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INDEPENDENCE POLICE DEPARTMENT INDOOR RANGE
INDEPENDENCE, MISSOURI

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I. SUMMARY

On February 14, 1990, the National Institute for Occupational Safety and Health **(NIOSH)** received a request from a management representative of the Independence, Missouri, Police Department Headquarters for a Health Hazard Evaluation. The Police Department requested NIOSH to evaluate the effectiveness of a newly redesigned air handling system installed inside their indoor firing range.

On August 6, 1991, NIOSH investigators met with the firing range supervisor and toured the facility. On August 8, ten personal breathing-zone (**PBZ**) air samples and 3 area air samples were collected on filters inside the range and the filters were subsequently analyzed for lead by atomic absorption spectroscopy **(AAS)**. Surface lead contamination inside the firing range was measured in two locations and hand **(dermal)** lead contamination was measured on two instructors and two field officers. These samples were also analyzed for lead by AAS.

Eight shooters and two range officers were found to be exposed to airborne lead concentrations ranging from 132 to 254 micrograms of lead per cubic meter of air **($\mu g/m^3$)** during a 70 minute firearm training exercise. These levels correspond to 8-hour time-weighted average lead concentrations (assuming there is no other lead exposure throughout the day) ranging from 20 to 38 $\mu g/m^3$. The OSHA standard is 50 $\mu g/m^3$, averaged over an 8-hour workday, 40-hour work week. General-area samples measured airborne lead concentrations in the range of 152 to 342 $\mu g/m^3$. Desk surfaces inside the range were heavily contaminated with lead, with levels measured up to 10,330 micrograms of lead per square meter of surface **($\mu g/m^2$)**. Lead was also detected on hands of employees, up to 740 μg/2-hands.

On August 9, 1991, a smoke generator was used to evaluate air patterns at several locations inside the firing range; the flow patterns were recorded on video tape. Additionally, specific design features and flow parameters were measured in the ventilation system and recorded. The smoke generator revealed back flow eddies throughout the range, especially at the firing line, indicating the newly redesigned air handling system was not effectively removing lead from PBZs.

On the basis of the data obtained in this investigation, NIOSH has determined that a potential hazard from overexposure to lead via inhalation and ingestion did exist at the Independence, Missouri Police Department Indoor Firing Range at the time of this investigation. Furthermore, the potential problems of "take-home" lead contamination are discussed (para-occupational exposure) that may expose young children to lead. Recommendations for modifications to the firing range's ventilation system and for the safe use of the range are offered in Section VIII of this report (please see pages 15-18).

KEYWORDS: SIC 9221 (Police Protection), indoor firing ranges, inorganic lead, ventilation system design, engineering controls, wipe sampling, para-occupational exposure, copper-jacketed bullets.

II. INTRODUCTION

On February 14, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation from the Independence, Missouri, Police Department Headquarters. The Police Department requested NIOSH to evaluate their newly redesigned indoor firing range. The requestors were concerned about exposures to lead during handgun qualifying sessions and the possible health hazards associated with these exposures.

On August 8, 1991, NIOSH investigators collected environmental samples for airborne lead, surface lead and hand lead contamination, during a 70 minute handgun training activity. On August 9, 1991, a ventilation survey was conducted.

III. BACKGROUND

The Independence, Missouri, Police Headquarters was constructed approximately twenty years ago. Part of the facility includes an indoor firing range. About ten years ago, after the city discovered a serious lead contamination problem had developed inside the firing range, a decision was made to close the range. The lead contamination problem was made evident by high blood lead levels (**BLLs**) measured in the firing range instructors. The range remained closed until 1988, when a contract was awarded to an engineering firm to redesign and install a new air handling system. In the same year, after the renovations were completed, the range was reopened. Shortly thereafter, the Police Department requested NIOSH to evaluate their new air handling system.

A. Firing Range Description

As shown in Figure I, the firing range is 96 feet long by 18 feet wide. The range has five firing lanes, which are 75 feet long. An enclosed control booth, that is ventilated by an independent air handling system, is also located in the range. Ceilings are 8 feet high behind the firing line and 20 feet high downrange.

The bullet trap, Detroit Bullet Trap Corporation Model 2400S, consists of angled steel plates that deflect bullets into steel pans.

B. Firing Range Ventilation System

The firing range ventilation system includes 5 supply air registers (each 13.5" x 29.5") mounted in a bulkhead next to the ceiling, 10 feet behind the firing line. Air is exhausted from the range through two 36" x 16" exhaust grilles located directly above the bullet trap. All of the exhaust air is passed through high efficiency particulate air (**HEPA**) filters and exhausted outside. The maintenance and cleaning of the ventilation system is performed by an outside contractor. A differential pressure sensing system, connected to an indicator light located inside the control booth, notifies the range instructor when filters need to be changed. Annual filter changing is the average for this department.

C. Firing Range Instructors Activities

The primary range instructor operates movable, track targets and delivers verbal commands from the control booth, while a secondary instructor works on the floor directly behind the shooters during training and qualification exercises. Seven other officers are rotated as secondary instructors to minimize individual lead dose. Each secondary instructor works in the firing range about one week per year. The one primary range instructor works in the range more frequently (usually whenever the range was in use).

D. Firing Range Use

On a routine basis, the firing range is used for continuing quarterly and semi-annual qualification sessions, each lasting 45 minutes to one hour with 2-4 police officers firing 100 rounds each. Off-street police officers are required to complete handgun refresher training classes three times per year, each lasting about 30 minutes with 50 rounds fired. Other non-routine practice includes shooting from behind removable barricades located downrange of the booths.

It is the responsibility of the shooters to clean the range after each session. The firing range is swept with a broom after shooting is completed, with the ventilation system running, by one or all of the shooters to collect the spent shells and to remove the target pieces scattered on the floor.

On the day of the NIOSH environmental sampling survey, the range was used for a transitional handgun training session. Police officers were trained and instructed in the use of newly issued Sig Sauer P220 45-caliber semi-automatic handguns. This transitional training represents a "worst case" scenario in regards to the normal weapon firing load. Approximately 1200 rounds were fired by the eight police officers during the 70 minute training exercise. This represents 3 to 10 times the normal firing load.

Handgun firing during this session was almost continuous, with 8 officers alternating shooting positions in four firing lanes, two officers per lane. While waiting for their turn to shoot, the officers remained inside the firing range behind the safety line (see Figure I). The secondary range instructor remained positioned continuously between the safety line and the firing line, directly behind the shooters. The primary range instructor operated from within the enclosed control booth.

Forty-five caliber copper-jacketed, 230-grain Hard Ball ammunition was used inside the firing range during this health hazard evaluation. The police department uses only copper-jacketed ammunition in the indoor range. The use of copper-jacketed bullets has been shown to reduce airborne lead fume generated from the bullet as it travels down the barrel.[(1)]

Ear muffs and safety glasses were donned by all personnel inside the firing range, while shooting was in progress.

E. Firing Range Medical Surveillance

The Police Department collected baseline BLLs on the range instructors prior to reopening the range, and continued to monitor BLLs at four-month intervals. Last year (July 1, 1991), because baseline BLLs have remained stable, testing frequency was reduced to annual measurements.

IV. EVALUATION DESIGN AND METHODS

The environmental measurements made during this survey included: A.--both personal breathing-zone (**PBZ**) and area air samples, collected and analyzed for lead by NIOSH Method 7082,[2] B.--surface lead samples, collected using a U.S. Department of Housing & Urban Development (HUD) approved sampling method,[3] and C.--hand (dermal) lead samples. There is no "standard" hand sampling technique as yet; however, the literature describes similar procedures used in various research projects.[4-9] It should be noted, both the surface and hand wipe sampling techniques are, at best, semi-quantitative measures of lead contamination, and the amount of lead detected is not necessarily indicative of the quantity of lead entering the body.[8]

PBZ air samples were collected during handgun firing instruction from eight police officers and two instructors engaged in the transitional handgun course. Area air samples were collected at three locations during the use of the range: 1) on the target table between the safety line and the firing line, 2) on the desk between the back wall and the safety line, and 3) on the control panel next to the phone inside the control booth. Surface wipe samples were collected on high contact surfaces where two area samples were located, samples 1 and 3 above. Four hand-wipe samples were collected from two officers before they washed their hands and two officers after they washed their hands.

Ventilation design specifications were reviewed and the system was visually inspected for proper function. Air currents in the firing range were observed and video taped, with the aid of a Roscoe Model 8500 Fog Machine™, in numerous locations throughout the range.

A. Air Sampling

Samples for airborne lead were collected on 0.8 micrometer (µm) pore size cellulose ester membrane filters connected via Tygon® tubing to battery powered sampling pumps calibrated to provide a volumetric airflow rate of 2.5 liters per minute (lpm). After collecting the samples, the filters were ashed with nitric acid and then quantitatively transferred to 25-milliliter (ml) volumetric flasks and analyzed by atomic absorption spectroscopy (AAS), (NIOSH Method 7082[2]). The limit of detection (LOD) was 2 µg/filter and the limit of quantitation (LOQ) was 6.3 µg/filter.

B. Surface Sampling

Surface wipe samples were collected using commercial pre-moistened baby wipes (Wash a-bye Baby™). Wipe samples were collected on hard flat desk surfaces, from an area measuring 30.5 X 30.5 centimeter (cm) (929 cm^2). Then, disposable gloves were put on, the first wipe from the package was discarded, the second wipe was handled for an imaginary (approximate) sampling time and placed in a clean labeled Zip-Loc™ bag (this is a sample blank), the third wipe was folded in half and placed on the surface to be sampled. The wipe was rubbed in an "S" pattern over the entire measured area, then refolded with the dust side in, rubbed in an "S" pattern again, at a 90° angle to the first "S" pattern, refolded and rubbed over the surface a third time, in the same direction as the first. The wipe was then folded and placed in a clean labeled Zip-Loc™ bag. To reduce possible cross-contamination, the disposable gloves were discarded after each sample. The wipe samples were analyzed for lead by NIOSH Method 7082(2), with modifications to accommodate the sample type. The samples were ashed with 9 milliliters (**ml**) nitric acid and 3 ml hydrogen peroxide. The samples were then heated on a hotplate to near dryness in order to complete digestion. Samples were then quantitatively transferred to 50 ml volumetric flasks and analyzed by AAS. The LOD and LOQ were 4 μg/wipe and 13 μg/wipe, respectively.

C. Hand Sampling

Hand wipe samples were collected by discarding the first wipe in the package and asking the employee to pull the second wipe from the package. The employee was instructed to thoroughly wipe both hands for one minute, after which time the employee placed the used baby wipe into a clean labeled Zip-Loc™ bag. It was not necessary to wear gloves during this procedure because the sample wipe only came in contact with the employee. The hand wipe samples were analyzed identically to the surface wipe samples.

D. A Roscoe Fog Machine™ (MN 8500) was used to visualize the airflow patterns in the range. This machine generates a non-toxic, visible aerosol (referred to as smoke for this report) into the air. The smoke is generated from a proprietary mixture of three glycols and water.

The smoke machine was placed on the shelf in the booths and on the floor beneath the shelf. At each location, smoke was released until a determination was made that the smoke backflowed uprange or flowed downrange.

V. EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure which most workers may be exposed up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. It is; however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage of workers may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects, even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes; and thus, potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of the environmental evaluation criteria for the workplace are: 1) NIOSH criteria documents and recommendations, including recommended exposure limits (RELs), 2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs). In evaluating the exposure levels found in this report, it should be noted that the company is required by the OSHA to meet those levels specified in an OSHA standard. A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday.

A brief discussion of the toxicity and evaluation criteria for inorganic lead is presented as follows.

1. Lead Toxicity

Inhalation (breathing) of lead dust and fume is the major route of lead exposure in the industrial setting. A secondary source of exposure may be from ingesting (swallowing) lead deposited on skin, food, cigarettes, or other objects. Once absorbed, lead is excreted from the body very slowly. Absorbed lead can damage the peripheral and central nervous systems, gastrointestinal system, kidneys, reproductive system, hematopoietic system (blood forming organs, mainly bone marrow), and virtually all other systems of the body.[10] These effects may be manifested as weakness, tiredness, irritability, reduced intelligence, slowed reaction times, abdominal pain, or high blood pressure.[11] Chronic lead exposure can cause infertility, kidney damage, and, in pregnant women, fetal damage manifested as prematurity, reduced birth weight, reduced red blood cell production, and reduced intelligence.[12-16] The blood lead test is one measure of the amount of lead in the body and is the best available measure of recent absorption. The mean blood lead level (BLL) for U.S. men between 1976 and 1980 was 16 micrograms per deciliter (µg/dl);[17,18] however, with the implementation of lead-free gasoline and reduced lead in food, it is predicted that the 1991 average BLL of U.S. men will decrease to below 9 µg/dl.[10]

2. Medical Exposure Criteria

The OSHA lead standard (29 CFR 1910.1025) requires semi-annual blood lead testing for employees who are or may be exposed to lead above the action level (30 µg/m^3) for more than 30 days per year.[19] If an employee's BLL is at or above 40 µg/100 grams of whole blood (approximately equivalent to 40 µg/dl),[20,21] the employee must have his or her blood lead checked every 2 months. If an employee's BLL averages 50 µg/100 grams of whole blood or more, he must be removed from areas containing more than 30 µg/m^3 airborne lead, and have monthly blood lead tests.[19] For employees removed from lead exposure, the OSHA lead standard requires the employer to maintain the earnings, seniority, and other employment rights and benefits of an employee as though the employee had not been removed.

For an employee to return to work in an area with excessive lead exposure, their BLL must be below 40 µg/100 grams of whole blood on two consecutive tests.[19] The blood samples must be analyzed by a OSHA-approved laboratory.[22]

Zinc protoporphyrin (ZPP) levels measure the effect of lead on the red blood cell enzyme ferrochelatase, the last enzyme involved in the process of heme synthesis. In men, ZPP levels increase abruptly when BLLs rise above 35 µg/dl, and they tend to stay elevated for several months.[23] In women, ZPP levels rise at BLLs of 25 µg/dl. Most laboratories consider 50 µg/dl ZPP the upper limit of normal.[24]

3. Occupational Exposure Criteria

The current OSHA lead standard (29 CFR 1910.1025) establishes a PEL for airborne lead of 50 µg/m^3, calculated as an 8-hour TWA, for daily exposure. The standard also specifies that if more than 8 hours is worked in any workday, the PEL should be adjusted accordingly, e.g., the PEL for a 10-hr workday is 40 µg/m^3.[19] Additionally, the OSHA lead standard establishes an "action level" of 30 µg/m^3 as an 8-hour TWA, which initiates several requirements of the lead standard, including periodic exposure monitoring, medical surveillance, training and education. If "there is a potential exposure to airborne lead at any level" the OSHA lead standard also requires that employers inform their employees of the content of Appendices A and B of the OSHA lead standard (1910.1025).[19] Appendix A is a summary of the toxic effects of lead and Appendix B is a summary of the key provisions of the lead standard that the worker should be familiar with. If the initial determination shows that any employee's 8-hour TWA PBZ air sampling results are above 30 µg/m^3, air monitoring must be performed every six months until the results show two consecutive levels of less than 30 µg/m^3 (measured at least 7 days apart). NIOSH is currently evaluating the health effects of lead to determine if new exposure criteria are warranted.

For lead contamination on surfaces, the U.S. Department of Housing and Urban Development (HUD) has set clearance levels to be achieved after a lead-based paint abatement.[3]

Floors: 200 µg/ft^2 (2150 µg/m^2)
Window sills: 500 µg/ft^2 (5380 µg/m^2)
Window wells: 800 µg/ft^2 (8600 µg/m^2)

These clearance levels are feasibility based, and are presented in this report as reference points to compare data collected during this survey to data collected elsewhere. The HUD clearance levels for surfaces should not be used to discern health hazards.

VI. RESULTS AND DISCUSSION

A. Air Samples

Table I presents PBZ air sample results for officers in the range during the shooting period, sample times ranged from 67 minutes to 87 minutes, and are graphically illustrated by location in Figure II. The person with the highest exposure to airborne lead was the secondary instructor (behind shooters, 254 $\mu g/m^3$). This high result reflects the position of the secondary instructor, remaining directly behind the shooters, between the safety line and the firing line for the duration of the transitional training course. The 8 officers being trained fired handguns, four at a time, while the officers not shooting stood at the back of the range. Airborne lead levels were lower near the back wall of the range than directly behind the firing line.

The lowest PBZ air sample was measured on the primary range instructor (control booth, 132 $\mu g/m^3$). Although this exposure is lower than the others, it raises concern for two reasons: 1) the control booth should have no airborne lead, because it has a separate ventilation system, and 2) the primary range officer works more frequently inside the firing range, as compared to other individuals. Therefore, cumulative lead dose absorbed by the primary range instructor is potentially greater than in other individuals.

Table II summarizes the PBZ data, breaking it down by firing lane number, with results converted to 8-hour TWAs. All samples were less than the OSHA PEL of 50 $\mu g/m^3$, (calculated by multiplying the airborne lead concentration measured by the sampling time [in minutes], and dividing the product by 480 minutes [8-hour workday]). However, this assumes no lead exposure occurred before or after the sampling period during the work shift. Depending on the amount of time spent inside the firing range area, the calculated 8-hour TWAs will vary. Additionally, the data broken down by firing lane number (Figure II) indicates that PBZ lead exposures were less in lane numbers 1 and 2, than in lane numbers 3 and 4, on the day of sampling.

The results of general area samples for airborne lead are summarized in Table III. The highest sample, 342 $\mu g/m^3$, was collected between the safety line and the firing line on the target table (refer to Figure I for location of target table) and the lowest sample, 152 $\mu g/m^3$, was collected inside the control booth next to the control panel. These results are slightly higher, but mirror the PBZ results measured on the secondary instructor (working near the target table), and the primary instructor (working inside the control booth).

Overall, the air sampling results were lower than expected given the amount of backflow in the range (discussed in the "Ventilation Results" section). The lower air sampling results may be due to the use of copper-jacketed bullets, which have been shown to reduce lead emissions rates.[1]

B. Surface Samples

Table IV contains the surface sampling data. The target table lead concentration was 10,330 µg/m^2 and the concentration inside the control booth, next to the phone, was 4950 µg/m^2. Interestingly, the ratio of these results (10330/4950 = 2.09), is very similar to the ratio of area air lead concentrations measured at the same locations (342/152 = 2.25). If the general-area air lead concentration ratios remain consistent whenever the range is used, this may suggest surface lead contamination results from airborne lead fallout that adheres to surfaces at a rate directly related to air lead concentration. Similarly, airborne lead could deposit on hair, skin, clothing (civilian clothes were worn during this survey and laundered at home), food, pens, and any other objects inside the firing range.

Recently, case studies have surfaced in the literature documenting exposure to family members and the hazards posed to young children from lead carried home by working parents.[25-39] While these studies have not directly documented increased lead burden in the homes of firing range users, this potential problem should be recognized and warrants further evaluation. In this light, firing range users may be unknowingly exposing their family members to lead from contaminated clothing, skin, hair, etc. (para-occupational exposure). This is of particular concern with respect to young children (< 7 years old), who are more affected by the subtle effects of low lead exposure than are adults.[10]

C. Hand Samples

Lead measured on the hands of personnel is presented in Table V. Information is also presented as to whether hands were washed prior to sampling and whether the officer cleaned a weapon. The highest result, 740 µg/2-hands, was collected from an officer after cleaning a weapon and prior to washing his hands. A second officer was sampled after cleaning a weapon and after washing his hands, and 130 µg/2-hands was measured. While it is difficult to draw conclusions from the data, it does indicate hands were contaminated with lead even after washing. Reasons for this may be a lead-contaminated towel was used to dry hands, lead- contaminated surfaces were touched after washing, and/or hand washing was inefficient in lead removal.

Firing range users should be aware their hands, face, hair, and clothing may be contaminated with lead, and hand-to-mouth activities, such as eating or smoking, will increase the potential for lead ingestion. Contaminated clothing may contaminate automobiles and homes with lead. Conveniently, locker room facilities are adjacent to the firing range. A shower and a change of clothing would help to minimize unnecessary lead spread.

D. Ventilation Survey

The typical airflow patterns in the firing range, determined using the smoke machine, are illustrated in Figure III. As shown, backflow through the shooting booths to the area behind the booths occurred at all positions. Air downrange of the booths backflowed from as far as halfway downrange.

The backflow phenomenum was caused by the airflow being supplied to the range in a jet. The dynamics of jets causes adjacent air to be inducted into the jet. Inside an enclosed space, such as a firing range, inducted air is pulled from downrange creating the backflow. During shooting, lead-contaminated air from downrange backflows to the booths and beyond. Shooters and anyone standing behind the shooting booths are exposed to the lead fume in the backflowing air.

This phenomenum was visualized using smoke generated by the Roscoe Fog Machine™. Smoke in the backflow air spread to the entire area behind the firing line, including the area behind the air plenum location. The smoke also migrated into the control booth. Smoke behind the firing line was slow to dissipate after the smoke machine was turned off, indicating that lead-contaminated air behind the line could be an lead exposure source for a period of time after shooting ceases. This is particularly relevant since the shooters clean their guns at a table located in the area behind the firing line after shooting.

Other observations about the design of the range and ventilation system are as follows:

1. The exhaust duct for the range runs along the ceiling inside the range. This duct had numerous bullet holes from misfired or ricocheting bullets. Furthermore, the duct was not designed for a 3500 feet per minute (fpm) transport velocity commonly recommended for dusts.

2. The trap design resulted in lead fragments wedging in several parts of the bullet trap and spent bullets accumulating on the floor in front of the trap. Cleaning the lead from the trap requires chiseling the lead from the trap crevices, and collecting spent bullets from the front of the trap. Both activities could be additional sources of lead exposure to employees.

3. During firing in the range, noise is readily transmitted through an unused locked door between the range and an adjacent breakroom, because the door is not sound-proofed.

4. Shooters cleaned up spent cartridges from the range after shooting. This activity serves as an additional source of exposure to lead accumulated on the floor and in the spent cartridges.

5. Periodically, the targeting equipment would malfunction, requiring one of the officers to walk downrange to pull the target carrier back to the start position, increasing the potential lead exposure for that officer.

E. Medical surveillance

Routine, annual BLLs were collected on the seven secondary firing range instructors and on the primary instructor shortly after the conclusion of this survey and the results were forwarded to NIOSH by the requestor.

The results for the secondary instructors ranged from 3 to 13 µg/dl, with a mean of 8 µg/dl. These levels fall into the normal BLL range as compared to the national averages,[9] but the relatively short and sporatic exposures to lead are probably keeping the BLLs down. The BLL measured in the primary instructor (24 µg/dl) is about 3 times higher than the national norms, but is still below the OSHA criteria level of 50 μ/m^3. Even though these most recently measured BLLs do not represent an increase over previous BLLs measured in the same individuals, the BLL measured in the primary instructor is of interest because there is ample opportunity to reduce it further. Due to the ineffective ventilation system, compounded by the infiltration rate of contaminated air into the control booth, and to the increased time the primary instructor spends inside the firing range (as compared to the secondary instructors), the primary instructor's baseline BLL was probably elevated, and continues to be elevated, due to working in the firing range.

VII. CONCLUSIONS

Based on the observed airflow patterns, the airborne lead concentrations measured by the PBZ, the general area air samples, and surface lead contamination, NIOSH investigators concluded that the firing range's ventilation system did not adequately remove lead from the range air. Consequently, users of the range were exposed to lead levels which are potentially hazardous to their health. An economical modification to the firing range ventilation system is suggested in the following section of this report.

VIII. RECOMMENDATIONS

A. Ventilation

Because the airflow patterns and the air sampling results are less than satisfactory, NIOSH researchers recommend modifying the existing ventilation system by installing a double open pegboard wall (OP2) in front of the bulkhead containing the supply air diffusers[(40,41)] (refer to Figure IV). This modified inlet, covering the full cross-sectional area inside the firing range, should produce a good, backflow-free airflow pattern. Its design is presented below.

1. Air Inlet Configuration

The double panel should be 1/4 inch perforated hardboard, or other panel with at least as much flow resistance (Figure V). The separation of the panels should be large enough that the jets produced by adjacent holes in the first panel merge before reaching the second panel (at least 5 inches for 1/4 inch pegboard). The panels should be supported in such a way that air is free to move laterally between the panels. Installation of the panels on a stud wall with offset studs is one acceptable approach. With the OP2, nearly any configuration of air inlet into the plenum produces an acceptable airflow pattern in the indoor firing range a distance of 8 feet or more downrange from the panels, thus, the existing supply air diffusers will suffice. The panels can be made of transparent material in locations where windows are necessary;

there is some visibility through double 1/4 inch pegboard panels. Also, a perforated door can be installed in an otherwise conventional manner in the OP2 with no significant degradation of its performance. A double door is not necessary. A diagram showing the main features of one successful OP2 installation is given in Figure VI.

2. Airflow Requirements

An average air speed of 50 ft/min at and behind the firing line is adequate to reliably remove the lead fume emissions from the indoor firing range. Motion of people using the range may cause a temporary backflow of contaminated air at this flow rate, as a result of wakes generated by this motion. However, the resulting exposures will be very short in duration if a minimum air speed of 50 ft/min is maintained. This flow rate also minimizes the possibility that thermal sources, such as incandescent lamps, might generate buoyant plumes that would overcome the otherwise downrange flow produced by the ventilation system alone.

3. Range Pressure Requirements

The range should be under negative pressure relative to the rest of the building and the control booth. Doors leading into the range should always be kept closed, except when personnel are entering or leaving, to maintain pressure in the range. Additionally, personnel should not enter or leave the range during shooting. Pressure monitors should be installed between the control booth interior and the firing range, and the area outside of the range and inside the range to alert the primary instructor when a loss of negative pressure in the range has occurred. Shooting should be discontinued if the range loses negative pressure, and maintenance personnel should be immediately notified to correct the problem. By maintaining a negative pressure inside the range, airborne lead exfiltration from the range to the adjacent areas should be controlled.

4. Industrial Hygiene Sampling

A sampling protocol similar to that used in this survey should be performed after modifications to the firing range are in place, and continued on an annual basis. This sampling protocol will provide a yearly test of the ventilation system's ability to protect the shooters and the instructors from exposure to lead.

B. Good Work Practices

1. Until further improvements are made to provide a more laminar airflow inside the range, instructors should limit their time inside the firing range.

2. After each use, the floor of the firing range should be thoroughly cleaned with a HEPA vacuum designed to collect lead dust. Dry sweeping should never be used in the range. The vacuum should have a plastic bag liner and a non-evaporating liquid, such as antifreeze or light oil, should be placed inside the

vacuum to wet the powder to prevent combustion of the powder. Recommendations for the wetting agent can be obtained from ammunition manufacturers.

Spent cartridges should not be picked up by hand. Instead, cartridges should be collected together using a floor squeegee and picked up using a dust pan or the HEPA vacuum. All cleanup should be performed with the ventilation system running.

3. Surfaces inside the range should be cleaned routinely with a high phosphate detergent, e.g., TSP (trisodium phosphate) or Spic and Span™, to reduce surface lead contamination.

4. Eating, drinking, or smoking inside the range should be prohibited to eliminate possible hand-to-mouth lead ingestion. Furthermore, after using the range, individuals should shower and change clothes.

5. Clothes worn inside the firing range should be laundered through the Police Department. If this is not done, care should be taken to not contaminate vehicles or the home environment with lead from contaminated clothing, including shoes. Clothing worn in the firing range should not be laundered with family members' clothing because of potential "lead spread." Work shoes should remain at work.

6. Eating, drinking, smoking, and hand contact with other people, especially children, should be avoided after working in the firing range, before showering and changing clothes.

7. Instructors should continue to undergo periodic blood testing. OSHA requires biological monitoring of lead exposed workers every 6 months (see section V, A, 3 pages 9-10 of this report) to those exposed above the TWA "action level" of 30 $\mu g/m^3$. During this survey, the secondary instructor was exposed to a TWA of 38 $\mu g/m^3$. Although this person does not work in the firing range more than 30 days per year, it would be prudent to increase the frequency of biological monitoring to 6 month intervals for all range instructors until industrial hygiene measurements show a reduction in lead exposure while using the range.

8. Personnel performing cleanup of lead at the trap should wear half-face respirators equipped with HEPA filters and full protective disposable clothing. Personnel performing the cleanup should be included in a respiratory protection program and smoking or eating should be prohibited while performing cleanup.

   Loose lead in the trap, including spent bullets and lead chiseled from the trap, should also be collected with the HEPA vacuum. Additionally, care should be taken to prevent over-filling the vacuum to the point that it is difficult to move or empty.

Personnel performing cleanup should remove disposable clothing inside the range area to prevent spreading lead to other parts of the building.

9. Only authorized personnel (e.g., range officer and maintenance personnel) should be permitted to go downrange of the firing line. Personnel going downrange should wear disposable clothing to cover portions of the body which will be in contact with lead-covered surfaces. Adequate time should be allowed for airborne lead fume in the range to be removed by the ventilation system before personnel are allowed downrange.

   Barricade shooting should only be performed from inside the shooting booth. Moving barricade shooting, which requires personnel to go downrange, should not be permitted. Further, malfunctioning target equipment should be promptly repaired or not used to prevent personnel from going downrange.

10. The exhaust ductwork in the range should be relocated outside of the range or shielded from stray bullets. Future plans should also include installing exhaust ductwork designed for a 3500 fpm transport velocity to prevent settling of lead dust inside the duct.

11. The door between the break room and the range, although not used, should be sound-proofed or replaced with a wall which attenuates noise from the range.

12. Copper-jacketed ammunition should continue to be the only ammunition used in the range, because it has been shown to reduce lead emissions.

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2. Facility Manager, Independence Police Department
3. Range Officer, Independence Police Department
4. OSHA, Region VII

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

TABLE I

Personal Breathing Zone Air Sampling Results For Lead

Independence Police Department
HETA # 90-168
August 8, 1991

Sample Location	Sample Time[1]	Sample Volume[2]	Concentration[3]
A: Behind Shooters	71	178	254
B: Control Booth	73	183	132
C: Lane # 1	67	168	167
D: Lane # 3	72	180	206
E: Lane # 4	87	218	211
F: Lane # 2	74	185	168
G: Lane # 4	71	178	225
H: Lane # 1	69	173	151
I: Lane # 2	69	173	145
J: Lane # 3	74	185	216

1. Sample time in minutes.
2. Sample volume in liters of air.
3. Concentrations expressed in micrograms of lead per cubic meter of air ($\mu g/m^3$).

TABLE II

Summary Data

Personal Breathing Zone Air Sampling Results For Lead

Independence Police Department
HETA # 90-168
August 8, 1991

Sample Location	Average PBZ[1,4]	8-Hour TWA[1,2]
Lane # 1	159	23
Lane # 2	157	24
Lane # 3	211	32
Lane # 4	218	36
Behind Shooters	254*	38
Control Booth	132*	20
OSHA PEL[3]		50

1. Concentrations expressed in micrograms of lead per cubic meter of air ($\mu g/m^3$).

2. 8-hour TWA (time-weighted averages) calculated by assuming zero exposure to lead when not engaged in handgun training in the firing range.

3. Occupational Safety and Health Administration Permissible Exposure Limit.

4. n = 2

* n = 1

TABLE III

General Area Sample Results For Airborne Lead

Independence Police Department
HETA # 90-168
August 8, 1991

Sample Location	Sample Time[1]	Sample Volume[2]	Concentration[3]
Between safety line and firing line on target table	79	158	342
Between back wall and safety line on desk	79	158	184
Inside control booth next to phone	79	158	152

1. Sample time in minutes.
2. Sample volume in liters of air.
3. Concentrations expressed in micrograms of lead per cubic meter of air ($\mu g/m^3$).

TABLE IV

Surface Lead Concentrations

Independence Police Department
HETA # 90-168
August 8, 1991

Sample Location	Surface Area Sampled[1]	Surface Concentration[2,3]	
Between safety line and firing line on target table	929	960[2]	10330[3]
Inside control booth next to phone	929	460[2]	4950[3]

1. Surface area sampled expressed in square centimeters.
2. Surface concentration expressed in micrograms of lead per square feet of surface ($\mu g/ft^2$).
3. Surface concentration expressed in micrograms of lead per square meter of surface ($\mu g/m^2$).

TABLE V

Hand Wipe Lead Concentration

Independence Police Department
HETA # 90-168
August 8, 1991

Sample Location	Were the Hands Washed?	Did Person Clean a Gun?	Hand Lead Concentration[1]
Secondary Instructor	NO	NO	83
Primary Instructor	YES	NO	170
Officer	NO	YES	740
Officer	YES	YES	130

1. Hand lead concentration expressed in micrograms of lead per two hands.