0.28	80	0.61	> 0.090	1.9	500 OSHA, NIOSH, ACGIH
Cadmium, MQC = 0.06	40	[0.0061]	> 0.019	[0.030]	5 OSHA
Calcium, MQC = N/A	95	76	> 9.5	226	None
Chromium, MQC = 0.35	30	[0.24]	> 0.090	0.37	500 NIOSH, ACGIH
Cobalt, MQC = 0.16	15	[0.059]	> 0.050	[0.078]	20 ACGIH
Copper, MQC = 0.16	90	0.60	> 0.070	2.3	1,000 OSHA, NIOSH, ACGIH
Iron, MQC = 0.57	95	25	> 0.19	82	5,000 NIOSH
Lead, MQC = 0.95	25	[0.47]	> 0.28	[0.69]	50 OSHA, NIOSH, ACGIH
Lithium, MQC = 0.11	5	[0.033]	> 0.038	[0.033]	25 OSHA, NIOSH, ACGIH
Magnesium, MQC = 7.1	95	8.0	> 1.9	26	10,000 ACGIH
Manganese, MQC = 0.045	95	0.90	> 0.0095	3.4	100 ACGIH
Nickel, MQC = 0.17	35	[0.08]	> 0.047	[0.14]	15 NIOSH
Phosphorus, MQC = 2.6	45	[2.2]	> 0.76	5.3	100 OSHA, NIOSH, ACGIH
Potassium, MQC = 1.4	95	3.5	> 0.47	9.4	2,000 NIOSH, ACGIH
Selenium, MQC = 4.4	10	[1.6]	0.95	[2.0]	200 OSHA, NIOSH, ACGIH
Strontium, MQC = 0.11	85	0.24	> 0.080	0.94	None
Titanium, MQC = 0.11	95	0.79	> 0.037	2.5	10,000 ACGIH
Vanadium, MQC = 0.46	10	[0.12]	> 0.095	[0.12]	50 ACGIH
Yttrium, MQC = 0.0089	70	0.017	> 0.0028	0.065	1,000 OSHA, NIOSH, ACGIH
Zinc, MQC = 0.29	90	1.3	> 0.085	2.9	5,000 NIOSH
Zirconium, MQC = 0.064	25	0.067	> 0.019	0.11	5,000 NIOSH, ACGIH

[ ] = Estimated concentration. When between the MDC and MQC, indicates more uncertainty associated with this value.

Note: Antimony, beryllium, lanthanum, molybdenum, silver, tellurium, thallium, and tin were analyzed for but not found in any air sample.

Table C4. Results of dermal handwipe samples for metals and metalloids

What we sampled, LOD	Dermal handwipes, mean micrograms per handwipe		
	Preshift (n = 15) No. (%) detected	Lunch (n = 15) No. (%) detected	Postshift (n = 17) No. (%) detected
Aluminum, LOD = 0.9	178 (100%)	251 (100%)	386 (94%)
Antimony, LOD = 0.7	ND (0%)	0.81 (6.6%)	1 (6%)
Arsenic, LOD = 0.9	ND (0%)	2.3 (13%)	4.3 (29%)
Barium, LOD = 0.02	8.2 (100%)	7.4 (100%)	12 (100%)
Beryllium, LOD = 0.008	ND (0%)	ND (0%)	0.0085 (6%)
Cadmium, LOD = 0.02	0.19 (73%)	0.16 (87%)	0.21 (88%)
Calcium, LOD = 7	628 (100%)	942 (100%)	1,269 (100%)
Chromium, LOD = 0.05	1.3 (100%)	0.97 (100%)	2.3 (100%)
Cobalt, LOD = 0.05	0.25 (73%)	0.24 (87%)	0.39 (76%)
Copper, LOD = 0.4	13 (100%)	17 (100%)	15 (94%)
Iron, LOD = 3	526 (100%)	460 (100%)	656 (94%)
Lanthanum, LOD = 0.03	ND (0%)	ND (0%)	ND (0%)
Lead, LOD = 0.3	2.5 (93%)	2.2 (100%)	3.3 (94%)
Lithium, LOD = 0.02	0.28 (100%)	0.45 (100%)	1.3 (94%)
Magnesium, LOD = 2	140 (100%)	139 (100%)	220 (94%)
Manganese, LOD = 0.09	11 (100%)	10 (100%)	16 (94%)
Molybdenum, LOD = 0.04	0.26 (100%)	0.25 (100%)	0.75 (82%)
Nickel, LOD = 0.06	2.6 (100%)	1.3 (100%)	2.0 (88%)
Phosphorus, LOD = 7	43 (93%)	26 (100%)	49 (82%)
Potassium, LOD = 7	1,431 (100%)	1,147 (100%)	1,436 (100%)
Selenium, LOD = 0.8	ND (0%)	ND (0%)	1.1 (100%)
Silver, LOD = 0.04	0.27 (53%)	0.08 (47%)	0.17 (71%)
Strontium, LOD = 0.03	1.7 (100%)	2.4 (100%)	3.0 (100%)
Tellurium, LOD = 0.8	1.5 (47%)	1.3 (47%)	1.7 (59%)
Thallium, LOD = 1	ND (0%)	ND (0%)	ND (0%)
Tin, LOD = 0.9	1.8 (33%)	0.96 (13%)	1.9 (6%)
Titanium, LOD = 0.02	6.6 (100%)	8.7 (100%)	13 (100%)
Yttrium, LOD = 0.01	0.21 (100%)	0.28 (100%)	0.34 (94%)
Zinc, LOD = 7	44 (93%)	46 (100%)	72 (94%)
Zirconium, LOD = 0.02	3.9 (100%)	1 (100%)	1.8 (94%)

Table C5. Full-shift personal air sample results for naphthalene and phenanthrene (n = 49)

What we sampled	% Detected	Air concentration, µg/m³			
		Mean	Min	Max	Lowest OEL
Naphthalene	100%	0.60	0.17	2.8	50,000
Phenanthrene	31%	[0.17]	ND	[0.33]	—

[ ] = Estimated concentration. When between the MDC and MQC, indicates more uncertainty associated with this value. The MDC of naphthalene was 0.07 µg/m³, and MQC was 0.24 µg/m³. The MDC of phenanthrene was 0.01 µg/m³, and MQC was 0.4 µg/m³.

Table C6. Number of interviewed employees by company and job title

Company	Number of employees interviewed (n = 40) by job title		
	Task force leaders (n = 5)	Operators (n = 14)	Laborers (n = 21)
B	3	0	0
C	2	0	0
D	0	2	6
E	0	6	4
F	0	6	11

Table C7. Demographic and work characteristics of interviewed operators and laborers

Demographic	No. (%) operators (n = 14)	No. (%) laborers (n = 21)
Age, median Range	37 years (21–52 years)	35 years (23–64 years)
Sex, male	13 (93%)	21 (100%)
Total years in construction, median Range	16.5 years (2–35 years)	6 years (0.1–28 years)
Had prior fire debris cleanup experience	10 (71%)	12 (57%)
Reported receiving adequate information and/or training on hazards	14 (100%)	21 (100%)
Reported frequency of handwashing		
After toilet use	12 (86%)	19 (90%)
Before lunch	9 (65%)	15 (71%)
At the end of the shift	9 (64%)	15 (71%)
Anytime leaving lot footprint	7 (50%)	15 (71%)
Does employer provide lead removal handwipes?		
Yes	1 (1%)	4 (19%)
No	8 (57%)	10 (48%)
Don’t know	5 (36%)	7 (33%)

Table C8. Number of employees who reported using various types of PPE

	Laborers (n = 21)			Operators (n = 14)		
	Always	Sometimes	Never	Always	Sometimes	Never
Hard hat	21	0	0	13	1	0
Safety glasses/goggles	20	1	0	12	1	1
Safety vest	15	5	1	14	0	0
Earmuffs	1	4	16	0	5	9
Earplugs	4	15	2	1	12	1
Dust mask	2	4	15	1	4	9
Disposable respirator (i.e., N95)	3	4	14	0	4	10
Half-mask respirator	14	5	2	11	2	1
Full-face respirator	1	1	19	1	3	10
Protective coveralls with hood	6	7	8	8	4	2
Protective coveralls without hood	10	2	9	3	1	10
Shoe covers/booties	11	8	2	10	2	2
Steel toed boots	17	1	3	10	2	2
Chemical resistant boots (i.e., rubber boots)	4	7	10	2	4	8
Leather work gloves	2	7	12	1	3	10
Nitrile/chemical resistant gloves	11	7	3	7	6	1

Section D: Occupational Exposure Limits

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

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

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

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

- OSHA, an agency of the U.S. Department of Labor, publishes permissible exposure limits [29 CFR 1910 for general industry; 29 CFR 1926 for construction industry; and 29 CFR 1917 for maritime industry] called PELs. These legal limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.

- NIOSH RELs are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2007]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, PPE, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.

- Another set of OELs commonly used and cited in the United States include the threshold limit values or TLVs, which are recommended by ACGIH. The ACGIH TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2019].

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.

Respirable Crystalline Silica

Silica, or silicon dioxide, occurs in a crystalline or noncrystalline (amorphous) form. In crystalline silica, the silicon dioxide molecules are oriented in a fixed pattern versus the random arrangement of the amorphous form. The more common crystalline forms in workplace environments are quartz and cristobalite, and to a lesser extent, tridymite. Occupational exposures to RCS have been associated with silicosis, lung cancer, pulmonary tuberculosis, and airway diseases. Several serious nonrespiratory diseases are associated with occupational exposure to crystalline silica. These include immunologic disorders and autoimmune diseases (including systemic sclerosis, rheumatoid arthritis, and systemic lupus erythematosis) and renal diseases [NIOSH 2002].

Silicosis is a fibrotic disease of the lung caused by the deposition of fine crystalline silica particles in the lungs. It is the disease most often associated with exposure to RCS. This lung disease is caused by the inhalation and deposition of crystalline silica particles that are 10 micrometers (μm) or less in diameter. Particles 10 μm and below are considered respirable particles and classified as having the potential to reach the lower portions of the human lung (alveolar region). Although particle sizes 10 μm and below are considered respirable, some of these particles can be deposited before they reach the alveolar region [Hinds 2012]. Symptoms of silicosis usually develop insidiously, with cough, shortness of breath, chest pain, weakness, wheezing, and nonspecific chest illnesses. Silicosis usually occurs after years of exposure (chronic), but may appear in a shorter period of time (acute) if exposure concentrations are very high. Acute silicosis is typically associated with a history of high exposures from tasks that produce small particles of airborne dust with a high silica content [NIOSH 2002]. Chronic silicosis can develop or progress even if exposure to silica ends [NIOSH 2002].

The International Agency for Research on Cancer (IARC) [2012] and NIOSH [2002] have classified inhaled crystalline silica in the form of quartz or cristobalite as carcinogenic to humans in reference to lung cancer. While individuals with silicosis clearly are at risk of lung cancer, exposure to silica in the absence of silicosis also increases the risk for lung cancer [Liu et al. 2013].

Several forms of nonmalignant respiratory disease are associated with exposure to silica [NIOSH 2002]. These include chronic obstructive pulmonary disease (emphysema and chronic bronchitis) and asthma. Silica exposure is also related to other abnormalities noted on pulmonary function tests.

Exposure to silica increases the risk of developing tuberculosis even in the absence of silicosis [NIOSH 2002]. This increase is due to impaired macrophage function from silica. This risk for individuals with silicosis is even higher. The odds of an individual with silicosis dying with tuberculosis are 19 to 40 times higher than for individuals without silicosis [Calvert et al. 2003].

Exposure to crystalline silica is also associated with development of several autoimmune diseases. The strongest evidence exists for an association with systemic sclerosis, rheumatoid arthritis, systemic lupus erythematosis, and antineutrophil cytoplasmic autoantibody related vasculitis [Cooper et al. 2002; Lee et al. 2014].

Silica exposure is also related to an increased risk of end-stage kidney disease [Ghahramani 2010; NIOSH 2002]. Kidney disease is associated with the effect of silica deposited in the kidneys and with an autoimmune process with activated macrophages. A wide range of kidney pathology is associated with silica exposure.

When proper practices are not followed or controls not maintained, RCS exposures can exceed the OSHA PEL, NIOSH REL, or the ACGIH TLV. For general industry, the OSHA PEL for respirable dust containing 1% or more of quartz is calculated by dividing 10 milligrams per cubic meter by the percent quartz in the sample, plus 2 [OSHA 2019b]. OSHA instituted an updated silica PEL on June 23, 2016. The updated silica PEL (50 $\mu g/m^3$ as an 8-hour TWA) is the same as the NIOSH REL (which is applied as a TWA up to 10 hours). This updated silica PEL is now being enforced for general industry, construction and the maritime industry, which began 2 years after the effective date (June 23, 2018). The NIOSH REL is intended to reduce the risk of developing silicosis, lung cancer, and other adverse health effects [NIOSH 2007]. The OSHA AL and the ACGIH TLV for quartz is 25 $\mu g/m^3$ as an 8-hour TWA [ACGIH 2019].

OSHA currently requires that medical surveillance for silicosis be offered to employees who will be exposed above the PEL for 30 or more days a year, and after June 23, 2020, employers must offer the same surveillance for employees exposed above OSHA AL of 25 $\mu g/m^3$ for 30 or more days per year. The OSHA standard calls for an initial examination within 30 days of initial assignment to the job. It should be noted that use of a respirator for any amount of time during the workday for potential silica exposures over the AL counts as a full day of respirator use toward the 30 days of use that would require the employee's enrollment in medical surveillance for silicosis.

The surveillance examination must include the following:

- A medical and work history with emphasis on past, present, and anticipated exposure to RCS, dust, and other agents affecting the respiratory system; any history of respiratory system dysfunction, including signs and symptoms of respiratory disease (e.g., shortness of breath, cough, wheezing); history of tuberculosis; and smoking status and history. The healthcare provider must also complete OSHA's Mandatory Medical Questionnaire or an equivalent.
- A physical examination with special emphasis on the respiratory system.

- A chest X-ray interpreted and classified according to the International Labour Office International Classification of Radiographs of Pneumoconioses by a NIOSH-certified B Reader.
- A pulmonary function test to include forced vital capacity and forced expiratory volume in one second administered by a spirometry technician with a current certificate from a NIOSH-approved spirometry course.
- Testing for latent tuberculosis infection.
- Any other tests deemed appropriate by the physician or licensed healthcare provider [NIOSH 2014].

Periodic examinations including the same elements must be offered at least once every 3 years or more often if recommended by the physician or licensed healthcare provider.

The healthcare provider conducting the silicosis medical surveillance must provide the employee a written medical report of the result of their evaluation within 30 days. This report must include "any recommended limitations on the employee's use of respirators, any recommended limitations on the employee's exposure to respirable crystalline silica, and a statement that the employee should be examined by a board certified specialist in pulmonary disease or occupational medicine if the chest X-ray is classified as 1/0 or higher by the B Reader, or if referral to a specialist is otherwise deemed appropriate by the primary licensed healthcare provider [OSHA 2017]." The healthcare provider must also provide documentation to the employer regarding the employee's medical condition. In order to protect their privacy, the contents must remain limited to the date of the examination with a statement that the examination contained all the required components and any recommendation regarding the employee's ability to safely wear a respirator unless the employee provides written authorization for the healthcare provider to release additional information to their employer.

Asbestos

Asbestos is a commercial name, not a mineralogical definition, given to a group of six different fibrous minerals (amosite, chrysotile, crocidolite, and the fibrous varieties of tremolite, actinolite, and anthophyllite) that occur naturally in the environment. One of these, chrysotile, belongs to the serpentine family of minerals, while all of the others belong to the amphibole family. These minerals possess high tensile strength, flexibility, resistance to chemical, biological, and thermal degradation, and electrical resistance. Because of these properties, asbestos has been mined for use in a wide range of manufactured products, mostly in building materials, friction products, and heat-resistant fabrics. Chrysotile, also known as white asbestos, is the predominant commercial form of asbestos. Amphiboles are considered of minor commercial importance. Historically, chrysotile accounted for more than 90% of the world's mined asbestos; it presently accounts for over 99% [Ross and Virta 2001; USGS 2019]. Chrysotile asbestos has been used in a number of applications in the United States, including thermal piping and industrial oven insulation, floor tile, vehicle brake pads, and in building material such as soffits. More information about asbestos is available at the NIOSH asbestos topic page http://www.cdc.gov/niosh/topics/asbestos/.

The current OSHA occupational 8-hour TWA exposure limit for airborne asbestos as determined by PCM is 0.1 f/cc for fibers greater than 5 μm in length and an aspect ratio (length to width) greater than or equal to 3:1 [29 CFR 1910.1001]. This includes Libby amphibole, a complex mixture of amphibole fibers found in the rocks and ore of Zonolite Mountain, 6 miles northeast of Libby, Montana. OSHA has also established an excursion limit that requires the employer to ensure that no employee is exposed to an airborne concentration of asbestos in excess of 1.0 f/cc as averaged over a sampling period of 30 minutes. Exposure limits or risk criteria for bulk or surface samples for asbestos have not been established. The OSHA definition of asbestos applies to chrysotile, amosite, crocidolite, tremolite asbestos, anthophyllite asbestos, actinolite asbestos, and any of these minerals that have been chemically treated and/or altered [29 CFR 1910.1001]. The OSHA definition of asbestos-containing material is any material containing more than 1% asbestos.

In 1990, NIOSH reviewed the available information on elongate mineral particles and concerns about potential health risks associated with employee exposures to the analogs of the asbestos minerals [NIOSH 1990a,b]. These analogs occur in a different mineral "habit" and are often referred to as cleavage fragments. PCM, the analytical method routinely used for characterizing airborne exposures, is incapable of differentiating these nonasbestiform analogs from asbestos fibers on the basis of physical appearance. To address these concerns and ensure that employees are protected, NIOSH defined "airborne asbestos fibers" to encompass not only fibers from the six asbestos minerals (chrysotile, crocidolite, amosite, anthophyllite asbestos, tremolite asbestos, and actinolite asbestos) but also elongate mineral particles from their nonasbestiform analogs as a precautionary measure. NIOSH retained the use of PCM for measuring airborne fiber concentrations and counting those elongate mineral particles having an aspect ratio of 3:1 or greater and a length greater than 5 μm. The REL (0.1 f/cc) was set at the limit of quantification for the PCM analytical method for a 400-liter sample, but risk estimates indicated that exposure at 0.1 f/cc throughout a working lifetime would be associated with a residual risk for lung cancer. No risk-free level of exposure to airborne asbestos fibers has been established [NIOSH 1984, 2011]. More information on asbestos from NIOSH can be found at http://www.cdc.gov/niosh/docs/2011-159/.

Inhalation exposure to asbestos can result in a scarring disease of the lung known as asbestosis, inflammation of the chest cavity (pleuritis) with or without fluid build-up, lung cancer, and another type of cancer known as malignant mesothelioma. The risk of these diseases, which can be disabling or fatal, generally increases with intensity and duration of exposure. The risk of lung cancer from inhaling asbestos fibers is also increased in smokers. Most people who get asbestos-related diseases have been exposed to high levels of asbestos for a long time. Most asbestos-related diseases rarely occur until at least 15 years after first exposure to asbestos. All forms of asbestos are hazardous, and all can cause cancer, but amphibole forms of asbestos are considered to be somewhat more hazardous to health than chrysotile [ATSDR 2001]. Asbestos fibers have no detectable odor or taste and fibers associated with these health risks are too small to be seen with the naked eye. A summary of asbestos-related diseases are listed below:

- Asbestosis – a serious, progressive, long-term disease of the lungs. It is caused by inhaling asbestos fibers that irritate lung tissues and cause the tissues to scar. The scarring makes it hard for oxygen to get into the blood.

- Lung cancer – people who mine, mill or manufacture asbestos, and those who use asbestos, and products containing asbestos, are more likely than the general population to develop lung cancer, as well as other cancers of the respiratory tract, including tracheal, laryngeal and bronchial cancers.
- Mesothelioma – a rare form of cancer that is found in the thin membrane lining (pleura) of the lung, chest, abdomen, and heart. The vast majority of cases are linked to asbestos exposure.

Exposure may also occur through ingesting (swallowing) asbestos, especially where airborne asbestos may deposit in the nose and mouth. Although some gastrointestinal cancers have been reported in asbestos-exposed employees, the evidence is considered suggestive, but not sufficient, to link asbestos exposure to those cancers [Institute of Medicine 2006].

Asbestos minerals are widespread in the environment. They may occur in large natural deposits, or as contaminants in other minerals. Low levels of asbestos can be detected in almost any air sample. The results of numerous measurements indicate that average concentrations of asbestos in ambient outdoor air are within the range of 10^{-8} to 10^{-4} f/cc; levels in urban areas may be an order of magnitude higher than those in rural areas [ATSDR 2001]. In indoor air, the concentration of asbestos depends on whether asbestos was used for insulation, ceiling or floor tiles, or for other purposes, and whether these asbestos-containing materials are in good condition or are deteriorated and easily crumbled.

Metals

Lead

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

Occupational exposure to inorganic lead occurs via inhalation of lead-containing dust and fume and ingestion of lead particles from contact with lead-contaminated surfaces. Exposure may also occur through transfer of lead to the mouth from contaminated hands or cigarettes when careful attention to hygiene, particularly hand washing, is not practiced. In addition to the inhalation and ingestion routes of exposure, lead can be absorbed through the skin, particularly through damaged skin [ATSDR 2019; Filon et al. 2006; Stauber et al. 1994; Sun et al. 2002].

Blood Lead Levels

In most cases, an individual's BLL is a good indication of recent exposure to lead because the half-life of lead (the time interval it takes for the quantity in the body to be reduced by half its initial value) is 1–2 months [CDC 2013a; Lauwerys and Hoet 2001; Moline and Landrigan 2005]. Most lead in the body is stored in the bones, with a half-life of years to decades. Measuring bone lead, however, is primarily done only for research. Elevated zinc protoporphyrin levels have also been used as an indicator of chronic lead intoxication. However, other factors, such as iron deficiency, can cause an elevated zinc protoporphyrin level, so monitoring the BLL over time is more specific for evaluating chronic occupational lead exposure.

BLLs in adults in the United States have declined consistently over time. The geometric means BLL decreased from 1.75 micrograms per deciliter (µg/dL) in 1999–2000 to 1.09 µg/dL in 2011–2012 [CDC 2015]. The NIOSH Adult Blood Lead Epidemiology and Surveillance System (ABLES) uses a surveillance case definition for an elevated BLL in adults of 5 µg/dL of blood or higher [NIOSH 2018]. Very high BLLs are defined as BLLs ≥ 40 µg/dL. From 2002–2011, occupational exposures accounted for 91% of adults with very high BLLs (where the exposure source was known) [CDC 2013b]. This underscores the need to increase efforts to prevent lead exposures in the workplace.

Occupational Exposure Limits

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 this standard, the PEL for airborne exposure to lead is 50 µg/m^3 of air for an 8-hour TWA. The standard requires lowering the PEL for shifts that exceed 8 hours, medical monitoring for employees exposed to airborne lead at or above the action level of 30 µg/m^3 (8-hour TWA), medical removal of employees whose average BLL is 50 µg/dL or greater, and economic protection for medically removed workers. Medically removed workers cannot return to jobs involving lead exposure until their BLL is below 40 µg/dL.

In the United States, other guidelines for lead exposure, which are not legally enforceable, are often followed. Similar to the OSHA lead standard, these guidelines were set years ago and have not yet been updated to reflect current scientific knowledge. NIOSH has a REL for lead of 50 µg/m^3 averaged over an 8-hour work shift [NIOSH 2007]. ACGIH has a TLV for lead of 50 µg/m^3 (8-hour TWA), with worker BLLs to be controlled to, or below, 30 µg/dL. ACGIH designates lead as an animal carcinogen [ACGIH 2019]. In 2013, the California Department of Public Health (CDPH) recommended that Cal/OSHA lower the PEL for lead to 0.5 to 2.1 µg/m^3 (8-hour TWA) to keep BLLs below the range of 5 to 10 µg/dL [Billingsley 2013].

Neither NIOSH nor OSHA has established surface contamination limits for lead in the workplace. The U.S. Environmental Protection Agency and the U.S. Department of Housing and Urban Development limit lead on surfaces in public buildings and child-occupied housing to less than 40 micrograms of lead per square foot [EPA 1998; HUD 2012]. 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 exposures to lead must implement regular and effective cleaning of surfaces in areas such as change areas, storage facilities, and lunchroom/eating areas to ensure they are as free as practicable from lead contamination [CFR 2019].

Health Effects

The PEL, REL, and TLV may prevent overt symptoms of lead poisoning, but do not protect employees from lead's contributions to conditions such as hypertension, renal dysfunction, reproductive, and cognitive effects [Brown-Williams et al. 2009; Holland and Cawthorn 2016; Institute of Medicine 2012; Schwartz and Hu 2007; Schwartz and Stewart 2007]. Generally, acute lead poisoning with symptoms has been documented in persons having BLLs above 70 µg/dL. These BLLs are rare today in the United States, largely as a result of workplace controls put in place to comply with current

OELs. When present, acute lead poisoning can cause myriad 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 2005].

The National Toxicology Program (NTP) recently released a monograph on the health effects of low-level lead exposure [NTP 2012]. For adults, the 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

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 2005]. The NTP recently released a monograph on the health effects of low-level lead exposure [NTP 2012].

Medical 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 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. These guidelines were endorsed by the Council of State and Territorial Epidemiologists (CSTE) and the CDPH in 2009 and the American College of Occupational and Environmental Medicine (ACOEM) in 2010 [CDPH 2009; CSTE 2009; Holland and Cawthon 2016]. CSTE published updated guidelines in 2013 to reflect the new definition of an elevated BLL in adults of 5 μg/dL [CSTE 2013]. The CDPH recommended keeping BLLs below 5 to 10 μg/dL in 2013 [Billingsley 2013] and updated their medical management guidelines in 2014 [CDPH 2014]. In 2015, NIOSH designated 5 μg/dL of whole blood, in a venous blood sample, as the reference BLL for adults. An elevated BLL is defined as a BLL ≥ 5 μg/dL. In 2016, the ACOEM released a position statement entitled *Workplace Lead Exposure* that reinforces the guidelines and recommendations above [Holland and Cawthorn 2016]. Table D2 incorporates recommendations from the expert panel guidelines and those from CDPH, CSTE, and ACOEM.

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 3 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 CDPH 2014

Take-home Contamination

Occupational exposures to lead can result in exposures to household members, including children, from take-home contamination. Take-home contamination occurs when lead dust is transferred from the workplace on employees' skin, clothing, shoes, and other personal items to their vehicle and home [CDC 2009, 2012].

The Centers for Disease Control and Prevention (CDC) considers a BLL in children of 5 μg/dL or higher as a reference level above which public health actions should be initiated. OSHA further states that there is no role for lead in the body and no safe BLL in children or adults [CDC 2013a].

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

Beryllium, Cadmium, Chromium, Nickel, Manganese, and Cobalt

Table D3 summarizes the OELs for the other common metals found in electronics, as well as a discussion of the potential health effects from exposure to these elements.

Table B3. Chemical health effects

Chemicals	Health effects	IARC	OEL (µg/m^3)
Beryllium	• Beryllium exposure may cause dermatitis, lung inflammation, and chronic beryllium disease in humans [Proctor et al. 1991]. • Exposure to beryllium can lead to sensitization. • Exposure also slightly increases the risk for lung cancer [Schubauer-Berigan et al. 2010].	Group 1: carcinogenic to humans [IARC 2012]	OSHA PEL: 0.2 NIOSH REL: 0.5 ACGIH TLV: 0.05
Cadmium	• Long-term occupational exposure to cadmium is associated with increased occurrence of lung cancer, kidney damage, and chronic obstructive lung disease [WHO 1992].	Group 1: carcinogenic to humans [IARC 2012]	OSHA PEL: 5.0 NIOSH REL: Cancer ACGIH TLV: 10 (2 respirable fraction)
Chromium	• The toxic effects of chromium exposure, including lung and nasal cancer, are primarily related to hexavalent chromium. • Skin exposure to chromium dust can cause skin irritation and skin ulceration, and allergic contact dermatitis.	Group 1: carcinogenic to humans [IARC 2012]	OSHA PEL: 1000 NIOSH REL: 500 ACGIH TLV: 500
Cobalt	• Exposure to elevated levels of cobalt can cause gastrointestinal irritation, nausea, and vomiting. • Skin exposure can cause irritant and allergic contact dermatitis [Vincoli 1997].	Group 2B: possibly carcinogenic to humans [IARC 2006]	OSHA PEL: 100 NIOSH REL: 50 ACGIH TLV: 20
Manganese	• Subclinical neurological effects, such as decreased performance on neurobehavioral tests; significantly poorer eye-hand coordination, hand steadiness, and reaction time; poorer postural stability; and lower levels of cognitive flexibility.	None	OSHA PEL: 5,000 NIOSH REL: 1,000 ACGIH TLV: 100
Nickel	• Allergic contact dermatitis, respiratory irritation, chronic bronchitis, asthma, reduced lung function.	Nickel compounds, Group 1: carcinogenic to humans; paranasal sinus, nasal cavity, and lung [IARC 2006]	OSHA PEL: 1,000 NIOSH REL: 15 ACGIH TLV: 1,500

IARC = International Agency for Research on Cancer

Polyaromatic Hydrocarbons

PAHs are products of incomplete combustion that can exist in particle and gas phases and are often found as a result of structural and wildland fires. Of the 18 PAHs that are commonly produced during fires, IARC classified benzo[a]pyrene as carcinogenic to humans; dibenz[a,h]anthracene as probably carcinogenic to humans; and seven others (benz[a]anthracene, benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, chrysene, indeno[1,2,3-c,d]pyrene, and naphthalene) as possibly carcinogenic to humans [IARC 2002, 2010]. Occupational epidemiology studies have primarily found associations between exposures to PAHs (typically as a mixture with other chemicals) and lung, skin, or bladder cancer, depending on the route of exposure [ATSDR 1995; Boffetta et al. 1997; IARC 2002, 2010]. Occupational exposure to benzene has been consistently linked to leukemia [ATSDR 2007; IARC 1982].

Additional information about PAH exposure in firefighters can be found in the NIOSH health hazard evaluation final (https://www.cdc.gov/niosh/hhe/reports/pdfs/2010-0156-3196.pdf) and summary (https://www.cdc.gov/niosh/hhe/reports/pdfs/2010-0156-3196S.pdf) reports [NIOSH 2013a,b].

Section E: Fire Debris Cleanup Exposure: Information for Construction Employees

Clearing a burned out area after the passage of a wildfire, including when the wildfire enters residential areas, can be handled by employees of general construction companies that may not have previous experience with fire debris cleanup. Although structural and wildland firefighters are typically well-informed of the potential health hazards associated with fires, construction employees may not be aware of hazardous exposures to things such as the carcinogens in soot and ash. However, the potential health hazards of on-site exposures vary depending on mineral deposits in the soil, materials used in the construction of the damaged buildings, and the items that were in the building. Clearing these residential areas must be done in a manner that protects the employees from harmful exposures and in compliance with local environmental regulations.

This section outlines the process developed by the state of California during the last several years of increased wildfire activity. The state agency typically approaches fire debris cleanup in the following manner:

- Once the wildfire has been contained, the state draws up a contract to clean up all occupied areas impacted by the wildfire. This contract is then placed for bidding, and it includes work practices and employee PPE to be used if specific hazards are likely to be found or have been identified on the site.
    - The state also contracts out to separate companies to do the following:
        - Conduct initial site sampling and periodic environmental sampling as the cleanup progresses.
        - Provide on-site supervision of cleanup crews as task force leader.
- Representatives of the state contact each lot owner. Those who want the state to handle their property cleanup sign a right of entry form. A property owner may decide to use a private contractor to clear and the prep site for rebuild.
    - The hazards associated with fire debris cleanup should be communicated to these construction companies as well.
- The state hires a company to perform an initial site hazard survey. Those companies select representative lots in a geographic area to sample for the following:
    - Asbestos (especially if worksite had structures on it known to have been built before 1984).
        - If asbestos is present, then the lot is identified as such and separated out to be worked by contractors as per asbestos remediation guidelines.

        - If asbestos is not present, then immediate safety hazards on site are identified (i.e., propane tanks and other safety hazards) and removed by the appropriate personnel.
    - Metals, including cadmium, chromium, copper, iron, lead, manganese, nickel, silver, and zinc.
    - RCS from soil, concrete, or other housing material.

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