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Forest Park Police Department
Forest Park, Ohio

Joshua M. Harney, MS
Michael E. Barsan

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Joshua M. Harney and Michael E. Barsan, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Krystyn Bussa and Keith Crouch. Analytical support was provided by Ardith Grote, Division of Physical Sciences and Engineering (DPSE). Desktop publishing was performed by Nichole Herbert. Review and preparation for printing was performed by Penny Arthur.

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Joshua M. Harney, MS
Michael E. Barsan

SUMMARY

On June 30, 1997, the National Institute of Occupational Safety and Health (NIOSH) received a Health Hazard Evaluation (HHE) request from the Forest Park Police Department (FPPD), of Forest Park, Ohio. The requestor was concerned about the potential for exposure to lead among police officers who use the indoor firing range. To determine exposure potential, environmental air samples and surface wipe samples were collected for lead, and the ventilation system was evaluated.

Air sampling results indicate that even while the general ventilation system is operating, range users can be overexposed to lead within a short time (about one hour). Area and personal breathing zone (PBZ) samples for lead ranged from "not detected" to 180 micrograms per cubic meter (µg/m^3) 8–hour time–weighted average (TWA) on July 29, 1997, and from "not detected" to 960 µg/m^3 8–hour TWA on December 10, 1998. During the first air sampling survey (July 1997) the average 8–hour TWA lead concentration measured in the range was 144 µg/m^3. During the second air sampling survey (December 1998) the average 8–hour TWA lead concentration measured in the range was 230 µg/m^3 as collected on 37–mm cassettes, and 433 µg/m^3 as collected on Institute of Occupational Medicine (IOM) samplers.

Wipes samples collected inside the range and in the work areas outside the range showed widespread lead contamination. Surface lead loading levels ranged from 130 µg/ft^2 in the men's locker room (outside the range) to 102,000 µg/ft^2 on the curved supply air diffuser inside the range.

Both air and wipe samples indicate that lead is escaping from the range into surrounding work areas of the police station. Also, airborne lead was detected downstream of the filter banks in the rooftop air handling unit (AHU) in the July 1997 survey, indicating that in the past, contaminated air had been recirculated into the range.

Currently the general ventilation system performs inadequately to control exposures to range users, range masters, and workers in areas nearby the range. The ventilation problems can be separated into three general categories: pressurization of the range, average downrange (from the firing line towards the bullet trap) air velocity near the firing line, and airflow patterns within the range.

The ventilation system at this indoor firing range does not control exposures to airborne lead. Wipe sampling on horizontal surfaces in the range and in work areas adjacent to the range indicate a potential lead hazard to those who use the range as well as to those who work nearby. To solve these problems the range should be negatively pressurized and adequate airflow through the range should move in a uniform (non–turbulent) manner from the firing line to the bullet trap and main exhaust plenum.

Keywords: SIC 9221, police, indoor firing range, IFR, lead, ventilation, wipe sampling, blood lead levels (BLLs), inhalable sampler, IOM sampler

TABLE OF CONTENTS

INTRODUCTION

On June 30, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a Health Hazard Evaluation (HHE) request from an employer representative of the Forest Park Police Department (FPPD). The requestor was concerned for potential exposure to lead among range users. NIOSH investigators originally assigned to this HHE request conducted a walk–through evaluation on July 14, 1997, and a more thorough industrial hygiene evaluation on July 29, 1997. In November 1998, this HHE was reassigned because of personnel changes within NIOSH. Subsequently, a walk–through survey of the police firing range was conducted by the new hygienist on November 4, 1998, and further evaluations were conducted on December 10th and 21st, 1998.

BACKGROUND

General

The FPPD employs approximately thirty officers who use the range monthly during firearms qualification tests. The five–booth indoor firing range, opened in 1983, is used by other departments and organizations as well. Each firing booth is approximately four feet wide. The range is 20 feet wide and 50 feet long. The distance from floor to ceiling is 8 feet at the firing line and increases to 11 feet at the bullet trap. The exposure frequency for FPPD officers averages about one hour once per month plus optional practice time, and one hour per week for range masters. The range is used approximately 10–15 hours per week. During shooting, the ventilation system runs at all times. There is no formal ongoing lead exposure monitoring program at this facility. In the last few years, several current and former range masters have voluntarily had blood lead measurements taken as a part of their annual physical examination.

Ventilation Design/Maintenance Practices

Ventilation for the range is handled by two dedicated rooftop air handling units (AHUs) which are independent of the rest of the facility. The larger of the two AHUs ("recirculation AHU") uses one fan (rated at 10,500 cubic feet per minute [cfm]) to exhaust air from the downrange end of the range, filter it, mix it with makeup air, and recirculate it back into the range without conditioning it. The inlet of the second unit, (the "exhaust–only AHU" rated at 2,700 cfm) is located in the ceiling midway between the firing line and the main exhaust plenum, and is for exhaust and filtration only.

The recirculation AHU passes air through two banks of filters listed by the manufacturer as 90–95% efficient. Each filter bank has a manometer monitoring the air pressure differential across the filters. The exhaust–only AHU filters air through one filter bank (rated by manufacturer as 90–95% efficient) before discharging it into the environment. There were no standard operating procedures (SOPs) for monitoring the effectiveness of this ventilation system or for maintaining its components at the time of the evaluation.

Housekeeping and Hygiene

Range users are responsible for cleaning the range when finished shooting. Clean–up consists of dry sweeping the range floor and picking up shell casings, separating them by caliber into buckets stored in the range, and removing any used targets or personal belongings. When the bullet trap is cleaned out, approximately once every two or three years, workers reportedly wear gloves while they shovel the debris into containers which are taken to a local recycling center. The bullet trap was not cleaned during this HHE.

Range users are not required to wear special clothing during range use. They may wear their duty uniforms, street clothes, or work clothes. A locker room is available to change clothes and shower. Currently the floors outside the range in the hallways and work rooms are mopped about once per week by a contract janitorial company. There is no regular schedule for mopping, washing, or otherwise thoroughly cleaning the interior surfaces of the firing range itself.

METHODS

Air Sampling

During the survey of July 29, 1997, air samples were collected on mixed cellulose ester membrane filters connected to battery–powered air sampling pumps calibrated at a flow rate of 2.4 liters per minute (Lpm). These samples were analyzed for metals using an inductively coupled plasma emission spectrometer according to NIOSH Method 7300.[1] Sixteen air samples were collected in and around the firing range. Five area samples were collected for a period of one hour with the ventilation system running, but prior to any weapons being fired in the range in order to measure background levels of airborne metals. For the second portion of the air sampling evaluation, two police officers fired approximately 450 rounds in about 45 minutes. During this time, an additional five area samples were collected, and a personal breathing zone (PBZ) air sample was collected on each officer during the shooting session. Two area samples were collected on the roof during the firing session: one near the mid–range exhaust stack and one near the make–up air intake grille. Also during this time, an area air sample was collected in two areas outside the range: the control booth and the hallway outside the control booth.

One officer fired a total of 400 rounds of .38 and .40 caliber ammunition in the 45 minute qualification simulation during the survey of December 10, 1998. While a standard 37–millimeter (mm) cassette is commonly used to collect “inhalable” or “total” particulate samples, in many situations the Institute of Occupational Medicine (IOM) sampler more representatively samples aerosols as they are inspired by humans,[2] especially with regard to larger particles (> ~25 micrometer [µm] aerodynamic diameter).[3] Because ingestion of larger inhaled leaded particulate is a potential contributor to exposure, in order to more accurately characterize the exposure it was desirable to also use a sampler in which larger particles in the aerosol, if present, were more representatively sampled. Therefore the second survey was conducted with side–by–side sampling done with closed–face, 37–mm cassettes, and with IOM samplers. A total of eight IOM samples and nineteen, 37–mm cassette samples were collected at a flow rate of 2 Lpm. Area samples were collected before shooting began in the control booth, on the uprange wall, above shooting booth 3, on the ceiling midrange, on the ceiling near the bullet trap, in the recirculation AHU housing, and near the rooftop exhaust–only AHU. During shooting exercises, samples were collected in these locations again, in addition to one environmental sample (for comparison to the AHU samples) and four PBZ samples. All air samples were analyzed for mass (NIOSH Method # 0500)[4] and for metals (NIOSH Method #7300).[1] Results from the 37–mm samplers are more suitable for comparison to the OSHA Permissible Exposure Limit (PEL) than are the IOM results because the IOM samplers will typically sample 2–3 times the contaminants the 37–mm samplers do.

Wipe Sampling

During the initial survey, three surface wipe samples were collected from 10 x 10–centimeter areas using Wash’n Dri® towelettes. The wipe samples were analyzed using graphite furnace atomic absorption spectrometry according to NIOSH Method 7105.[5] One wipe sample was collected from the inner surface of the curved air diffuser (supply inlet) behind booth 3, another wipe sample was taken from the top surface of the fold–down shooting bench in booth 2, and a sample was taken from the table top in the control booth.

On December 10, 1998, 12 wipe samples were taken as described above, and analysis was done by flame atomic absorption spectrometry according to NIOSH Method 9100.[6] In an attempt roughly to gauge the uniformity of contamination on a particular surface, in some cases side–by–side samples were collected. The curved air diffuser (where a thick layer of dark gray dust had accumulated), a shooting bench, and the table top in the control room were again wiped. To document contamination inside building areas near the range, wipes were also taken on the hallway floor immediately outside the range, in the men's locker room, on the hallway coffee table, and in the briefing room. One wipe was also collected in the recirculation AHU downstream from the filter banks to document any breakthrough, if present.

Ventilation Assessment

During the initial survey, airflow patterns in the range were observed using a Roscoe Fog Machine (Model 1500) to generate a visible, non–toxic "smoke." Smoke was released at different heights from floor to ceiling behind the firing line for all of the shooting stations. During the second survey, the smoke machine was again used to document whether the airflow patterns within the range had changed significantly in the time between surveys. Also, observations were made regarding whether the range was under positive or negative pressure, and a visual inspection of the AHUs was made.

A quantitative ventilation assessment was done by determining the volumetric flow rate of air being supplied to and exhausted from the range. Where possible, an Accubalance (TSI, Inc.) Flow Hood was used for direct measurement. In cases where the Flow Hood could not be used, a Velocicalc (TSI, Inc.) thermoanemometer was used to make a multi–point traverse of the airstream at the plenum and the flow rate was calculated.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to 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 even though their exposures are maintained below these levels. A small percentage 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 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 environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[7] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[8] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[9] NIOSH encourages employers to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by 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. Some substances have recommended short–term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short–term.

Lead

Lead is ubiquitous in U.S. urban environments due to the widespread use of lead compounds in industry, gasoline, and paints during the past century. Exposure to lead occurs via inhalation of dust and fume, and ingestion through contact with lead–contaminated hands, food, cigarettes, and clothing. Absorbed lead accumulates in the body in the soft tissues and bones. Lead is stored in bones for decades, and may cause health effects long after exposure as it is slowly released in the body.

Symptoms of lead exposure include weakness, excessive tiredness, irritability, constipation, anorexia, abdominal discomfort (colic), fine tremors, and "wrist drop."[10,11,12] Overexposure to lead may also result in damage to the kidneys, anemia, high blood pressure, infertility and reduced sex drive in both sexes, and impotence. An individual's Blood Lead Level (BLL) is a good indication of recent exposure to, and current absorption of lead.[13] The frequency and severity of symptoms associated with lead exposure generally increase with the BLL.

The overall geometric mean BLL for the U.S. adult population (ages 20–74 yrs) declined significantly between 1976 and 1991, from 13.1 to 3.0 micrograms per deciliter of blood (µg/dL)–this decline is most likely due primarily to the reduction of lead in gasoline. More than 90% of adults now have a BLL of <10 µg/dL, and more than 98% have a BLL <15 µg/dL.[14]

Under the OSHA general industry lead standard (29 CFR 1910.1025), the PEL for airborne exposure to lead is 50 micrograms per cubic meter (µg/m^3) (8–hour TWA).[15] The standard requires lowering the PEL for shifts exceeding 8 hours, medical monitoring for employees exposed to airborne lead at or above the action level of 30 µg/m^3 (8–hour TWA), medical removal of employees whose average BLL is 50 µg/dL or greater, and economic protection for medically removed workers. Medically removed workers cannot return to jobs involving lead exposure until their BLL is below 40 µg/dL. ACGIH has a TLV for lead of 50 µg/m^3 (8–hour TWA), with worker BLLs to be controlled to or below 30 µg/dL, and designation of lead as an animal carcinogen.[16] The U.S. Public Health Service (PHS) has established a goal, by the year 2000, to eliminate all occupational exposures that result in BLLs greater than 25 µg/dL.[17]

The occupational exposure criteria (above) are not protective for all the known health effects of lead. For example, studies have found neurological symptoms in workers with BLLs of 40 to 60 µg/dL, and decreased fertility in men at BLLs as low as 40 µg/dL. BLLs are associated with increases in blood pressure, even at levels less than 10 µg/dL. Fetal exposure to lead is associated with reduced gestational age, birthweight, and early mental development with maternal BLLs as low as 10 to 15 µg/dL.[18] Men and women who are planning on having children should limit their exposure to lead.

In homes with a family member occupationally exposed to lead, care must be taken to prevent "take home" of lead, that is, lead carried into the home on clothing, skin, hair, and in vehicles. High BLLs in resident children, and elevated concentrations of lead in the house dust, have been found in the homes of workers employed in industries associated with high lead exposure.[19] Particular effort should be made to ensure that children of persons who work in areas of high lead exposure receive a BLL test.

Lead – Surface Dust

Lead–contaminated surface dust represents a potential source of lead exposure, particularly for young children. This may occur either by direct hand–to–mouth contact, or indirectly from hand–to–mouth contact with contaminated clothing, cigarettes, or food. Previous studies have found a significant correlation between resident children's BLLs and house dust lead levels.[20] There is currently no federal standard which provides a permissible limit for lead contamination of surfaces in occupational settings. The Environmental Protection Agency (EPA) currently recommends the following clearance levels for surface lead loading be met after residential lead abatement or interim control activities: uncarpeted floors, 100 micrograms per square foot (µg/ft^2); interior window sills, 500 µg/ft^2; window wells, 800 µg/ft^2.[21] These levels have been established as achievable through lead abatement and interim control activities, and they are not based on projected health effects associated with specific surface dust levels.

Lead – Childhood Exposure

The adverse effects of lead on children and fetuses include decreases in intelligence and brain development, developmental delays, behavioral disturbances, decreased stature, anemia, decreased gestational weight and age, and miscarriage or stillbirth. Lead exposure is especially devastating to fetuses and young children due to potentially irreversible toxic effects on the developing brain and nervous system.[18]

No threshold has been identified for the harmful effects of lead in children; the Centers for Disease Control and Prevention (CDC) currently recommends a multitier approach to defining and preventing childhood lead poisoning, based on BLL screening.[22] The BLLs and corresponding actions which CDC has recommended are: $\geq$10 µg/dL, community prevention activities; $\geq$15 µg/dL, individual case management including nutritional and educational interventions and more frequent screening; $\geq$20 µg/dL, medical evaluation, environmental investigation and remediation. Additionally, environmental investigation and remediation are recommended for BLLs of 15–19, if such levels persist.

Overall, U.S. population BLLs have declined since 1976. A recent national survey found that the geometric mean BLL for children ages 1–11 ranged from 2.5–4.1 µg/dL, with the highest mean BLL among children aged 1–2 years.[23] However, it was estimated from the survey that 8.9% of U.S. children under 6 years, or about 1.7 million children, have elevated BLLs ($\geq$10 µg/dL).

Ventilation

To minimize exposures to contaminants resulting from weapons fire, ventilation systems of indoor firing ranges should provide favorable conditions with regard to at least four criteria: filtration efficiency, range pressurization, volumetric flow rate, and airflow patterns. Any air filtered and re–circulated through the range should be high–efficiency particulate air (HEPA) filtered. Firing ranges should be under slight negative pressure so that no contaminants escape the range under normal operating conditions. The volumetric flow rate of air being supplied to and exhausted from the range should provide a minimum average downrange air velocity at the firing line of 50 feet per minute (fpm).[24] Finally, it is desirable to have air moving downrange as laminar (nonturbulent) as possible, especially near the firing line. Even if the range is pressurized correctly and a minimum downrange air velocity of 50 fpm is achieved at the firing line, range users may still receive excessive exposures to lead if large scale eddies exist that create "backflow" and bring contaminated air back into their breathing zones.

RESULTS

Air Sampling

Presented in Table 1 are the results from area and PBZ air sampling from the first survey. Quantifiable amounts of lead were found only on those samples collected during the shooting exercises, and not on those collected before the shooting exercises. Assuming no lead exposure occurred during the day other than what was measured during sampling, the average 8–hour TWA lead concentration for the two PBZ samples collected in the range during shooting exercises was 144 $\mu g/m^3$. This is nearly three times the OSHA PEL of 50 $\mu g/m^3$. Because lead was detected in the control booth and in the hallway outside the range, it can be concluded that airborne lead escapes the range into the nearby work areas.

Of particular note are the results measured on the rooftop of the range. Detecting lead in an area where the air should have already been HEPA filtered may indicate failure of the control (filtration) system. Reportedly, during the 1997 survey, several filters were missing from the filter banks. During the 1998 survey all filters were in place, and no lead was detected on samples collected in or around the rooftop AHUs downstream from the filter banks.

On one of the pre–shooting general area samples collected on July 29, 1997, small amounts of beryllium and cadmium were unexpectedly detected. On a second pre–shooting area sample only cadmium was detected in quantifiable amounts. Similar results should be expected on the samples collected during weapons firing that day; however, this did not occur. No cadmium or beryllium was detected on any area or PBZ sample collected during firing exercises. During the second survey, no cadmium or beryllium were detected on any samples before or during shooting.

Air sampling results from the second survey are shown in Tables 2 and 3. All 8–hour TWA results assume that no further exposure occurred beyond what was measured during sampling. During pre–shooting sampling, any dust collected on the filters was below the minimum detectable concentration (MDC) of 0.1 $\mu g/m^3$ based on the limit of detection (LOD) of 0.02 milligrams and average sample volume of 170 L. As expected, the highest dust concentration was encountered by the officer doing the shooting. The 37–mm cassette gravimetric results ranged from nd – 0.54 mg/m^3 8–hour TWA. IOM results ranged from 0.13 – 1.27 mg/m^3 8–hour TWA. For side–by–side sampling done during shooting exercises, the concentration of dust collected by IOM samplers exceeded that of the 37–mm cassettes in five of six pairs.

All air samples taken indoors during shooting during the 1998 survey yielded 8–hour TWA lead exposures in excess of the OSHA action level of 30 $\mu g/m^3$ (Table 3). Even the area air sample collected in the control room resulted in an eight hour equivalent concentration of 40 $\mu g/m^3$. The highest 8–hour TWA concentrations were collected in a midrange–ceiling area sample (37–mm = 270 $\mu g/m^3$, IOM = 960 $\mu g/m^3$) and in the PBZ of the shooter (37–mm = 640 $\mu g/m^3$, IOM = 960 $\mu g/m^3$). As in the case for total dust, the concentration of lead collected by IOM samplers exceeded that of the 37–mm cassettes in five of six pairs during shooting exercises. The rooftop air samples and the environmental sample collected as a background level yielded nd results for lead.

Wipe Sampling

Table 4 shows wipe sampling results from both surveys. The highest concentrations of lead were found on the curved air diffuser of the range supply inlet. It is possible that this lead has merely accumulated through settling immediately after evolving from the discharge of firearms. But because the ventilation system is normally on at all times during shooting and cleanup, it is more likely that lead particulate has circulated through the ventilation system and impacted on the inner surface of the curved air diffuser after by–passing the AHU filters. It was reported that at some point in the past the ventilation system was operated without all the filters in the AHUs, making this possible. Wipe sample FP–8 shows that leaded dust remains in the recirculation AHU downstream of the filter banks. Small amounts of lead may continue to be re–entrained by the airflow and enter the range, even though the filter banks now work effectively.

The degree of contamination in the areas outside the range is indicated by the high lead concentrations found on nearby work and food preparation surfaces. These levels were generally far in excess of what would be allowed to pass a clearance test following a lead abatement project in a residential setting. Also, there seemed to be little variation in lead concentration between sample pairs obtained by side–by–side sampling. Only the sample pair taken from the floor outside the range, which is the only surface regularly cleaned among surfaces where paired wipes were taken, differed by as much as an order of magnitude. This may indicate that the lead contamination is more or less uniform in areas that are not regularly cleaned.

Ventilation Assessment

The range door was closed and locked during firing exercises. When firing exercises commenced during the latest survey, the smell of burned gunpowder became immediately noticeable to those outside the range. When placing a hand near the gasket material between the range door and doorjamb, one observer noted forceful streams of air escaping the firing range. In fact, the supply air forced the range door open and held it open as long as the ventilation system was turned on unless the door was bolted shut. This indicates that the range is under positive pressure (air flows out of the range and into surrounding areas) when the ventilation system is turned on.

To objectively document positive pressurization of the range, the volumetric flow rate of the range supply and exhaust was determined using a thermoanemometer and a flow hood. It was found that net airflow supplied to the range exceeded that of exhaust by 83%. Design specifications for the range call for 10,500 cfm of supply air. Only 4,100 cfm was measured, of which about 1,500 cfm was merely being recirculated. Likewise, the design specifications call for 10,500 cfm of exhaust while only 3,000 cfm was measured, of which 1,500 cfm was from recirculated air. These flow rates yield an average downrange air velocity at the firing line of approximately 25 fpm, which is below the ACGIH[24] recommendation of 50 fpm.

One of the two gauges that monitor the pressure drop across the high–efficiency filters of the recirculation AHU did not work during the second survey. The second gauge on this AHU registered 0.5 inches water–gauge (in. wg), which is less than what the manufacturer states is the initial pressure drop (0.65 in.wg) for these filters even before they become dirty with use and the pressure drop increases. Both pressure gauges on the exhaust–only AHU appeared to be working, but one of them also reads less than the manufacturer's initial pressure drop rating. In both cases, this indicates that either these pressure gauges are not yielding accurate readings or there are leaks in the filter banks through which air by–passes the filters. Because no lead was detected on air samples collected in the AHUs during the second survey, which would have indicated leakage, it is more likely that the pressure gauges need to be repaired or replaced. Currently there is no monitoring system for the recirculation airstream as required by the OSHA lead standard.[15]

When smoke was released behind the firing line, the airflow patterns within the range were revealed. The airflow past the firing line was not laminar; two large zones of backflow were created even without someone standing at the firing line to create turbulence. One zone of backflow recirculates air in the area between the supply inlet to the firing line and back again to the uprange wall and supply inlet. The second eddy carries air from bench–height at the firing line to an area several feet downrange, and then up and back into the breathing zones of those standing at the firing line.

DISCUSSION

Air Sampling

Results from the initial industrial hygiene survey indicated that range users were exposed to airborne lead levels in excess of that permitted by OSHA for an eight hour day. Assuming no other lead exposure occurred during the day other than what was measured during sampling, the average 8–hour TWA lead concentration for samples collected in the range during shooting exercises was 144 µg/m^3. This is nearly three times the OSHA PEL. Chronic workplace exposures to airborne lead at these levels has been reported to result in local paralysis such as "foot drop" or "wrist drop."[25]

All air samples taken indoors during the second survey exceeded the OSHA action level, 30 µg/m^3 8–hour TWA. Not surprisingly, the highest 8–hour TWA concentration was measured in the PBZ of the shooter (37–mm = 640 µg/m^3, IOM = 960 µg/m^3). For side–by–side sampling done during shooting exercises, the concentration of lead collected by IOM samplers exceeded that of the 37–mm cassettes in five of six pairs. This may indicate that a more accurate measure of lead exposure can be obtained by using a sampler that has size–selective sampling efficiencies approximating those of human breathing. This would be particularly important when the particle size distribution of the exposure aerosol is comprised of a sizeable percentage of particles larger than 25–30 µm aerodynamic diameter.[3]

During the second sampling survey no lead was detected on samples collected in the AHUs downstream from the filter banks, therefore, it appears that the ventilation system efficiently filters the range air before recirculating it.

The range master, who most likely will have the highest number of exposures in a year, was also probably overexposed (8–hour TWA 37–mm = 50 µg/m^3). When workers are exposed above the PEL, the OSHA lead standard (29 CFR 1910.1025) requires that the employer take certain actions to lower exposures. Some of these requirements include, but are not limited to, the following:

- quarterly air monitoring
- engineering and work practice controls to reduce exposures to below 200 µg/m^3 (if exposures exceed the PEL for more than 30 days in one year)
- any combination of engineering controls, work practice controls, and respiratory protection, once exposures fall below 200 µg/m^3
- mandatory respiratory protection program if exposures not controlled to below the PEL
- written compliance program
- quarterly range ventilation system evaluation
- provide and launder protective clothing such as coveralls or other such materials
- range users must shower at end of shift, and store range clothes separately from clean clothes
- if exposed above the PEL for more than 30 days per year, mandatory medical surveillance program including blood lead and zinc protoporphyrin tests

If FPPD could document that by implementing engineering controls, for example, effective ventilation, and the range users' exposures were below the PEL, many of these mandates of the standard would no longer apply. The OSHA standard itself should be referred to for a full treatment of the requirements.[15]

Wipe Sampling

Wipe sampling results revealed high lead concentrations on surfaces within the range. Because of the availability of this lead, ingestion becomes a second route of exposure the FPPD needs to address. If after shooting, range users do not thoroughly wash their hands and face, they may inadvertently ingest lead in addition to that which they may have inhaled. As well, if their clothing (including shoes) touches any contaminated range surfaces, then lead could be transported from the range into other parts of the building, personal automobiles, and homes. In this latter case, the possibility of lead exposure extends past the range user to include those living in the same home as the range user. This is of great concern especially if the officers have contact with young children, whose bodies more readily uptake lead than do adults.

Although there are currently no legally enforceable exposure limits for surface lead dust levels in occupational settings, it is useful to compare these results to the EPA Guidelines[21] for residential settings. In residential settings where a lead abatement project has been completed, clearance wipe sampling results must fall below 100 $\mu g/ft^2$ (for uncarpeted floors) in order for the residence to be re–occupied. With the exception of the sample taken on the briefing room table, all wipes yielded results in excess of this level. As a group, these results spanned four orders of magnitude (100–100,000 $\mu g/ft^2$). This indicates that even officers who are not using the range may be exposed to lead without their knowledge because it is available even on surfaces used to prepare coffee, for example.

The wipe collected (FP–8, Table 4) in the AHU housing downstream of the filter banks indicates that there is still lead in the unit that is potentially available to be re–entrained into the airstream and recirculated into the range. Because the most recent air sampling results demonstrate that the filters effectively filter the air that passes through them, this lead in the AHU likely accumulated during the time when the system was operated without all the filters in place.

Ventilation

Achieving the correct balance between air supply and exhaust is a first step in limiting the risk of occupational lead exposures resulting from firing range use. The second key step is to have adequate and uniform airflow within the range, from the uprange end near the firing line to the downrange end near the bullet trap and main ventilation exhaust plenum. Even when the volumetric airflow within the range is adequate, if it is too turbulent it can result in eddy currents and backflow which recirculate lead fume and other contaminants back into the breathing zone of range users. The latter condition was observed during shooting exercises, and was clearly demonstrated after shooting exercises were finished by using a fog machine to create a large cloud of visible aerosol. The location of the air supply inlet in the ceiling by the uprange wall behind the firing line creates eddies, resulting in two large recirculation zones. One zone recirculates air in the area between the supply inlet to the firing line and back again to the uprange wall and supply inlet. The second eddy carries air from bench–height at the firing line to an area several feet downrange, and then up and back into the breathing zones of those standing at the firing line.

One of the keys to any effective control measure involves maintaining it in a workable condition so that it provides the same measure of protection at all times. Currently there is no maintenance schedule for the range's AHUs. Reportedly, the filters had all been changed over one year ago, but currently no one is in charge of monitoring the filters. A visual inspection of the filters revealed that, while some of them appear to be relatively new, others appear quite old, displaying manufacturer's inspection stickers dated April 7, 1981.

Recirculating air, rather than bringing in 100% fresh air, can be a cost–saving tool especially effective if the air has already been tempered or humidified. Because of the concern for re–introducing contaminated air into the workplace, the OSHA lead standard has certain requirements for ventilation systems which recirculate a portion of the filtered airstream back into the workplace. Paragraph (e)(4)(ii) states "If air from exhaust ventilation is recirculated into the workplace, the employer shall assure that (A) the system has a high efficiency filter with reliable back–up filter; and (B) controls to monitor the concentration of lead in the return air and to bypass the recirculation system automatically if it fails are installed, operating, and maintained." The ventilation system of the FPPD is not designed to comply with part B of this requirement of the standard because there is no monitoring or bypass mechanism in place. Although air sampling during the last survey indicated that the air being reintroduced into the range is free from detectable amounts of lead, there is no mechanism in place which would alert FPPD should filter breakthrough occur. Nor is there a means to bypass the recirculation loop and bring 100% fresh air into the range.

CONCLUSIONS

Air sampling results from two industrial hygiene surveys conducted at the FPPD firing range indicate that even while the general ventilation system is operating, range users can be overexposed to lead within a short time (about one hour). The ventilation system, in its current condition, is inadequate to control exposures of range users, range masters, and workers in areas adjacent to the range. Specifically, the pressurization of the range, average downrange air velocity near the firing line, and airflow characteristics within the range minimize the effectiveness of the ventilation system. Both air and wipe samples indicate that lead is escaping from the range into surrounding work areas of the police station, and that breakthrough may have occurred in the rooftop AHU filter banks during or prior to the July 1997 survey. Inhalable lead particles contribute to one's total exposure (in addition to those only in the respirable fraction) when they are ingested. Therefore, using true inhalable samplers for airborne lead exposure assessments in indoor firing ranges may provide a more accurate measure of exposure than traditional closed face 37–mm cassette samplers.

RECOMMENDATIONS

To reduce exposures to lead for all workers at the FPPD, the following recommendations are offered:

1. The uniformity of downrange airflow should be improved to decrease or eliminate the eddies which currently cause backflow of weapons fire contaminants into the breathing zones of range users. NIOSH has successfully developed engineering controls, based on a "double–open pegboard" design which can dramatically improve the uniformity of airflow within firing ranges when implemented correctly.[26]

2. The firing range should be maintained under negative pressure (air flows from surrounding areas into the range) when the ventilation system is running while at the same time maintaining adequate volumetric flow to assure an average downrange air velocity of 50 fpm at the firing line. This will require a ventilation professional skilled in pressure balancing ventilation systems. The firing range ventilation system should be in operation at all times while the range is in use and during clean–up.

3. Written SOPs for preventive maintenance on the ventilation system should be developed and implemented to assure that filters are maintained and changed as needed, adequate airflow within the range is maintained, pressure gauges work

correctly, and filter breakthrough can be detected if it occurs. Part of the initial effort should include cleaning the interior surfaces of the recirculation AHU where lead dust has accumulated downstream of the filter banks. Proper personal protection equipment should be worn by cleanup personnel.

4. After each use, the floor of the firing range should be thoroughly cleaned with a HEPA vacuum cleaner designed to collect lead dust. Dry sweeping should never be used in the range. The vacuum cleaner should have a plastic bag liner. A non–evaporating liquid, such as a light oil, should be placed inside the liner to wet the gun powder and therefore prevent combustion.

5. To minimize the accumulation of leaded dust on outer garments, if shooting is done from a prone position the floor should first be covered with a disposable material.

6. To avoid dermal contact with lead on the spent cartridges and the floor, cartridges should be gathered using a floor squeegee (or with some other implement that would not generate more airborne lead dust) and picked up using a dust pan or a HEPA vacuum cleaner (assuming that doing so does not result in spark generation).

7. Surfaces inside the range should be cleaned routinely with a high phosphate detergent, such as trisodium phosphate, to reduce surface lead contamination. There are also cleaning agents on the market that are specifically designed for this application.

8. Eating, drinking, and smoking inside the range should be prohibited to eliminate possible lead ingestion by hand–to–mouth contact.

9. Employees should be provided with two lockers to allow them to separate street clothes from lead–contaminated work clothes.

10. Eating, drinking, smoking, and hand contact with other people, especially children, should be avoided after working in the firing range, until personnel have showered and changed clothes.

11. Personnel performing clean–up of lead at the trap should wear appropriate respiratory protection (for example, the appropriate NIOSH approved respirator equipped with HEPA filters) and full protective outer clothing (which may be disposable). Personnel performing the clean–up should be included in a respiratory protection program. After clean–up, they should remove their outer clothing inside the range area to prevent spreading lead to other parts of the building. Non–disposable outer protective clothing should be laundered by the employer or a contractor. It should not be laundered by the employees at their homes.

12. Enough time should be allowed for the ventilation system to remove airborne lead fume and dust before personnel are allowed downrange. The amount of time needed to adequately remove the airborne lead fume and dust should be determined after the ventilation system is adjusted according to the recommendations in this report. At that time, further air monitoring will be needed to determine how the lead concentration in the range decreases across various time intervals.

13. Non–lead or copper–jacketed bullets should be used because they have been shown to reduce lead emissions. Substituting copper–jacketed slugs has been shown to provide significant reduction in lead emission compared with traditional lead ammunition in some situations.[27] However, there will still be some lead generated during shooting from the combustion of primer, which contains lead styphnate and lead peroxide.

14. If engineering controls that lower exposures are not effectively implemented, instructors, regular range users, and maintenance personnel may need to undergo periodic blood testing. The OSHA lead standard (29 CFR 1910.1025) requires biological monitoring of lead exposed workers every six months for those exposed above the

8–hour TWA action level of 30 µg/m^3 for more than 30 days per year.

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Table 1
Area and PBZ Airborne Lead Concentrations
Forest Park Police Department Indoor Firing Range
Forest Park, Ohio
July 29, 1997
HETA 97–0255–2735

Sample Number	Location Sampled	Sample Type	Sample Time (minutes)	Lead Concentration (µg/m^3)**	Lead Concentration (µg/m^3), 8–hr TWA
*A–1	Uprange wall behind booth 3	Area	60	nd	nd
*A–2	Above booths 4/5, just behind firing line	Area	60	nd	nd
*A–3	Uprange wall behind booth 2	Area	60	trace	trace
*A–4	Downrange ceiling near bullet trap	Area	62	nd	nd
*A–5	Halfway downrange, ceiling	Area	63	nd	nd
A–6	Booth 3	PBZ	43	1460	130
A–7	Booth 2	PBZ	44	1890	170
A–8	Uprange wall behind booth 3	Area	57	1170	140
A–9	Above booths 4/5, just behind firing line	Area	57	1610	190
A–10	Uprange wall behind bay 2	Area	59	280	30
A–11	Downrange ceiling near bullet trap	Area	61	1370	170
A–12	Halfway downrange, ceiling	Area	63	1390	180
A–13	Rooftop: makeup air inlet	Area	68	30	4
A–14	Rooftop: midrange exhaust	Area	69	50	7
A–15	Control booth	Area	66	180	25
A–16	Hallway by control booth	Area	68	200	30
Evaluation Criteria		ACGIH Threshold Limit Value			50
		OSHA Permissible Exposure Limit			50

* Sample collected prior to shooting
** Indicates Time–Weighted Average over the sample time for that sample

nd = not detected
PBZ = Personal Breathing Zone
trace = between Limit Of Detection and Limit Of Quanitification

Table 2
Area and PBZ Total Dust Concentrations
Forest Park Police Department Indoor Firing Range
Forest Park, Ohio
December 10, 1998
HETA 97–0255–2735

Sample Number	Location Sampled	Sample Type	Sample Time (minutes)	Dust Concentration (mg/m^3)*	Dust Concentration (mg/m^3), 8–hr TWA
P–1	ceiling, near bullet trap	area, 37mm	73	nd	nd
P–1a	ceiling, near bullet trap	area, IOM	73	nd	nd
P–2	ceiling, midrange	area, 37mm	74	nd	nd
P–3	rooftop, exhaust–only AHU	area, 37mm	89	nd	nd
P–4	recirculation AHU housing	area, 37mm	94	nd	nd
P–5	control room	area, 37mm	69	nd	nd
P–6	uprange wall	area, 37mm	73	nd	nd
P–6a	uprange wall	area, IOM	72	nd	nd
P–7	uprange wall, near door	area, 37mm	70	nd	nd
P–8	above booth #3	area, 37mm	72	nd	nd
S–1	ceiling, near bullet trap	area, 37mm	91	0.63	0.12
S–1a	ceiling, near bullet trap	area, IOM	95	1.48	0.29
S–2	ceiling, midrange	area, 37mm	97	1.61	0.33
S–2a	ceiling, midrange	area, IOM	97	2.22	0.45
S–3	rooftop, exhaust–only AHU	area, 37mm	101	nd	nd
S–4	recirculation AHU housing	area, 37mm	101	nd	nd
S–5	control room	area, 37mm	79	0.226	0.04
S–6	uprange wall	area, 37mm	101	0.25	0.05
S–6a	uprange wall	area, IOM	94	0.9	0.18
S–7	uprange wall, near door	area, 37mm	99	0.15	0.03
S–8	above booth #3	area, 37mm	101	2.11	0.44
S–8a	above booth #3	area, IOM	94	2.02	0.4

Table 2–*continued*

Sample Number	Location Sampled	Sample Type	Sample Time (minutes)	Dust Concentration (mg/m^3)*	Dust Concentration (mg/m^3), 8–hr TWA
S–9	range master	PBZ, 37mm	65	0.39	0.05
S–9a	range master	PBZ, IOM	65	0.93	0.13
S–10	shooter	PBZ, 37mm	80	3.23	0.54
S–10a	shooter	PBZ, IOM	78	7.79	1.27
S–11	environmental	area, 37mm	87	nd	nd
Evaluation Criteria		ACGIH Threshold Limit Value			10
		OSHA Permissible Exposure Limit			15

PBZ = Personal Breathing Zone
nd = not detected
P–series samples collected prior to shooting,
S–series samples collected during shooting

* Indicates Time–Weighted Average over the sample time for that sample

Table 3
Area and PBZ Airborne Lead Concentration
Forest Park Police Department Indoor Firing Range
Forest Park, Ohio
December 10, 1998
HETA 97–0255–2735

Sample Number	Location Sampled	Sample Type	Sample Time (minutes)	Lead Concentration (µg/m³)*	Lead Concentration (µg/m³), 8–hour TWA
P–1	ceiling, near bullet trap	area, 37mm	73	nd	nd
P–1a	ceiling, near bullet trap	area, IOM	73	nd	nd
P–2	ceiling, midrange	area, 37mm	74	nd	nd
P–3	rooftop, exhaust–only AHU	area, 37mm	89	nd	nd
P–4	recirculation AHU housing	area, 37mm	94	nd	nd
P–5	control room	area, 37mm	69	nd	nd
P–6	uprange wall	area, 37mm	73	nd	nd
P–6a	uprange wall	area, IOM	72	nd	nd
P–7	uprange wall, near door	area, 37mm	70	nd	nd
P–8	above booth #3	area, 37mm	72	nd	nd
S–1	ceiling, near bullet trap	area, 37mm	91	680	130
S–1a	ceiling, near bullet trap	area, IOM	95	1110	220
S–2	ceiling, midrange	area, 37mm	97	1320	270
S–2a	ceiling, midrange	area, IOM	97	5900	960
S–3	rooftop, exhaust–only AHU	area, 37mm	101	nd	nd
S–4	recirculation AHU housing	area, 37mm	101	nd	nd
S–5	control room	area, 37mm	79	230	40
S–6	uprange wall	area, 37mm	101	220	50
S–6a	uprange wall	area, IOM	94	690	135
S–7	uprange wall, near door	area, 37mm	99	196	40
S–8	above booth #3	area, 37mm	101	2060	430
S–8a	above booth #3	area, IOM	94	1120	220

Table 3–*continued*

Sample Number	Location Sampled	Sample Type	Sample Time (minutes)	Lead Concentration (µg/m³)*	Lead Concentration (µg/m³), 8–hour TWA
S–9	range master	PBZ, 37mm	65	370	50
S–9a	range master	PBZ, IOM	65	740	100
S–10	shooter	PBZ, 37mm	80	3860	640
S–10a	shooter	PBZ, IOM	78	5910	960
S–11	environmental	area, 37mm	87	nd	nd
Evaluation Criteria		ACGIH Threshold Limit Value			50
		OSHA Permissible Exposure Limit			50

P–series samples collected prior to shooting
S–series samples collected during shooting
*Indicates Time–Weighted Average over the sample time for that sample

nd = not detected
PBZ = Personal breathing Zone

Table 4
Surface Wipe Lead Concentrations
Forest Park Police Department Indoor Firing Range
Forest Park, Ohio
July 29, 1997 and December 10, 1998
HETA 97–0255–2735

Sample Number	Location Sampled	Lead Concentration (μg/ft^2)
W–1	inner surface of curved air diffuser behind booth 3	54,800
W–2	shooting bench tray table, booth 2	7,250
W–3	control room table top	360
FP–1	inner surface of curved air diffuser behind booth 2	102,190
FP–1a	inner surface of curved air diffuser behind booth 2	102,190
FP–2	shooting bench tray table, booth 3	22,300
FP–2a	shooting bench tray table, booth 3	16,720
FP–3	hallway floor outside range	1,670
FP–3a	hallway floor outside range	450
FP–4	men's locker room	130
FP–5	coffee table by soft drink machines	850
FP–6	briefing room center table, top	trace
FP–7	control room table top	1,300
FP–7a	control room table top	1,300
FP–8	recirculation AHU housing	1,670

μg/ft^2 = micrograms per square foot
trace = between Limit of Detection and Limit of Quantification

W–series from 1997 survey, FP–series from 1998 survey

National Institute for Occupational Safety and Health (NIOSH) Study of Lead Exposures to Firing Range Users

What NIOSH Did

Collected air samples for lead before and during shooting exercises

Collected surface samples for lead in the range and in the building areas just outside the range

Measured the airflow through the range's ventilation system

Used a smoke machine to see the airflow patterns in the range

What NIOSH Found

Shooters are being exposed to too much lead when they use the range.

Lead is escaping from the range and contaminating other work areas.

The range's ventilation system doesn't supply enough air to move the smoke downrange fast enough.

The range's air supply inlet makes the smoke recirculate back to where the shooter can breath it in.

There is no way to tell if the range's ventilation system filters are doing a good job.

What Forest Park Police Department Managers Can Do

Improve ventilation to lower lead exposures to shooters to as far below 50 $\mu g/m^3$ as possible.

Develop a written lead program so officers know how to protect themselves.

Have the range and indoor areas outside the range cleaned regularly.

Make airflow enter the range instead of leave it.

Write and follow standard operating procedures for ventilation system maintenance.

What Forest Park Police Department Employees Can Do

Be sure to wash hands and face after shooting.

If after the ventilation system is fixed you can still smell gunsmoke outside the range when the range door is shut, report it to the range master.

After shooting, shower and change into a set of clean clothes before going home and wash the set you used on the range. Don't wash the dirty clothes at home.

When shooting from a prone position, put down a disposable floor covering (like paper) first.

CDC
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What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call at 1–513–841–4252 and ask for HETA Report # 97–0255–2735

National Institute for Occupational Safety and Health
NIOSH

For Information on Other
Occupational Safety and Health Concerns

Call NIOSH at:
1–800–35–NIOSH (356–4676)
or visit the NIOSH Homepage at:
http://www.cdc.gov/niosh/homepage.html

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