Evaluation of Lead Exposure to Bureau of Forensic Services Firearm Examiners

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EXECUTIVE SUMMARY

1. Air monitoring indicates that BFS Firearm Examiners are not usually exposed above the regulatory action level or the PEL in the course of their work when using copper jacketed ammunition. However, in circumstances where a lot of test firing may occur during a single day where only one FE was performing the testing, procedures should be implemented at the Riverside and Chico labs to ensure that employee's exposure stays below the action level.

2. Ventilation at the Sacramento Firing Range and the Santa Barbara lab do not meet recommended standards. Current levels of shooting do not require that it be upgraded. However, to keep employee exposure levels as low as achievable, the systems should be modified.

3. The Chico lab does not have any ventilation. Administrative controls can be instituted to keep employee exposures low if multiple weapons will be fired in the same day. However, Cal/OSHA prefers exposure control through adequate mechanical ventilation. Installing a local exhaust system should be considered.

4. Based on the air monitoring data and the blood lead results from the existing firearm examiners, an on-going blood lead-monitoring program is not necessary.

5. High levels of lead dust were detected on the top of the cotton box in the Fresno firearms testing shed and on the top of the water tank. The dust probably contributed to high air lead levels without the ventilation on. These areas should be wiped down with a wetted, disposable cloth and gloves. Additionally, the ventilation must always be on in the shed when shooting firearms until the cleanup has occurred and follow-up air monitoring indicates safe exposure levels.

6. Lead dust is present in the test firing areas. The amount of lead detected, and current blood lead levels indicate that employees do not seem to be significantly effected by it. However, a reminder that no eating or drinking is allowed in these areas and handwashing after test firing should be made.

7. To determine worst-case scenarios, breathing zone air monitoring should also be done for large caliber handguns with non-jacketed ammunition.

Introduction

The Bureau of Forensic Services (BFS) Firearm Examiners (FE) must test fire weapons used in crimes for forensic firearm examinations. Firing these weapons involves the use of a water tank (horizontal or vertical), a bullet trap, a cotton box or a shooting range. Typically, the FE will fire several rounds into one of these devices, which may be indoor or outdoor. Some of the indoor BFS

facilities have ventilation systems and some do not. The use of outdoor facilities presumes that adequate mixing will occur due to natural ventilation.

The California Code of Regulations, Section 5216 of Title 8, requires employers to evaluate employees who are exposed to lead as part of their occupation. If exposures exceed the action limit of 0.03 mg/m^3 (30 $\mu g/m^3$), certain health and safety measures must be implemented such as continued air monitoring and medical monitoring. If the Permissible Exposure Limit (PEL) of 0.05 mg/m^3 is exceeded, further action must be taken, such as installation of ventilation systems.

While considerable research has been done on exposure at firing ranges during target practice or law enforcement qualifying, only one research paper exists that addresses the FE community (1). The air monitoring conducted in that paper involved a facility that had significantly upgraded their ventilation system.

In order to meet the requirements of Section 5216, BFS authorized the Health and Safety Program to conduct air monitoring during test fires at various BFS facilities, to conduct a survey of FE lead exposure practices, and to collect medical monitoring data with respect to blood lead levels in all FEs.

Methods

The facilities were chosen to represent the worst potential in terms of employee exposure. All BFS facilities with indoor facilities were monitored, as well as two facilities that were outdoors, but with limitations on natural ventilation. Worker breathing zone air samples and surface wipe samples were collected between April 28 and June 2, 1999.

The FEs fired 5 rounds each of .38, .40, and .45 semi-jacketed ammunition. Five rounds was chosen as the maximum number that might typically be fired (The FE Questionnaire indicated that BFS FEs fire 3.5 rounds on average; two FEs indicated that up to 6 rounds might be fired in unusual cases. See Attachment #1). Semi-jacketed ammunition is most typically used now. A higher number of rounds, larger caliber or non-jacketed ammunition could have been chosen to give the absolute worst case, however those instances would represent rare occasions. The circumstances chosen were to be the most representative of normal operations.

Each series of rounds with and without ventilation (where possible) were fired in the water tank and at the bullet trap. This was evaluated to determine whether more exposure occurs when firing downward (water tank) then when firing horizontal (bullet trap).

Worker Breathing Zone air monitoring was conducted for 4 minutes during each test fire with an average flow rate of 2.5 liters/minute. NIOSH Method #7105, “Lead by GFAAS”, was used for analysis because it has a very low detection level.

Surface wipes were collected at each facility as well. NIOSH Method # 9100, “Lead in Surface Wipe Samples”, was used. No standard currently exists for lead on surfaces in the workplace. HUD has

standards for various locations in a living unit. A suggested standard of 200 μg/100 cm^2 for work areas where there is no eating and probability of ingestion is negligible has been proposed (2).

Blood lead evaluation was offered to each FE in BFS. Analysis was done under contract to UC Davis. All the results were screened by Dr. Stephen McCurdy, the Occupational Physician at UC Davis.

Results by Laboratory

SACRAMENTO

The Sacramento Lab has an indoor room within the lab where the water tank is located. The tank is located on the second floor of the building, which extends down into another area. Ventilation is provided by a hood that is placed over the opening of the tank that exhausts air from where the muzzle of the weapon is placed. Testing was conducted first with the ventilation off, then with the ventilation on. At the end of the test for .45 ammo, the air-sampling cassette fell into the water tank, and had to be redone. Wipe samples were collected from the wall adjacent to the tank, on top of the ventilation hood, on the counter next to the water tank and from the table in the adjacent room.

Ammo	8 hr TWA μg/m3	Location	Conditions
.38 spec	1.5	Water Tank	No Ventilation
.38 spec	0.9	Water Tank	Ventilation On
.40 cal	1.1	Water Tank	No Ventilation
.40 cal	0.3	Water Tank	Ventilation On
.45 cal	1.2	Water Tank	No Ventilation
.45 cal	1	Water Tank	Ventilation On
.38 spec	0.03	Firing Range	No Ventilation
.38 spec	0	Firing Range	Ventilation On
.40 cal	0.1	Firing Range	No Ventilation
.40 cal	0	Firing Range	Ventilation On
.45 cal	0.6	Firing Range	No Ventilation
.45 cal	0.1	Firing Range	Ventilation On

Results: No significant airborne exposure of lead to FE exists under these circumstances. There is observable reduction in lead exposure with the ventilation on. However, even without the ventilation on the exposure levels are very low. It should be noted that the highest exposures were with the .38 ammo. This is probably because much of the combustion gases are discharged outside the revolver and closer to the person firing the weapon. Wipe samples showed measurable lead that was well below the proposed criteria. Any handling of lead should require handwashing afterwards.

Sacramento also has an indoor firing range located in the basement of the building. The room is approximately 90 feet by 15 feet. Shots are fired through a piece of plywood to a bullet trap consisting of an angled steel plate. The spent ammunition lands in a pit. A ventilation duct is located on the south wall adjacent to the target wall. With the fan on, room flow rates varied from 0-50 fpm.

No makeup air is provided. Test firing was conducted at the 15-yard line. Wipe samples were collected from the tops of two tables and the north wall.

Results: No significant airborne exposure of lead to FE exists under these circumstances. The ventilation made a measurable reduction. Wipe samples showed measurable lead that was well below the proposed criteria. Any handling of lead should require handwashing afterwards.

Conc. μg/100 cm^2	Location
21	Counter top next to water tank
48	Top of ventilation housing
4	West wall next to water tank
4	Counter top next to microscope in adjacent room
14	North wall of Firing Range
45	Bench top against south wall
60	Bench top in center of room

It was also noted that the pit in the bullet trap contained a considerable amount of spent ammunition. If any significant shooting is to take place, additional lead may become airborne due to this pit. The contents should be removed and clean fill provided. The waste will have to be disposed of as a hazardous waste.

FRESNO

The Fresno lab has their firing facilities all located outdoors. The bullet trap and cotton box are located in a covered cinderblock room that is open on one-side. The water tank is located at grade immediately next to the lab building. A mechanical ventilation system is available for the cinderblock room. At the entrance, the flow rate was approximately 150 fpm. There is only natural ventilation for the water tank.

Ammo	8 hr TWA (μg/m^3)	Location	Conditions
.38 spec	27.6	Bullet Trap	No Ventilation
.38 spec	0.3	Bullet Trap	Ventilation On
.40 cal	25	Bullet Trap	No Ventilation
.40 cal	0.3	Bullet Trap	Ventilation On
.45 cal	21.7	Bullet Trap	No Ventilation
.45 cal	0.4	Bullet Trap	Ventilation On
.38 spec	0.5	Water Tank	No Ventilation
.40 cal	1.3	Water Tank	No Ventilation
.45 cal	2.5	Water Tank	No Ventilation

Bullet trap results: Without the ventilation on, exposure levels were close to the action level. Test firing two separate weapons on the same day would exceed the action level, and may exceed the

PEL if the ventilation is not on. However, with the ventilation on, the exposures are insignificant. Therefore, the ventilation MUST be on when the bullet trap is being used.

Water Tank results: No significant airborne exposure of lead to FE exists under these circumstances.

Conc. μg/100 cm^2	Location
2876	On top of cotton box, 3' from trap
73	Leftside wall, 5' high, 3' from trap
657	Top of water tank cover

Wipe sample results: In the bullet trap area, wipe samples on the top of the cotton box were ten times the recommended standard (200 μg/100 cm^2). This area should be wiped down with moist wipes while wearing gloves to remove excess lead. This lead is probably re-entrained in the air during test firing and is the cause of the very high exposure levels experienced when the ventilation was not on.

Wipe results on the top of the water tank cover were three times the recommended standard. This area should be wiped down with moist wipes while wearing gloves to remove excess lead and disposed of with normal solid waste.

SANTA BARBARA

The Santa Barbara lab has the water tank, bullet trap and cotton box indoors in the same room. A fan is located in the ceiling, which is about 20 feet high. Stairs lead to the top of the water tank, which is adjacent to the north wall. Smoke candles have shown that the ventilation is inadequate in this area due to the lack of fresh air supply. No measurable airflow was found there with the ventilation on. Cutting holes in the wall to provide supply air have been suggested in the past. Airflows of 0-30 fpm were measured at the firing location for the bullet trap. On the day previous to testing, approximately 50 rounds were discharged in the room. Therefore, a background sample of the room, as well as an outside background sample were collected for comparison.

Ammo	8 hr TWA μg/m^3	Location	Conditions
.38 spec	0.6	Water Tank	No Ventilation
.38 spec	0.7	Water Tank	Ventilation On
.40 cal	0.5	Water Tank	No Ventilation
.40 cal	0.69	Water Tank	Ventilation On
.45 cal	0.7	Water Tank	No Ventilation
.45 cal	0.5	Water Tank	Ventilation On
.38 spec	1.1	Bullet Trap	Ventilation Off
.38 cal	1.2	Bullet Trap	Ventilation On
.40 cal	1.3	Bullet Trap	Ventilation Off
.40 cal	1.2	Bullet Trap	Ventilation On
.45 cal	1.4	Bullet Trap	Ventilation Off
.45 cal	1.3	Bullet Trap	Ventilation On

Water Tank results: No significant airborne exposure of lead to FE exists under these circumstances. There was no real difference whether the ventilation was on or off. In two out of three circumstances, the ventilation value was higher than the non-ventilated value. However, the variation in the values is not significant.

Bullet Trap results: No significant airborne exposure of lead to FE exists under these circumstances. These results were approximately twice the values found at the water tank. Ventilation made a very small improvement.

Conc. μg/100 cm^2	Location
45	Counter top next to water tank
62	Edge of cart top
39	East hall door, 6" above handle
39	North wall acoustic tile next to water tank

Wipe Sample results: The wipe sample on the wall next to the water tank was within the proposed standard. Wipe samples of horizontal surfaces near the bullet trap were within the proposed standard.

RIVERSIDE

The Riverside lab has their entire facilities outdoors. Cal/OSHA Consultation Service did an evaluation at the Riverside facility on February 16, 1981 when the bullet trap was located in the garage (3). After firing seven rounds from a .357 and eight rounds of .44 Magnum, the Cal/OSHA 8 hour PEL was exceeded. Subsequently, the bullet trap was moved to the outside hallway of the building. The area is under an overhang. The water tank is located next to a stairwell nearby, also outside, in a more open area.

Ammo	8 hr TWA (μg/m^3)	Location
.38 spec	1.8	Water Tank
.40 cal	Not tested	Water Tank
.45 cal	5.2	Water Tank
.38 spec	0.02	Bullet Trap
.357 cal	0.3	Bullet Trap
.45 cal	6.5	Bullet Trap

Water Tank results: No significant exposure of lead to FE exists under these circumstances (see EXCEPTION below). The Riverside lab did not have a .40 caliber weapon to use for the test, so that ammunition was not fired. However, in all previous tests, the exposure levels of the .40 ammo was always below either the .38 or the .45 ammunition. Wind in the area of the water tank was measured at 30-70 fpm (0.8 mph).

EXCEPTION: Even with the natural ventilation, the exposure value for the .45 ammo was the highest recorded of all the lab water tanks evaluated. Based on these results, no more than five weapons of this caliber or larger could be tested by a single person in a single day unless respiratory protection were used. Alternatively, multiple persons could do test fires if a number of weapons had to be tested.

Bullet Trap results: No significant exposure of lead to FE exists under these circumstances (see EXCEPTION below). Wind in the area was measured at 70-130 fpm (0.8-1.5 mph).

EXCEPTION: Even with the natural ventilation, the exposure value for the .45 ammo was the highest recorded of all the bullet traps evaluated. Based on these results, no more than four weapons of this caliber or larger could be tested by a single person in a single day unless respiratory protection were used. Alternatively, multiple persons could do test fires if a number of weapons had to be tested.

To make a comparison with the 1981 exposure monitoring results, cumulative lead exposure was measured while 5 rounds each of .38, .357 and .45 were fired. The cumulative result for an 8 hour PEL was 9.35 $\mu g/m^3$. In 1981, seven rounds of .357 and eight rounds of .44 magnum were fired resulting in an 8 hour PEL of 636 $\mu g/m^3$. The combination of moving the bullet trap to an outside location, as well as the use of copper jacketed ammunition show the large reduction in exposure.

Conc. $\mu g/100\ cm^2$	Location
92	Railing next to cotton box
21	5' from floor at "20" marker, stucco wall near bullet trap

Wipe sample results from the handrail and nearby wall were all within the proposed standard and considerably less than was measured in the garage in the 1981 survey (4,500-115,000 $\mu g/100\ cm^2$).

CHICO

The Chico lab has an indoor horizontal water tank and a cotton box. No bullet trap is available. No ventilation is provided. Employees sometimes use a household fan to provide air movement.

Ammo	8 hr TWA ($\mu g/m^3$)	Location	Conditions
.38 spec	1.6	Water Tank	No Ventilation
.40 cal	0.7	Water Tank	No Ventilation
.45 cal	5.6	Water Tank	No Ventilation

Water Tank results: No significant airborne exposure of lead to FE exists under these circumstances. However, exposure when firing five rounds of .45 ammunition was one tenth of the PEL and one sixth of the action level. Therefore, no more than 5 weapons of this caliber or greater may be tested in any one day by a single person. A greater amount of testing would require the use of a respirator.

μg/100 cm^2	Location
74	Top right corner of water tank
46	Vertical wall 18" from cottonbox opening, 5' high
3	Bottom left corner of table 15' from water tank

Wipe samples collected in the area were all within the proposed standard.

Blood lead levels

8 CCR 5216 requires that employees who are exposed above the action level (30 μg/m^3 TWA) for 30 days per year must have medical monitoring of their blood every 6 months. If anyone is found to have blood lead levels exceeding 40 μg/100 ml blood, that employee has to be removed from lead exposure until the blood lead levels drop below that value. Levels as low as 10 μg/100 ml may be associated with hypertension(4).

BFS FEs were provided the opportunity to participate in blood lead monitoring. Twenty-two FEs participated. Of those measured, none had a blood lead level exceeding 5.2 μg/100 ml (average = 2.3 where <2 was considered 1.9 μg/dl, range = <2-5.2). Whereas not all FEs participated, these results indicate that lead exposure is slight and a routine blood lead exposure monitoring is not necessary.

Please note that the type of testing performed does not indicate whether the current blood level is from recent exposure or is from lead that may be leaching out of bone from previous exposure [about 95% of lead that is absorbed into the body ends up in bone (4)].

Dr. Stephen McCurdy, Occupational Health Physician for U.C. Davis Medical Group reviewed the blood lead results. His only concern was with the person who had the highest level of all the FEs who participated. He felt that that person's activity should be reviewed to determine possible lead exposure pathways. That has been done, without identifying any unusual circumstances. Dr. McCurdy did not recommend an on-going blood lead monitoring program.

Firearm Examiners Questionnaire

All BFS FEs were sent an anonymous and voluntary questionnaire regarding their length of experience, firearm usage and habits as well as personal use of firearms. This information is found in Appendix A. The information showed that five rounds was an appropriate number of rounds to evaluate. It also verified that 74% of the FEs also use firearms on their personal time. This could be a contributing factor if any FEs have elevated blood lead levels in the future.

Discussion

Lead Exposure during firearms testing

The data collected show that neither the PEL nor the regulatory action level for lead are exceeded when using copper jacketed ammunition. Exposure levels increase as the caliber increases. Exposure would be expected to increase when using non-copper jacketed ammunition as well. Since copper jacketing is very common today, it is likely that lead exposures will usually be below the regulatory levels even without ventilation. However, non-jacketed ammunition was not tested. Additionally, some circumstances may occur where the employee may fire more that five rounds, which will increase exposure. Finally, it is best to keep lead exposure levels as low as reasonably achievable since the true threshold of effect is still not known. It will also help limit the amount of lead that will accumulate in the test room environment. Therefore, the use of ventilation should be used where possible, and local ventilation installed at indoor facilities where none currently exist.

Horizontal verses Vertical Firing and Lead Exposure

It would be expected that when comparing water tank and bullet trap results, that shooting downward would cause greater exposure than shooting horizontally. This was observed in the Sacramento lab and partially at Riverside (.38 ammo). However, the opposite was observed at the Santa Barbara lab and partially at Riverside (.45 ammo). Fresno was distorted by possible excessive lead-containing dust and Chico did not permit comparison. Under the current test-fire conditions, the posture of firing does not make a difference in lead exposure.

Use of Ventilation

The American Conference of Governmental Industrial Hygienists (ACGIH) makes recommendations on the requirements for a properly operating ventilation system for an indoor firing range (5). While this is not applicable to water tanks and bullet traps, it is useful information concerning ventilation flow rates (50 fpm or greater) necessary to remove aerosolized lead particles from the shooters breathing zone. Of the facilities tested, only the Fresno facility meets and exceeds the 50 fpm level.

The Santa Barbara facility does not provide adequate flow at the water tank. Holes need to be cut in the wall to allow air to flow through and allow the smoke to be exhausted from the shooter's platform.

The Sacramento water tank only provides a cowl in which to place the gun muzzle. Side blast from revolvers is not captured with this system. The firing range downstairs does not provide sufficient ventilation according to ACGIH standards for use as a firing range with multiple shooters (approximately 4800 cubic feet per minute would be needed; the current level is less than half of that). Occasional test firing as described earlier in this report is not a problem.

Chico is an indoor firing situation without any ventilation. While under normal conditions, the action level is not exceeded, the need to fire a large number of weapons would probably cause over-exposure. If this happens more than rarely, the preferable solution would be to install an appropriate

local exhaust system. Alternatively in these instances, several personnel could perform the task to reduce exposure or the employee should wear a respirator. If the later method is chosen, then that person must meet all the requirements of the BFS Respiratory Protection Program.

The Fresno outdoor firearms testing shed was equipped with a powerful fan. With the fan in operation, exposure levels were very low. However, without it on, the exposure levels were the highest of all labs, and approaching the action level. This is probably due to excessive lead dust on the cotton box. To avoid this potential problem, the fan MUST always be on when shooting. The cotton box should also be cleaned.

Natural ventilation is normally sufficient as was indicated at Fresno and Riverside. However, consideration should be given to ensuring that doors are completely closed when firing to prevent contaminated air from being pulled into the building. Additionally, some limit on weapons testing may be needed if a large number weapons needs to be tested in one day. Several people may have to perform the operation since the cumulative exposure may exceed the action limit. Alternatively, the person could wear a respirator. If the later method is chosen, then that person must meet all the requirements of the BFS Respiratory Protection Program.

Cleanup of lead-containing dust and debris

Wipe sampling indicated that most of the BFS facilities do not have a significant level of lead dust inside the firing areas. However, the Fresno shed had two areas that may have been the cause for excessive levels when ventilation was not being used. This was found on top of the cotton box and on the lip of the water tank. Therefore, both should be wiped down with a damp disposable cloth and disposable gloves that are disposed of into the standard solid waste stream.

The debris bed under the bullet deflector in the Sacramento Firing Range was not tested. However, due to the large number of spent bullets in it, it is likely that this debris will have to be disposed of as hazardous waste when it is cleaned out. If significant shooting occurs in the range, dust from this debris pile may contribute to employee exposure.

<u>Conclusions and Recommendations</u>

1. Air monitoring indicates that BFS FEs are not usually exposed above the action level or the PEL in the course of their work when using copper jacketed ammunition.

2. Ventilation at the Sacramento and Santa Barbara labs does not meet recommended standards. However the measured exposures do not require upgrading. In the interest of keeping employee exposure levels low, the systems should be modified to meet ACGIH standards.

3. Chico does not have any ventilation. To avoid reliance on procedure to control exposures in unusual situations, a local exhaust system should be installed.

4. Chico and Riverside personnel should be advised about situations where exposure limits could be exceeded and instructed how to avoid that. Specifically:

- Individual Chico FEs should not fire more than five .45 weapons in a single day if firing five rounds each. If necessary, personnel could be rotated to reduce the exposure. Alternatively, a mechanical ventilation system will eliminate the possibility of overexposure.

- Individual Riverside FEs should not fire more than five .45 weapons in a single day at the water tank if firing five rounds for each test. At the bullet trap, an individual FE should not fire more than four .45 weapons in a single day if firing five rounds for each test. If necessary, personnel should be rotated to reduce the exposure or wear a respirator.

5. An on-going blood lead-monitoring program is not necessary.

6. The Fresno lab should clean the wood surfaces in the firearms testing shed and the top of the water tank to remove excess lead dust.

7. Lead dust is present in the test firing areas. The amount of lead detected, and current blood lead levels indicate that employees do not seem to be significantly effected by it. However, a reminder that no eating or drinking is allowed in these areas and handwashing after test firing should be made.

8. To determine worst-case scenarios, breathing zone air monitoring should also be done for large caliber handguns with non-jacketed ammunition.

References

1. Mirkin, G.M. and E. Williams: Lead Sampling in a Bullet Recovery Room, Journal of Applied Occupational and Environmental Hygiene, 13, pages 713-718 (1998)
2. Caplan, K.J., "The Significance of Wipe Samples", Journal of the American Industrial Hygiene Association, 53(2), pages 70-75 (1993)
3. March 13, 1981 letter from Cal/OSHA to Fred Tulleners, Criminalist, Bureau of Forensic Services, Riverside.
4. "Lead Toxicity", page 6, Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, September 1992.
5. Industrial Ventilation, A Manual of Recommended Practice, 23rd edition, pages 10-172. American Conference of Governmental Industrial Hygienists, 1998

Attachment #1
Firearm Examiners Questionnaire Results

The Lab Directors identified twenty-eight FEs at the time of sampling. Twenty questionnaires were returned, one was rejected since the person submitting the information indicated that they had not yet started working as a FE.

1. number of rounds fired per examination: Ave = 3.5, Range = 3-6
2. number of weapons examined weekly: Ave = 2.1, range = 1-5
3. percentage of time spent in firearm examination
    90%: 5 %
    80%: 11%
    70%: 21%
    60%: 5%
    50%: 21%
    40%: 5%
    30%: 0
    20%: 5%
    10%: 26%
4. number of years worked as a Firearm Examiner: Ave = 12.7, range = 3-29
5. shooting on personal time: 74% yes, 26% no
6. number rounds shot on personal time: Ave = 60, range 10-200
7. military experience: 32% yes, 68% no
8. number of years of military experience: Ave = 2.75, range 2-4 years
9. had a blood lead test before: 26% yes, 58% no, 16% no answer
10. previous blood lead test result: none could remember it