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NIOSH ALERT

Preventing Occupational Exposures to Lead and Noise at Indoor Firing Ranges

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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WARNING!

Workers at indoor firing ranges may be exposed to hazardous lead concentrations and noise levels.

Employers and firing range operators should take the following steps to protect their workers and shooters from exposure to hazardous lead concentrations and noise levels at indoor firing ranges:

1. Provide workers and shooters with information about hazards and appropriate training to prevent hazardous exposures.

- Provide general information and specific hazard warnings through workplace postings and targeted training programs.
- State the precautions and hygiene practices required of the firing range workers and shooters.
- Train workers and shooters on the actions and means available to eliminate or limit potential exposures.
- Inform workers and shooters about symptoms that may indicate a health problem. Also inform workers that elevated lead levels can occur without overt symptoms and that a blood lead level test should be done if there is concern about an exposure to lead.
- Inform pregnant workers and shooters, or those considering pregnancy, about the possible adverse health effects to the fetus.

2. Establish effective engineering and administrative controls.

- If feasible, provide workers with cleaning facilities and lockers and develop a mandatory washing and hygiene program for shooters and workers to limit personal and take-home contamination.
- Install a well-designed supply air and exhaust ventilation system.
- Maintain and replace air filters regularly.
- Design and maintain the firing range structure to limit the transmission of harmful noise levels to adjacent areas.
- Incorporate effective administrative controls in the workers' schedules to limit their exposure time and ensure safe and clean working conditions.

3. Provide workers and shooters with personal protective equipment and other protective measures.

visited on 1/19/2017

- Provide a variety of hearing protection devices including earplugs and earmuffs.
- Provide skin protection, eye protection, and NIOSH approved respirators for workers involved in cleaning lead-contaminated surfaces and areas.
- Provide floor mats, knee pads, and shoe covers when necessary to limit transfer of lead to clothing.

4. Provide workers with health and medical monitoring.

- Provide workers with initial and periodic medical monitoring as required by the OSHA lead standard (29 CFR 1910.1025(j)).
- Best medical management practices, from organizations such as the Association of Occupational and Environmental Clinics or those provided in the journal Environmental Health Perspectives [Kosnett et al. 2007] should be recommended for all lead-exposed adults (workers and shooters).
- Provide workers with audiometric evaluations as required by OSHA noise standard (29 CFR 1910.95(d)(e)(g)(h)).

For additional information, see ***NIOSH Alert: Preventing Occupational Exposures to Lead and Noise at Indoor Firing Ranges*** [DHHS (NIOSH) Publication No. 2009–136]. Single copies of the Alert are available free from the following:

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WARNING!

Workers at indoor firing ranges may be exposed to hazardous lead concentrations and noise levels.

Workers should take the following steps to reduce exposure to hazardous lead concentrations and noise levels at indoor firing ranges:

1. Stay informed.

- Understand the safety issues and health hazards associated with lead and noise exposures.
- Follow safe work practices identified by your employer or range operator.
- Participate in all safety training and health monitoring programs offered by your employer or range operator.

2. Protect yourself.

- Use double hearing protection (earplugs and earmuffs) whenever possible.
- Wear respirators and full protective outer clothing when performing range maintenance.
- Wear gloves and eye protection when using chemicals to clean weapons or firing range surfaces.

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3. Use good work practices and personal hygiene.

- Wash hands, forearms, and face before eating, drinking, smoking, or contact with other people.
- Change clothes and shoes before leaving the firing range facilities.
- Wash clothes or uniforms used at the firing range separately from family's clothing.

4. Know and report symptoms.

- Common symptoms of lead poisoning in adults include nausea, diarrhea, vomiting, poor appetite, weight loss, anemia, excess lethargy or hyperactivity, headaches, abdominal pain, and kidney problems.
- If you suspect you may have been exposed to lead, even if you have no symptoms, ask about having a blood lead level test done.
- Exposure to high levels of noise can lead to hearing loss, tinnitus (ringing in the ear), stress, anxiety, high blood pressure, gastro-intestinal problems, and chronic fatigue.
- Report any of these symptoms to your employer or range operator.
- Seek medical attention when appropriate.

For additional information, see ***NIOSH Alert: Preventing Occupational Exposures to Lead and Noise at Indoor Firing Ranges*** [DHHS (NIOSH) Publication No. 2009–136]. Single copies of the Alert are available free from the following:

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WARNING!

Workers at indoor firing ranges may be exposed to hazardous lead concentrations and noise levels.

The National Institute for Occupational Safety and Health (NIOSH) requests help in preventing injury and illness in workers at indoor firing ranges in the United States. Workers are potentially exposed to hazardous amounts of lead and noise at these ranges. They include thousands of employees at the firing ranges as well as more than a million Federal, State, and local law officers who train regularly at these facilities. In addition to workers, 20 million active target shooters are potentially exposed to lead and noise hazards at indoor firing ranges.

This Alert presents five case reports that document lead and noise exposures of law enforcement officers and students. The Alert examines firing range operations, exposure assessment and control methods, existing regulations, and exposure standards and guidelines.

NIOSH requests that the recommendations in this Alert be brought to the attention of all firing range owners, operators, workers, and users as well as safety and health officials, industry associations, unions, and editors of trade journals.

BACKGROUND

The Bureau of Justice Statistics estimates that 105,000 Federal law enforcement officers and more than 1 million State and local police officers are employed in the United States [DOJ 2004]. These officers are required to train regularly in the accurate and proficient use of firearms. Indoor firing ranges have gained wide appeal among law enforcement agencies because they offer protection from inclement weather conditions and can be operated around the clock under controlled environmental conditions. The National Shooting Sports Foundation estimates that there are 20 million active target shooters in the United States. Of those, 13.8 million are rifle shooters and 10.7 million participate in handgun target shooting [NSSF 2006]. NIOSH estimates that 16,000 to 18,000 firing ranges

visited on 1/19/2017

operate in the United States. Some are operated without the benefit of sufficient environmental and occupational health controls in place to effectively protect the health of shooters and firing range personnel from the adverse effects of exposure to lead, noise, and other contaminants. The hazards from exposure to lead (airborne, ingestion, and skin), noise, and other contaminants at indoor firing ranges have been widely investigated [Valway et al. 1989; Novotny et al. 1987; Price 1989]. Some of these investigations have documented elevated blood lead levels and hearing loss—particularly among employees and instructors.

During the last 2 decades, NIOSH has performed numerous Health Hazard Evaluations (HHEs) of indoor firing ranges and documented the hazards of exposure to lead and noise among firing range operators, workers, and shooters. In 1975, NIOSH published a technical document titled *Lead Exposure and Design Considerations for Indoor Firing Ranges* to provide recommendations for reducing or eliminating hazards associated with indoor firing ranges [NIOSH 1975]. This Alert highlights the issues inherent in operating such facilities and addresses advances in exposure assessment methods, control technologies, and new regulations and exposure guidelines.

Although the scope of this Alert is specifically targeted at indoor firing ranges, overexposures to lead and noise at outdoor firing ranges have been documented in several studies [Tripathi et al. 1991; Goldberg et al. 1991; Murphy 2007]. Many of the recommendations that are outlined in this Alert can also be applied to protecting workers and shooters who use outdoor and covered firing ranges.

CURRENT REGULATIONS, RECOMMENDATIONS, AND OTHER GUIDELINES

The primary sources of exposure standards and guidelines for the U.S. workplace are the Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs) (29 CFR* 1910) and the NIOSH recommended exposure limits (RELs) [NIOSH 1992a]. Most employers are mandated to follow the OSHA standards; however, since current standards and regulations are based on outdated medical information, employers are encouraged to follow the most protective criteria.

OSHA Regulations

The Federal OSHA General Industry Lead Standard (29 CFR 1910.1025) establishes specific airborne lead exposure levels for employees working in areas where airborne lead is present. Lead exposure is determined through air sampling that measures the concentration of lead in the air (the number of micrograms of lead present in a cubic meter of air). The standard creates two levels of exposure, the action level and the PEL. The action level for airborne lead exposure is 30 micrograms per cubic meter ($\mu g/m^3$) of air as an 8-hour time-weighted average (TWA). If it is determined that airborne lead concentrations exceed the action level for more than 30 days per year, an employer must provide a medical surveillance program to the worker consisting of biological monitoring and medical examinations and consultations. Should a worker's average blood lead level (BLL) meet or exceed 50 micrograms of lead per deciliter (μg/dL) of blood, the employer is required to temporarily remove

**Code of Federal Regulations*. See CFR in references.

visited on 1/19/2017

the worker from the work area. The OSHA standard does provide for economic protection for such medically removed workers. Medically removed workers cannot return to jobs involving lead exposure until their BLLs are below 40 μg/dL. Benefits must be provided during the period of temporary medical removal—i.e., the employee continues to receive the same earnings, seniority, and other rights and benefits he or she would have had if they had not been removed. The OSHA PEL for airborne exposure to lead is 50 μg/m^3 as an 8-hour TWA. The PEL is reduced for shifts greater than 8 hours using the formula:

maximum PEL in μg/m^3 = 400 / hours worked per day

If airborne lead levels exceed the PEL for more than 30 days per year, then an employer is required to implement additional monitoring and management activities.

Currently, 24 States and 2 territories administer and enforce their own occupational safety and health programs. A list of these "State Plan States" can be obtained by contacting the appropriate authority in the State where the firing range is operated or through the OSHA Web site at *www.osha.gov*. It is important to note that State Plans must be at least as protective as the Federal OSHA standards.

For noise exposure, the Federal OSHA standard for occupational noise exposure (29 CFR 1910.95) specifies a maximum PEL of 90 decibels, A-weighted (dBA), averaged over an 8-hour time period. Noise generated from weapons is classified as impulse noise. The OSHA standard states that exposure to impulse noise should not exceed 140 decibels (dB) sound pressure level (SPL). The regulation uses a 5-dB exchange rate. This means that when the noise level is increased by 5 dBA, the amount of time a person can be exposed is cut in half. For example, a person who is exposed to noise levels of 95 dBA can be exposed to only 4 hours in order to be within the daily OSHA PEL. The OSHA standard has an action level of 85 dBA, which stipulates that an employer shall administer a continuing, effective hearing conservation program when the 8-hour TWA equals or exceeds the action level. The program must include exposure monitoring, employee notification, observation, an audiometric testing program, hearing protection, training programs, and maintenance of records. The standard also states that when workers are exposed to noise levels in excess of the OSHA PEL of 90 dBA (8-hour TWA), feasible engineering or administrative controls shall be implemented to reduce workers' exposure levels.

NIOSH Recommendations

The NIOSH REL for airborne lead is 50 μg/m^3 as an 8-hr TWA; airborne concentrations should be maintained so that a worker's BLL remains below 60 μg lead/100 g of whole blood [NIOSH 1992a].

In addition to inhalation exposures, lead from contaminated surfaces and from firearms discharge can be transferred to people's skin, especially the hands. Lead-contaminated hands can contribute to ingestion while handling food, beverages, and other items that contact the mouth. Skin exposures often result from hidden hazards that are not anticipated or recognized, and hence are inadequately controlled. Controlling lead-contaminated surfaces (and skin contamination) is highly dependent on anticipation and identification of lead contamination on surfaces; strict attention and

visited on 1/19/2017

adherence to personal hygiene practices; and appropriate administrative controls (e.g., hazard communication). Currently, there are no Federal occupational exposure limits for lead contamination of surfaces. However, NIOSH researchers have investigated surface and skin contamination from lead in a variety of occupational settings and developed two analytical methods for identifying lead contamination. NIOSH Method 9100 is a surface-wipe collection method that can be used to quantitatively determine surface lead concentrations to a detection limit of 0.1 μg per sample. Method 9105 is an instant qualitative wipe method that was initially designed to detect the presence of lead on workers' skin with a limit of identification of 15 μg per sample. The method is commercially available under the brand name *Full Disclosure for Lead (US Patent 6,248,593)* and can be used for identifying the presence of lead contamination on environmental surfaces [NIOSH 1994]. Both methods are practical and appropriate for identifying workplace surface lead contamination and evaluating the effectiveness of skin and surface decontamination for the purpose of reducing exposure risks. Both methods will detect the presence of lead contamination and lead from residues emitted from firearms usage.

NIOSH research shows that washing hands with soap and water is not completely effective in removing lead (and other toxic metals) from the surface of the skin [NIOSH 1992b; NIOSH 1996; NIOSH 1999]. To remove lead from skin, NIOSH researchers recently developed a novel and highly effective skin decontamination/cleansing method [Esswein and Boeniger 2005].

Regarding noise, the NIOSH REL for noise (8-hour TWA) is 85 dBA using a 3-dB exchange rate (see OSHA regulations in previous section for an explanation of exchange rates). NIOSH also recommends that no exposure be allowed above 140 dB SPL [NIOSH 1998].

Other Guidelines and Best Management Practices

In addition to the standards and guidelines identified above, U.S. government agencies (including the Department of Defense), the firearm industry, and shooting-sports organizations have created guidance documents and best management practices for firing ranges. Furthermore, the U.S. government and several professional organizations have general guidance documents concerning occupational exposure to lead and noise.

U.S. Government Agencies/Military Industrial Hygiene Standards and Guidelines for Firing Ranges

The U.S. Department of Justice (DOJ), Immigration and Naturalization Service[†] published a document titled *INS/NFU Firing Range Design Standard,* which focuses on necessary considerations for both indoor and outdoor firing ranges that meet the needs of DOJ training criteria. These considerations include lead and noise exposure controls and evaluations of environmental, occupational health, and training issues at existing firing ranges. The standard is intended as a supplemental guide to the *U.S. Border Patrol Facilities Design Guide* [DOJ 2002].

The U.S. Environmental Protection Agency (EPA) Best Management Practices at Outdoor Shooting Ranges, while targeted for outdoor ranges, provides owners and operators of outdoor firing ranges with information

[†]Immigration and Naturalization Service is now called the U.S. Citizenship and Immigration Services and is part of the U.S. Department of Homeland Security.

visited on 1/19/2017

on lead management and recommendations for reducing lead contamination [EPA 2005].

The U.S. military operates more than 3,000 indoor firing ranges. The U.S. Navy Environmental Health Center developed a reference guide titled *Indoor Firing Ranges Industrial Hygiene Guide* to provide firing range operators, industrial hygienists, safety professionals, and technicians with guidelines and recommendations on firing range operation and maintenance [USN 2002]. In addition, the U.S. Army Corps of Engineers published *Design Manual for Indoor Firing Ranges* in 1990 to provide guidance for new design considerations, retrofitting existing indoor firing ranges, and safety and maintenance requirements for Department of Defense range facilities [USACE 1990]. Although these publications discuss numerous issues involved with firing range operation, they do not represent a comprehensive listing of the material available from government agencies and the military.

Firearm Industry Guidelines

The National Association of Shooting Ranges (NASR), a division of the National Shooting Sports Foundation (NSSF), has developed a manual titled *Lead Management and OSHA Compliance for Indoor Shooting Ranges* [NASR 2004]. This manual addresses the potential of lead exposure at firing ranges and presents methods for managing exposures as well as compliance with the OSHA lead standard 29 CFR 1910.1025. This document was developed in partnership with OSHA and NIOSH.

Shooting Sports Organizations

The National Rifle Association (NRA) manual titled *The NRA Source Book: A Guide to Planning and Construction* provides basic and advanced guidance to assist in planning, designing, constructing, and maintaining shooting range facilities [NRA 1999].

General Guidance Concerning Occupational Exposure to Lead and Noise from the U.S. Government and Professional Organizations

Department of Health and Human Services

The Department of Health and Human Services (DHHS) identified occupational lead exposure as one of the national health objectives. In its publication *Healthy People 2010*, the DHHS proposed the elimination of occupational lead exposures that result in workers having blood lead concentrations greater than 25 μg/dL, and encouraged health departments to make elevated BLLs in children and adults a notifiable condition nationwide [DHHS 2000].

American Conference of Governmental Industrial Hygienists (ACGIH)

The American Conference of Governmental Industrial Hygienists (ACGIH) has adopted a threshold limit value (TLV) for lead of 50 μg/m^3 (8-hour TWA), with worker BLLs to be controlled at or below 30 μg/dL. The ACGIH has designated lead a confirmed animal carcinogen [ACGIH 2006]. The ACGIH also states that evidence suggests exposure during pregnancy to BLLs in excess of 10 μg/dL results in developmental effects such as depressed intellectual development in children [ACGIH 2001].

The ACGIH TLV for noise is 85 dBA (8-hour TWA) with a 3-dB exchange rate and 140 dB SPL as a maximum exposure limit. The ACGIH states that exposure to certain

visited on 1/19/2017

chemicals may result in hearing loss. In settings where workers might be exposed to noise as well as organic solvents (e.g., toluene, styrene, or xylene), heavy metals (e.g., lead, manganese, or organo-tin compounds), or other compounds (e.g., n-butyl alcohol or carbon monoxide), periodic audiograms are advised and should be carefully reviewed. The ACGIH also states that evidence suggests noise exposure in excess of a C-weighted, 8-hour TWA of 115 dB or a peak exposure of C-weighted 155 dB to the abdomen of pregnant workers beyond the fifth month of pregnancy may cause hearing loss in the fetus.

Association of Occupational and Environmental Clinics

The Association of Occupational and Environmental Clinics (AOEC) has reviewed current literature concerning lead exposure and health effects [AOEC 2007]. The AOEC has determined that the evidence provided by current health effects studies calls for an update of guidance for professionals involved with medical assessment and treatment of lead-exposed workers. Among other provisions in their guidance, the AOEC has determined that current evidence supports the need for: 1) qualitative assessment of the need for inclusion in a medical surveillance program for lead workers in addition to inclusion in a medical surveillance program based on documentation of exposure to airborne lead at a concentration above the OSHA action level; 2) increased frequency of BLL testing; 3) removal from exposure to lead for workers with BLL of 30 μg/dL or more; and 4) education of workers concerning occupational exposure to lead and provision of necessary personal protective equipment and administrative measures to prevent both occupational and take-home exposure to lead.

Environmental Health Perspectives Mini-Monograph

The March 2007 edition of Environmental Health Perspectives included a Mini-Monograph on adult lead exposure. Recommendations in this document include the following: 1) medical surveillance for all lead-exposed workers should include quarterly BLL testing for individuals with blood lead concentrations between 10 and 19 μg/dL, and semiannual testing when sustained blood lead concentrations are < 10 μg/dL; 2) pregnant women should avoid occupational or avocational lead exposure that would result in blood lead concentrations > 5 μg/dL; 3) removal from exposure to lead for workers with BLL of 30 μg/dL or more or if a worker has a sustained BLL above 20 μg/dL; and 4) annual education of lead workers concerning occupational exposure to, and control of, lead hazards as well as ongoing access to health counseling regarding lead-related health risks to prevent both occupational and take-home exposure to lead [EHP 2007].

CASE REPORTS

Many studies have shown health risks to workers from lead and noise exposures at firing ranges. The five case reports presented here describe the causes of these exposures and methods for controlling them.

Case 1—Lead exposures of law enforcement trainees

Seventeen law enforcement trainees were studied for 3 months during firearms instruction at an indoor firing range to determine their risk from lead exposure [Valway et al. 1989]. BLLs were measured before training began and every 4 weeks during the

visited on 1/19/2017

training. Airborne lead concentrations were measured three times during the instruction period. BLLs rose from a pre-training mean of 6.5 to 50.4 μg/dL post training. Mean airborne lead concentrations were greater than 2,000 μg/m^3, more than 40 times the OSHA PEL of 50 μg/m^3. During the study, two changes were made to the ventilation system. The first corrected the positive pressure inside the range that had allowed lead-contaminated air to flow from the range into other parts of the building whenever the range door was opened. The second change consisted of placing fins on the air supply grille to cause smoother air flow across the firing line and to decrease air turbulence. The adjustments resulted in a large decrease of airborne lead concentrations, depending on booth location. Airborne lead concentrations dropped to below detectable levels in the control room and classroom after the first adjustment. Airborne lead concentrations were reduced substantially (94% to 97%) by using ammunition that had nylon-coated and copper-jacketed bullets.

Case 2—Lead exposures of school rifle teams

The Alaska Environmental Public Health Program initiated a statewide review of school-sponsored rifle teams after a team coach was found to have an elevated BLL of 44 μg/dL [State of Alaska 2003]. The review initially examined six rifle teams using three indoor firing ranges. Thirty-six students and 35 adults (including family members and 6 coaches) participated in the blood lead

Figure 1. A law enforcement agency five-booth indoor firing range.

visited on 1/19/2017

testing. Two teams used a firing range that observed a regularly scheduled cleaning procedure and had a written protocol for maintenance and lead concentration monitoring. The geometric mean BLL measurements for those two teams were not elevated (1.3 μg/dL and 3.9 μg/dL, respectively).

One team used a firing range-multi-use area that for 11 years had not been evaluated for lead. The student shooters showed small but measurable lead exposure with a geometric mean of 8.1 μg/dL.

The other three teams used a firing range that was later documented to have extensive lead contamination. The teams showed elevated blood levels with geometric means of 27.9 μg/dL, 12.0 μg/dL, and 12.2 μg/dL respectively. The coaches of the 3 teams had BLLs with a geometric mean of 12.4 μg/dL; the highest level was 31 μg/dL, which is above the level considered elevated ($\geq$ 25 μg/dL) for adults. That firing range was voluntarily closed and arrangements were made for a thorough environmental evaluation.

Case 3—Lead exposures of police officers

A NIOSH Health Hazard Evaluation [NIOSH 1997] was conducted in a five-booth indoor firing range to examine potential exposure to lead among 30 police officers who used the firing range for training and firearms qualification (Figure 1). The firing range, which was located in a police department building, was used by other area police departments as well. The firing range ventilation system was independent of the rest of the building, but most of the firing range's exhaust air was recirculated through 90% to 95% efficient filters before being directed back into the firing range. Users cleaned the firing range by dry sweeping and collecting shell casings from the floor by hand. The bullet trap was cleaned every 2–3 years. Average airborne lead concentrations were 144 μg/m^3 and 230 μg/m^3 on 2 separate survey dates. Area airborne lead samples detected lead in the control room, in a hallway outside the firing range, and at the rooftop air handling unit. Inspection of the HVAC system on the first survey found several filters missing, but were in place during the second survey. NIOSH found that the firing range was under positive pressure, with the smell of gun smoke noticeable immediately when firing started on the firing range. The measurements of supply air and exhaust air-flow rates were much lower than designed and yielded an average air velocity of 25 feet per minute (fpm) or 0.127 meters per second (m/s) at the firing line. Pressure gauges on the HVAC system did not appear to be working properly. Smoke tests revealed backflow patterns even when no one was standing at the firing line. NIOSH recommended changes in the ventilation system, a standard operating procedure for maintenance, improved clean-up and personal hygiene practices, a written respiratory protection program, ammunition substitution, and BLL monitoring.

Case 4—Lead, *take-home* lead, and noise exposures of Federal law enforcement students

NIOSH and the National Center for Environmental Health (NCEH) participated in a series of collaborative evaluations of indoor and outdoor firing ranges and related facilities at the FBI Firearms Training Unit (FTU) [NIOSH 1991]. FTU facilities consisted of an indoor training range with 23 shooting booths, a one-booth firearms testing range, and seven outdoor training ranges. The evaluations included lead and noise exposures during firearms training among firing range

visited on 1/19/2017

Figure 2. Noise and lead exposure assessment of law enforcement officers at a 20-lane indoor firing range.

technicians, gunsmiths, and firing range instructors. The evaluations also included the potential for take-home lead contamination of workers' vehicles and homes, and for exposure of their families.

Sixteen full-time firearms instructors spent approximately 30 hours per week on the firing ranges. Sixty-one personal breathing zone samples and 30 area samples were collected to measure airborne lead. Airborne lead concentrations ranged up to 51.7 $\mu g/m^3$ for the instructors, 2.7 $\mu g/m^3$ for firing range technicians, and 4.5 $\mu g/m^3$ for gunsmiths. Short-term exposures while the custodians cleaned the firing range were as high as 220 $\mu g/m^3$. Results of carpet dust sampling collected in 14 dormitory rooms used by FBI students and 14 rooms used by non-students showed that significantly higher lead concentrations were found in the students' rooms (means of 214 $\mu g/g$ and 65 $\mu g/g$ respectively). The presence of lead in carpet samples suggests that FBI students unknowingly contaminated their living quarters with lead residues brought back to their quarters from the firing range.

The baseline and the most recent audiometric testing results were available for 14 of the 16 FBI instructors. Evaluations of the audiograms revealed that 9 of the 14 instructors (64%) had hearing losses that met the OSHA standard threshold shift criterion (i.e., changes relative to baseline of 10 decibels or more in the average hearing level at 2000, 3000, and 4000 Hz). Audiometric testing results were only available for one of the six firing range technicians, and this worker's results also met the OSHA standard threshold shift criterion. No audiometric testing results were available for the gunsmiths.

NIOSH recommended modifications to the indoor firing range ventilation system,

visited on 1/19/2017

improved personal hygiene practices, ammunition substitution, using double hearing protection devices, establishing a hearing conservation program for workers exposed to gunfire, and continued BLL monitoring.

Case 5—Noise exposures of Federal and local law enforcement officers

NIOSH investigators conducted live-fire noise exposure evaluations [Kardous et al. 2003; NIOSH 2003; Murphy 2007] of Federal and local law enforcement officers at indoor and outdoor firing ranges to characterize salient acoustic parameters associated with weapons noise and to provide guidelines for safe exposure (Figure 3). Measurements were conducted on a representative cross section of law enforcement firearms (the Beretta .40-caliber pistol, Remington 12-gauge shotgun, and Bushmaster M4 .223-caliber assault rifle). Indoor and outdoor measurements were also obtained for the Smith and Wesson .357-caliber revolver, the Colt .45-caliber and 9-mm pistols, the Glock .40-caliber pistol, the Heckler & Koch H&K 53 and H&K 36 assault rifles, and Colt AR15 .223-caliber rifles. Measurements were conducted using a ¼-inch Bruel & Kjaer model 4136 microphone, digital audio tape recorders with a 48 kHz sampling rate or were acquired directly to a computer laptop using 96 kHz data acquisition board. Analyses on the digitized waveforms were conducted using software tools built in Matlab. Peak sound pressure levels ranged from 155–168 dB SPL. Figure 4 shows the peak sound pressure levels generated from various weapons at an indoor firing ranges. A-weighted, equivalent (averaged) levels ranged from 124–128 dBA. Hearing protectors were

Figure 3. Emissions from the discharge of firearms.

visited on 1/19/2017

evaluated using the *Institut de Saint-Louis* (ISL) artificial head mannequin built specifically for measuring impact and impulse noise. Earmuffs with safety glasses had a peak reduction of 18 dB. The mean peak reduction for earmuffs was 26 dB, while earplugs alone provided a mean peak reduction of 24 dB. The mean peak reduction for the combined earmuff and earplugs was 44 dB.

NIOSH recommended several noise abatement strategies and modifications to the firing range structure to reduce the transmission of airborne and structural borne sounds; the use of double-hearing protection to ensure maximum protection against impulsive noise, improper fitting and other incompatibility with other protective equipment; and the establishment of a hearing conservation program.

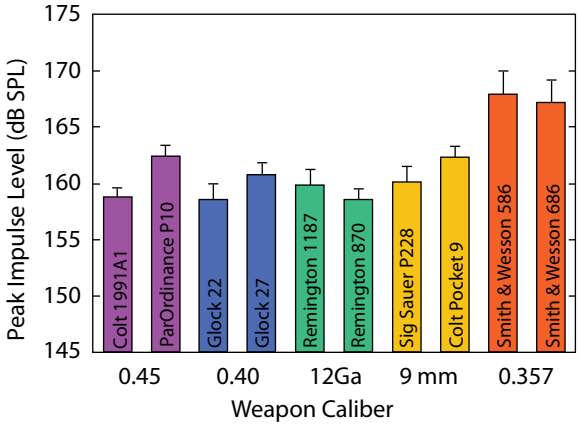

Figure 4. Peak noise levels from various small firearms.

CONCLUSIONS

The case reports described in this Alert suggest that employers, workers, and the general public may have an increased likelihood of exposure to lead through inhalation, skin contamination, and ingestion, and therefore the increased risks associated with the potential toxic health effects from lead. Numerous factors and routes of exposure can contribute to workers' and patrons' exposures to lead. Environmental factors include the type of ventilation system used at the firing range, the types of ammunition used, and the length of time that shooting occurs. Exposure risk factors include the type and frequency of work practices conducted at the range, particularly those involving cleaning the firing range and other maintenance activities.

As demonstrated by the case studies, proper ventilation, good housekeeping practices, and basic personal hygiene practices will limit or eliminate the risk of lead exposure.

In addition to lead exposure, the discharge of firearms produces peak noise levels that exceed the occupational health limits of 140 dB SPL. The case studies illustrate the need to assess impulse noise exposure correctly by using proper sound measuring instruments and techniques, and the importance of using double hearing protection while shooting as part of an overall hearing conservation program.

Potential health problems from exposure to lead and noise can be reduced or prevented by following the recommendations outlined in this Alert.

RECOMMENDATIONS

Controlling exposures to occupational hazards is the fundamental method of protecting workers. Traditionally, NIOSH uses a hierarchy of controls as a means of determining how to implement feasible and effective solutions to reduce or eliminate workplace hazards. One representation of this hierarchy can be summarized as follows:

- Elimination or substitution

visited on 1/19/2017

- Engineering controls
- Administrative controls
- Personal protective equipment

Control methods high on the list above are potentially more effective and protective than those appearing lower. Following the hierarchy normally leads to the implementation of inherently safer systems that substantially reduce the risk of illness or injury. The *elimination and substitution* control methods are most effective at reducing hazards, but they are also the most difficult to implement within an existing process. If the process is still at the design or development stage, elimination and substitution of hazards might be inexpensive and simple to implement. *Engineering controls* are used to remove a hazard or place a barrier between the worker and the hazard. Well-designed engineering controls can be highly effective in protecting workers and are typically independent of worker interactions. *Administrative controls* and *personal protective equipment* are frequently used with existing processes where hazards are not particularly well controlled.

In addition to the previous control methods, employer and worker education and training are an essential part of any comprehensive management program.

Pursuant to OSHA's lead standard, worker exposure monitoring is covered under 29 CFR 1910.1025(d), and the medical surveillance provisions of the standard are covered at 29 CFR_1910.1025(j). Medical removal protection is covered in paragraph (k).

Controlling lead and noise hazards at indoor firing ranges may present unique and different challenges depending on several factors. These include appropriate design, construction, and maintenance of the range, appropriate and engineered ventilation systems, proper management, adequate and proper housekeeping and personal hygiene practices to limit exposures to lead.

Ammunition substitution

The substitution of less-toxic materials in the workplace is a primary preventive measure in occupational health. The primary sources of lead exposure at indoor firing ranges are lead bullets and cartridge primers. Lead fumes and dust are emitted from the exposed base of an unjacketed bullet due to contact with hot propellant gases and the physical effects of heat and friction acting on the bearing surface of an unjacketed bullet passing through the bore at high velocity. The use of jacketed (both base and bearing surface) or non-lead bullets are shown to reduce lead emissions at the firing range by as much as 80%.

It is important to note that product substitution is not necessarily an effective solution for indoor firing ranges due to certain training restrictions and operational requirements. Issues such as differences in trajectory, unknown reliability, increased cost of non-lead primers and bullets, and increased barrel wear can play a major role in determining whether substitution is a viable solution. Further, mixing spent lead bullets with metals from non-lead alternatives may render the material unfit for recycling and therefore require costly and otherwise unnecessary disposal of the spent ammunition as a hazardous waste.

Firing range operators should consider the following recommendations when assessing ammunition substitution:

visited on 1/19/2017

- Use non-lead primers designed specifically for firing ranges. Cartridges already loaded with non-lead primers are commercially available for the most popular calibers.
- Jacketed or non-lead bullets should be used to help reduce lead exposure [NIOSH 1986; NIOSH 1995].[‡] When selecting copper-jacketed bullets, the firing range operator should ensure that the jacket covers the base and the bearing surface of the bullet. Some "full-metal jacket" bullets (sometimes called "ball ammunition") have a lead-exposed base that is not visible in a loaded cartridge. This type of bullet emits lead fume due to contact with hot propellant gases. Also, some companies manufacture half jacketed bullets that have a lead-exposed bearing surface. These bullets emit lead particles from the mechanical effects of passing through the bore. It is important to note that while some jacketed bullets present no airborne lead hazard, at the firing line, impact with the bullet trap may generate lead dust at the trap. This lead dust may present a source of lead exposure to workers performing range maintenance, cleaning of traps, and removing and disposing of spent bullets.
- Use jacketed lead bullets (as opposed to dip-coated copper plating) to minimize lead exposure in firing ranges. Most commercially available copper coatings are generally too thin or too soft to effectively isolate lead from the firing process.
- Zinc bullets should not be used without a careful assessment of safety hazards caused by their propensity to "bounce back" from the bullet traps in some firing ranges. Also, firing range operators should consider the potential for zinc bullets to damage concrete and steel surfaces in firing ranges. Operators might instead consider using frangible ammunition which can be be ideal for use with steel outdoor targets or portable "shoot houses."
- Firing range operators who depend on using lead substitutes for reducing lead exposure should ensure that firing ranges and firearms previously used with lead ammunition are appropriately cleaned and evaluated before being used in the firing range.
- Electronic simulation systems using guns equipped with lasers can provide an alternative solution for training new recruits in effective gun handling and marksmanship without using live ammunition.

Engineering controls

Ventilation is the most important engineering control for protection against primary lead exposure in indoor firing ranges (Figure 3). Well-designed supply air and exhaust ventilation systems have been shown to control exposures to lead fumes and dust in firing ranges [NASR 2004]. Monitoring and control systems that ensure proper operation of ventilation systems are also important parts of this engineering control. These systems check the operating parameters of the ventilation systems, alert firing range operators, and prevent use of the firing range when systems are not operating within specifications. When automatic control systems are not used to monitor the effective operation of the ventilation systems, OSHA requires that measurements that demonstrate the effectiveness of the systems in controlling exposure, such as capture velocity, duct velocity, or static pressure be made every 3 months. In addition, measurements of

[‡]NIOSH examined potential hazardous exposure to copper and zinc oxide ammunition substitutes and found levels to be far below the OSHA PEL.

visited on 1/19/2017

the system's effectiveness must be made within 5 days of any change in the operation of the firing range, and/or engineering control which might result in a change in employee exposure to lead.

The following recommendations are based on NIOSH research and are intended to show the range of solutions that may be implemented by firing range operators, depending on cost and availability of resources [Crouch et al. 1991].

Lead

Supply Ventilation System Recommendations:

- Ensure that supply air systems are designed to distribute air evenly across the area of the firing range, floor to ceiling and wall to wall. If the supply air is not evenly distributed, air flow at the firing line will likely contain regions of reverse flow, causing lead and other contaminants to be carried back into the shooter's breathing zone.
- Introduce supply air as far up range as possible. A perforated wall plenum has been shown to provide uniform air distribution at the firing line. Perforated radial air diffusers mounted at ceiling height have been tested and demonstrated effective in meeting established industry and regulatory airflow criteria. Diffusers that produce jets of air can create turbulence at the firing line.
- Airflow along the firing line should be no more than 75 fpm (0.381 m/s) with a minimum acceptable flow of 50 fpm (0.254 m/s) [NIOSH 1976]. If it is desired to minimize fall-out of gun emissions downrange of the firing line, downrange airflow should be maintained at a minimum of 30 fpm (0.152 m/s) and should be evenly distributed.
- There should be no obstructions (e.g., target or ammunition storage cabinets) to the airflow between the supply air inlets and the firing line so that the supply air is distributed uniformly across the width (cross-sectional area) of the firing range.

Exhaust Ventilation System Recommendations:

- The total or combined exhaust airflow for the firing range should always be greater than the total supply airflow to ensure the firing range is maintained under negative pressure, and to prevent migration of lead-contaminated air from the firing range to the surrounding environment. Exhausting slightly more air than supplied is a general recommendation for maintaining appropriate negative pressure in the firing range. If the building envelope is not sealed, negative pressure within the building can create undesirable drafts through unplanned air pathways entering through openings in the building structure. These drafts can result in back flow at the firing line, which defeats the purpose of the ventilation system. Unplanned pathways can also result in a higher mechanical operating cost (requiring additional heating or air-conditioning). The magnitude of the negative pressure should be just sufficient to produce an inflow of air at openings such as windows and doors between the firing range and adjacent areas or surrounding environment. This can easily be evaluated using a chemical smoke tube to visually evaluate pressurization at doors, windows, etc. that are slightly open to the flow of air.

visited on 1/19/2017

- The air should be exhausted at or behind the bullet trap. Some firing ranges are designed to have multiple exhaust points downrange to maintain downrange flow and desired velocities at the firing line.
- The exhaust system should be designed to provide minimum duct air velocities of 2500–3000 fpm (12.7–15.24 m/s) (*Industrial Ventilation Manual*, 24th Edition, Table 3–2) [ACGIH 2004]. Excessively high duct velocities are unnecessary, waste energy, and may cause rapid abrasion of ductwork.
- The ventilation system that serves the range area should be completely separated from any ventilation for the rest of the building. The exhaust air from the range should not feed into air supplies for offices, meeting rooms, or other businesses.

Air Filtration Recommendations:

- All air filtration systems should be installed in a location where they can be easily serviced.
- Air exhausted from the firing range should be appropriately filtered or the area near the outside vent be managed to prevent access and lead mobility in accordance with EPA best management practices [EPA 2005]. If lead-contaminated air is released outside the building and left unmanaged, the exterior walls of the building and surrounding grounds and waterways can become contaminated. Lead released outdoors can be re-aerosolized and result in subsequent contamination of the firing range or other buildings, and present unwanted hazards to humans if the range is in a populated area.
- The minimum filtration recommended is high-efficiency particulate air (HEPA) filtration or a minimum efficiency reporting value (MERV) of 18–19. The Institute of Environmental Sciences and Technology specifies that a certified HEPA filter must capture a minimum 99.97% of contaminants at 0.3 micron in size. This filter specification is also endorsed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).
- All filters potentially exposed to lead-contaminated air should be equipped with side and face gaskets to eliminate filter bypass, and air passing between the filters and the filter racks. Filter racks should also be engineered and tested to ensure that leaks do not occur after installation.
- The filtration system should be located as close to the firing range as possible to minimize the distance that lead dust needs to travel in the exhaust system before it passes through the filter. Filter systems should always be located upstream of the exhaust fan to prevent contaminating the fan with lead.

Filter System Maintenance Recommendations:

- Filter end-of-service life is indicated by a high-pressure drop (more resistance to air flow) across the filter bank. Filters should be changed according to the static pressure guidelines provided by the manufacturer. Since pre-filters are the first to encounter contaminated exhaust air from the firing range, they will load fastest. Therefore, pre-filters require more frequent change-outs than HEPA-rated filters.
- Filter change-out should be performed by personnel trained in the removal and disposal of dirty filters and in lead safety. They should use appropriate personal protective equipment and environmental precautions. Loaded filters will likely contain lead in sufficient quantity to classify

visited on 1/19/2017

the used filter as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) (40 CFR 260–279). A Toxicity Characteristics Leaching Procedure (TCLP) test will determine whether the filter is a regulated hazardous waste under the RCRA regulation. If the filter does not meet the criteria of a hazardous waste, it can be disposed of as normal solid waste. However, if the filter does have sufficient lead to be considered a hazardous waste, there are two options: first is to recycle or reuse the filter, in which case it is not considered a waste (RCRA recycling exemption 40 CFR 261.4(a)(13)) and there are no hazardous waste handling procedures required. If the filter is not recycled, and it fails the TCLP, then it must be transported and disposed of properly in accordance with Federal, State and local regulations.

Control System Recommendations:

- A warning light should be added to warn shooters and the firing range operator that a critical system has been inactivated by a safety interlock system. Modern computer-operated firing ranges can incorporate specific warning indicators in the computer programming.
- Exhaust and supply fans should be interlocked so that all fan systems operate at the same time during active range use. Air flow from the fans should be monitored and interlocked with a critical firing range operating system to disable the firing range and alert the firing range officer when the air flow from any fan is inadequate.
- Filter access doors should be interlocked with the fan system to deactivate the fans when the door is opened.
- Pressure gauges on HVAC systems should be maintained and calibrated regularly.
- The pressure drop across each filter should be monitored and checked regularly.
- Exhaust air from the firing range should not be recirculated back into the range when economically feasible. However, exhaust air may be recirculated if a real-time particle detection system is installed downstream of the filter system. It must be demonstrated that the particle detection system is sensitive enough to detect any aerosol size range and number concentration combination of lead particles that might exceed the OSHA PEL. ANSI/ASHRAE Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality, [ANSI/ASHRAE 2007] provides dilution ventilation guidelines for recirculating clean and breathable air in an energy-efficient manner.

Noise

Effective noise control measures are imperative to reducing noise-induced hearing loss among firing range operators, employees, and users. It is important to understand that noise control of high intensity impulse sounds might help reduce overall noise levels inside a firing range and adjacent facilities, but it has limited effect on the noise exposure of the person firing the weapon. There is no noise control that alleviates the requirement for wearing hearing protection because the primary source of noise exposure is the weapon itself. Noise control measures should be compatible with ventilation requirements and meet fire and building codes. Noise controls typically address the primary two components of noise transmission—airborne and structural-borne sounds:

- To reduce transmission of airborne sounds, no leaks can exist between the firing range and adjacent spaces. Small openings such as electrical outlets, spaces around doors, and joints at the walls,

visited on 1/19/2017

ceiling, and floor should be sealed with insulation and/or weather stripping as needed. Ventilation ducts that provide a direct acoustic path into adjacent spaces can be fitted with acoustic absorptive materials, both to remediate vibrations in the walls of the duct and to absorb noise transmitted along the duct. Special care must be paid to the maintenance and handling of acoustic absorptive materials to prevent lead dust accumulation. The design of walls can minimize transmission of airborne sounds through combinations of gaps, absorptive materials, and different wall thicknesses.

- To reduce the transmission of structural-borne sounds and vibration, acoustical absorptive materials should be applied to walls, windows, doors, ventilation ducts, and ceilings. Use special care when applying acoustical absorptive materials to prevent them from damage or becoming dust-laden. Typical metal or wooden stud construction has wall cavities that can be filled with insulation material. Walls that separate the firing range from adjacent parts of the building should be double thickness with offset studs. They should provide an air gap as well as insulation on the inside of one of the walls. The interior surface of firing range walls should be treated to minimize absorption of airborne particulates, to make cleaning easier, and to resist lead and nitrate penetration. Doors should be made of metal with a foam core to reduce vibration caused by impulsive noise. The entrance to the firing range should be a 4–6 foot passageway with self-closing doors at both ends. The passageway provides an additional gap to reduce noise emissions. Observation room windows should be designed to withstand bullet impacts and to maximize sound reduction. The glass should be laminated and certified as bullet-impact resistant. If double panes of glass are used, then the glass that is in the firing range should be bullet-impact resistant and of a different thickness than the interior pane to increase noise reduction.

Recently, state-of-the-art systems and training equipment designed to reduce lead and noise exposures have been introduced and are gaining wide acceptance among firing range operators and law enforcement agencies. Specifically, new backstop systems are available that eliminate bullet fragmentation and airborne lead by capturing whole, intact bullets into their rubber media. These backstops also reduce noise exposures compared to steel backstops.

Work practice and administrative controls

When engineering controls are not feasible or are inadequate, supplemental work practice and administrative controls may be needed to limit noise and lead exposures. Work practice controls are procedures or actions firing range users can take themselves to ensure their own safety and health. Administrative controls, on the other hand, are those generally implemented by management or firing range operators to safeguard the shooters. The following work practice and administrative recommendations are offered:

Preventing the potential for lead exposure by ingestion and by avoidance of skin contamination and appropriate decontamination

- Eating, drinking, and smoking should be prohibited in the firing range.
- All personnel should wash their hands, forearms, and faces before eating, drinking,

visited on 1/19/2017

smoking, or having any hand contact with the face or with other people. Hands should be washed with soap and water or cleaned with lead decontamination wipes after shooting, handling spent cartridge cases, or cleaning weapons. Wipes for cleaning skin without water are commercially available and should be used if access to soap and water is limited.

- Skin contact with spent cartridges should be avoided whenever possible. Disposable gloves should be worn when removing larger objects that cannot be removed with a HEPA vacuum cleaner.
- Floor and horizontal surfaces inside the firing range should be cleaned routinely with a detergent, or in some specific and tough cases, a cleanser designed for lead decontamination. EPA studies show that general all-purpose cleaners are adequate for both general cleaning and post-intervention cleaning [EPA 1997, Lewis et al. 2006].

Reducing lead contamination inside the firing range

- The ventilation system should be operating at all times while the firing range is in use and during clean-up.
- The firing range operator should require that all shooters immediately discontinue shooting and place their weapons in safe mode whenever the firing range operation is inactivated by a monitor. All non-essential persons should leave the firing range until the problem is fixed.
- Carpeting should not be used anywhere inside a firing range or in rooms adjacent to the range. Accumulation of lead dust in carpets is a health hazard, and accumulation of unspent primer in carpets is a fire hazard.
- The firing range should be equipped with automatic target retrieval systems to allow shooters to examine their performance without crossing the firing line.
- After use, the floor of the firing range should be thoroughly cleaned with an explosion-proof HEPA vacuum cleaner designed to collect lead dust. Dry sweeping should never be used in the firing range.

Preventing “take-home” lead exposure

- Shooters using a kneeling or prone position over lead contaminated surfaces should place a sheet of paper or other disposable material on the ground beneath them to minimize accumulation of leaded dust on their outer garments. Knee pads or mats may be used to reduce lead contamination but they should be cleaned after each use.
- Shooters and workers should shower, whenever possible, and change clothes at firing range facilities after shooting or performing maintenance or cleaning activities at the range.
- Provide workers with two lockers to allow them to separate street clothes from lead-contaminated work clothes.
- Workers’ non-disposable outer protective clothing should be laundered by the employer or a contractor. It should not be laundered by the employee at home. Non-employees who take contaminated clothing home should bag the clothes before leaving the range. Contaminated clothing should be washed separately from the family’s clothing.
- Leave shoes worn on the firing range at the range or bag them before leaving the range to prevent lead from being tracked into cars and onto home floors

visited on 1/19/2017

and carpets. As an alternative, use step-off cleaning pads at the exit of the firing range to help reduce the amount of lead contamination on shoes. Disposable shoe coverings can also be used while firing and cleaning, then discarded upon leaving the range.

Administrative control of noise and lead exposure can be accomplished by limiting the length of time shooters and employees use the firing range, by assignment and work rotation, and by providing quiet and clean lunch and break areas to give periodic relief from noise. The firing range should also be cleaned at least weekly.

Personal protective equipment

Provide personal protective equipment to workers and indoor range users to protect against the potential effects of exposure to lead and noise.

- All workers and shooters should be required to use dual hearing protection devices (earmuffs and earplugs) when the range is in use. For shooters requiring improved communication, NIOSH recommends using electronic level-limiting or sound restoration earmuffs with passive earplugs. In addition to the electronic earmuffs, commercially available communication headsets exist that would permit the range master to transmit instructions via short range radio to the shooter's headset. Shooters should also be encouraged to wear eye protection in the form of safety glasses or goggles that are compatible with hearing and other head protection devices. NIOSH research has shown that wearing earmuffs on top of safety glasses created a leakage in the seal of the earmuff cushions with the ear and reduced the effectiveness and peak noise level reduction of the earmuffs. NIOSH recommends that shooters wear the safety glasses over the top of the earmuff cushions, or use glasses with a strap or low profile stem. Ideally, the safety glasses should be an integral part of the earmuff or other head protection devices. A training program in the appropriate use and fitting of hearing and eye protection should be implemented by firing range training staff.
- Personnel performing lead clean-up at the trap should wear appropriate NIOSH-certified respiratory protection and full protective outer clothing (which may be disposable). If respirators are part of the lead management plan, firing range operators must develop and implement a respiratory protection program that meets the requirements of the OSHA respiratory protection standard [29 CFR 1910.134] and document it in writing.
- Personnel cleaning weapons should be encouraged to use chemical-resistant gloves and tight-fitting goggles for skin and eye protection against potential chemical hazards. Range operators should provide specific guidance about proper and appropriate use of skin and eye protection.

Employer and worker education

Firing range operators and employers should be fully aware of the potential for hazardous lead and noise exposures in their facilities, and they must communicate this information to workers to ensure safe and healthful working conditions.

- Inform workers about the potential for exposure to lead, noise, and other toxicants and tell them the nature of the hazard.

visited on 1/19/2017

- Provide general information and specific hazard warnings through workplace postings, training, and stating the precautions and hygiene practices required of firing range users.
- Train workers regarding the means available at the firing range to eliminate or limit exposure and the actions that limit potential exposures for themselves and fellow workers.
- Inform workers about symptoms that may indicate a health problem. Although not all exposed workers may show overt symptoms, common symptoms of lead poisoning in adults include nausea, diarrhea, vomiting, poor appetite, weight loss, anemia, excess lethargy or hyperactivity, headaches, abdominal pain, and kidney problems. Exposure to high noise levels can cause hearing problems, stress, poor concentration, insomnia, nervousness, anxiety, and depression. It can also cause accelerated heartbeat, high blood pressure, gastro-intestinal problems and chronic fatigue. Employers should advise employees to report these symptoms to their supervisors and physicians.
- Inform pregnant workers and shooters, or those considering pregnancy, about the possible adverse health effects to the fetus from exposure to lead and noise. A fetus can be poisoned in utero. Studies show that fetal blood contains approximately 80% of the blood lead concentration of the mother. Pregnant workers and shooters, or those considering pregnancy, also need to know about the increased chance of miscarriage at blood lead levels $> 5\ \mu g/dL$. Evidence also suggests that exposure to peak sound pressure levels above 155 dBC can cause hearing loss in the fetus beyond the fifth month of pregnancy. The evidence of whether the particular noise exposure associated with firing ranges is harmful to the developing fetus and warrants removal of the pregnant woman from exposure is ambiguous. This issue is further complicated because female workers may be exposed to lead and noise even before they know they are pregnant. Firing ranges might wish to establish guidelines for pregnant workers exposed to lead and noise.

Worker exposure and medical health monitoring

OSHA's lead standard requires each employer who operates a firing range to determine if any workers may be exposed to lead at or above the action level ($30\ \mu g/m^3$ as an 8-hour TWA). Worker exposure is defined as that exposure which would occur if the workers were not using a respirator.

The results of initial and periodic monitoring determine whether subsequent monitoring is necessary. Monitoring also determines whether other protective provisions of the standard need to be implemented.

If the initial determination or subsequent determinations reveal workers' exposure to be at or above the action level but at or below the PEL, the employer is required to perform monitoring at least every 6 months. If the initial determination reveals that workers' exposure is above the PEL, the employer must perform monitoring at least quarterly. If any worker is determined by the initial monitoring to be exposed to lead below the action level, then no further monitoring is required for that worker, except where firing range operations or controls change that could result in additional exposure.

visited on 1/19/2017

Exposure monitoring

- Monitoring procedures should be specifically defined to ensure consistency. Instrumentation, calibration, measurement parameters, and methods for linking results to worker records should be clearly outlined.

- Exposure assessment should be conducted under the direction of a certified industrial hygienist or other safety and health professional with appropriate training and expertise.

- Workers should be permitted and encouraged to observe and participate in monitoring activities as long as they do not interfere with monitoring procedures. Their participation will help ensure valid results.

- Monitoring should be repeated periodically to ensure continued effectiveness of worker protection measures and to help identify changes in noise controls, work practices, equipment, and maintenance procedures.

- Perform wipe sampling on surfaces in the firing range on a regular basis. Wipe sampling can provide information about how well these surfaces are being cleaned, whether lead is being transported from the firing range to other parts of the facility, and about the potential for lead exposure. See information about the NIOSH wipe sampling methods in *Current Regulations, Recommendations, and Other Guidelines* section of this Alert.

- Employers should notify workers of any hazardous exposure levels determined for their particular jobs and provide information about the health risks associated with such exposures.

Worker health monitoring

Blood lead levels are currently the best indicator of personal lead exposure. Workers potentially exposed to lead should therefore be monitored for the presence of lead in blood. This assessment is necessary to ensure that engineering controls, personal hygiene practices, and PPE are preventing lead exposure. It is recommended that the employer's medical monitoring program be supervised by a physician trained and experienced in occupational medicine.

- The OSHA general industry lead standard contains provisions for the medical monitoring of workers exposed to lead (29 CFR 1910.1025(j)). NIOSH supports using these provisions for firing range workers, especially those who routinely use or work at these ranges, but acknowledges that current understanding of health risks associated with lead exposure may require updated/additional provisions for medical surveillance. Recommendations from the March 2007 edition of Environmental Health Perspectives' Mini-Monograph on adult lead exposure and from the Association of Occupational and Environmental Clinics (AOEC) include the following elements:

  - Informing workers and shooters that levels of lead once thought safe are now known to be harmful. Advise that blood lead levels be kept below 10 μg/dL of blood.

  - Informing pregnant workers and shooters, or those considering pregnancy, about the possible adverse health effects to the fetus as well as the increased chance of miscarriage at blood lead levels > 5 μg/dL.

visited on 1/19/2017

- Workers should be included in a medical surveillance program whenever they are handling or distributing materials with lead content that could potentially cause exposure through inhalation or ingestion.
- New employees and those newly assigned to work in areas with potential lead exposures should have a preplacement lead medical examination and a BLL test, followed by periodic BLL monitoring, blood pressure testing, and health status review.
- Monthly BLL testing is recommended for the first three months of employment in order to assess the adequacy of exposure control measures.
- Testing frequency can be reduced to every six months as long as BLLs remain below 10 μg/dL or quarterly for individuals with blood lead concentrations between 10 and 19 μg/dL.
- Any increase in BLLs of 5 μg/dL or greater should trigger a re-examination of control measures.
- Workers with BLLs of 30 μg/dL or more, or ones with a sustained BLL above 20 μg/dL should be removed from lead exposure.
- All lead-exposed workers should receive, annually, educational materials and prevention information about the health effects of exposure to lead from a clinician and the employer, and they should be provided necessary protections including protective clothing, clean eating areas, and hygiene measures such as wash facilities and/or showers to prevent both ingestion and take-home exposures.

- The OSHA noise exposure standard (29 CFR 1910.95(d)(e)(g)(h)) requires the employer to establish a monitoring program and provide audiometric testing to all employees whose exposures equal or exceed an 8-hour TWA of 85 dBA under the action level monitoring criteria. All workers with regular exposure to weapons firing should undergo annual audiometric monitoring at test frequencies of 500, 1000, 2000, 3000, 4000, and 6000 Hz. Annual audiograms should be compared to a baseline audiogram to determine if hearing loss is occurring. If a standard threshold shift (STS), defined as a change in the pure-tone average of more than 10 dB at 2000, 3000, and 4000 Hz, occurs in either ear, the employer must follow certain procedures outlined in the standard, including notifying the affected employee in writing. Occupational exposure to lead can have an additive or potentiating effect on the auditory system and increase the potential for hearing loss. Pure-tone audiometric testing may conceal certain hearing difficulties caused by exposure to lead or other chemicals. Professionals who review the audiometric results should be alerted to this issue and should consider a referral for further testing and medical evaluation [Morata, 2007].

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visited on 1/19/2017

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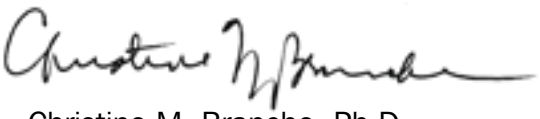

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