Lead Exposure at a Firing Range and Gun Store

Elena Page, MD, MPH
Catherine Beaucham, MPH, CIH
Mark Methner, PhD, CIH

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Contents

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The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation. Photo by NIOSH.

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from employees at a firing range and gun store. Employees were concerned about lead exposure.

What We Did

- We evaluated the firing range and gun store in December 2013.
- We interviewed employees about their medical and work history and reviewed their medical records. The records included results of blood lead testing.
- We sampled air and surfaces for lead.
- We evaluated the ventilation system performance.

We evaluated lead exposure in an indoor firing range and gun store. We found lead in the air and on all surfaces tested, including employees' skin. All employees had elevated blood lead levels. We found a health hazard for employees and customers. We recommended removing employees from lead exposure until the hazard was abated and blood lead levels decreased.

What We Found

- Three current or former employees reported symptoms of lead poisoning, and all employees had elevated blood lead levels when tested by the employer in November 2013.
- Air sampling results for lead were below the California Occupational Safety and Health Administration's permissible exposure limit.
- We found lead on all tested surfaces in the range and in the showroom. Employees also had lead on their hands and shoes as they left work to go home.
- The ventilation system had numerous deficiencies, and lead-contaminated air circulated throughout the building.

What the Employer Can Do

- Switch to lead-free ammunition.
- Remove all employees with blood lead levels of 20 micrograms per deciliter or higher from exposure to lead until two blood lead levels taken a month apart drop below 15 micrograms per deciliter.
- Hire a ventilation engineer to modify or redesign the ventilation systems.
- Remove lead contamination from the showroom.
- Follow the medical surveillance requirements of the California Occupational Safety and Health Administration.

What Employees Can Do

- Talk to your doctor about your exposure to lead at work.
- Do not eat, drink, or smoke inside the facility.
- Wash your hands with a lead-removing soap before leaving the facility.
- Change your clothes and shoes before leaving work to decrease the amount of lead transferred to your car or home.

Abbreviations

$\mu g/m^3$	Micrograms per cubic meter
ACGIH®	American Conference of Governmental Industrial Hygienists
BLL	Blood lead level
Cal/OSHA	California Occupational Safety and Health Administration
fpm	Feet per minute
CFR	Code of Federal Regulations
µg/dL	Micrograms per deciliter
MERV	Minimum efficiency reporting value
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
REL	Recommended exposure limit
STEL	Short-term exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average
WEEL™	Workplace environmental exposure level

Introduction

The Health Hazard Evaluation Program received a request for an evaluation from employees of a firing range and gun store in California. Employees were concerned about lead exposure. They reported being diagnosed with lead poisoning and being medically removed from the workplace by an occupational physician. We visited the facility in December 2013 to interview employees and assess their exposure to lead. In December 2013, we sent a letter to employee and employer representatives outlining our preliminary findings and recommendations. In February 2014, we provided a summary of the environmental sampling results to the employer and employee representatives and personal sampling results were sent to each employee who participated in the evaluation.

Facility Description

The firing range and gun store had five full-time employees (including the manager) and one part-time employee. Employees generally spent most of their work day at the sales counter in the showroom or in the office. They occasionally entered the ranges to assist shooters who were experiencing difficulty or to supervise league shooting. Range A (Figure 1) was used more frequently for public firearms practice. The part-time employee taught a concealed carry weapons class 3 days per week in the classroom and entered firing range B several times throughout each class to supervise shooters. Employees cleaned the showroom and range at the end of the day. On Saturday employees performed a deep cleaning of the firing ranges. The cleaning activities are described in detail in the results section of this report. They alternated between range A and range B, cleaning each range every other week.

Each range had a separate single-pass ventilation system that supplied outside air to the range and exhausted the air directly outdoors without recirculation. The areas of the facility other than the range were served by two recirculation ventilation systems. These systems are more fully described in the results and discussion section of this report.

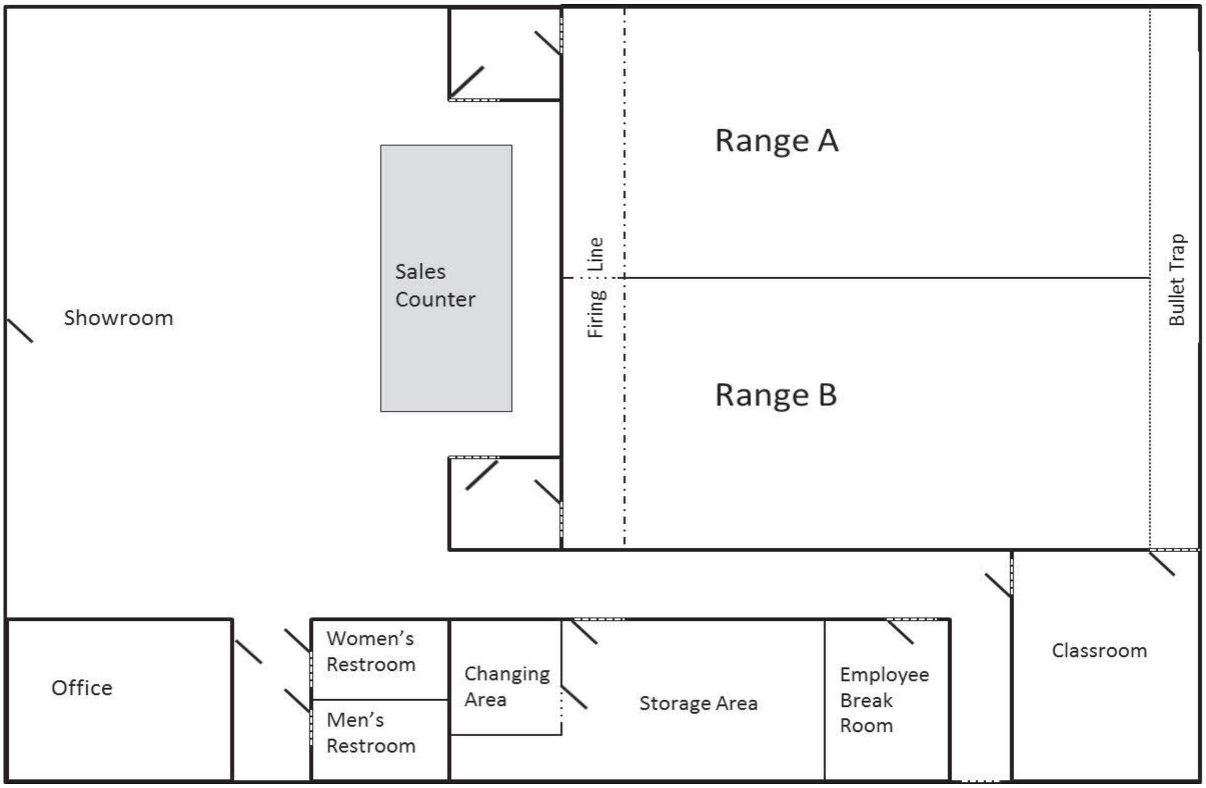

Figure 1. Firing range and gun store layout.

Methods

The objectives of this evaluation were to determine the extent and routes of exposure to lead in the range and store and to make recommendations to minimize exposure. We observed workplace conditions and work processes and practices. We reviewed exposure records from the workers' compensation carrier; records from a March 2013 California Occupational Safety and Health Administration (Cal/OSHA) inspection; and employee medical records, including blood lead levels (BLLs). We interviewed all employees present during the evaluation and asked them individually about health issues and job duties. We obtained a complete medical history to help detect unrecognized occupational illnesses. We also interviewed two employees who had been medically removed for lead poisoning.

We collected personal and area air samples and analyzed them for lead according to National Institute for Occupational Safety and Health (NIOSH) Method 7303 [NIOSH 2014].

We collected surface and hand wipe samples for lead using premoistened SKC Inc. Ghostwipes or a commercially available dust wipe (Full Disclosure® Instant Wipes, SKC Inc.). Surface wipe samples were collected using the procedure in NIOSH Method 9102 [NIOSH 2014]. Hand wipe samples were collected by a NIOSH investigator wiping the employees' dominant hand for 30 seconds. Some of these samples were evaluated only using a Full Disclosure® kit which is a qualitative screening method for the presence of lead, while others were quantitatively analyzed according to NIOSH Method 9102 [NIOSH 2014].

We inspected the air handlers, supply air diffusers, return air grilles, ductwork, and exhaust outlets for the two showroom air handling systems (Appendix A, Figure A1) and for the two in the firing ranges (Appendix A, Figure A2). We removed a few ceiling tiles near the wall that separates the ranges from the showroom to examine ductwork and determine if the wall extended up to the roof. We used qualitative and quantitative methods to characterize the airflow in and around the firing ranges. We used a Rosco Laboratories Inc. Model 1500 aerosol generating machine to generate "smoke" to visualize airflow patterns within the two ranges. We generated the smoke at the following five locations along the length of each range: behind the firing line, at each shooting position, 5 feet downrange, 15 feet downrange, and at the front of the bullet trap. We determined whether the ranges were under positive or negative pressure relative to the showroom by using ventilation smoke tubes in the connecting doorways.

We used a TSI VelociCalc® Plus Model 8386A anemometer to measure the air velocity (in feet per minute [fpm]). We measured air velocity at the firing line, at three distances downrange (5 feet, 10 feet, and 20 feet from the firing line), and at the front of the bullet trap. At each firing lane position, we took single measurements at six locations in a grid pattern centered in the standing shooter's breathing zone. We followed the same procedure at the other measurement locations downrange and at the bullet trap. We averaged the measurements for each location, and show the results on a schematic diagram (Appendix A, Figure A2).

Results and Discussion

Observations

We found many areas in the facility containing porous materials that could hold on to lead dust. The showroom had carpet throughout, as did the inside of the firing ranges behind the firing line. We learned that the carpet was last replaced in 2004. With the exception of vacuuming, the employees could not recall when it was last cleaned. The ranges had porous material throughout, including spongy soundproofing material. According to the employees it had never been cleaned or replaced.

Clean and dirty areas of the employee changing/restroom area were not separated and the partitioning wall between this and the storage area did not extend above the drop ceiling (Figure 1). The changing area contained separate sealed bins for each employees' clean and dirty clothes, as well as a sink and toilet. The area had no shower. We saw lead-contaminated rags in an open bin (Figure 2) and used coveralls hanging in the storage room (Figure 3). Employees used these dirty coveralls each night for range cleaning, and once a week for the deep cleaning and bullet trap scraping. The coveralls were laundered by the company every other week. The tools used for deep cleaning were covered loosely with a black plastic bag and kept in the storage room.

Figure 2. Lead contaminated rags in an open bin in the storage room located directly outside of the employee changing/restroom area. Photo by NIOSH.

Figure 3. Employee coveralls in the storage room. Photo by NIOSH.

Before closing at night, the employees secured all of the firearms in the showroom and then cleaned the facility. They wiped down the counters and shelves with D-Lead® wipes and rags. Employees then donned company issued washable coveralls, disposable booties, nitrile gloves, and an N95 filtering facepiece respirator for nightly range cleaning. They used a squeegee to push all of the spent bullet casings ("brass") to one area and collected the brass in a bucket. Next, they used a high-efficiency particulate air filtered vacuum cleaner backpack to vacuum in front of the firing line. Finally, they used a carpet attachment for the vacuum cleaner to clean the carpet behind the firing line. They put the used booties, respirator, and gloves in a sealed trashcan in the storage room. They hung the coveralls on a rack in the storage room and then proceeded to the changing area to put on their personal clothes.

For weekly deep cleaning, the employee donned the same coveralls used for the nightly range cleaning, disposable booties, nitrile gloves, and an N95 filtering facepiece respirator. During the deep cleaning, we observed the employee wearing a personal hat into the range. The employee's head, face, and neck were exposed. The employee placed a rubber band around each wrist to seal the gap between the sleeve of his/her coverall and his/her glove. The employee then got a cart with cleaning supplies from the storage room. Next, the employee removed the filters from the three range exhaust ventilation units and replaced them with new filters. The employee used a scraping tool to remove the dust and oil build up from the bullet trap. The employee used a push broom to sweep the dust and oil into the pit below the bullet trap and back into the airspace behind the bullet trap. The employee then applied motor oil to the bullet trap with a paint roller. The employee returned the tools to the cart, placed a black plastic bag over the broom and scraping tool, and returned the cart to the storage room. Next, the employee removed the respirator, washed his/her hands and face, and removed the coveralls and placed them back on the hanger in the store room. After this, the employee changed into work or street clothes to work at the showroom counter.

Document Review

In the year before our visit, the workers' compensation insurance carrier and Cal/OSHA collected full-shift personal air samples for lead. Both organizations documented airborne lead exposures above the permissible exposure limit of 50 micrograms per cubic meter of air. Cal/OSHA also documented numerous violations of the lead standard, including (1) lack of exposure monitoring; (2) failure to perform quarterly measurements of the ventilation system's effectiveness; (3) poor housekeeping (including dry sweeping); (4) allowing employees to consume food and beverages in the work area; (5) lack of a changing room with separate storage facilities for work and street clothes; (6) lack of a lunchroom; (7) having employees launder lead contaminated clothing at home; (8) failure to conduct required medical surveillance; (9) lack of a written lead hazard management program; (10) failure to implement engineering controls to reduce exposure to airborne lead; and (11) failure to provide appropriate protective clothing. Cal/OSHA also noted several violations of the respiratory protection standard including lack of (1) a written respiratory protection program; (2) medical clearance to wear a respirator; (3) fit testing; (4) maintenance and care of respirators; and (5) training of employees prior to respirator use. Cal/OSHA also reported that the range had been inspected in 2007 with similar findings and that no changes had been made.

Medical Record Review

The employer tested employee BLLs for the first time in November 2013. All six employees had elevated BLLs, defined as greater than or equal to 10 micrograms of lead per deciliter of blood (µg/dL) [CDC 2012a]. Employee BLLs ranged from 19.9–40.7 µg/dL. A detailed discussion of the health effects of lead and of the occupational exposure limits is in Appendix B. Table B1 discusses the evidence regarding health effects of lead in adults, while Table B2 provides health-based medical surveillance recommendations for lead-exposed employees by BLL.

No employees had undergone the medical surveillance required by Cal/OSHA. The physician who evaluated employees to determine their fitness to wear a respirator did not mark the clearance form to convey whether employees were medically cleared or for the exact level of respirator they were to use. Copies of each employee's breathing test result and the respirator medical clearance questionnaire were sent to the employer. We noted that these results contained confidential medical information from each of the employees that should not have been shared with the employer. The employer should have only received an "approved" or "rejected" medical clearance form on each employee.

Confidential Medical Interviews

We interviewed five of six current employees, including the general manager. One employee was not present during the evaluation. Length of employment at the facility ranged from 7 months to 13 years. All employees reported recreational use of firearms. One employee also works part-time as a firearms instructor for local law enforcement. Two employees reported past employment as correctional officers, which required periodic range shooting. One employee reported onset of symptoms consistent with chronic lead poisoning, including lethargy, fatigue, and muscle and joint aches since beginning work at the facility. The other four employees reported no symptoms related to work.

We also interviewed two employees on medical removal, who reported that they had sought medical care when they developed symptoms consistent with lead poisoning. BLLs were drawn as part of their medical evaluation and were elevated. They were removed from work by the physician. They reported that new employees were hired to replace them, but that workplace conditions had not changed.

Air Sampling

The six full-shift personal air samples had concentrations ranging from 5.5–19 micrograms of lead per cubic meter of air (µg/m³), below the Cal/OSHA limit of 50 µg/m³, but above the California Department of Public Health recommended limit range of 0.5–2.1 µg/m³ (Table 1) [CDPH 2009; Cal/OSHA 2014]. Employees worked varied shift lengths. Two task-based personal air samples for lead were 54 µg/m³ (55 minutes for nightly range maintenance) and 64 µg/m³ (52 minutes for the weekly range cleaning). Cal/OSHA does not have an exposure limit for short-term or task based air samples.

Table 1. Full-shift personal air sampling results

Job title/task	Sample duration (minutes)	Lead concentration (µg/m^3)
Day 1		
Manager	562†	19
Showroom employee	316	8.5
Showroom employee	260	5.5
Showroom employee*	449	16
Day 2		
Manager	409	9.1
Showroom employee	395	7.0
Cal/OSHA action level	—	30
Cal/OSHA PEL, NIOSH REL, ACGIH TLV	—	50

ACGIH = American Conference of Governmental Industrial Hygienists

PEL = Permissible exposure limit

REL = Recommended exposure limit

TLV = Threshold limit value

*This employee cleaned the range nightly.

†Ordinarily this employee only works 8-hours, however due to our visit the manager worked longer than his normal shift.

We took 11 area air samples in the firing ranges and showroom (Table 2). Outside of the ranges, the highest lead concentration was in the classroom, where concealed carry weapons classes were taught. The second highest lead concentration was behind the showroom counter, where employees spend the majority of their day.

Table 2. Full-shift area air sampling results

Area	Sample duration (minutes)	Lead concentration (µg/m^3)
Day 1		
Classroom, by bullet trap entrance door	481	20
Employee changing area	502	1.9
Behind showroom counter	219*	19
Storage room	497	2.3
Day 2		
Classroom, by bullet trap entrance door	484	19
Behind showroom counter	486	15
Inside range A	486	183
Storage room	457	1.3
Employee changing area	455	1.1

*The sampling pump stopped after 219 minutes.

Table 3. Wipe sampling results

Sample type and location	Lead detected with laboratory analysis (yes/no)	Lead detected with Full Disclosure® (yes/no)
Area surface wipe samples		
Prior to employee arrival		
Purchasing counter	Yes	No
Counter above where targets are stored	Yes	Yes
Rental counter	Yes	No
Cashier keyboard*	Yes	Yes
Long gun purchase counter	Yes	No
Air intake by purchasing counter*	Yes	Yes
Clean towel after arrival from laundry	Yes	No
After employee arrival		
Carpet outside of range B	Yes	Yes
Carpet in front of the entrance	Yes	Yes
Door handle to range A*	Yes	Yes
Door handle to range A after Hygenall®*	Yes	No
Handle of doorknob to women's restroom*	Yes	Yes
Office, owner's computer keyboard*	Yes	Yes
Office, air intake grill*	Yes	Yes
Break room table	Yes	Yes
Break room table, after cleaning with D-Lead	Yes	Yes
Classroom, counter next to water fountain	Yes	Yes
Women's customer restroom sink*	Yes	Yes
Ceiling tile near range*	Yes	Yes
Skin/clothing surface wipe samples		
Employees' left shoulder immediately after arrival*	Yes	No
Employee uniform clothes bin	Yes	Yes
Employee clean/street clothes bin	Yes	Yes
Employees shirt worn under coveralls during range cleanout*	Yes	—†
Employee shirt, at the start of the shift*	Yes	No
Employees hands, before going to lunch*	Yes	No
Sole of employee shoe before going home for the day*	Yes	Yes
Limit of detection	0.4	~20

*Estimated 100 cm^2

†Not evaluated with the Full Disclosure kit.

Surface Sampling

We detected lead on surfaces throughout the facility and on employees' shoes as they prepared to leave from work, hands after they had washed them, and on their personal clothing as they started their shift (Table 3). We also detected lead on the handle of the coffee pot, on the sink in the employee break room, inside the downspout from the roof, on plant leaves outside of the range, on all three air supply diffusers in the showroom, and on the return air intake for the showroom. Surface lead contamination can contribute to overall lead body burden because lead dust can get on employee's hands and then be transferred from their hands to their mouth. Employees likely transferred lead to their vehicles and homes on their clothing, shoes, and exposed skin. Wipe samples on all air supply diffusers and return air grilles confirmed distribution of contaminated air from the ranges into the rest of the building.

Ventilation System Evaluation

Firing ranges A and B, the showroom and office, and the storage, employee break room, and classroom area, were each served by separate ventilation systems. Unconditioned supply air was delivered to each firing range by a single 24-inch square plenum duct equipped with five 13 × 7-inch rectangular diffusers. These diffusers were spaced unevenly along the plenum (Appendix A, Figure A2). The plenum was mounted at ceiling height (9 feet) along the back wall of each range and approximately 12 feet behind the firing line. This plenum configuration was designed to direct air toward the firing line and downrange past the shooter.

Air was exhausted from each range at two areas downrange of the firing line. At the first, approximately 15 feet downrange, a 20-inch square exhaust outlet containing a minimum efficiency reporting value (MERV) 4 filter was positioned 10 feet above the floor. Further downrange, approximately 40 feet from the firing line, two 20-inch square exhaust outlets were suspended 10 feet above the floor in front of the bullet trap. Exhaust air passed through MERV 4 type filters before delivery outdoors.

The ventilation systems used to condition the air within the showroom and office area, and classroom, break room, and storage area, consisted of a two recirculating style, dual mode air handling units capable of using natural gas for heating and a roof-mounted condenser coil for cooling. Outdoor air was supplied to the unit through a rooftop vent stack that also provided combustion air needed when operating in heating mode. However, the unit also used air from the area between the building's interior drop ceiling and the underside of the roof. Conditioned air was supplied to the building through insulated flexible ducts in the space above the drop ceiling. Multiple supply diffusers and return grilles were located in the drop ceiling (Appendix A, Figure A1).

Achieving the correct balance between air supply and exhaust is important in limiting the risk of lead exposures resulting from firing range use. Firing ranges should be under slight negative pressure relative to adjacent areas so that no airborne contaminants migrate from the range. Our observations of air movement in range A indicate that a higher volume of air was being supplied than was exhausted and that range A was under positive pressure relative to the airspace over the showroom and to range B. This means that lead dust generated in range A could migrate to these adjacent spaces through openings we observed in the wall above the drop ceiling (Figure 4) and to range B through several holes in the wall that divided the two ranges (Figure 5). Appendix A, Figure A2 shows airflow patterns and velocity inside the firing ranges. We generated smoke in the airspace above the showroom and in range A and range B to visualize air movement. We observed that air moved from each range into the airspace above the showroom where it was drawn into the air handling unit that supplies conditioned air throughout the building.

Figure 4. Hole between the firing ranges and showroom, above the ceiling. Photo by NIOSH.

Figure 5. Large hole in the wall that divided ranges A and B. Photo by NIOSH.

Air flow velocities in range A were variable. Some firing lines did not meet the NIOSH recommended minimum average air velocity of 50 fpm while others exceeded the recommended 75 fpm at the firing line [NIOSH 2009]. Air velocity measurements varied considerably among the lanes, indicating turbulent air at the firing line, which was confirmed visually by smoke. The downrange air velocity measurements were also variable. Many areas downrange did not meet the recommended 30 fpm minimum air velocity [NIOSH 2009]. Visual smoke tests confirmed areas of backflow and stagnant air.

The measurements for range B showed that the range operated under negative pressure relative to adjacent areas such as the airspace above the showroom (Appendix A, Figure A2). Air velocity measurements at the firing line in range B were above the NIOSH minimum recommended average air velocity of 50 fpm, and the airflow was less turbulent than in range A. However, air velocities further downrange did not meet the NIOSH recommended minimum average air velocity of 30 fpm [NIOSH 2009].

It is desirable to have laminar airflow (streamlined airflow without cross currents or eddies) downrange, especially near the firing line. Even if the range is pressurized correctly and air moves downrange at the minimum velocity of 50 fpm (at the firing line), range users may receive excessive exposures to lead if cross currents or eddies create backflow of air and bring lead-contaminated air back into their breathing zones. Backflow was evident when we observed airflow patterns with the smoke machine. The location of the air supply diffusers on the plenum behind the firing line created eddies that resulted in two zones of recirculated air. One zone recirculated the air between the supply diffuser and the firing line, and then back again to the rear wall and supply diffuser. The second zone carried air from each shooting lane at the firing line to an area several feet downrange and then back up into the breathing zones of those standing at the firing line.

We also noted little downrange air movement at multiple areas between the firing line and the bullet trap. This finding may be a result of the placement of the exhaust hood openings, which were 10 feet above the floor. We observed little capture of the smoke generated at a height that roughly corresponded to the muzzle of a firearm (approximately 4 feet above the floor). Therefore, it appeared that at the current exhaust airflow rates, all exhaust inlets are too high to adequately capture gun emissions. As a result of this inadequate airflow, lead dust from gun emissions falls out of the horizontal downrange airflow, and then builds up on the floor. We found no evidence that the ventilation system had ever been evaluated for proper performance. Cal/OSHA requires measurements such as capture velocity, duct velocity, or static pressure every 3 months to demonstrate the effectiveness of ventilation systems in controlling lead exposure [Cal/OSHA 2014].

We inspected the filters in each firing range exhaust outlet and noticed these filters have a MERV value of 4. This inadequate level of filtration would allow lead-contaminated air to be released outside the building. In addition, during the weekly range cleanout, we noticed that the filter in one of the range exhausts had been dislodged, allowing unfiltered air to be exhausted (Figure 6). The filters inside the range ventilation system should be equipped with side and face gaskets to prevent lead-contaminated air from bypassing the filter. Without these gaskets, lead can accumulate in the ducts and on the fan, which reduces the efficiency and affects the balance of the system.

Figure 6. Dislodged, buckled air filter inside one exhaust outlet in range A. Photo by NIOSH.

Customers of the facility, including children, are likely exposed to lead, given the conditions that we found. We reported our findings to the county public health officer and to the California Department of Public Health so that action could be taken to protect the public.

Conclusions

A health hazard from exposure to lead exists in this firing range and gun store. The ventilation system was not performing as recommended by NIOSH. Multiple openings between the ranges and the wall separating them from the showroom allowed lead dust to migrate to the air handling units that serve the showroom and office/classroom area. Housekeeping practices are insufficient, and the medical surveillance program does not contain all the required elements. The risk of lead exposure is not limited to employees, but extends to customers and children who visit the facility.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage the firing range to use a labor-management health and safety committee or working group to discuss our recommendations and develop an action plan. Those involved in the work should have input to set priorities and assess the feasibility of our recommendations for the specific situation at the firing range.

Our recommendations are based on an approach known as the hierarchy of controls (Appendix B). This approach 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 feasible, administrative measures and personal protective equipment may be needed.

Elimination and Substitution

Eliminating or substituting hazardous processes or materials reduces hazards and protects employees more effectively than other approaches. Prevention through design, considering elimination or substitution when designing or developing a project, reduces the need for additional controls in the future.

1. Use lead-free ammunition. Use of ammunition that does not contain lead will not eliminate the need to clean and dispose of contaminated items; however, it would prevent additional buildup of lead in the range and showroom. While lead-free ammunition may pose some health risks, it is preferable to leaded ammunition. The measures recommended below to control lead exposure will also help prevent possible adverse effects regardless of the type of ammunition.

Engineering Controls

Engineering controls reduce employees' exposures by removing the hazard from the process or by placing a barrier between the hazard and the employee. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee.

1. Ask a ventilation engineer with experience in designing firing range systems to repair, modify, or design an appropriate ventilation system for the firing range. The NIOSH website has useful information about firing range ventilation at http://www.cdc.gov/niosh/topics/ranges/.
2. Address the range ventilation system as the top priority. Do a test and balance evaluation after the system is repaired, modified, or designed. Do a smoke test in each range to make sure air is moving downrange with as little turbulence/eddy currents as possible. Research possible grants for making range improvements.
3. Seal all openings between the showroom wall and the ranges to prevent lead dust from entering the airspace used by the air handling unit serving the showroom/office area. Persons doing this work must be informed of the presence of lead and take appropriate precautions such as wearing personal protective equipment (i.e., respirators, gloves, coveralls) to prevent exposure.
4. Use appropriately rated filters on all exhaust outlets. NIOSH recommends either a high-efficiency particulate air filter or MERV 18 or 19 rated filters [NIOSH 2009].

Administrative Controls

The term administrative control refers to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently.

1. Comply, at a minimum, with all aspects of the Cal/OSHA general industry safety orders, California Code of Regulations, Title 8, section 5198, Lead [Cal/OSHA 2014], which mandate numerous practices to reduce employee lead exposures. The firing range is required by law to comply with this standard. This requirement includes providing annual training to employees about lead, posting signs regarding lead work areas, and carrying out medical surveillance and air sampling, among many other actions.
2. Follow the guidelines for medical surveillance of employees in Appendix B. These guidelines are also available online at http://www.cdph.ca.gov/programs/olppp/Documents/medgdln.pdf.
3. Post signs that comply with California Proposition 65 regarding hazards of lead exposure. These signs are available at http://oehha.ca.gov/prop65/background/p65plain.html.
4. Use a healthcare provider who is familiar with current scientific information about the hazards of lead exposure, the Cal/OSHA lead and respiratory protection standards, and

respirator use. The American College of Occupational and Environmental Medicine provides guidelines about the confidentiality of medical information in the workplace at http://www.acoem.org/Confidentiality_Medical_Information.aspx.

5. Remove all employees with a BLL above 20 µg/dL from any lead exposure immediately. Consider return to work after two BLLs < 15 µg/dL a month apart. With medical removal, the employee should retain full pay and benefits. Employees should not have to file for workers' compensation, which provides reduced wages.
6. Provide uniforms that are laundered frequently by a company that knows how to remove lead from clothing. Provide employees shoes or disposable shoe covers to wear while working in the showroom. Require employees to change into clean clothes and shoes that have not been worn in the building before leaving.
7. Do not reuse contaminated coveralls. Either use clean coveralls each time range maintenance is done and have coveralls laundered after each use, or use disposable coveralls.
8. Do not allow food or beverages in the facility until lead-free areas where they can safely be stored and consumed are created.
9. Ensure employees wash their hands with a lead-removing soap before leaving the facility.
10. Remove porous material, including noise proofing material and carpeting, from the firing range and rooms adjacent to the range, and replace it with materials that can be cleaned more easily. Persons performing this work must be informed of the presence of lead and take appropriate precautions such as wearing personal protective equipment (i.e., respirators, gloves, coveralls) to prevent lead exposure. Contact the County Health Department, Environmental Health Division, or the California Environmental Protection Agency to determine if these items and the used air filters need to be treated as hazardous waste for disposal.
11. Identify and remove lead from all surfaces within the building excluding the area downrange from the firing line. Include the ventilation system that serves the showroom, offices, and classroom. Persons doing this work must be informed of the presence of lead and take appropriate precautions such as wearing personal protective equipment (i.e., respirators, gloves, coveralls) to prevent exposure.
12. Install an employee shower and a clean clothes changing room. Separate these areas from the storage room. Design the changing room and shower area so that once employees shower, they cannot re-enter the potentially contaminated changing area. Clean items should be stored in changing rooms separate from areas where contaminated work items are stored.
13. Consult a certified industrial hygienist to repeat air and surface wipe sampling after implementing these changes to evaluate their efficacy.
14. Encourage employees to talk to their healthcare provider about their exposure to lead and about the possibility of take-home contamination with lead. Encourage employees to have family members and other individuals who live with employees or regularly ride in their vehicles get their BLLs tested.

Personal Protective Equipment

Personal protective equipment is the least effective means for controlling hazardous exposures. Proper use of personal protective equipment requires a comprehensive program and a high level of employee involvement and commitment. The right personal protective equipment must be chosen for each hazard. Supporting programs such as training, change-out schedules, and medical assessment may be needed. Personal protective equipment should not be the sole method for controlling hazardous exposures. Rather, personal protective equipment should be used until effective engineering and administrative controls are in place.

1. Provide personnel doing nightly range maintenance, changing ventilation system air filters, and scraping the bullet trap with appropriate protective outer clothing, which may be disposable. If nondisposable clothing is provided, have it laundered after each use by a company that knows how to remove lead from clothing. If disposable clothing is worn it may need to be disposed of as hazardous waste; consult your state or local environmental regulatory authorities to help make this determination.
2. Develop and implement a respiratory protection program that, at a minimum, meets the requirements of Cal/OSHA general industry safety orders, California Code of Regulations, Title 8, section 5144, Respiratory Protection. See the Cal/OSHA consultation service educational unit guide "Respiratory Protection in the Workplace, A Practical Guide for Small-Business Employers" at http://www.dir.ca.gov/dosh/dosh_publications/respiratory.pdf.
3. Provide personnel doing nightly range maintenance, changing ventilation system air filters, and scraping the bullet trap with appropriate NIOSH certified respiratory protection until engineering or other controls can keep exposures below occupational exposure limits. Appropriate respirators can be determined using the NIOSH Respirator Selection Logic, available at http://www.cdc.gov/niosh/docs/2005-100/pdfs/05-100.pdf.

Appendix A: Figures

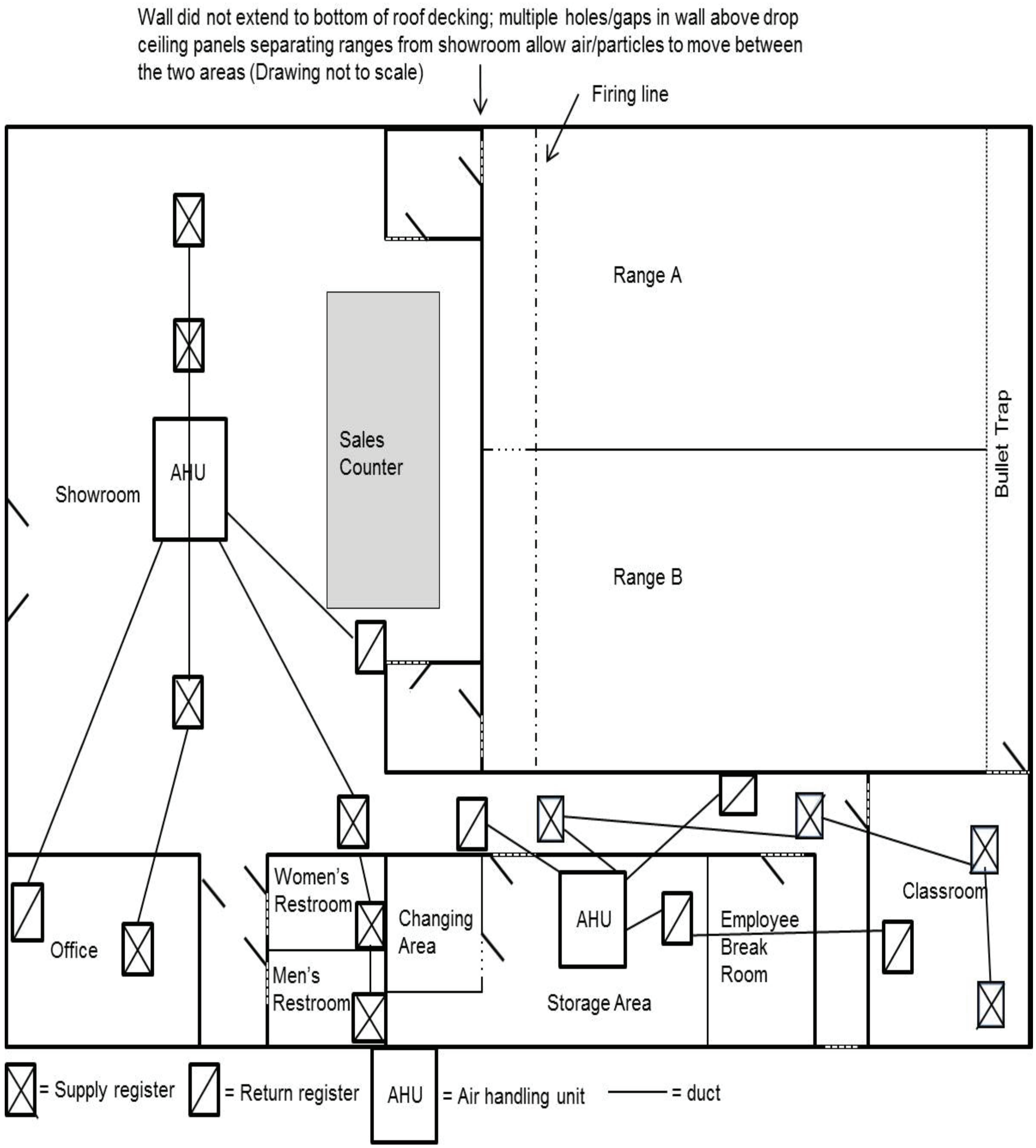

Figure A1. Schematic drawing of the facility showing the locations of ventilation systems outside the firing ranges.

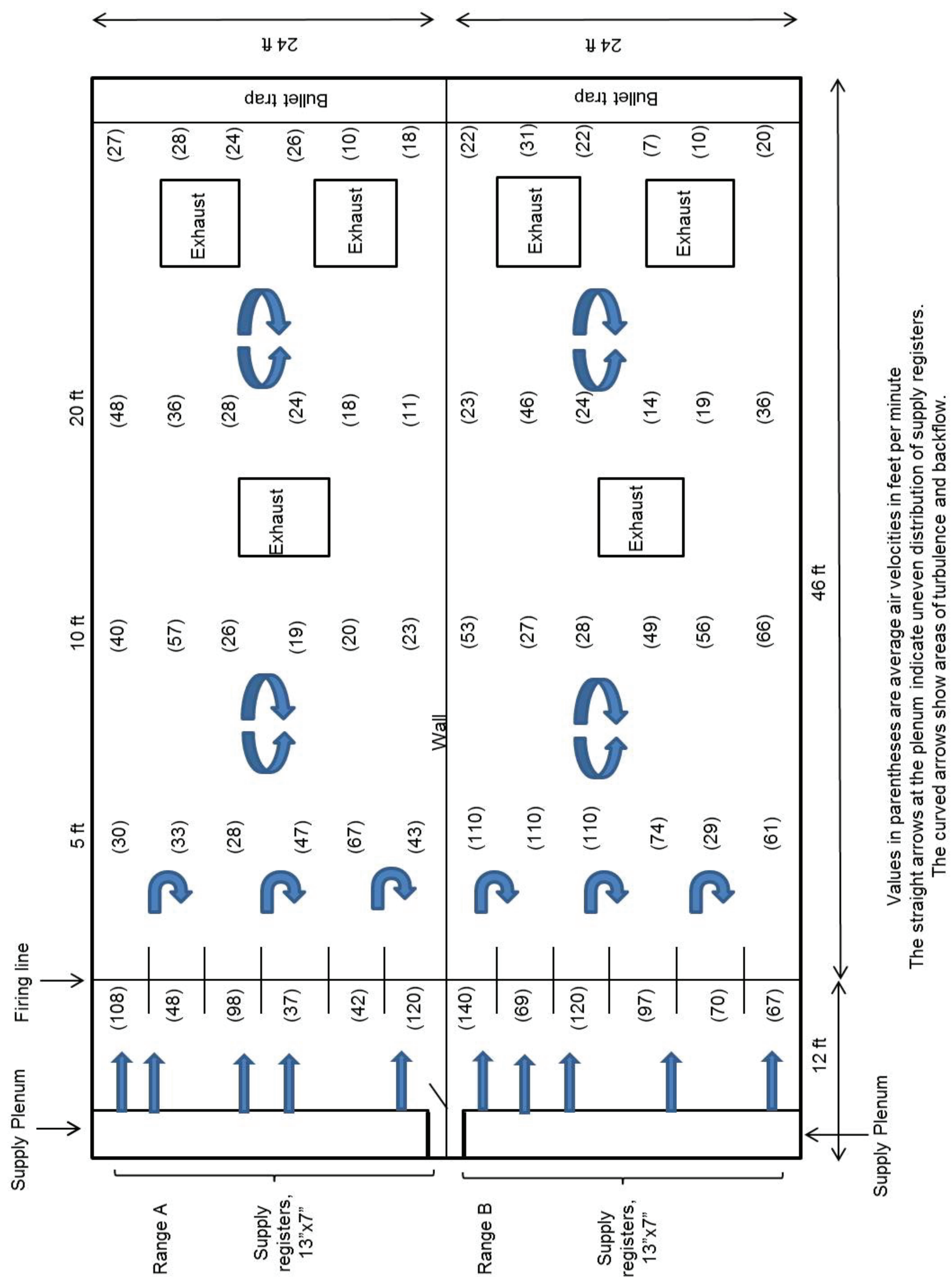

Figure A2. Airflow and air velocity inside the firing ranges.

Appendix B: Occupational Exposure Limits and Health Effects

NIOSH investigators refer to mandatory (legally enforceable) and recommended occupational exposure limits (OELs) for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a pre-existing medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended 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.

- The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits. These 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 2010]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Other OELs commonly used and cited in the United States include the TLVs, which are recommended by ACGIH, a professional organization, and the workplace environmental exposure levels (WEELs), which are recommended by the American Industrial Hygiene Association, another professional organization. The TLVs and WEELs are developed by committee members of these associations from a review of the published, peer-reviewed literature. These OELs are not consensus standards. TLVs 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 2014]. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2014].

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 http://www.dguv.de/ifa/Gefahrstoffdatenbanken/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 1,500 hazardous substances and is updated periodically.

OSHA 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 [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. 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. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize workplace hazards. This includes, in order of preference, the use of (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs.

Below we provide the OELs and surface contamination limits for lead, as well as a discussion of the potential health effects from exposure to lead.

Background

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 [Stauber et al. 1994; Sun et al. 2002; Filon et al. 2006].

Workplace settings with exposure to lead and lead compounds include smelting and refining; scrap metal recovery; automobile radiator repair, construction, and demolition (including abrasive blasting); and firing ranges. Occupational exposures also occur among workers who apply or remove lead-based paint and among welders who burn or torch-cut metal structures.

Blood Lead Levels

In most cases, an individual's BLL is a good indication of recent exposure to lead because the half-life of lead (the time interval it takes for the quantity in the body to be reduced by half its initial value) is 1–2 months [Lauwerys and Hoet 2001; Moline and Landrigan 2005; CDC 2013a]. 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. In the last 10 years alone, the geometric mean BLL went from 1.75–1.23 µg/dL [CDC 2013b]. The NIOSH Adult Blood Lead Epidemiology and Surveillance System uses a surveillance case definition for an elevated BLL in adults of 10 µg/dL of blood or higher [CDC 2012a]. 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 exposure source was known [CDC 2013c]. This high level of occupational exposure 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 an REL for lead of 50 µg/m³ averaged over an 8-hour work shift [NIOSH 2010]. ACGIH has a TLV for lead of 50 µg/m³ (8-hour TWA), with worker BLLs to be controlled to, or below, 30 µg/dL. The ACGIH designates lead as an animal carcinogen [ACGIH 2014]. In 2013, the California Department of Public Health recommended that Cal/OSHA lower the PEL for lead to 0.5–2.1 µg/m³ (8-hour TWA) to keep BLLs below the range of 5–10 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 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 change areas, storage facilities, and lunchroom/eating areas to ensure they are as free as practicable from lead contamination.

Health Effects

The PEL, REL, and TLV may prevent overt symptoms of lead poisoning, but do not protect workers from lead's contributions to conditions such as hypertension, renal dysfunction, and reproductive and cognitive effects [Schwartz and Hu 2007; Schwartz and Stewart 2007; Brown-Williams et al. 2009; Institute of Medicine 2012]. 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].

People with chronic lead poisoning, which is more likely at current occupational exposure levels, 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 National Toxicology Program recently released a monograph on the health effects of low-level lead exposure [NTP 2012]. For adults, they concluded the following about the evidence regarding health effects of lead (Table B1).

Table B1. 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	< 10 μg/dL
	Limited	Psychiatric effects, decreased hearing, decreased cognitive function, increased incidence of amyotrophic lateral sclerosis	< 10 μg/dL
	Limited	Increased incidence of essential tremor	< 5 μg/dL
Immune	Inadequate		Unclear
Cardiovascular	Sufficient	Increased blood pressure and increased risk of hypertension	< 10 μg/dL
	Limited	Increased cardiovascular-related mortality and electrocardiography abnormalities	< 10 μg/dL
Renal	Sufficient	Decreased glomerular filtration rate	< 5 μg/dL
Reproductive	Sufficient	Women: reduced fetal growth	< 5 μg/dL
	Sufficient	Men: adverse changes in sperm parameters and increased time to pregnancy	≥ 15–20 μg/dL
	Limited	Women: increase in spontaneous abortion and preterm birth	< 10 μg/dL
	Limited	Men: decreased fertility	≥ 10 μg/dL
	Limited	Men: spontaneous abortion in partner	≥ 31 μg/dL
	Inadequate	Women and men: stillbirth, endocrine effects, birth defects	Unclear

Various organizations have assessed the relationship between lead exposure and cancer. According to the Agency for Toxic Substances and Disease Registry [ATSDR 2007] and the National Toxicology Program [NTP 2011], inorganic lead compounds are reasonably anticipated to cause cancer in humans. The International Agency for Research on Cancer classifies inorganic lead as probably carcinogenic to humans [WHO 2006]. According to the American Cancer Society [ACS 2011], some studies show a relationship between lead exposure and lung cancer, but these results might be affected by exposure to cigarette smoking and arsenic. Some studies show a relationship between lead and stomach cancer, and these findings are less likely to be affected by the other exposures. The results of studies looking at other cancers, including brain, kidney, bladder, colon, and rectum, are mixed.

Medical Management

To prevent acute and chronic health effects, a panel of experts published guidelines for the management of adult lead exposure [Kosnett et al. 2007]. The complete guidelines are available at http://www.cdph.ca.gov/programs/olppp/Documents/medmanagement.pdf [CDPH 2009]. The panel recommended BLL testing for all lead-exposed employees, regardless of the airborne lead concentration. The panel's recommendations are outlined in Table B2. 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 are endorsed by the Council of State and Territorial Epidemiologists [CSTE 2009] and the American College of Occupational and Environmental Medicine [ACOEM 2010]. The California Department of Public Health recommended keeping BLLs below 5 to 10 µg/dL in 2013 [Billingsley 2013].

Table B2. 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 < 10 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 10–19 µg/dL	• As above for BLL < 10 µg/dL, plus: BLL every 3 months; evaluate exposure, engineering controls, and work practices; consider removal • Revert to BLL every 6 months after three BLLs < 10 µg/dL
BLL ≥ 20 µg/dL	• Remove from exposure if repeat BLL measured in 4 weeks remains ≥ 20 µg/dL, or if first BLL is ≥ 30 µg/dL • Monthly BLL testing • Consider return to work after two BLLs < 15 µg/dL a month apart, then monitor as above

Adapted from Kosnett et al. 2007

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, 2012b].

The Centers for Disease Control and Prevention considers a BLL in children of 5 µg/dL or higher as a reference level above which public health actions should be initiated and states that no safe BLL in children has been identified [CDC 2013a].

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

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This report is available at http://www.cdc.gov/niosh/hhe/reports/pdfs/2013-0119-3219.pdf.

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