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I. SUMMARY

On December 1, 1989, the National Institute for Occupational Safety and Health **(NIOSH)** received a request for a Health Hazard Evaluation (HHE) from a management representative of the Kansas City, Kansas, Police Department Headquarters. The Police Department requested NIOSH to evaluate lead exposures incurred by the range master, his assistant, and fellow police officers while working and firing weapons at their outdoor firing range.

On August 6, 1991, NIOSH investigators met with the police department safety officer and toured the facility. On August 7, personal breathing-zone (PBZ) and general-area (GA) samples for airborne lead were collected, surface lead contamination was measured at two locations inside the firing range office/classroom, hand lead (dermal) contamination was measured, and clothing contamination was evaluated.

The results of PBZ air samples showed that officers were exposed to 8-hour time weighted average (TWA) concentrations of airborne lead ranging from nondetectable to 8 micrograms per cubic meter ($\mu g/m^3$), the PBZ 8-hour TWA of the Range Master was approximately 4 $\mu g/m^3$. All PBZ air sample results were below the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) of 50 $\mu g/m^3$. The results of GA air sampling showed airborne lead concentrations ranging from nondetectable to trace concentrations. While the results of PBZ and GA air sampling indicate that lead concentrations generated from weapons fired at this outdoor range did not exceed the existing environmental criteria the day of the NIOSH survey, the effects of different meteorological conditions were not evaluated and should be considered. The wind direction on the day samples were collected was observed blowing the gun smoke downrange, away from the breathing-zones of the officers. However a previous NIOSH HHE at an outdoor firing range documented airborne lead concentrations in excess of the OSHA PEL, demonstrating that different meteorological conditions can adversely influence airborne concentrations, resulting in airborne concentrations above the OSHA PEL. The wind direction in this latter study blew gun smoke into the breathing zone of the range users.

Surface wipe sample results indicated that high-contact surfaces inside the range office/classroom were contaminated with lead, concentrations measured on two surfaces were 1350 $\mu g/m^2$ and 1180 $\mu g/m^2$. The results of hand wipe samples indicated that the hands of officers using the range were contaminated with lead. The highest dermal concentration found (290 μg/2-hands) was collected from a patrolman after cleaning a weapon and prior to washing his hands. The results of two other dermal wipe samples showed that the hands of two patrolman were contaminated with lead even after washing their hands, concentrations of 210 and 110 μg/2-hands were detected. Lead concentrations found on six patches, cut from the tee-shirt of an officer, were all below the analytical limit of quantitation (LOQ = 23 μg of lead/g of shirt), except the patch cut from the chest, this sample contained 110 $\mu g/g$.

On the basis data collected during this evaluation, exposures to airborne lead did not exceed the OSHA or NIOSH criteria, however dermal and surface lead contamination was documented, increasing the potential for hand-to-mouth lead ingestion. The presence of lead on clothing may also contribute to the contamination of automobiles and homes. Recommendations for reducing the potential spread of lead and medical surveillance of the range master and other frequent firing range users are contained in section VIII of this report.

KEYWORDS: SIC 9221 (Police Protection), outdoor firing ranges, inorganic lead, wipe samples, para-occupational exposure, copper-jacketed bullets.

II. INTRODUCTION

On December 1, 1989, the National Institute for Occupational Safety and Health **(NIOSH)** received a request for a Health Hazard Evaluation from a management representative of the Kansas City, Kansas, Police Department Headquarters. The Police Department requested NIOSH to evaluate lead exposures incurred by the range master, his assistant, and fellow police officers while working and firing weapons at their outdoor firing range.

On August 6, 1991, NIOSH investigators met with the police department safety officer and toured the facility. On August 7, environmental samples were collected at the range to measure airborne and dermal lead exposure to personnel during routine handgun qualifying activities and during a 4-hour general tactical unit (SCORE UNIT) training exercise.

III. BACKGROUND

The Kansas City, Kansas, Police Department outdoor firing range is located on land owned by the Board of Public Utilities' (BPU's) Nearman Power Plant and was constructed approximately 15 years ago. The range measures 30 by 100 meters, with a grass ground cover and dirt barriers on three sides. The downrange dirt berm is 18 feet high and is at the north end of the range. The east and west berms are 8 feet high. The range can accommodate 15 shooters at one time. Approximately 200,000 rounds of ammunition are fired at the range each year. An enclosed office and classroom is at the far south end of the range, with an attached garage. The office/classroom area is equipped with a desk for the range master and has adequate space and chairs to instruct small classes. A small refrigerator and a carboy water dispenser are located in the classroom area on top of a table next to several tables which are used as gun cleaning surfaces. Hand washing (non-potable) water is supplied to the office by an on-site well. The garage houses targets, various other firing range accoutrements, and lawn care equipment.

Since the NIOSH survey, the outdoor firing range has begun to undergo changes. The changes include changing the direction of fire from northward to westward, thereby creating a 40 yard pistol and shotgun range. The north and east berm are to remain the same, while the west berm height will be increased to 25 feet. A 150 yard sniper range will be constructed behind the range office. After the renovations are completed, gun fire frequency at the range is expected to rise.

For the purpose of this report, the range will be referred to as it was relevant to this investigation.

Several years ago, the police department utilized an indoor firing range located in the basement of City Hall. However, serious health problems, due to an ineffective ventilation system and possibly from reloading ammunition on-site, were manifested by symptoms of lead poisoning and high blood lead levels (BLLs) in two Range Masters. The indoor range has remained closed ever since, and the practice of reloading ammunition has ceased.

A. Range Master Activities

The range master and his assistant work at the outdoor range at least 15 days per month. Their work schedule is as follows:

1. Eight days per month for Qualifying sessions
2. One day per month overseeing SCORE UNIT exercises
3. One day per week during in-service training activities (September-June)
4. Various times while other agencies (Prairie Village P.D., US Postal Service, US Marshall Service, etc.) use the range

Additionally, the range master and his assistant mow the grass cover once a week in the summer and are responsible for any other range upkeep, including picking up spent shells with their hands.

B. Firing Range Use

Each officer in the police department is required to successfully qualify at the range twice a year. Standard qualification consists of firing 12 rounds at 25 yards, 12 rounds at 15 yards, and 26 rounds at 7 yards (total of 50 rounds). The Police Department supplies 9-millimeter (mm) full-copper jacketed and .38 caliber non-jacketed ammunition for qualification with authorized duty guns. Personnel also qualify with personal weapons, and provide their own ammunition. During each qualifying session, the range master, or his assistant, stand next to the shooters to direct and evaluate each officer's performance. Personnel are also entitled to shoot 50 practice rounds at the range per month, and approximately 10% of the officers utilize this benefit.

The SCORE UNIT (approximately 15 officers) uses the range one day a month and typically fires M-P5s, M-16s, 223s, 308s, and 12-gauge shot guns while performing tactical exercises. The range master directs some of the activities.

During the fall, winter, and spring months (September through June), the range is used one day per week for in-service training (required for all officers). During this full day of firing, the range master and his assistant instruct 10-12 officers, and each officer fires 100-150 rounds.

While other agencies are using the range, the range master, or his assistant, are present to insure the firing range is used appropriately and safely.

The Police Department does not provide blood lead level (BLL) monitoring for the range master, or for his assistant and there is no hearing conservation program.

IV. EVALUATION DESIGN AND METHODS

Seventeen personal breathing-zone (PBZ) and 2 general-area (GA) samples for airborne lead were collected on 0.8 micrometer (μm) pore size mixed 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 analyzed by atomic absorption spectroscopy (AAS) according to NIOSH Method No. 7082.[1]

Surface lead contamination was measured at two locations inside the firing range office/classroom by following a U.S. Department of Housing & Urban Development (HUD) approved surface wipe sampling method.[2] The HUD method specifies using commercial pre-moistened baby wipes (Wash a-bye Baby™ wipes were used) for surface wipe samples. Surface wipe samples were collected on hard flat surfaces. A 30.5 X 30.5 centimeter (cm) area (929 cm^2) was measured. Disposable gloves were worn while collecting the surface wipe samples. The first wipe from the package was discarded. The second wipe was handled for an imaginary approximate sample time period, placed in a clean labeled Zip-Loc™ bag and submitted to the laboratory as 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, the wipe was 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, disposable gloves were discarded after each sample. Surface wipe samples were analyzed for lead by NIOSH Method 7082.[1] The samples were ashed with 9 ml nitric acid and 3 ml hydrogen peroxide, heated on a hotplate to near dryness to complete digestion, quantitatively transferred to 50 ml volumetric flasks and then analyzed by AAS.

Hand lead (dermal) contamination was measured on three police officers and the shirt of one officer was obtained for lead analysis. Hand wipe samples were collected using the same brand of baby wipes mentioned above. The first baby wipe in the package was discarded and the employee pulled the second wipe from the package. Each officer 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. The hand wipe samples were analyzed identically to the surface wipe samples. The shirt sample was a tee-shirt worn by a SCORE UNIT member during the sampling day. Pieces of the shirt (chest, stomach, shoulders and back area) were analyzed for lead as described above.

Currently there are no "standard" dermal or shirt sampling techniques for lead, but the literature describes similar dermal sampling procedures,[3-8] and other contaminants have been successfully measured on clothing; e.g., the United States Environmental Protection Agency (EPA) describes methods to measure pesticides on clothing.[9] It should be noted the surface, hand wipe, and shirt sampling techniques are, at best, semi-quantitative measures of lead contamination.

Airflow patterns in the downrange area were observed by watching the smoke generated by the firing of the weapons.

V. EVALUATION CRITERIA

A. Environmental 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 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 if 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 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 environmental evaluation criteria for the workplace are: 1) NIOSH Recommended Exposure Limits (RELs),[10] 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs),[11] and 3) the U.S. Department of Labor/Occupational Safety and Health Administration (OSHA) occupational health standards.[12] The OSHA standards may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is required by the Occupational Safety and Health Act of 1970 (29 USC 651, et seq.) 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 high, short-term exposures.

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

1. 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.[13] The effects may be manifested as weakness, tiredness, irritability, reduced intelligence, slowed reaction times, abdominal pain, or high blood pressure.[14] 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.[15-19] 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 µg/dl;[17,18] however, with the implementation of lead-free gasoline and reduced lead in food, it is estimated that the 1991 average BLL of U.S. men will drop below 9 µg/dl.[13]

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 airborne lead above the action level (30 µg/m^3) for more than 30 days per year.[22] If an employee's BLL is at or above 40 µg/100 grams of whole blood (approximately equivalent to 40 µg/dl),[10,23] 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/she must be removed from areas containing more than 30 µg/m^3 airborne lead, and have monthly blood lead tests.[22] 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.[22] The blood samples must be analyzed by an OSHA approved laboratory.[24]

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.[25] In women, ZPP levels rise at BLLs of 25 µg/dl. Fifty µg/dl ZPP is usually considered the upper limit of normal.[26]

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 work day, the PEL should be adjusted accordingly, e.g., the PEL for a 10-hr work day is 40 µg/m^3.[22] 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).[22] Appendix A is summary of the toxic effects of lead and Appendix B is summary of the key provisions of the lead 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 ug/m^3, air

monitoring must be performed every six months until the results show two consecutive levels of less than 30 ug/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 contaminated surfaces, the U.S. Department of Housing and Urban Development (HUD) has set clearance levels to be achieved after a lead-based paint abatement.[2]

Floors:	200 $\mu g/ft^2$	(2150 $\mu g/m^2$)
Window sills:	500 $\mu g/ft^2$	(5380 $\mu g/m^2$)
Window wells:	200 $\mu g/ft^2$	(2150 $\mu g/m^2$)

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

The results of sampling for airborne lead are presented in Table I. General area air samples showed airborne lead concentrations ranged from none detected to trace concentrations. Sixteen officers were exposed to 8-hour TWA concentrations ranging from none detected to 8 $\mu g/m^3$, assuming no other lead exposures, during their work shift, before and after samples were collected. These officers were exposed to airborne lead concentrations below the OSHA PEL of 50 $\mu g/m^3$. The PBZ 8-hour TWA of the Range Master was approximately 4 $\mu g/m^3$, again below the OSHA PEL. While these results indicate that airborne lead concentrations generated from weapons fired at the outdoor range are not excessive, the effects of different meteorological conditions should be considered. During this survey the wind was observed blowing the gun smoke downrange, away from the breathing-zones of the shooters. As an example of the influence of meteorological conditions on air sampling results, measurements from a previous NIOSH HHE conducted at the Cincinnati Police Department Outdoor Target Range (HETA 89-073, a copy of this report is enclosed) documented high airborne lead exposures (up to 2222 $\mu g/m^3$) to range personnel. The wind in this latter study blew gun smoke into the breathing zone of the shooters. It is possible the airborne lead concentrations measured during the present survey represent a "best case" scenario, meaning measured lead levels were lower than the norm. Ideally, measurements should be made in the future to also evaluate the "worst case" scenario. PBZ samples for airborne lead should also be collected on the range master, and his assistant, while mowing the firing range lawn. Indoor firing range floors become heavily contaminated with lead after weapons are fired, similarly, the grass growing at the outdoor range may become heavily contaminated with lead. Until measurements are made, the possibility of high lead exposures (and clothing contamination) while mowing the lawn can not be ruled out.

High-contact surfaces inside the range office/classroom were found to be contaminated with lead, as shown in Table II. The lead concentration measured on the table supporting the refrigerator was 1350 $\mu g/m^2$ and the concentration on the right side of the range master's desk was 1180 $\mu g/m^2$. Because these surfaces are not used as gun

cleaning surfaces, "lead spread" from contaminated skin, clothing and objects is the probable source.

The results of lead measured on the hands of SCORE UNIT patrolmen after cleaning weapons is presented in Table III. Information is also presented as to whether hands were washed prior to sampling. The highest result (290 µg/2-hands) was collected from a patrolman after cleaning a weapon and prior to washing his hands. Two other patrolman were sampled after washing their hands, and 210 and 110 µg/2-hands were measured. While it is difficult to draw conclusions from this type of data, it does indicate that hands were contaminated with lead even after washing. Reasons for this may be that a lead contaminated towel was used to dry hands, lead contaminated surfaces were touched after washing, and/or hand washing was ineffective in lead removal.

Lead concentrations found on the six patches (each approximately 8 cm^2) cut from an officers tee-shirt were all below the analytical limit of quantitation (LOQ = 23 µg of lead/g of shirt), except the patch cut from the chest, which contained 110 µg/g. 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.[27-41] While studies have not directly documented increased lead burden in the homes of firing range users, there is no reason to rule out this possibility.[13] Officers reported that their clothing was laundered at home, therefore, 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 for young children (< 7 years old), who are more affected by the subtle effects of low lead exposure than are adults.[10]

Firing range users should be aware that 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. Wearing lead contaminated clothing may also result in contamination of each officers automobile and home with lead. Unfortunately there are no shower or laundry facilities located at the outdoor firing range.

VII. CONCLUSIONS

Although airborne lead exposure did not appear to be a significant route of exposure during this NIOSH investigation, a previous NIOSH HHE documented high airborne lead concentrations at an outdoor firing range (e.g., HETA 89-073).

Dermal and surface lead contamination was documented, increasing the potential for hand-to-mouth lead ingestion. The presence of lead on clothing may also contribute to the contamination of automobiles and homes.

VIII. RECOMMENDATIONS

1. Blood lead testing should be an integral component of the range personnel physical examinations. Even though airborne lead levels were low in this study, as compared to the OSHA action level (30 µg/m^3), other routes of lead exposure are possible. Considering the Police Department's past experience with lead

poisoned instructors, it would be prudent to measure BLLs in the Range Master, his assistant, SCORE personnel, and others with frequent firing range use. The OSHA lead standard (29 CFR 1910.1025) should be consulted for medical surveillance requirements.

2. An air sampling protocol similar to that used in this survey should be performed under different meteorological conditions. Repeated over time, results will give a representative distribution of personal breathing-zone airborne lead concentrations generated at the range.

3. A wind sock should be positioned at the range to determine wind direction. If the wind is blowing up range, the range should not be used.

4. Indoor surfaces inside the range should be cleaned routinely with a high phosphate detergent, e.g., Spic and Span™, to reduce surface lead contamination.

5. Eating, drinking, and smoking inside the range office/classroom area should be prohibited to reduce possible hand-to-mouth lead ingestion from the cleaning of guns. The refrigerator and water carboy dispenser should be removed from the office and placed in a newly constructed, separate "lead free" eating room. Personnel should be aware that their skin and any surfaces, within the range area, may be contaminated with lead. Signs to remind firing range users of potential lead contamination should be designed and displayed at the range.

6. Inexpensive, disposable, white cotton gloves should be purchased by the Police Department and worn by the Range Master, and others, while picking up spent shells from the grounds, the gloves should be discarded after each use. This will reduce unnecessary dermal lead exposure. If it is feasible, these gloves should be worn while cleaning weapons.

7. After using the range, individuals should shower and change clothes. The Police Department should inquire into installing showers at the range. If the well water is not satisfactory for this purpose, it may be possible to run a city water line from the nearby BPU Nearman power plant.

8. Ideally, clothing worn by frequent users of the firing range should be laundered through the Police Department. Separate lockers for street clothes should be also installed at the range. Care should be taken to avoid contaminating vehicles or the home environment with lead from contaminated clothing and shoes. Work shoes should remain at work. Clothing worn in the firing range should not be laundered with family members' clothing.

9. Before showering and changing clothes, contact with other people, especially children, should be avoided after working in the firing range.

10. The use of copper-jacketed ammunition has been shown to reduce airborne lead concentrations, and therefore, should be used as much as possible to reduce the potential for employee exposures to airborne lead.[42]

11. A recent NIOSH HHE (HETA 91-117) investigated the use of double hearing protection by U.S. Secret Service agents during routine qualification rounds. This

study is currently ongoing and a final report has not been issued as yet, however interim letter with data has been issued with the conclusion that double hearing protection (both ear plugs and ear muffs) should be donned at firing ranges. Furthermore, it is highly recommended the Police Department conduct annual audiometric testing on the range master, his assistant, and SCORE unit members.

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