Characterizing Lead Exposure at a U.S. Coast Guard Indoor Firing Range

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Introduction

Exposure to airborne and settled lead dust at firing ranges is a well-known hazard that puts employees, fire arms instructors (FAIs), customers, and their families at risk for lead poisoning. Workers are exposed to lead in firing ranges when they fire weapons, instruct shooters, clean the range, clean firearms, empty bullet traps or sort brass (Fisher, 2013). Recently, several indoor firing ranges in Oregon and Washington State have been scrutinized by federal and state agencies for lead exposures. On November 2012, the U.S. Coast Guard Sector Columbia River in Astoria, OR, secured an indoor firing range after they discovered that one of their active duty members had an elevated blood lead level (BLL). It was later determined that the ventilation system was non-operational (Riutta, 2012) and the range was reopened after the ventilation issues were fixed and the internal CG standard was met (50 fpm). On January 2013, a health assessment survey determined that the U. S. Coast Guard Base Seattle indoor firing range's ventilation system was not operating to internal Coast Guard standards while the heating unit was operating (Riutta, 2013).

On February and March 2013, the same indoor firing range at U.S. Coast Guard Sector Columbia River in Astoria, OR, composed of two trailers were restricted from normal operations after it was discovered that several users had elevated blood lead levels (BLLs) (Riutta, 2013). After a more thorough assessment, it was revealed that the mechanical ventilation system used to remove lead dust and fume suspended in the air was operating inefficiently. Moreover, during an interview with one of the workers at one of the ranges, a potential source of lead exposure was identified; range workers were not donning personal protection equipment (PPE) during clean-up operations.

Each year, approximately 4,100 users from different local and federal agencies visit the U.S. Coast Guard Base Seattle’s indoor firing range, potentially exposing FAIs and the shooters to elevated levels of lead. It is expected that the number of users will increase as a result of the possible closing of nearby federal firing ranges. According to the Department of Defense (DoD), their new budget will increase from fiscal year 2013 to fiscal year 2017; however, the total U.S. defense budget, including funding for military firing ranges, will drop by approximately 22% (DoD, 2012).

The purpose of this study is to evaluate the relationships between determinants (hygiene practices, rounds fired, type of round or weapon used, etc.), air lead (PbA) exposures and blood lead levels (BLLs) as well as relating PbA and BLL to each other in Coast Guard personnel instructing on the range.

The rationale for the study is to determine if the Coast Guard is maintaining the range in a manner that will protect FAIs from elevated lead exposure. We will pursue this study in three specific aims:

Aim 1: Recruit and observe FAIs on the range while they work and collect personal air samples, work-related questionnaires, and capture weaponry usage information (i.e., shooting logs).

Aim 2: Measure the association between FAIs' lead exposure and BLLs. We will do this by collecting two blood samples: One prior to the first firing session (baseline) and one 30 days after the first firing session.

Aim 3: Measure the association between FAI's lead exposure (airborne lead) and the amount of ammunition (full metal jacket and lead) by collecting weaponry usage information.

Aim 4: Measure the association between BLLs and the amount of ammunition (full metal jacket and lead) by collecting weaponry usage information.

Aim 5: Evaluate engineering controls during the use of the firing range and the weekly and monthly cleaning of the range.

In this study, we will examine the prediction that high BLLs are related to greater airborne lead exposures and other exposure factors relating to the inhalation and ingestion of lead. It is important to note that the research presented here is innovative for the U. S. Coast Guard, which has never conducted an indoor firing range study of this scope including BLLs as a potential exposure determinant.

Background and Significance

Lead and lead compounds, which are toxic to humans, are ubiquitous in the environment. Lead-containing ammunition is heavily used in the military. Modern military forces, including the U. S. Coast Guard, are trained in using one or more small arms, including handguns, shotguns, rifles, and machine guns. Most of the ammunition used in military small arms contain lead (Dorman, 2013). Therefore, exposure to lead during weapons training at indoor firing ranges is a crucial occupational-health concern. Since the February and March 2013 incidents, the U.S. Coast Guard's District 13 Safety and Environmental Health Office (SEHO) has become more interested in controlling lead exposures; in particular, for the FAIs that work in and around indoor firing ranges for long periods of time.

Chemical & Physical Properties of Lead

Lead is a malleable, dense (density=11.3 gm/cm^3), low melting (melting point= 327 ^{o} C), bluish-gray naturally occurring metal and is a post-transition element on the periodic table (Group 14). It is a mixture of four stable isotopes, 208 Pb (51 – 53%), 206 Pb (23.5 – 27%), 207 Pb (20.5 – 23%), and 204 Pb (1.35 – 1.50%). “Lead is exceptionally dense, making it ideal for projectiles. It is also relatively soft, which allows it to be formed, even in home environments, into a variety of bullet and shot gauges” (Verbrugge, 2009). When lead comes in contact with air and water, films of lead sulfate, lead oxides, and lead carbonates are formed. These films act as a protective barrier that prevents corrosion of the original metal (King, 2005). Lead exists in both organic and inorganic forms. The organic form, which is generally more toxic, will not be discussed here because it is the inorganic form that is found in ammunition.

Historic Use of Lead

Lead is found in very high amounts in a mineral called galena, a metallic, lead-gray mineral with cubic cleavage and a distinctly high density. “Because it melts at a relatively low temperature and is so easily worked, lead was one of the first metals to be extensively used by many societies” (UMN, 2014). Galena is formed at low to medium temperature hydrothermal veins in igneous rocks, pegmatites, and contact-metamorphosed sedimentary rock. In North America, for example, one of the most economically important galena deposits is found in altered carbonate and chert rocks of the Upper Mississippi River Valley area (UMN, 2014).

There is scientific evidence that suggests lead was being used very early in the development of the human race. Lead was one of the seven metals of antiquity. Its discovery dates back to at least 3500 B.C. and lead artifacts have been discovered widespread throughout the ancient world

(Waldron, 1973). Lead was also found as a by-product when gold and silver were being mined. Between 40-90 AD, a well-known Greek pharmacist and botanist, Pedanius Discorides, noted in one of his written works that “lead makes the mind give away” (Gilbert, 2012). With their navigational skills and large mines, Spain and Greece were able to distribute lead to other parts of the globe.

Easy to handle, lead was used by the Romans in plumbing. From their early use of the element, the word plumbing is derived from plumbum, Latin for lead. The use of this word gave rise to the chemical symbol for lead, Pb. Lead is slightly sweet to the taste, making it an excellent additive for fine Roman wines that were shipped all over Europe (Gilbert, 2012). Hundreds of years ago lead was used in objects such as; coins, bullets, and fishing weights. More recently, the metal was extensively used in paints, as the solder for food cans, and as an additive to gasoline, but many of these uses have been reduced or eliminated in western society because they can lead to lead poisoning (UMN, 2014). In 1971, lead-based house paint was banned in the US (Altera, 2004) and in 1976, leaded gasoline was banned in the US (Freeman, 2012).

Current Uses of Lead

According to OSHA inspection data, the industries that expose workers to the highest levels of lead in the U.S are primary/secondary smelting, battery manufacturing, brass/bronze and copper foundries and pigment manufacturing (Froines, 1990). The Washington State Department of Labor & Industries (L & I), however reported that the top 5 industries in the state with highly exposed workers to lead are in; bridge/tunnel/elevated highway construction, automotive repair shops, painting/paper hanging, electronics/electrical equipment, and motor vehicle parts/accessories (L & I, 1999).

Radiator replacement in vehicles, for example, is a very common repair in the auto industry and in the public sector. In 1988, seven state health agencies, in collaboration with NIOSH, maintained registries of BLLs in adults (L & I, 2014). It was reported that 83 automotive repair workers had BLLs higher than 25 µg/L; 18 of them (22%) greater than 50 µg/L (MMWR, 1991).

In 1992, NIOSH discovered that 42 workers developed lead poisoning while conducting jobs on bridges. Processes like abrasive blasting, sanding, burning, cutting, and welding on steel structures coated with lead-containing paints were likely to produce high concentrations of lead dust and fumes (NIOSH, 1992).

House painters are other workers who if not properly trained could be highly exposed to lead based paint (LBP). The Washington State Safety and Health Assessment and Research for Prevention (SHARP) Program conducted five site visits at pre-1950 single-family homes to determine whether or not workers were being exposed to lead during surface preparation work. Of the nine painters measured for lead exposure, four (44%) were overexposed to lead on the days of the survey. It was later determined that the lead exposures were due to power sanding/grinding (range from 100-2142 $\mu g/m^3$) and hand scraping (108 $\mu g/m^3$) (Altera, 2004).

Lead is commonly used in the health arena as radiation shielding to protect patients and employees during x-ray procedures. Molten lead is even used to cool certain types of nuclear reactors. Additionally, lead's usage is also found in the weight adding of sailboats' keels and divers' belts.

Lead ammunition manufacturing and exporting in the U. S. is a large industry, with approximately 10 million shipments per year worth approximately 37.70 billion (NSSF, 2013). It is also estimated that there are approximately 270 million firearms owners in the US (SAS, 2011). Users firing conventional ammunition first get exposed to ammunition's primer, which contains lead styphnate and initiates the explosion in the mercury fulminate and lead azide propellant (Fischbein, 1979). The second potential source of lead comes from the extreme environment created by the burning the propellant in the cartridge. Temperatures can exceed 1100 ^{o}F (Fischbein, 1979) and can vaporize the base of the bullet if it's not jacketed (or clad) in copper (U.S. Navy, 2002). The final exposure source can come in the form of dust and lead oxide fumes, when the bullet strikes a hard target, bullet trap or back stop (Fischbein, 1979).

There are calls, however, to remove lead from bullets and shot, especially for hunting. Some animal species, like the California Condor, become lead poisoned by accidentally ingesting bullet fragments and/or shot from carcasses left by hunters (California Fish and Wildlife, 2007). A bill would require the use of non-lead rifle and pistol ammunition when taking big game and coyote within specified areas (California Fish and Wildlife, 2007).

Lead is also broadly used in the household craftwork because of its remarkable properties, such as corrosion resistance, density, and low melting point (Abadin, 2007). Common examples are pipes, solder, weights, storage batteries, pottery glazes, and leaded glass.

Toxicokinetics of Lead

Absorption from Inhalation

In the occupational settings, inhalation of lead is generally the most significant route of exposure; "however, hygienic improvements in industry have resulted in reduced airborne lead levels, making routes of exposure other than inhalation increasingly important" (ACGIH, 2013). Inorganic lead can be deposited in the respiratory tract when the aerosols are inhaled. This is dependent upon the size of the inhaled particles, the age of the person exposed, pre-existing conditions (i.e., asthma, COPD), breathing patterns (i.e., nose or mouth breathing), airway makeup, and air-stream velocity within the respiratory tract (James, 1994). Lead absorption is also influenced by particle size, solubility, and pattern of regional deposition within the respiratory tract. Larger particles (>4.5 µm), that are deposited in nasopharyngeal and tracheobronchial areas can make it to the esophagus and be swallowed via mucociliary transport. Once swallowed, this lead can be absorbed in the gut. Additionally, smaller inhaled particles (< 4.5 µm), can reach the alveolar region and absorbed after extracellular dissolution or ingestion by macrophages (Abadin, 2007). Studies have suggested that 95% of inorganic lead inhaled as submicron particles gets absorbed by the human body (Wells, 1975).

Oral Absorption

It is important to note that oral (gastrointestinal) absorption of ingested inorganic lead is highly influenced by the individuals' age, fasting condition, nutrition (i.e., calcium and iron), and pregnancy, as well as characteristics of lead being ingested (i.e., particle size, mineralogy, solubility, and lead species) (Abadin, 2007) (Verbrugge, 2009).

Gastrointestinal absorption of inorganic lead (i.e., lead chloride, lead nitrate, lead acetate) tends to be higher in children than in adults (approximately 40–50%) (Ziegler, 1978); in adults, 3 to 10% in fed individuals (Rabinowitz, 1976). In animal studies, with oral administration of lead acetate, absorption occurred at a higher rate (38% of the dose) in young monkeys than in adult monkeys (26% of the dose). It is believed that the reason why absorption is dependent on age is due to developmental shift from neonatal to adult diet (Weis, 1991). The presence of food in the digestive tract is known to decrease absorption of water-soluble (inorganic) lead. The composition of a mineral, like calcium or phosphate, in normal diet would decrease the absorption capabilities of ingested lead (Heard, 1982).

Dermal Absorption

Dermal absorption of inorganic lead is considered to be in a lesser category than either oral or inhalation routes. However, several studies have been able to quantify estimated absorption through the dermis (Abadin, 2007). A study conducted on lead battery workers detected quantities of lead in the upper layers of the stratum corneum even before the workers started their shift and after cleaning of the skin surface; thus, suggesting penetration of lead into the skin (Sun, 2002).

Exfoliation, the natural removal of dead cells from the skin, has been associated with the elimination of other types of metals, like mercury. Lead concentrations in sweat collected from the right arm increased 4-fold following the application of lead to the left arm, indicating that some lead had been absorbed (Hursh, 1989). In industrial settings, skin contamination is fairly common, and the cleaning procedure may visibly remove most of the toxic agent. However, washing may also increase skin uptake by the penetration-enhancing effect of the surfactants in soap (Larese, 2006).

Distribution of Lead in the Human Body

The term body burden is defined as “the total amount of lead in the body” and will be used throughout this section (Abadin, 2007). Most of the data regarding lead’s body burden is available through autopsy studies between 1960 and 1970 and reflect eras when ambient and occupational exposure levels were much higher than in present times (Barry, 1975).

Concentrations of lead in blood vary significantly with age, physical state, and several of other factors that could affect exposure to lead (i.e., anemia) (Abadin, 2007). The excretory half-life of lead in blood in adults is estimated to be 30 days (Griffin, 1975). Approximately 99% of lead in blood is found in the red blood cells and is bound to proteins within the cell, not the erythrocyte membrane. It is estimated that the geometric mean of blood lead levels (BLL) in the U.S (20–59 years of age) is 1.5 µg/dL (95% CI, 1.5–1.6); in children (1-5 years of age), the geometric mean of BLL is 1.9 µg/dL (95% CI, 1.8–2.1). However, the geometric mean of BLL for non-Hispanic black children is higher than that for Mexican-American and non-Hispanic white children, displaying variances in risk for exposure (CDC, 2005).

It is estimated that 94% of total body burden of lead in adults is found in the bones; in children, storage in the bone accounts for 73% of total body burden (Barry, 1975). Lead concentrations in bone increase with age, a marker of a moderately slow turnover of lead in adult bone with a half-life of approximately 27 years (Gross, 1975). "This large pool of lead in adult bone can serve to maintain blood lead levels long after exposure has ended" (Fleming, 1997). Lead accumulation is not equally distributed in the skeletal system; it is found where bone had the most active calcification at the time of exposure (Abadin, 2007). However; as age progresses, lead levels would decrease over time (O'Flaherty, 1995).

Metabolism of Inorganic Lead

Inorganic lead absorption from the gastrointestinal tract in both humans and animals is highly influenced by age, fasting/fed status, diet, solubility and particle size. There isn't any scientific data out there suggesting that the fraction of lead absorbed from inhalation exposures relies upon the amount of lead in the lung. Even though particle deposition is highly dependent on particle size and ventilation rate, all the amount of lead deposited deep in the lung is eventually absorbed (IARC, 2006).

Although several studies have indicated that inorganic lead is slightly absorbed through the skin, it has been determined that high perspiration in humans show notable increase (IARC, 2006). Additionally, in both humans and experimental animals, the swift absorption of inorganic is easily distributed from blood plasma into erythrocytes, soft tissues, and bone; the half-life of lead in blood and soft tissues is between 20 to 30 days in adult humans and 3 to 5 days in adult rats (IARC, 2006). "The only organ only organ containing an amount of lead sufficiently large to cover slow compartment is the skeleton, which is known to harbor more than 90 per cent of the body burden of lead" (Skerfving, 1983).

Excretion of Lead

Regardless of how lead is absorbed in the body, it is excreted primarily in urine and feces; sweat, saliva, hair and nails, and breast milk are minor routes of excretion (Griffin, 1975). Not many studies have investigated the relationship between sweat and lead exposure; however, one group of workers exposed to lead had extremely high levels in sweat even though their lead in blood was only moderately elevated (Lilley, 1988). A study investigating lead exposed children and non-exposed children suggest that lead is present in the saliva and that differences can be reliably measured. The results showed good correlation between Pb saliva and lead encountered in the plasma or blood, suggesting that Pb saliva may be valuable in the assessment of lead exposure (Costa de Almeida, 2009). Based on intravenous studies in humans, fecal excretion accounts for nearly one-third of the total excretion of absorbed lead (fecal/urinary excretion ratio of approximately 0.5) (Abadin, 2007).

Health Effects Caused by Lead Exposure

According to the International Agency for Research on Cancer (IARC), inorganic lead is considered to probable human carcinogen (group 2A); however, limited evidence has been found in humans. On the other hand, there is sufficient evidence of carcinogenicity in experimental animals (IARC, 2006).

Animals Studies Dealing with Lead Exposure

Current animal studies are investigating the association of lead exposure and respiratory and carcinogenic outcomes. Studies of rats and mice suggest that lead inhalation, especially for extended periods of time, can cause serious adverse effects in the lung. A study of rats exposed to lead by inhalation was conducted using two doses: The first group was exposed to 500 μg Pb/0.1 m^3/day for 1 week; the second was exposed to the same amount of lead but for 2 weeks. The results suggested that the chronic lead exposure may cause irreversible morphological alterations in the rat lung tissue (Onarlioglu, 1999).

A study of mice exposed to lead as 0.1 mL or 0.2 mL of lead nitrate solution (0.1 mg/mL) by venous injection every other day for 15 days suggested that lead or nanoparticles including lead compounds can damage lung macrophages, resulting in lung fibrosis (Sun, 2009).

Another study was conducted in female CH3 mice infected with murine mammary tumor virus (MMTV). They were strictly on a diet containing either 0.15 or 0.65 ppm of selenium (believed to prevent cancer) and exposed to only 0.5 ppm of lead in the water over their entire post-weaning lifespan. The results of this study showed that lead diminishes the antitumorigenic effects of Selenium (Schrauzer, 2008).

Other studies in rats and mice also suggest that exposure to lead was associated with adenoma, carcinoma, and adenocarcinoma in the kidneys, tumors of the brain, hematopoietic system, and lung (NTP, 2011). Lead acetate has been introduced in the sustenance of rats and has been proven to cause benign and malignant kidney tumors (adenoma and carcinoma); additionally, lead acetate has amplified the incidence of virus-induced lymphocytic leukemia in mice (NTP, 2011). Furthermore, lead acetate has been added in the water consumption of pregnant mice from gestation day 12 to four weeks postpartum; the results have shown a dose-related increase in proliferative lesions of the kidneys including atypical hyperplasia, adenoma, and adenocarcinoma in the offspring (NTP, 2011).

Human Studies Dealing with Lead Exposure

Although lead exposure has been associated with increased risk of lung, stomach, and urinary-bladder cancer in diverse human populations, the evidence for lung and stomach cancer in occupational settings seems to be weak. A study of blood lead levels in 12 newly diagnosed breast cancer cases in Nigerian women who were exposed to contaminated soil and water from toxic metals (including lead), was found to be directly correlated with lead in tumors ($p = 0.05$), directly correlated with selenium in blood ($p = 0.02$), and inversely correlated with hair selenium ($p = 0.04$). Lead in tumors, on the other hand, was inversely associated with blood selenium ($p = 0.04$). These results indicate that lead interacts (or inhibits) with selenium in vivo (Altaise, 2010).

Cytogenetic studies of exposed workers have shown increases in DNA chromosome aberrations or sister chromatid exchange, including some studies with positive-exposure response trends. There are eight studies of cancer mortality or incidence among highly exposed workers to lead; more so in lead smelter and battery plants (Steenland, 2000).

Many of the above mentioned lead studies had several limitations. For example, poor exposure assessment or failure to control for confounding by other factors that could increase the risk of cancer (i.e., exposure to other carcinogens, smoking), did not demonstrate correlation between the level or duration of exposure and the degree of cancer risk (NTP, 2011).

BLLs, however, are constantly compared in other studies. A study examined a population of 20,700 workers who had been biologically monitored for their blood lead levels from 1973 to 1983. After comparing the Finnish general population with this cohort, a 1.4-fold increase in the overall cancer incidence and a 1.8-fold increase of lung cancer among those who had ever had a blood lead level of more than 1.0 µmol x 1^{-1} were found. Additionally, no bias or confounding was found to explain the odds ratio of squamous cell carcinoma in the lung with only a slight elevation in blood lead levels (Anttila, 1995).

Depending on how high the lead exposure level, lead can adversely affect the nervous system, kidney function, immune system, reproductive organs, developmental and the cardiovascular system. In men more than women, high levels of lead in the body can affect the sex drive (loss of libido); it can also cause infertility, modify spermatogenesis and possibly teratogenicity (Martinez, 1993).

Lead exposure may also block calcium transport, which could have a detrimental effect on cellular process in the nervous system and other vital organs in the body. It also disrupts the synthesis of heme groups, which are a part of the hemoglobin molecule that carries oxygen in red blood cells and in other enzymes in the body (Abadin, 2007).

The lead effects most commonly encountered in current populations are neurological effects in children and cardiovascular effects in adults (TCEQ, 2014).

Hearing loss may also be attributed to occupational lead exposure. The health records of 183 workers who visited a private civilian occupational health screening clinic showed a correlation between BLLs and hearing loss at 4000 Hz, which is traditionally, the frequency initially affected by noise-induced hearing loss (Forst, 1997). Some believe that audiometric testing should be included in medical screening of confirmed lead exposed workers.

Pulmonary Function Abnormalities after Recent Lead Exposure

One of the most controversial issues with respect to lead exposure and health, is whether or not exposure affects workers' lung function. Recently, researchers from the Oslo University Hospital and the Norwegian Defense Research Establishment examined 55 healthy subjects (non-smokers) from the Norwegian Armed Forces that were exposed to 3 different kinds of military ammunition (one lead, two unleaded) using an assault rifle. Pulmonary function tests were conducted on the subjects at 3 different times: baseline (prior to shooting), after a firing, and 24 hours after the last firing session took place. In order to control for outside exposures or other confounders, a tent was used during firing sessions. The results suggested a decline in lung function shortly after shooting and at 24 hours after exposure, compared with the pre-test levels. The results showed that lung function, measured by FEV1, declined by a mean average of 5% after 1 hour of shooting and by 7% at 24 hours after shooting (European Lung Foundation, 2013).

Blood Lead Levels (BLLs)

A clear indication of high blood lead levels (BLLs) is lead toxicity. Severe lead toxicity is often associated with BLLs of greater than 70 µg/dL in children and 100 µg/dL in adults. For example, lead-induced anemia could be a reliable indicator that BLLs are being lingering around the human body for prolonged periods of time (Gracia, 2007). In fact, low BLLs can dramatically affect glomerural and tubular renal function. A study in young adults with a mean BLL of 2 µg/dL showed a correlation between serum cystatin C, biomarker of kidney function, and urine beta-2-microglobulin , a measure of tubular function, with BLL suggesting renal dysfunction due to reduction in renal excretion of lead and thus increased blood lead levels. (Rossi, 2008).

Another well discussed symptom believed to be related to lead toxicity is hypertension. Systolic pressure, for example, may increase 1-2 mmHg with each doubling of BLLs (Gracia, 2007). "Other over signs and symptoms include hypertension, peripheral neuropathy, ataxia, temor, gout, nephropathy, and anemia. In general, symptoms increase with increasing BLLs" (Tak, 2008). Table 1 shows some of the clinical presentation of lead toxicity based on BLLs.

Although BLLs can cause very serious adverse health effects, it can be medically managed. Chelation therapy successfully lowers elevated BLLs but may not mitigate lead-induced cognitive defects associated with lower lead levels. This may be caused by the inability to eliminate sufficient amounts of lead from the tissues or reverse preexisting tissue damage. Chelation therapy, however, is not recommended when adults have BLL concentrations of less than 45 µg/dL; a potential risk of adverse drug or remobilized lead should be a call for medical concern (Gracia, 2007).

Table 1 Clinical Presentation of Lead Toxicity Based on BLLs (Gracia, 2007).

Level of Toxicity	BLL (ug/dL)˟	Children	Adults
Asymptomatic or impaired abilities	< 10	Diminished learning and memory, decreased verbal ability, impaired fine motor coordination, signs of ADHD or hyperactivity, lower IQ˘, impaired speech and hearing	Not applicable
Mild	10-39	Myalgia or parasthesia, irritability, mild fatigue/lethargy, occasional abdominal discomfort	Not applicable
Moderate	>40-50	Arthralgia, trouble concentrating, general fatigue, headache muscular exhaustibility, tremor, weight loss, vomiting, constipation, diffuse abdominal pain	Fatigue, somnolence, moodiness, lessened leisure interest, impaired psychometrics, chronic hypertensive effects, reproductive effects
Severe	>70-80	Lead lines (bluish black appearance on gingival tissue), colic (intermittent, severe cramps), parasthesia or paralysis, encephalopathy	Headache, memory loss, diminished libido, insomnia, metallic taste, abdominal pain, constipation, myalgia/arthralgia, nephropathy
Severe, acute	>100-150	Encephalopathy, seizures, anemia, nephropathy	Encephalopathy, various CNS† effects, anemia, nephropathy

˟µg/dL: Micrograms per deciliter.
°ADHD: Attention-deficit/hyperactivity disorder.
˘IQ: intelligence quotient.
†CNS: Central nervous system.

Occupational Lead Exposure Studies

There are a number of occupational studies that deal with lead exposure in firing ranges; the earliest found was in 1957, where a small arms instructor at a Canadian indoor firing range was discovered to have lead poisoning while he donated blood. After a further assessment of the instructor's urine it was discovered that the levels were 1000 µg/L, approximately 7 times the threshold limit (Ross, 1960). This finding triggered an exposure assessment evaluating airborne lead concentrations during firing practice, surface wipe sampling, and ventilation measurements. The results found that many of the air and wipe lead concentration measurements were elevated and the ventilation system was substandard (Ross, 1960).

Another study conducted in a police department's indoor firing range in Kalb County, Georgia showed 3 FAIs having lead poisoning with BLLs greater than 100 µg/dL with free erythrocyte protoporphyrin (FEP) levels greater than 450 µg/mL of red blood cells, abdominal pain and abnormal conduction of motor and sensory nerves. Again, flawed ventilation was believed to be at fault. It was found that the filter and screen at the air intake system appeared to have never been replaced, blocking air supply and that a fire damper, which was part of the air intake system, was believed to have been closed for an unknown amount of time (Landrigan, 1975).

A 3-month study of 17 law enforcement trainees undergoing weaponry instruction at an indoor firing range were observed for their lead exposure risks. BLLs were taken from each of the trainees in four different occasions as follows: Prior to weaponry training and once a month for 4 months after training began. Additionally, airborne lead exposures were measured at three different times during weaponry instruction. After the study concluded, BLLs showed a mean of 6.5 (pre-training) to 50.4 ug/dL (post-training); mean airborne lead concentrations were above

2,000 ug/m^3, which is 40 times the OSHA PEL. The ventilation system and heavy use of lead bullets contributed to these elevated exposures (Valway, 1989). Between 1980 and 1982, National Institute for Occupational Safety and Health (NIOSH) investigators conducted firing range studies using personal breathing zone (PBZ) air sampling on 90 individuals at municipal/state/federal governnment firing ranges in the states of Alabama, Georgia, Missouri, Nebraska, Ohio, Vermont, and Washington, D. C. During firing, shooters were exposed to an average airborne lead concentration of 100 ug/m^3; 47 of them exceeded OSHA's PEL of 50 ug/m^3 as 8-hour TimeWeighed Average (TWA) (CDC, 1983). A lead exposure study conducted at the FBI Firearms Training Unit's indoor firing range (composed of 23 shooting booths, a one-booth firearms testing range, and 7 outdoor training ranges) used 16 FAIs (a combination of firing range technicians, gunsmiths, and firing range instructors) to determine airborne lead concentrations. Sixty-one personal breathing zone (PBZ) samples and thirty area samples were collected. Mean concentrations were as follows: 51.7 ug/m^3 for instructors, 2.7 ug/m^3 for firing range technicians, and 4.5 ug/m^3 for gunsmiths (NIOSH, 1991). Additionally, carpet sampling collected from 14 dormitory rooms used by FBI students and 14 FBI permanent staff rooms showed extremely high lead concentrations (means of 214 ug/g and 65 ug/g, respecively). This was believed to be caused by FBI students carrying the lead from the range to the dorm on their shoes and clothes. NIOSH recommended that the range modify its ventilation system and train FBI personnel (staff and students) in personal hygiene practices (NIOSH, 1991).

In 1997, NIOSH investigators conducted a lead exposure study at the Forest Park Police Department using 30 subjects (composed of different police officers in the Forest Park, OH area) who used the firing range for firearms qualification and training (NIOSH, 2009). During the study, it was determined that the firing range was operating under positive pressure, contrary to recommended design (Anania, 1975) and with gunsmoke smell immediately noticeable when firing sessions commenced. Measurements of supply/exhaust air flow rates were much lower than design specifications [50-75 feet per minute (fpm)] (Anania, 1975) with an average velocity of 25 fpm. Additionally, a smoke test revealed backflow patterns (i.e., eddies) even if no one was standing at the firing line (NIOSH, 2009).

Non-occupational Lead Exposures

Lead is not only found in the occupational setting; it can reach our daily lives without us even knowing it. "The most common non-occupational exposures to lead were shooting firearms; remodeling, renovating, or painting; retained bullets(gunshot wounds); and lead casting" (CDC, 2011). Certain hobbies can bring lead directly into the home, like such as; hunting and eating game, or home automotive repair, can infiltrate lead to the home and expose family members; to include: soldering glass or metal, making bullets, or slugs, or fishing weights, making stained glass, or glazing pottery. "You can bring lead home in the dust on your hands or clothes if lead is used in the place where you work" (ATSDR, 2005).

Federal/State Regulations, Standards and Guidelines for Lead

Overexposure to lead at indoor firing ranges has been a concern at both local and U.S. Coast Guard ranges. As previously mentioned, a King County Washington firing range was found to have overexposed workers to lead causing adverse health effects (Fischer, 2013). Similarly, U.S. Coast Guard indoor ranges in Seattle, WA and Astoria, OR were temporarily shut down as a result of either users having elevated blood lead levels or ranges not operating satisfactorily; thus, creating a possible overexposure environment (Riutta, 2013).

As a federal agency, the U.S. Occupational Safety and Health Administration (OSHA) mandates that the U.S. Coast Guard follow its standards in the workplace. If lead is suspected within the workplace environment, employers are required to initially determine if worker airborne lead exposures exceed the Action Level (AL) of 30 micrograms per cubic meter of air (30 $\mu g/m^3$) averaged over an 8-hour period. This determination should be established with the use of personal air monitoring with an emphasis on the employees identified as being the most exposed (OSHA, 1993). This assessment is done without regard to the use of a respirator. According to the U.S. Coast Guard Ordnance Manual, if military or civilian personnel are enrolled in the Occupational Medical Surveillance Evaluation Program (OMSEP) they are required to be tested for lead poisoning and monitored if the following conditions take place: (1) if air testing yields results greater than 25 $\mu g/m^3$ of lead in the air, members on the range must have blood lead levels tested, (2) if blood lead levels are greater than or equal to 25 µg/100 g (25 µg/dL) of whole blood averaged over a 3-month period, the member shall be removed from any firing range operations, (3) if blood lead levels are greater than or equal to 30 µg/100 g (30 µg/dL) of whole blood at any time, the member shall be removed from any firing range operations, and (4) a member may only return to work on a range if the average blood lead level over a 6-month period is less that 20 micrograms per 100 grams of whole blood (USCG Ordnance Manual, COMDINST M8000.2D).

If federal employees, including FAIs are being exposed to lead above the OSHA permissible exposure limit (PEL) of 50 $\mu g/m^3$, for more than a total of 30 days per year, the employer is required by law to implement engineering, administrative, and work practice controls to mitigate and maintain lead exposures below the PEL (USCG Medical Manual COMDINST M6000.1E). "Where any employee is exposed to lead above 200 $\mu g/m^3$, but for 30 days or less per year, the employer shall implement engineering controls to reduce exposures at or below 200 μg/m^3. If the employee exposure is below 200 μg/m^3 but above 50 μg/m^3 any combination of engineering, work place (including administrative controls), and respiratory controls may be implemented to reduce and maintain employee lead exposure to or below 50 μg/m^3" (SAIF, 2010).

The National Institute for Occupational Safety and Health (NIOSH), has a recommended exposure limit (REL) for lead that is the same as the PEL, but NIOSH also has a level that is Immediately Dangerous to Life and Health (IDLH) equal to 100 mg Pb/m^3 (NIOSH, 2013). The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLVs) are the same as the PEL and the biological exposure index (BEI) is equal to30 μg/dl of whole blood (ACGIH, 2013). Guidelines for surface contamination have also been developed and adapted from a variety of groups. The U.S. Department of Housing and Urban Development (HUD) has developed standards for lead contamination on surfaces for housing and remediation of lead-based paint on houses (HUD, 2010; HUD, 2014). According to HUD standards where indoor firing ranges are near residential areas, the allowable lead dust level on floors is 4.3 ug/100 cm^2 (40 ug/ft^2) Since this level is protective of children in homes, we will focus on the value OSHA has adopted from HUD, of 21.5 g/100 cm^2 (200 ug/ft^2) [OSHA, 29 CFR 1926.62, Lead (Construction), 1993]. Table 2 gives a summary of federal and state regulations, standards and guidelines for lead.

Table 2 Summary of the Federal/State Regulations, Standards and Guidelines for Lead.

Agency/Organization	Medium	Limit Value	Remarks
OSHA	Air	30 µg/m^{3} °	Action level
OSHA	Air	50 µg/m^{3}	Permissible exposure limit (8-hour TWA˟)
NIOSH	Air	50 µg/m^{3}	Recommended exposure limit (8-hour TWA)
NIOSH	Air	100 µg/m^{3}	Immediately dangerous to life and health
ACGIH	Air	50 µg/m^{3}	TLV ˘ (8-hour TWA)
OSHA	Blood	40 µg/dL*	Written notification from employer and medical exam
OSHA	Blood	50 µg/dL	Immediate removal from work exposure above the AL
ACGIH	Blood	30 µg/dL	Biological exposure index (advisory info)
OSHA	Surfaces	21.5 µg/100 cm^{2} (BNL, 2014)	Floor surfaces outside indoor firing range
HUD	Surface	4.3 µg/100 cm^{2} (BNL, 2014)	Floor surface at/near housing/public places

*µg/dL: Micrograms per deciliter.
°µg/m^{3}: Micrograms per cubic meter.
˟TWA: Time weighted average = Average exposure over a specified period of time, usually a nominal eight hours
˘ TLV: Threshold limit value = Level to which a worker can be exposed day after day for a working lifetime without adverse health effects.

Types and Designs of Firing Ranges

There are two types of firing ranges: outdoor and indoor. Although they are both important in nature and considered potential sources of lead exposure if not managed correctly, we will only discuss indoor firing ranges.

Indoor firing ranges are enclosed facilities having a very distinctive operation. Even though military and civilian personnel that use them take advantage of their controlled environment, improper use and design could be detrimental to human health. Lead and other type of metals could reach extreme concentrations in the air and floor, causing elevated exposures. That is why the range must be a safe, efficient operation and should be maintained as designed or as per manufacturer's specifications (NAVFAC, 1992). The main design criteria for firing ranges deal with preventing armament penetration, safe removal of lead fume and dust, safe containment of the spent rounds, and reduction of noise.

Baffling System

"The range must be designed to withstand the most powerful cartridge authorized for use on the range" (NAVFAC, 1992). A baffling system must be provided/installed inside the range to protect inside lighting fixtures, pipes, and ceiling from poorly aimed shots. Baffles should be placed at 30 degree angles to the ceiling and constructed of steel plating, whose thickness depends on the type of ammunition approved for use (NAVFAC, 1992).

The firing range's surfaces should be of flat concrete slab or comparable material (NAVFAC, 1992). These should also be smooth in nature with no extended edges, easy to clean/maintain, with no carpeting (to prevent lead dust accummulation) (Navy, 2002). Walls must be constructed of flat reinforced concrete or core-filled masonry to prevent bullets from penetrating or exiting the range. "Walls, floors, and roof construction must be bulletproof" (NAVFAC, 1992).

Bullet Traps

The sole purpose of the bullet trap (or stop) is to capture the bullet (and its generated energy) to avoid projectiles or their remnants from escaping (NAVFAC, 1992). There are a myriad of bullet traps; plate and pit, escalator, venetian blind, snail type, rubber lamella, and granular rubber. All the different types of traps have their advantages and disadvantages, which won't be discussed, though two of these are described below.

A plate and pit bullet trap includes a steel plating mounted at a 45 degree angle; it's thickness/hardness depends on the ammunition used. Once the shooter begins firing, the bullets strike the steel plating and the force created will direct them into a 6-8 inch deep sand pit (Navy, 2002).

An escalator or total containment bullet trap, the type located at our study site, consists of sloping steel surfaces that direct bullets into a swirl area or decelaration chamber in order to disperse their projectile energy in a safe manner. Once the bullets lose their energy, they fall into a tray for future collection (Navy, 2002).

In-Range Systems

The target retrieval system is very important for the users of the range because it allows personnel to change their targets without going down range, where there is more lead on surfaces and a potential to be in the line of fire (NAVFAC, 1992). The target is either placed or retrieved using either a motorized system or a hand crank moving back and forth to the desired position.

Target holders should not present a flat surface perpendicular to the line of fire to prevent bullet ricocheting (Navy, 2002).

Noise

The use of weapons at an indoor firing range is a very loud operation and can affect the hearing of anyone inside the range. When a bullet is fired, there are a number of sources of noise including the explosion caused by the firing pin striking the primer at the base of the cartridge, the ignition of the powder, and the bullet as it breaks the sound barrier (Anania, 1975), in addition to the bullet striking the back stop. The impact noise can be made worse if the range has been designed without noise absorptive surfaces. Frequently hearing protection devices are required for those in the range during shooting. Double hearing protection may also be required.

Exhaust and Supply Air Systems

The design of how clean air is supplied and exhausted out of an indoor firing range is crucial in dealing with lead and other possible contaminants (i.e., copper, selenium, antimony). Extremely high exposures, up to 35 mg/m^3 (Schaeffer, 1990) have been documented in ranges with poorly designed ventilation systems.

Air supply systems should be provide 100% outside air (no recirculation) equally across the width of the firing range to avoid turbulence that could cause lead to be pulled back (i.e., eddies) into the user's breathing zone (Navy, 2002).

"For optimum air distribution there should be a minimum distance of 15 feet from the shooters position to the wall directly behind the shooter" (Anania, 1975). With the use of a perforated wall, a constant, laminar air flow toward the firing line forces contaminants away from shooters into the downrange section of the firing range (Navy, 2002; NAVFAC, 1992) and exhausted out of the range. For optimal protection against airborne contaminants, the air supply system must sustain a laminar flow of between 50 and 75 feet per minute (fpm) across the sectional area of the firing line, regardless of the number of firing lanes (Navy, 2002).

Air exhaust systems should remove 3 to 7% more air than being supplied to the range to maintain a negative pressure with respect to outside of the range (approximately -0.04 ± 0.02 inches of water) (Navy, 2002; NAVFAC, 1992). Additionally, the system should be designed to provide a minimum duct air velocity of 2500 to 3000 fpm (ACGIH, 2004) to prevent the settling of the heavy lead dust. Figure 1 shows a schematic for an indoor range and its ventilation system (Alvarez, 2014). An optional exhaust opening approximately 15 feet forward of the firing line may be used but should not exhaust more than 25% of the total air flow (NAVFAC, 1992). To avoid improper supply and exhaust operation, interlocks should be used that require both systems to be running simultaneously (Navy, 2002). Figures 2 and 3 show how poorly provided supply air can increase exposures at the firing line (Action Target, 2011). Supply and exhaust air systems must be installed in locations that will avoid cross contamination.

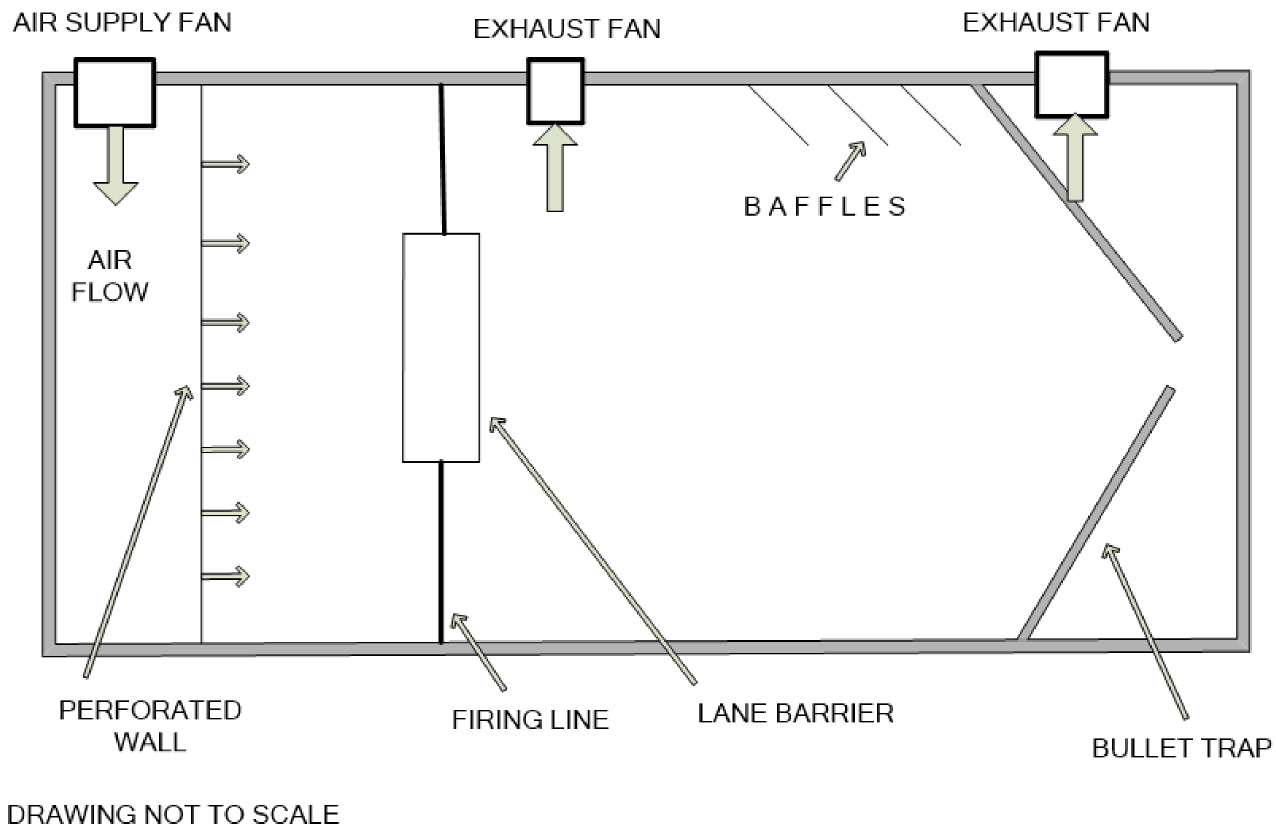


Figure 1 Current indoor firing range ventilation system (Drawing by JV Alvarez).

Air Filtration Systems

According to the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), both the supply and exhaust air has to be filtered through a series of minimum efficiency reporting value (MERV) pre-filters and then through high efficiency particulate air (HEPA) filters before the air either enters or leaves the indoor firing range (Morgenthaler, 2002). Pre-filters are very important because they are the first to contact contaminated exhaust air from the range and will be loaded with lead. These filters require a more stringent replacement regime than HEPA filters (NIOSH, 2009).

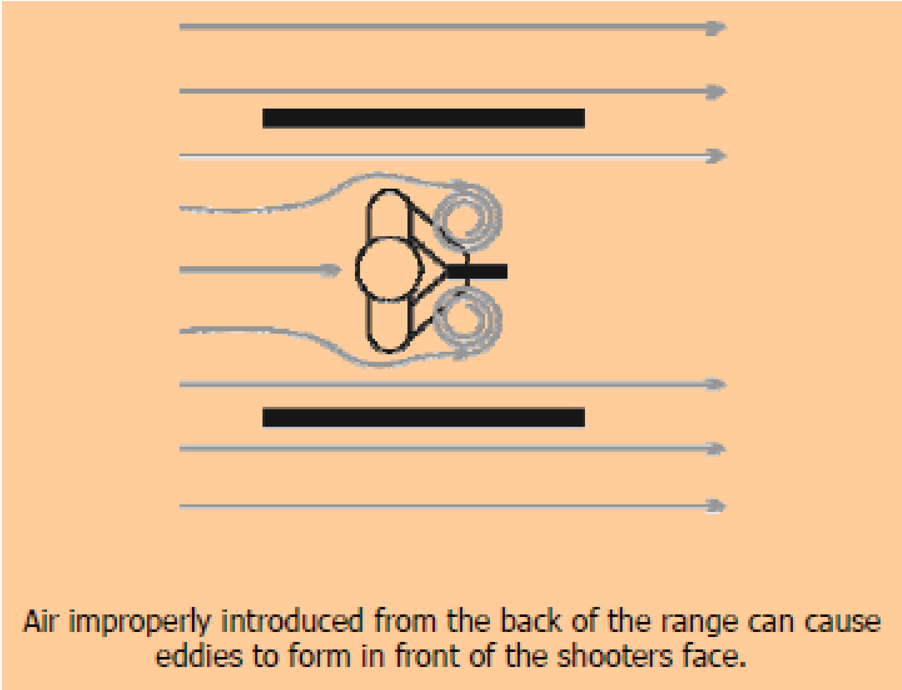


Figure 2 Turbulence at the firing line caused by elevated air velocities at the firing line (Action Target, 2011).

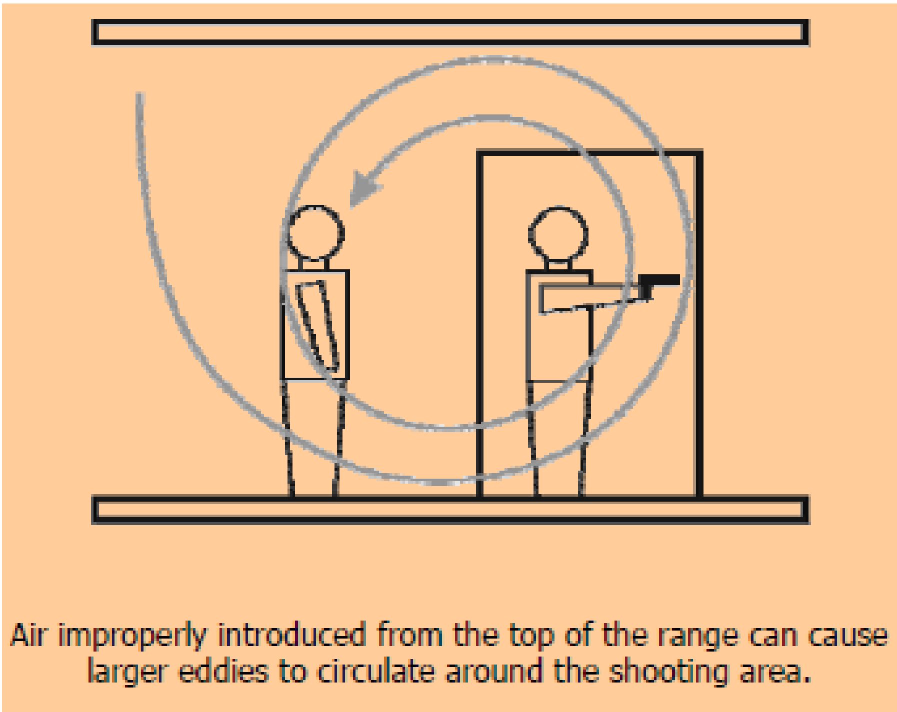


Figure 3 Turbulence caused by poorly aimed supply air (Action Target, 2011).

Range Cleaning and other administrative controls

"Personnel performing range maintenance, cleaning, and reclamation activities are typically at the highest risk for airborne lead exposure" (USCG, 2012). Lead dust that settles on the floor cannot be dealt with using engineering controls. To avoid overexposure to lead, the indoor firing range's floors and horizontal surfaces should be cleaned regularly; booth shelves or target retrieval systems should also be cleaned. Cleaning methods should include the use of an explosion-proof HEPA vaccum or wet methods (i.e., exclusive use of vacuum and mop). Use of a broom, however, should be prohibited during range cleaning operations (Navy, 2002; Anania, 1975). Figures 4 and 5 show cleaning personnel conducting reclamation and vacuuming operations.

Figure 4 Cleaning personnel conducting reclamation activities (Photo by MA Torres).

Figure 5 Cleaning personnel using HEPA vacuum cleaner inside the range (Photo by MA Torres).

In order to minimize lead exposure at the indoor firing ranges, a variety of practices and prohibitions are implemented. Below are some of these:

- Personnel are not allowed to walk forward of the firing line,
- Sticky walk-on mats should be used outside of the range exit door to remove lead dust from boots and shoes,
- Consumption of food, beverages, smoking or chewing tobacco, gum or application of cosmetics is prohibited during firing range use, and during fired brass collection, gloves should be worn and it is prohibited to use baseball caps to collect spent brass.

Background Information of Study Site

The indoor firing range used in this study is located in downtown Seattle on Pier 36, at the U.S. Coast Guard Base. It was built in 1978 and operated by the Federal Protective Services (FPS), which provides integrated security and law enforcement services to federally owned and leased buildings, facilities, properties and other assets. In 1994, the range was given to the U. S. Coast Guard since FPS could not maintain lead exposure below the PEL and no funding was available to improve the ventilation system. When transfer of ownership took place, the U.S. Coast Guard Civil Engineering Unit (CEU) Oakland, CA was responsible for designing and installing a new ventilation system.

After installations were complete, the range supervisor at the time was very concerned about not having sufficient airflow to remove lead and other contaminants from the range. U. S. Coast Guard District armory personnel and contracting representative conducted a smoke test to determine air flow patterns within the range. It was later determined that eddies were developing at the firing line and recirculating air back to the firing line. It was determined that one of the two supply air vents was causing the air to form eddies at the firing line Figure 6 shows how the indoor firing range looked like back in 1978 (Alvarez, 2014). The Safety and Environmental Health Officer (SEHO) was asked to conduct air sampling to determine whether or not lead exposures were above OSHA's PEL.

Three personal breathing zone samples (3 shooters at the firing line) and one area sample (on a table near ventilation controls) were collected for 7.5 hours. All personal samples were above OSHA's PEL 50 $\mu g/m^3$ based upon an 8-hr time weighted average. However, blood samples were taken from the shooters were between 5-12 µg/dL (below OSHA's medical removal standard of 40 µg/dL). It was recommended that a perforated wall-type of supply air system be used. Later that year, this type of system was installed in the range.

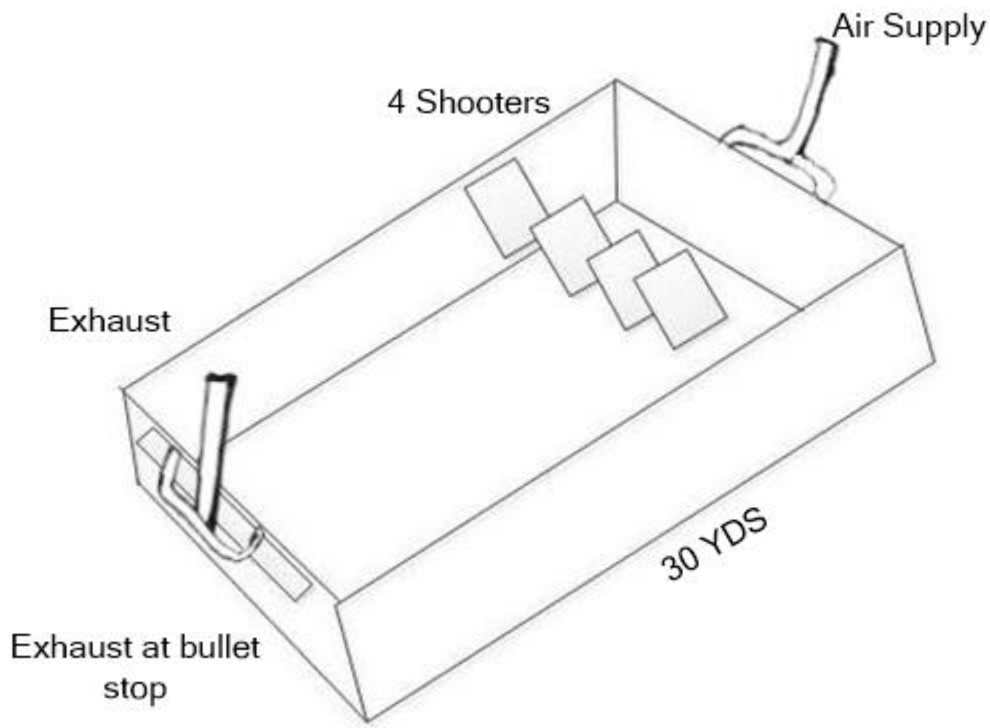


Figure 6 Indoor firing range design prior to perforated wall-type of supply air system installation (Drawing by JV Alvarez).

In 2008, an escalator plate type of bullet trap with a circular deceleration chamber (Snail Type, by Savage Range Systems, Inc.) was installed (Figure 7). Recently, the firing range supervisor requested CEU Oakland to re-evalulate the firing range's heat and ventilation system.

One of the issues that the range has is that the heating system, when turned on, alters the laminar air flow; thus, the range is only operated with the heater off, which is problematic in the winter.

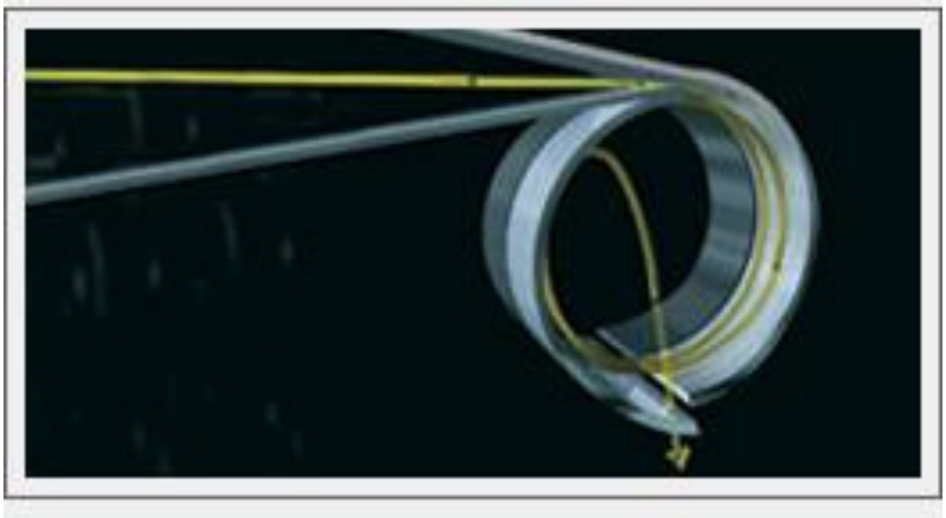


Figure 7 Escalator type of bullet trap with circular deceleration chamber (Savage Range Systems, 2011).

Study Subjects

For this project, we only studied FAIs' exposures due to the fact that they are the employees who are on the range most frequently. To become an FAI, one must be a 2nd Class Petty Officers (E-5s) or above (U.S. Coast Guard Active Duty or Reserve), have stellar appraisals (evaluations), be within military weight standards, enrolled in the Occupational Medical Surveillance Program (OMSEP), and cleared to participate in range operation duties by the medical authority (USCG Medical Manual, COMDTINST M6000.1E). FAIs are looked upon to deliver effective weaponry qualification and instruction to military personnel. Aside from technical skills with a variety of firearms, FAIs will have a high degree of accountability, leadership and train-the-trainer experience. Once an FAI is designated as such by their unit, their primary task is training.

Before taking on FAI duties, candidates are required to attend the Fire Arms Instructor Course, which will provide students with the skills and knowledge necessary to act as an independent FAI in accordance with all applicable Coast Guard instructions. This training takes place at the U. S. Coast Guard Training Center in Yorktown, VA and consists of the following; classroom instruction, practical exercises on instructional techniques, range and weapon safety requirements, course of fire, marksmanship skills and coaching techniques, target reading analysis and scoring, and administrative duties. There are rigorous pre-requisites that have to be met before U. S. Coast Guard personnel can attend the FAI course. Students must be qualified in following minimum levels: (1) Sharpshooter - Basic Rifle Marksmanship Course (BRMC), (2) Sharpshooter - Basic Pistol Marksmanship Course (BPMC), (3) Practical Pistol Course (PPC), (4) Practical Rifle Course (PRC), (5) Riot Shotgun Course (RSC), and (6) Judgmental Pistol Course (JPC) (TQC, 2013).

Duties as FAI

The most important task that the FAI has to accomplish is to assist their fellow Coast Guardsmen in qualifying in the use of a variety of weaponry skills. As part of the Coast Guard mission to protect U.S. coast assets, law enforcement personnel either intercontinental or abroad must be prepared to act and qualify in the use the three types of small arms: pistol, rifle, and shotgun.

The qualification process, however, could take weeks, even months. There are instances where law enforcement personnel are not able to qualify in all of the required weaponry. This situation places a heavy burden on the FAI because, depending on the unit, there must be a predefined number of qualified law enforcement personnel. This means that for the less skilled law enforcement personnel, the more ammunition rounds and time is spent at the range, and thus, potentially increasing lead exposure.

Before firing (qualification) sessions take place, FAIs are required to test all weapons to ensure they work as designed. Additionally, they are responsible for accounting for all the rounds spent at the firing range. They have to know what kind of bullets (i.e., leaded, unleaded, frangible, green) and their caliber are being used at the range at all times.

As a safety and health measure, a pre-fire brief takes place within 30 minutes of the start of the qualification process. There, FAIs discuss the rules that everyone inside the firing range need to follow. For example, wearing hearing and eye protection, ball caps and working boots, no smoking or eating inside the range, never point a firearm at a person, wash hands with liquid soap after all range activities and before eating, smoking, applying cosmetics or leaving the range, etc. (Coast Guard Range Training Handbook, 2013).

FAI or any shooters' duties do not include cleaning inside the range, other than picking up slugs, casings, etc. behind the firing line. As part of the USCG Base Seattle indoor firing range's standard operating procedure (SOP), no one is allowed to walk forward of the firing line. This has been implemented to prevent unnecessary injury (i.e., people firing) and/or the spread of lead dust.

Non-FAI Duties and Assignments

Being an FAI for one's unit isn't one's "full-time job." The jobs or ratings typically carried by the FAIs are Gunner's Mate (GM), Maritime Enforcement Specialist (ME), and Boatswain's Mate (BM). The work conducted by the individuals in these ratings are listed in Table 3.

Table 3 Brief explanation of ratings in the Coast Guard designated as FAIs (Dolbow, 2010).

Rating	Abbreviation	Job Description
Gunner's Mate	GM	Responsible for training personnel in proper handling of weapons, ammunition, and pyrotechnics, maintenance on all ordnance/gunnery equipment.
Maritime Enforcement Specialist	ME	Maritime law enforcement, anti-terrorism, force protection, port security and safety, and unit-level training in these fields.
Boatswain's Mate	BM	In charge of small boat operations, search and rescue, aids to navigation, law enforcement and security operations.

Ammunition used at the Coast Guard firing range

A bullet typically consists of a casing, primer, propellant, and projectile. Bullet casings are typically made of brass and contain a propellant and a primer. The propellant provides the expanding gas that propels the projectile and is typically a mixture of nitrocellulose and nitroglycerin. The propellant is ignited by a primer (explosive), which commonly contain shock sensitive metallic salts and metallic nitrate compounds such as fulminates of lead (lead staphynate or lead peroxide) (Fischbein, 1979; Navy, 2002; USCG, 2012). These materials may be a source of lead dust and fume generation in the ranges during weapons firing. Lead can also be generated when the projectile fragments travels through the barrel and rifling. The projectile is usually a dense material such as lead and may or may not be jacketed with a copper- zinc alloy. Non-jacketed bullets are projectiles that are completely exposed, while partially and fully jacketed bullets have portions of the projectile exposed. Higher airborne concentrations of lead are typically found as the exposed area of lead projectiles increase (Fischbein, 1979; Navy, 2002; USCG, 2012). Additionally, fragmentation as a result of bullets impacting the target or backstop (bullet trap) may contribute to the general air lead concentration in the firing range (Valway, 1989). The anatomy of a common bullet and how it operates as a cartridge-based ammunition is shown below on Figure 8. “The cartridge partially seals the firing chamber of the weapon. On firing, a pin strikes the primer at the base of the cartridge (1) and ignites it. This ignites the powder, which burns rapidly and generates expanding gases. The gases are forced down the length of the barrel, pushing the bullet in front of them (2) and eventually out of the barrel (3). Simultaneously, the cartridge case expands, thereby completing the firing chamber seal. The momentum imparted by the process propels the bullet but there is no process within the bullet that sustains movement. As a consequence, the bullet begins to lose velocity shortly after it leaves the barrel” (Bevan, 2006).

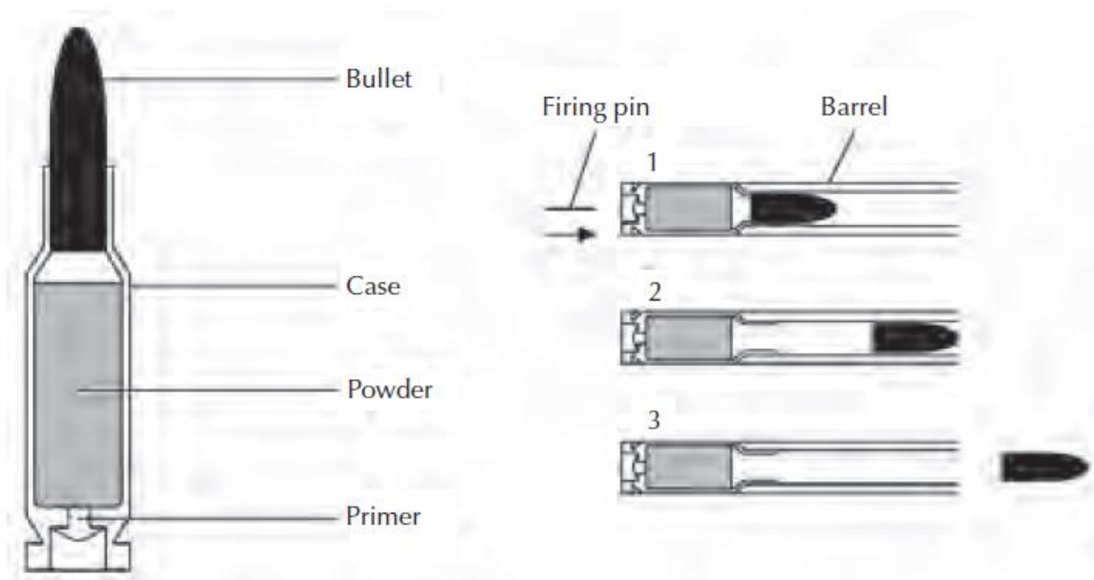


Figure 8 A self-contained cartridge and the process of firing the bullet out of a weapons’s barrel (Bevan, 2006).

Ammunition Study Review

There are various studies that have shown a strong association between standard lead ammunition, airborne lead, and BLLs in shooters and instructors at indoor and outdoor ranges.

A study was conducted using 3 different types of standard lead ammunition (0.38 caliber, 148 grain, and semi-wadcutter bullets) and 2 different types of unleaded ammunition (copper-jacketed and nylon jacketed bullets). Using a personal air sampling pump attached to a shooter's lapel, all types of bullets were fired in an indoor range at a set rate and duration. The results of the study showed a reduction of air lead exposure using copper-jacketed and nylon jacketed bullets (factors of 28 and 9, respectively) compared to the other conventional bullets (Fischbein, 1980).

In another study, to assess the effect of using jacketed ammunition, civilian firearm instructors used three different types of ammunition: Leaded bullets, nylon-coated bullets, and copper-jacketed bullets. Each test timeframe required the firearm instructors to fire 60 rounds over approximately 10 minutes. First, copper-jacketed ammunition was used; second, nylon-coated ammunition and third, leaded ammunition. Results of the study clearly showed a substantial reduction in airborne lead when jacketed bullets were used; even more so if using copper-jacketed bullets (97% decrease) (Valway, 1989).

Weaponry Used at the Coast Guard Firing Range

The U.S. Coast Guard commonly uses three types of small arms for weaponry training: The Sig Sauer P229 DAK pistol, the M-16 A2 rifle, and the Remington 870 shotgun. The Sig Sauer is a short recoil, semi-automatic, magazine-fed, recoil-operated, double-action pistol, with an intermediate trigger, reset point, chambered for the .40 caliber S & W (Smith & Wesson) cartridge. Each trigger pull cocks and releases the hammer to fire the pistol from the first to the last round (Coast Guard Range Training Handbook, 2013). The most commonly seen ammunition used for the Sig Sauer pistol were DWGX (.40 caliber full metal jacket) and DWGW (.40 caliber full metal jacketed hollow point).

The M16 A2 rifle is lighweight, gas-operated (facilitates motion for loading/extracting of the spent case, ejection, cocking of the hammer or striker, chambering of a fresh cartridge, and locking of the action), magazine-fed, shoulder-fired weapon with the capacity to fire either in semiautomatic, burst fire, or fully automatic by simply pressing a selector lever (Coast Guard Range Training Handbook, 2013). The most commonly seen ammunition used for the M16 rifle were A059 (5.56 mm 62 grain lead core, full metal jacket) and A071 (5.56 mm 553 ball, full metal jacket).

The M870 Remington shotgun is manually-operated, action-pumped, shoulder-fired weapon with a parkerized metal finish. This shotgun has a synthetic stock and fore-end with a pistol grip. It has a 14-inch barrel with a tritium front bead sight and fitted with cylinder choke tube to increase accuracy when firing 00 Buck ammunition (leaded shot) (Coast Guard Range Training Handbook, 2013). The most commonly seen ammunition used for the Remington shotgun were A011 (leaded 00 Buck shot) and A023 (12 gauge leaded slug).

Materials and Analytical Methods

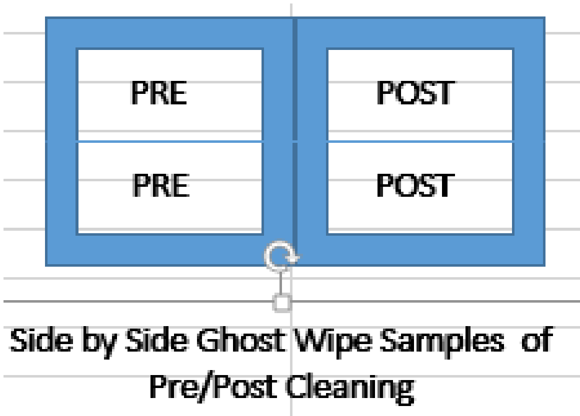
Study Design

Two Institutional Review Board (IRB) entities, the University of Washington's Human Subjects Division (HSD) and the U. S. Coast Guard Headquarters' Command (CG-113) Office reviewed and approved our study before we begin gathering data (Appendix A and B, respectively).

Nine subjects (FAIs) were recruited for a 4-week long study inside the USCG Base Seattle's indoor firing range, their normal work setting, to determine whether or not their duties placed them at risk of overexposure to lead. After consenting to the study, whole blood was collected from all subjects at the beginning and at the end of the study to determine whether or not a change in blood lead levels (BLLs) had occurred throughout the study period. Additionally, a two-year BLL history from the FAIs was requested to determine any possible trends or indicators of overexposure to lead. After analyzing the data, BLLs were very low, indicating exposures lower than the action level of 30 µg/dL (as high as 11.4 µg/dL; as low as 1.5 µg/dL); thus, the BLL history was not included in the study.

Three questionnaires (one demographical/one occupational before and after the study) were issued to obtain work-related information (i.e., number of rounds used), hygiene practices (wash hands before eating or drinking) and extra-curricular activity (i.e., consume game) information to determine any other potential sources of lead exposure. To test whether or not the ventilation system was performing to specification, the system was assessed before and after the study. Personal air lead exposures were measured for the FAIs between 2-4 times (depending on availability) throughout the study while they oversaw weaponry qualification. Shooting logs were also retrieved and analyzed to determine whether or not the type of ammunition (i.e., leaded, jacketed) was correlated with either BLL or airborne lead exposure.

To verify the effectiveness of two different range cleaning practices (weekly and monthly), surface wipe samples of lead dust before and after cleaning were collected from the floor of the firing range (Figure 9 and 10).



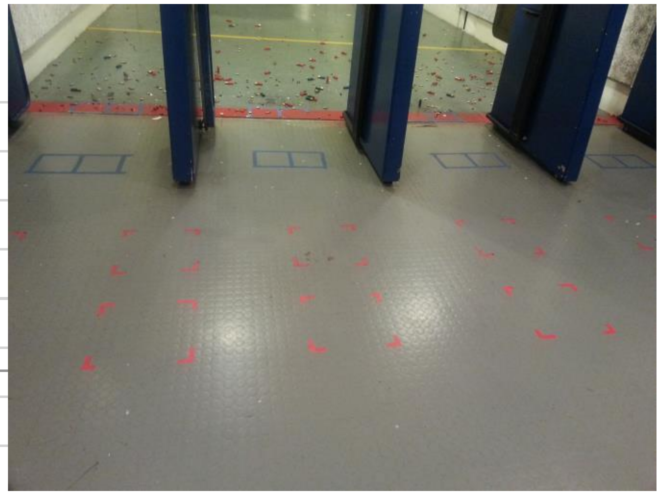


Figure 9 (left) and Figure 10 (right). Surface wipe sampling scheme (By GA Croteau). On the left (Figure 9), the diagram represents the 10 x 10 cm template used to take 2 sets of pairs (pre-cleaning and post-cleaning) collected each time weekly or monthly cleaning took place. On the right (Figure 10), the two regions (noted in red tape) consisting of 5 quadrants where samples were taken. The first region was located 5 feet south from the firing line; the second was located 5.6 feet from the firing line. The blue taped regions near the firing line were used for a different experiment.

Study Subjects

FAIs based in the Seattle, Oregon, and surrounding units during the study period were the potential population for this study. Because the size of this population was constantly changing, it is impossible to fully quantify the number of FAIs available for the study. A total of 53 FAIs were asked to participate in the study and 9 (17%) agreed to participate; 41 (77%) of them were deployed to an undisclosed location, 2 (4%) of them could've started the process but were scheduled to leave the state of Washington in the middle of the study, and 2 (4%) of them did not want to participate due to personal reasons. All participants completed all aspects of the study in full. After verbally agreeing to participate in the study, the FAI were given; informed consent forms to read and sign (Appendix C), a demographic questionnaire (Appendix E), and a pre-firing work and hygiene practices questionnaire (Appendix F). Additionally, to review pertinent medical history, subjects were required to fill out a HIPAA authorization form (Appendix D).

All forms were given and collected in person and stored in a locked cabinet at the University of Washington. Figure 11 shows how the information for the FAIs was captured starting at the consent phase to the end of the study. The pre-firing work and hygiene practices questionnaire was issued to determine any potential determinants of lead exposure, such as smoking in the range, welding lead-containing scrap metal, making bullets or fishing sinkers, etc. An identical questionnaire was also given post-firing to determine whether any of the factors had changed.

Ventilation Assessment

There are three main test procedures commonly used to evaluate the operation of ventilation systems used to control lead expsoures at indoor firing ranges; a smoke test, air velocity measurements, and a negative pressure test (Navy, 2002). A “smoke test” uses a smoke tube, smoke candle, or smoke (fogging) machine to observe air flow patterns. Laminar flow at the firing line is the ideal. A Rosco® 1500 (Rosco Laboratories Inc.) theatrical fog machine was used as per manufacturer’s instructions for this purpose. Prior to starting the test, the ventilation system was turned on for approximately 30 minutes. Smoke was released in all firing lanes simulating each firing positions (prone, kneeling, standing) in two instances; with a person present and without a person present. Observations of smoke (airflow) patterns were done during normal ventilation operations throughout the firing range (Figure 12).

Flow of events for the Characterization of Lead Exposures at a Coast Guard Firing Range study

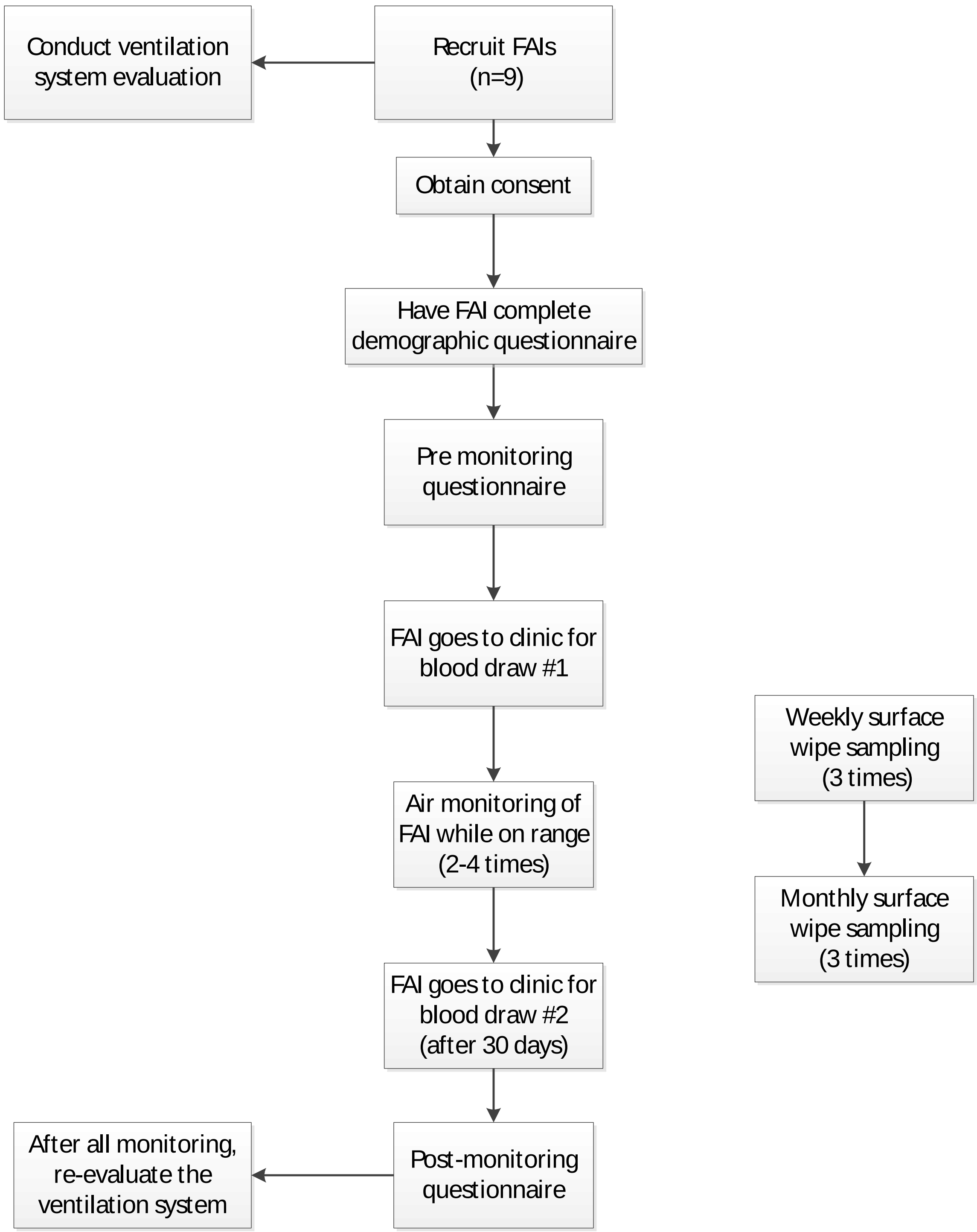


Figure 11 Flow of events for the Characterization of Lead Exposure at a Coast Guard Firing Range Study (Diagram by MA Cohen).

Figure 12 A Rosco® 1500 smoke machine. Smoke was released in all firing lanes simulating each firing positions (prone, kneeling, standing) to observe airflow patterns during normal ventilation operations throughout the firing range (Photos by MA Torres).

The next atribute of the ventilation assessment was to take air velocity measurements at the firing line. According to the U.S. Occupational Safety and Health Administration (OSHA), which has jurisdition over the Coast Guard, whenever a ventilation system is employed as a measure of exposure control for lead, measures like capture velocity, duct velocity, or static pressure should be conducted every 3 months (OSHA, 1993). A VelociCalc® Multi-Function Ventilation Meter 9565 (heated element anemometer) was used to measure the air velocity at each of the three firing positions in all four firing lanes. At each firing location, a nine-point grid was used to take measurements and the measurements averaged for that firing position (Figure 13). Lastly, a pressure differential evaluation was conducted in order to test whether or not air contaminants generated in the space would be carried out of the range or contained in the range. A TSI Model 8705 DP-Calc™ Micromanometer was used to check pressure differential at the entrance door to the range. Additionally, with the use of a fog machine, air flow patterns were witnessed at the entrance to the range.

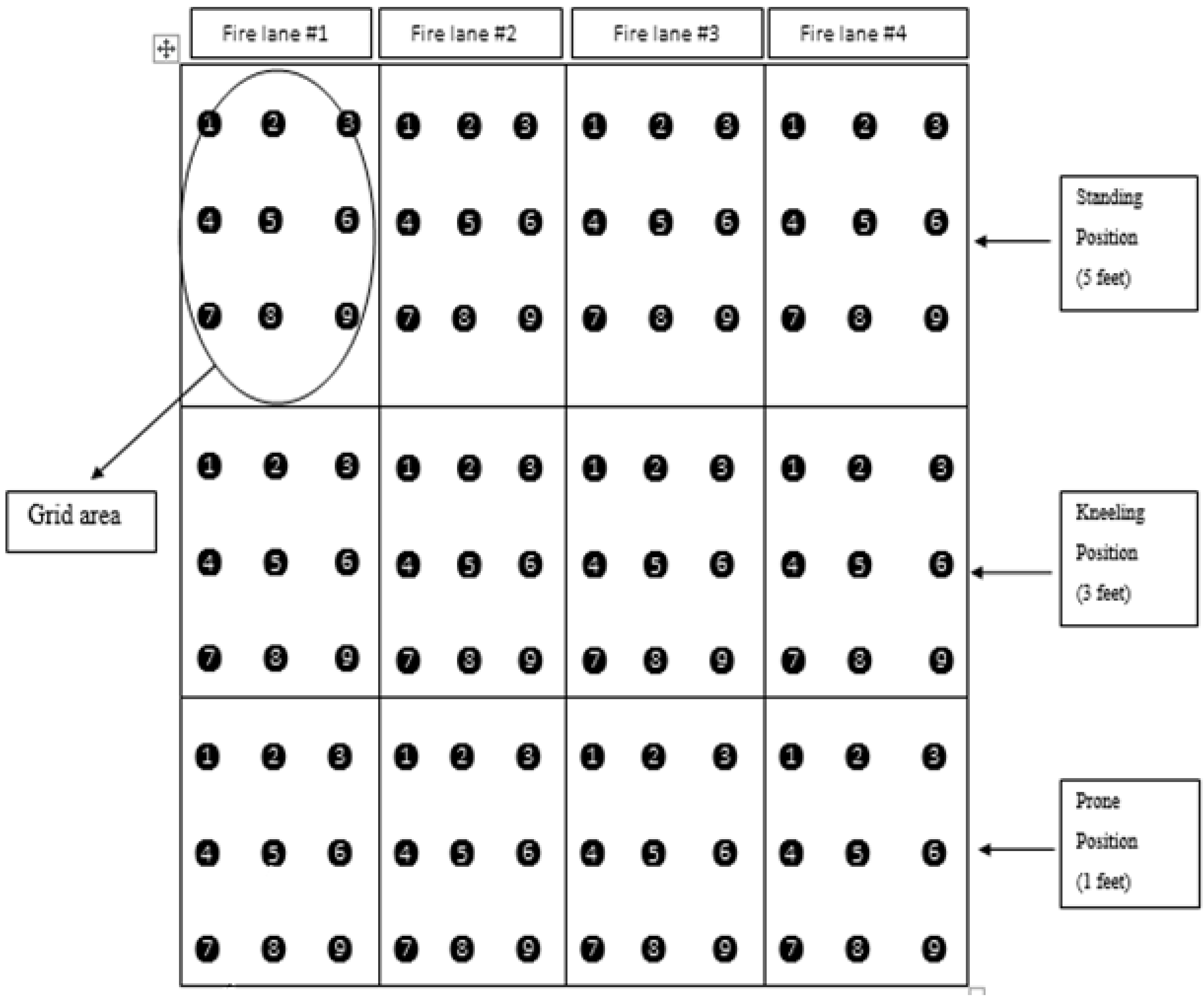


Figure 13 Cross-sectional view of four lanes each with nine air velocity measurement grid areas representative of all firing positions (standing, kneeling, and prone) (Navy, 2002).

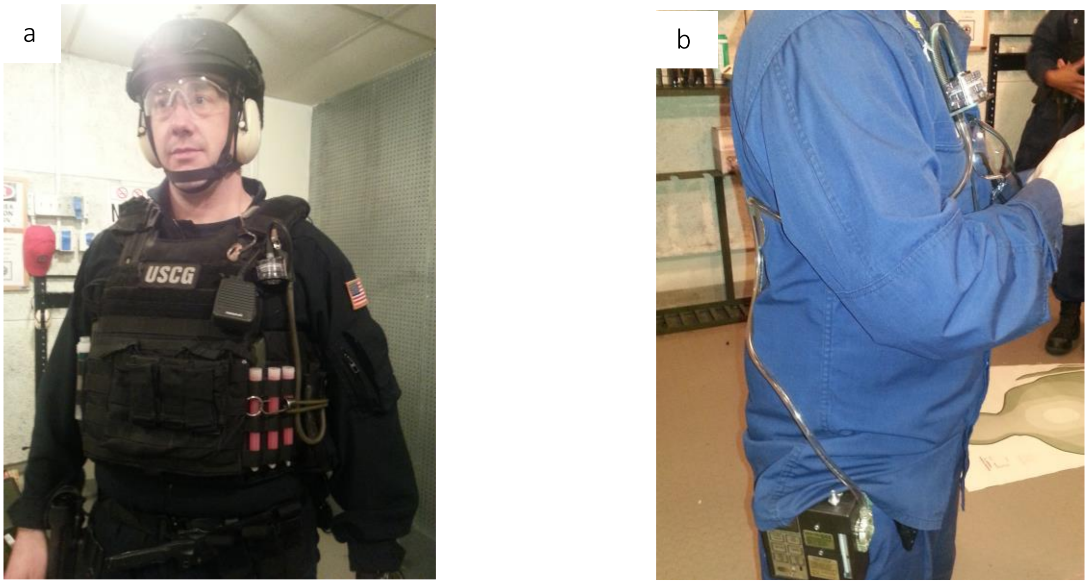
Blood Sampling

Blood samples from all subjects were collected on two different occasions: one before the subjects' first firing session and one at the end of the study. Certified phlebotomists from the U.S. Coast Guard Medical Clinic in Seattle, WA were charged with the collection of all blood draws. A 1-3 mL sample was drawn from the FAI's anticubital region on either right or left arm, depending on the accessibility of the vein.

Air Sampling Methods

Air samples were collected in accordance with NIOSH Method #7082. Air sampling pumps (SKC Inc., XR5000) were calibrated using a DryCal air flow meter (Bios, Defender 520) for both personal and area samples prior to and after monitoring. Pumps were fully charged prior to calibration. The sampling train consisted of an air sampling pump calibrated to approximately 2 liters per minute (lpm), ¼ inch ID Tygon tubing, a 37 mm, 0.8 µm pore sized, mixed cellulose ester (MCE) filters in a closed faced polystyrene cassettes. Prior to personal air sampling, we explained to the subjects the purpose of why we were sampling and if they had any questions regarding the study or the equipment.

A pump was attached to each FAI's belt and the cassette assembly attached the FAI's collar. The position of the cassette assembly was placed within 1 foot from the FAI's head (nose and mouth). Figure 14a and b shows how the sampling train is set up on two FAIs. Three pumps were used for area sampling; in lanes #2 and #3 at the standing firing position (5 feet) and outside of the firing range, but still indoors. The two in-range area samples were used to estimate the shooter's exposures and the sample collected outside of the range used to determine whether lead was migrating out of the range. Figures 15a, 15b, and 16a show the locations where the area samples were collected.



Figures 14a and b FAIs wearing personal air sampling pumps. (a), an MCE filter with a cassette holder is attached with a clip into the FAI's lapel. (b), an FAI has the air sampling pump attached with a clip on his belt.

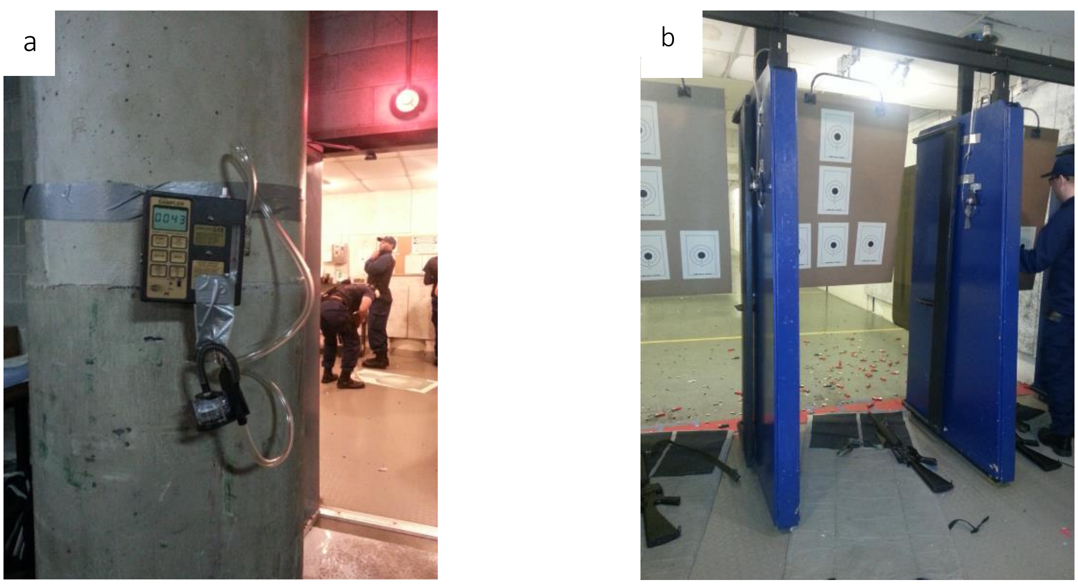


Figure 15a and b Area sampling pumps. On the left, one area sampling pump is located approximately 5 feet from the range's door at a height of 5 feet from the ground. On the right, two area sampling pumps; one placed in firing lane #2 and the other at firing lane #3 (both at a height of 5 feet).

As a quality control check, for every 10 MCE filters used, an additional one was taken to the field and used as a field blank. These filters were handled and analyzed identically to the sample filters.

Wipe sampling methods

Surface wipe sampling helped us determine the efficacy of weekly and more indepth monthly cleaning for lead removal inside the firing range. Surface wipe samples were collected using GhostWipes™ (Environmental Express®) over a 10 cm x 10 cm area using a template, in accordance with the modified NIOSH Method #9100. Wiping the surface was done with firm pressure, using “S” strokes, covering the entire surface (edge to edge) twice horizontally and once vertically at five locations behind the firing line both before and after the cleaning. Each sample was collected as a pair of collocated duplicates (Figure 9) to help determine the spatial homogeneity of lead on the surfaces. The collocated pairs were placed next to each other. The pre- and post-cleaning samples were also located adjacent to each other (Figure 10). The weekly cleaning was typically conducted on the first through third Fridays of the month and the monthly cleaning conducted on the fourth Friday of the month. Tape was used to identify sampling locations so the post samples could be collected from the correct location. After each week’s wipe sampling, the location was changed. Some samples were also collected outside of the range to determine whether lead was being tracked out of the facility.

In order to prevent cross-contamination, a new set of nitrile gloves were used every time to collect dust from horizontal surfaces inside the square template and the template cleaned between samples. Wipes were placed into plastic collection bags, labeled, and sent to the UW's AIHA accredited Environmental Health lab for analysis. As a control measure, one field blank was collected each day wipe sampling was conducted. Figure 16b shows one of the researchers taking wipe samples from the floor inside the firing range.

Figure 16a and b UW researcher at work. On the left, researcher setting up area sampling pump at firing lane #2. On the right, researcher taking surface wipe samples from the floor inside the firing range (Photos by MA Torres).

Study Observations

All FAIs were randomly observed each time they went in and out of the range. It is not customary to have individuals (other than the trainees and FAIs) inside the range for observational purposes. Figure 16 and 17 show FAIs observing/instructing shooters in the range.

Figures 16 and 17 FAI in action (Photo by MA Torres). On the left (Figure 16), FAI is instructing shooters on how to properly fire and qualify for the M-16 rifle. On the right (Figure 17), FAI is observing the firing techniques he just taught to the shooters.

Sample Analysis

Blood lead levels were strictly handled (collected, labeled, and processed) by the U.S. Coast Guard Medical Clinic laboratory personnel. A contracted third party laboratory, Quest Diagnostics®, was in charge of picking up the specimens for analysis. BLLs were analyzed using atomic absorption spectrometry (AAS). Results were given to the Coast Guard clinic who forwarded them to us.

Air and Wipe Sample Analysis

After collection, filters and wipes were processed at the University of Washington's AIHA accredited Environmental Health Laboratory. Filters were digested using microwave digestion with concentrated nitric and hydrochloric acids (EHLSOP-11). Samples were analyzed using inductively coupled plasma mass spectroscopy (ICP-MS EHLSOP-07). The metals analyzed were antimony (Sb), copper (Cu), selenium (Se), tin (Sn), zinc (Zn), and lead (Pb) because they are commonly found associated with lead and jacketed ammunition; however, we will only report results for lead (Pb).

After MCE filters and Ghost Wipes™ were analyzed, several results were found to be below the limit of detection (LOD) for lead of 0.02 µg/sample. To handle these censored data, we replaced the values reported as less than the LOD with LOD divided by the square root of 2 (Succop, 2004; Croghan, 2003).

Results

Ventilation Assessment

Smoke from the smoke test was observed to move down range with relatively little turbulence. However, turbulence was observed at an overhead area near a "can" light fixture approximately 6 to 8 inches from the #2 firing lane. This finding did not alter the result that the range has good, non-turbulent flow, but raised questions about air flow from the drop ceiling.

The pressure differential test found the range negative with respect to the outer area by 0.499” of H_2O. Both negative pressure and smoke tests were considered satisfactory.

We assessed the range’s ventilation system at the beginning (Pre) and at the end of the study (Post) to verify that the conditions in all 4 firing lanes at the 5 ft, 3 ft, and 1 ft heights were maintained. Results are shown in Table 4. According to NIOSH, an indoor firing range should have air velocities at the firing line of between 50-75 fpm (Anania, 1975). Our results show that all 4 firing lanes were above 50 fpm. Interestingly, firing lane #1, which is the closest to the only entrance to the range, generally showed a higher average air velocity measurement compared to the farthest firing lane (#4). This phenomenon may possibly be the result of a design flaw in the ventilation system of the range; eddies or turbulence (as in Figure 2) in firing lane #1 may form. The air flow within the four firing lanes should be very similar; here, we saw a lot of variability between lanes.

Demographic and Pre/Post Questionnaire Information

Demographic descriptors of our study population are shown in Table 5. The typical FAI was a Gunner’s Mate First Class, between 31-40 years old, and extensively experienced (5-9 years as an FAI). Other rates, like Maritime Enforcement Specialists (MEs), can be assigned as FAIs; however, they have to be at least E-5 in pay grade. E-5s are considered non-commissioned officers (NCOs), and called “petty officers”. Onboard a “cutter” or a Coast Guard vessel 65 ft in length or longer, when an E-5 reaches the next pay grade (E-6 or First Class Petty Officer) he or she becomes part of leadership group: The First Class Mess. This group is mentored by the Chief Petty Officer (CPO) Mess, the highest enlisted rank system composed of E-7 through E-9 pay grades [i.e., E-7 (Chief Petty Officer), E-8 (Senior Chief Petty Officer), and E-9 (Master Chief Petty Officer)] (Dolbow, 2010).

Table 4 Pre/Post Ventilation Assessment.

PRE	**Lane** (each measurement is an average of 9 measurements in ft/min) Avg (std)			
Position	**1**	**2**	**3**	**4**
Standing	110.2 (14.6)	78.2 (19.3)	70.5 (15.6)	54 (11.9)
Kneeling	80.4 (15.1)	86.2 (8.8)	66.2 (16.5)	60.2 (16.3)
Prone	69.3 (29.8)	82.7 (17.2)	86.5 (5.9)	60.7 (11.5)
POST	**Lane** (each measurement is an average of 9 measurements in ft/min) Avg (std)			
Position	**1**	**2**	**3**	**4**
Standing	92 (13.1)	63 (7.9)	68 (4.9)	55.7 (7.9)
Kneeling	103.1 (9.7)	74.4 (17.5)	70.7 (8.0)	56.1 (11.1)
Prone	111.1 (6.3)	99.8 (9.4)	82.6 (10.0)	57 (9.7)

Table 5 Demographic information on subjects with duties as FAIs.

Variable	***N***	***%***
Age (Yrs)		
25-30	2	22
31-35	3	33
36-40	3	33
>40	1	11
Gender		
Male	9	100
Ethnicity		
White	9	100
Country of Birth		
US	9	100
Rank		
CPO (E-7)	2	22
PO1 (E-6)	6	67
PO2 (E-5)	1	11
Rate (job position) tasked with FAI duties		
Gunner's Mate (GM)	7	78
Maritime Enforcement Specialist (ME)	2	22
FAI activities		
Administrative	3	33
Training	9	100
Supervisory	3	33
Law Enforcement	2	22
Maintenance	1	11
Total experience as FAI (Yrs)		
0-3 years	2	22
3-5 years	2	22
5-9 years	4	44
>10 years	1	11
Time working as an FAI at the USCG firing range (days)		
Once a month	2	22
2-3 times per month	7	78

Table 6 shows pre/post monitoring exposure determinants gathered from the FAIs. Nearly all used jacketed ammunition and approximately half of the FAIs used standard lead ammunition at the Coast Guard range at some point in time. Two-thirds of the FAIs consumed tap water on the base that is potentially contaminated with lead, and half were involved in home car maintenance.

Before subjects entered the study, FAIs spent an average of 8 hours/month with an average of 1239 rounds fired at the CG range; conversely, at the end of the study FAIs spent an average of 53 hours/month with an average of 370 rounds fired at the CG range.

Table 6 Occupational/non-occupational exposure determinants from FAIs.

Exposure sources of interest (Pre/Post Monitoring Questionnaires)	***Number (Pre)***	***%***	***Number (Post)***	***%***
Cutting or burning iron work with a torch	1	11	0	0
Cleanup of leaded material	2	22	1	11
Ammunition manufacturer	0	0	1	11
Making bullets or shot	1	11	1	11
Average hours spent last month at the CG range	8	--------	53	------
Average hours spent last month at the other range(s)	5	--------	2	-------
Average number of bullets fired at the CG range	1239	--------	370	-------
Types of bullets fired (multiple responses is acceptable)				
Standard lead	5	55	5	55
Full metal jacket	9	100	8	88
Frangible	2	22	2	22
Green	0	0	0	0
Drinking water from buildings with possible traces of	9	90	7	77
Frequency of drinking water with possible traces of lead				
Multiple times a day	4	44	6	66
Once a day	3	33	0	0
Once a week	0	0	0	0
Once a month	0	0	0	0
> Once a month	1	11	0	0
Do not drink water on base	1	11	2	22
Home or other building renovation	1	11	0	0
Home car maintenance	5	55	5	55
Do you hunt for game?	2	22	2	22
Do you eat you eat your game?	2	22	2	22

Table 7 presents summary statistics for the BLLs, where the difference is defined by subtracting the pre-monitoring BLL from the post-monitoring BLL. It can be seen that BLLs are relatively variable between subjects. In 4 subjects (45%), BLLs decreased from baseline (Pre-BLL). The rest of the subjects' (55%), BLLs increased but slightly, almost unrecognizable, more than 20 times lower than OSHA's medical removal level of 40 µg/dL.

We conducted a paired t-test to verify whether or not there is a statistically significant difference between post and pre BLLs. Our results showed that difference between post and pre BLLs (Δ) was $p>0.05$; not statistically significant. Figure 18 shows the differences in Pre and Post BLLs per each FAI. The variability between subjects is probably dependent upon many factors. To name a few: individual metabolism, personal hygiene (i.e., washing hands before placing them into the mouth), or time spent at the range. "Sometimes workers with a high exposure to airborne lead appear to have only moderate PbB-levels, whereas workers with a low exposure may have relatively high PbB-levels" (Williams, 1975).

Table 7 Summary of Blood Lead Concentrations (µg/dL).

Statistic	**Pre-BLL**	**Post-BLL**	**Post-Pre BLL**
Average	2.4	2.3	2.4
Standard Deviation	1.6	1.2	1.4
Minimum	0.9	0.9	0.9
Maximum	5.6	4.6	5.1

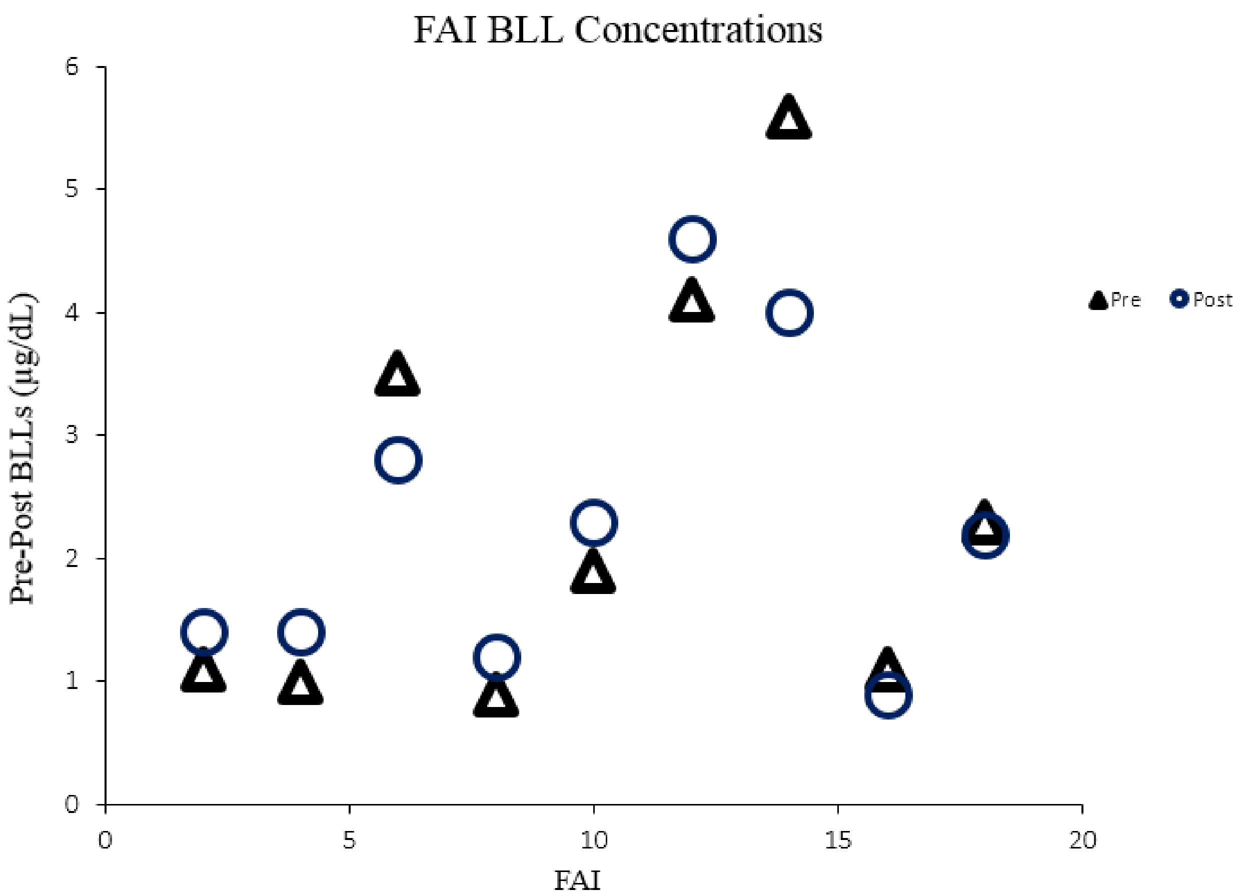


Figure 18 Differences in Pre and Post BLLs per each FAI.

Before and after BLLs were platted against one another, including a symmetry (1:1) line, as shown in Figure 19. Symbols above the symmetry (1:1) line have higher post BLLs and values observed below the symmetry (1:1) line have higher pre BLLs.

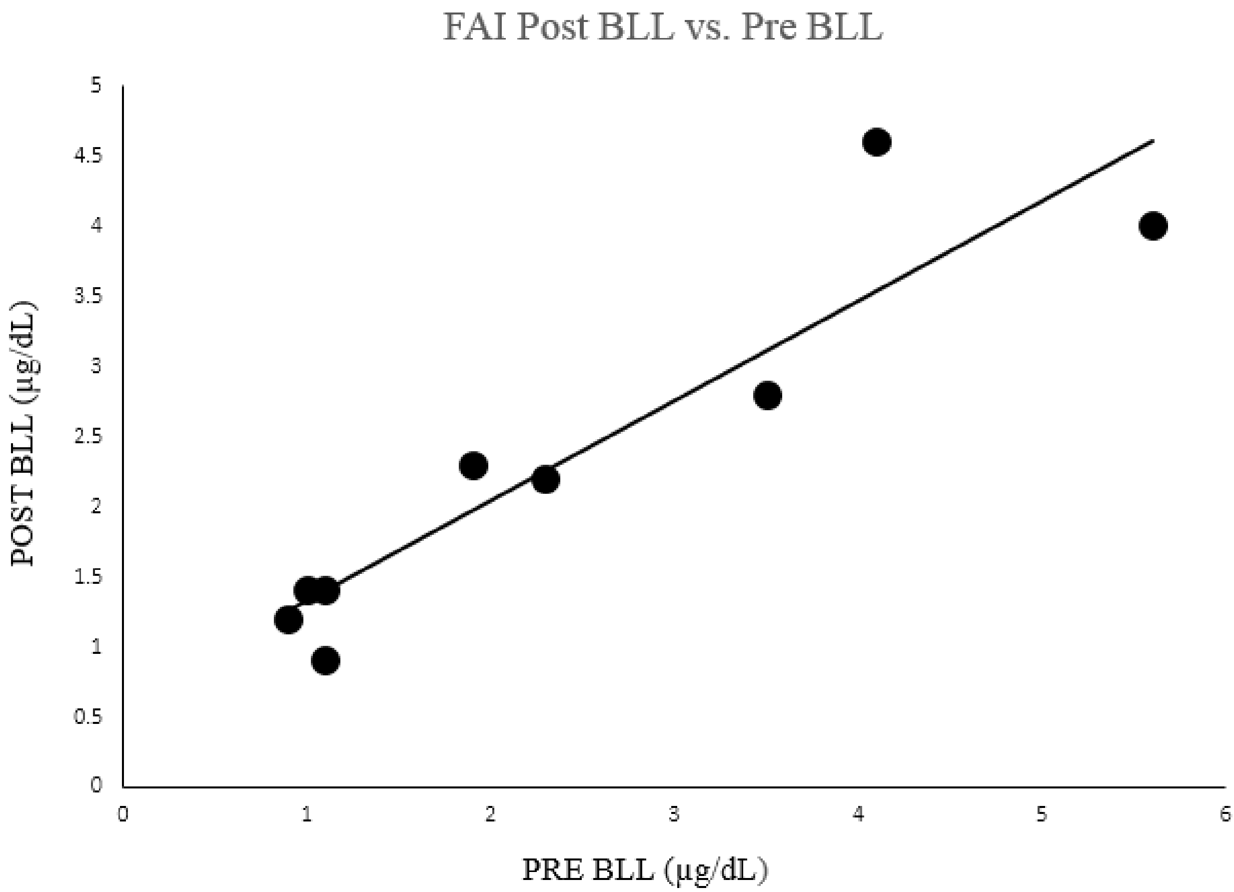


Figure 19 FAI Post vs. Pre BLLs Scatterplot.

Table 8 lists a summary of PbA personal exposures throughout the study. Figure 20 shows the PbA exposures by FAI which displays the variability of the levels by person and time. For the most part, exposures were relatively low, well below OSHA's action level of 25 µg/m^3.One subject (#10), however, had a PbA exposure of 20.5 µg/m^3. We believe that this result was isolated given the fact that the subject's average BLL was 2.1 µg/dL, more than 20 times below OSHA's medical removal level of 40 µg/dL. We were not able to attribute the high exposure to any observations or other factors.

It should be noted that the collection of PBZ samples was not equally distributed among subjects, because FAI's had between 2 and 4 samples collected. It all was dependent upon subject availability. Regardless of this fact, on average the PbA concentrations were very low, also more than 20 times below OSHA's standard of 50 µg/m^3.

Table 8 Summary of Air Lead Exposures (2-4 samples per FAI).

	Exposures (µg/m^3)				
FAI	**Average (µg/m^3)**	**Maximum**	**Minimum**	**Range**	**Number**
2	0.3	0.4	0.2	0.2	3
4	1.3	2.0	0.6	1.4	3
6	0.3	0.3	0.2	0.1	2
8	0.2	0.35	0.04	0.31	4
10	10.3	20.5	0.07	19.8	2
12	4.3	7.8	0.8	7.0	2
14	6.7	8.5	4.9	3.6	2
16	0.7	2.0	0.3	1.7	4
18	0.2	0.2	0.1	0.1	3

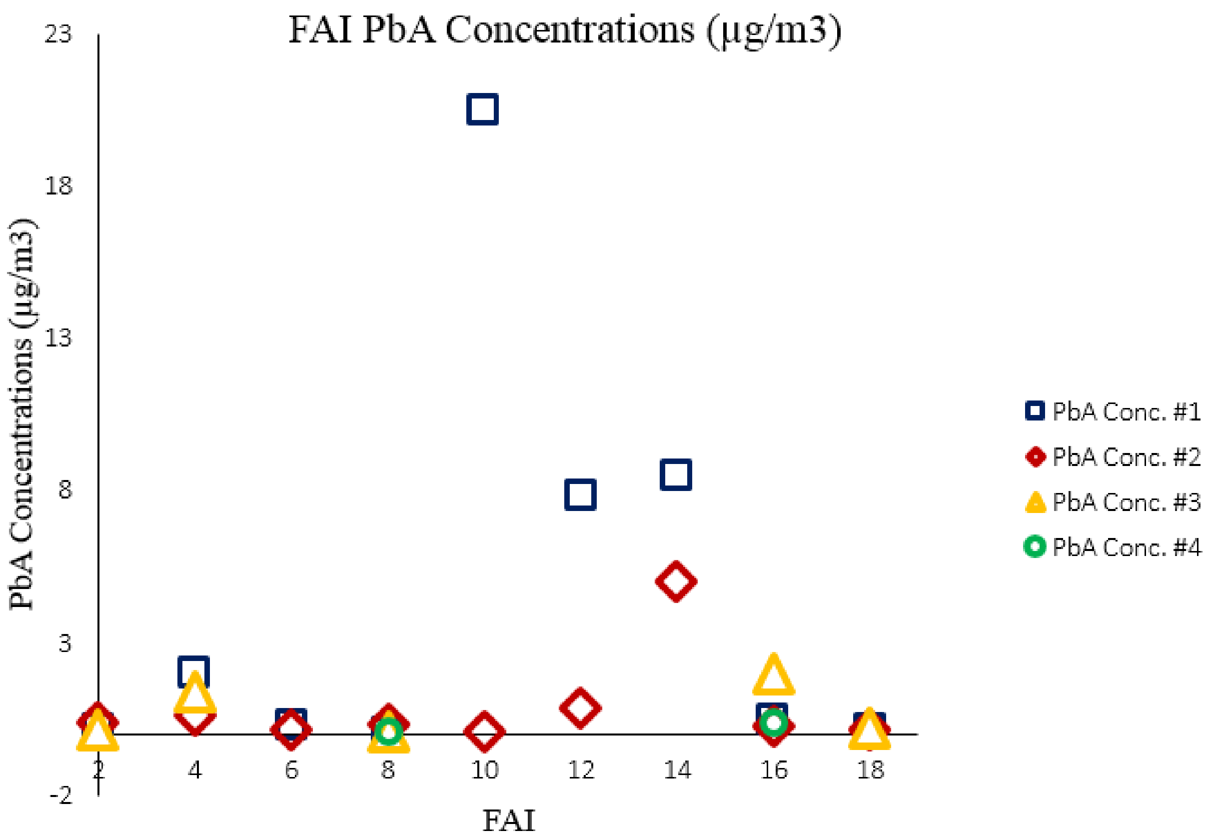


Figure 20 PbA Concentration vs. FAI # Scatterplot.

PbA vs. Total Full Metal Jacket (FMJ)/Leaded Rounds

Table 9 shows a summary of ammunition used (full metal jacket (FMJ) and lead rounds) that subjects were exposed to while they were conducting weaponry training with military personnel.

Table 9 Summary of Ammunition Rounds Exposed to During Training Sessions: Full Metal Jacket (FMJ) and Lead.

	FMJ Rounds				Lead Rounds			
FAI	Avg.	SD	Max	Min	Avg.	SD	Max	Min
2	1190	114	1285	1064	0	0	0	0
4	1190	114	1285	1064	0	0	0	0
6	632	484	974	290	38	53	75	0
8	824	661	1658	265	123	138	290	0
10	685	296	894	475	40	0	40	40
12	3600	877	4200	2980	0	0	0	0
14	685	296	894	475	40	40	40	40
16	920	217	1210	710	70	97	205	0
18	806	707	1322	0	54	37	94	20

To test the hypothesis that the type and number of rounds fired while on the range can influence the air lead exposure (hypothesis #2), we plotted graphs to investigate these relationships. Figures 21 and 22 show the relationship between air lead exposures and rounds fired [Lead rounds (shotgun) and full metal jacket (FMJ), respectively]; each data point represents the number of rounds (lead or FMJ) expended at the range per FAI air monitoring session. As it can be seen, there is no association between the type or number of rounds fired and air exposures. However, subjects #10 and #14 had PbA exposures of 20.5 µg/m^3 and 8.5 µg/m^3, respectively. We believe that, although it is not common for FAIs to personally fire rounds, in this particular air monitoring session, both FAIs did fire several rounds. There are several instances where FAIs personally fire rounds: To maintain weaponry qualifications or when weapons jammed or a shooter had issues with handling weapons. FAIs mainly observe and instruct shooters during weaponry qualifications.

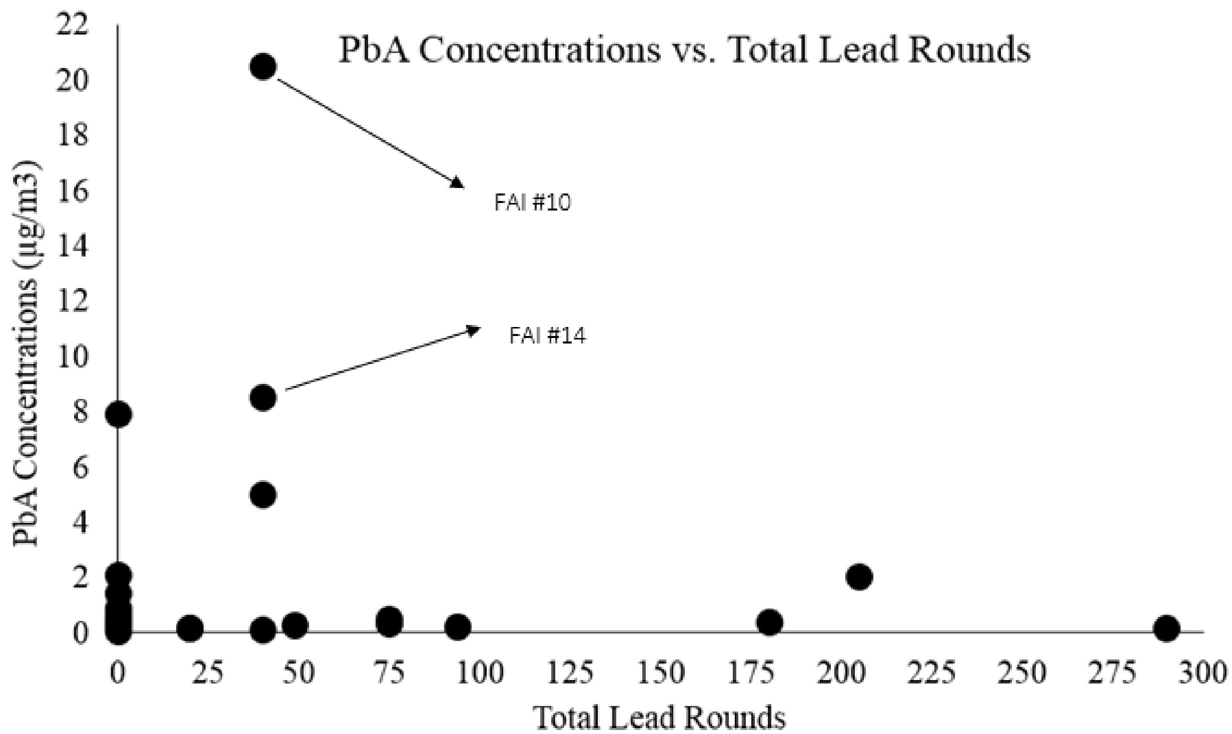


Figure 21 PbA Concentration vs. Total Lead Rounds Scatterplot.

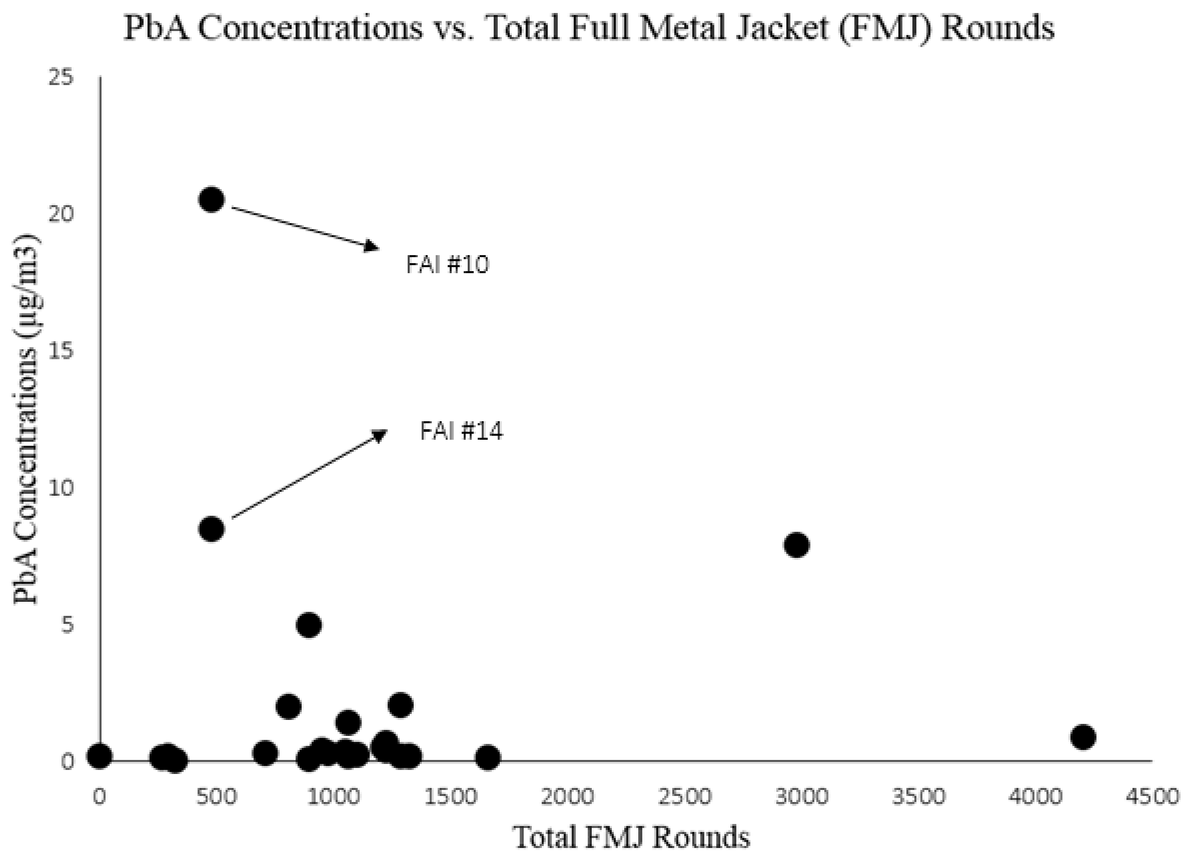


Figure 22 PbA Concentrations vs. Total Full Metal Jacket (FMJ) Rounds Scatterplot.

Δ BLLs vs. Average PbA Concentration

To evaluate whether there was a relationship between air and blood leads (hypothesis #1), we plotted the Δ BLLs and the average PbA of FAIs (Figure 23). However, some of the average PbA concentrations were in a slight cluster. So, to spread the data more uniformly we log-transformed them. Figure 24 shows the log-transformed data. After regressing the data, we determined that there was no relationship ($p>0.05$) between Δ BLLs and average PbA concentrations.

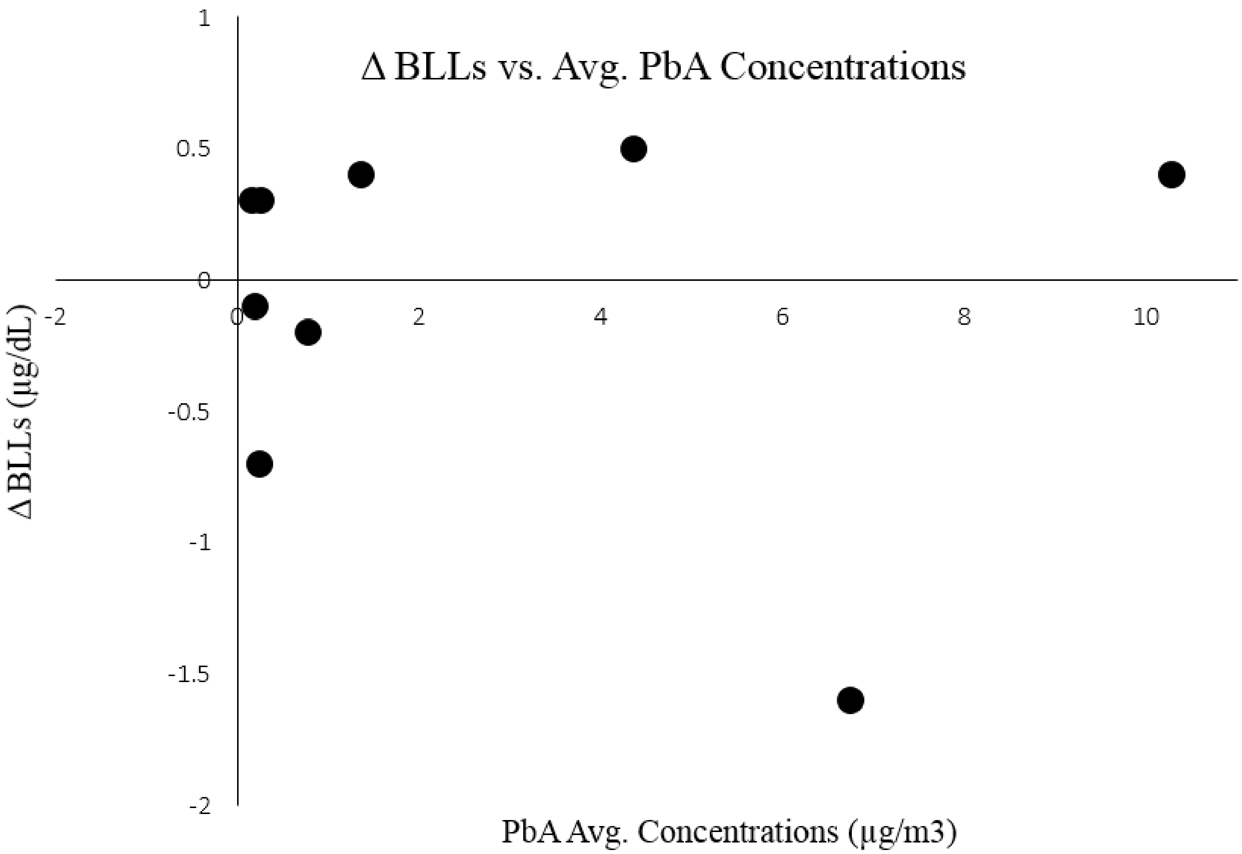


Figure 23 Δ BLLs vs. PbA Concentrations Scatterplot.

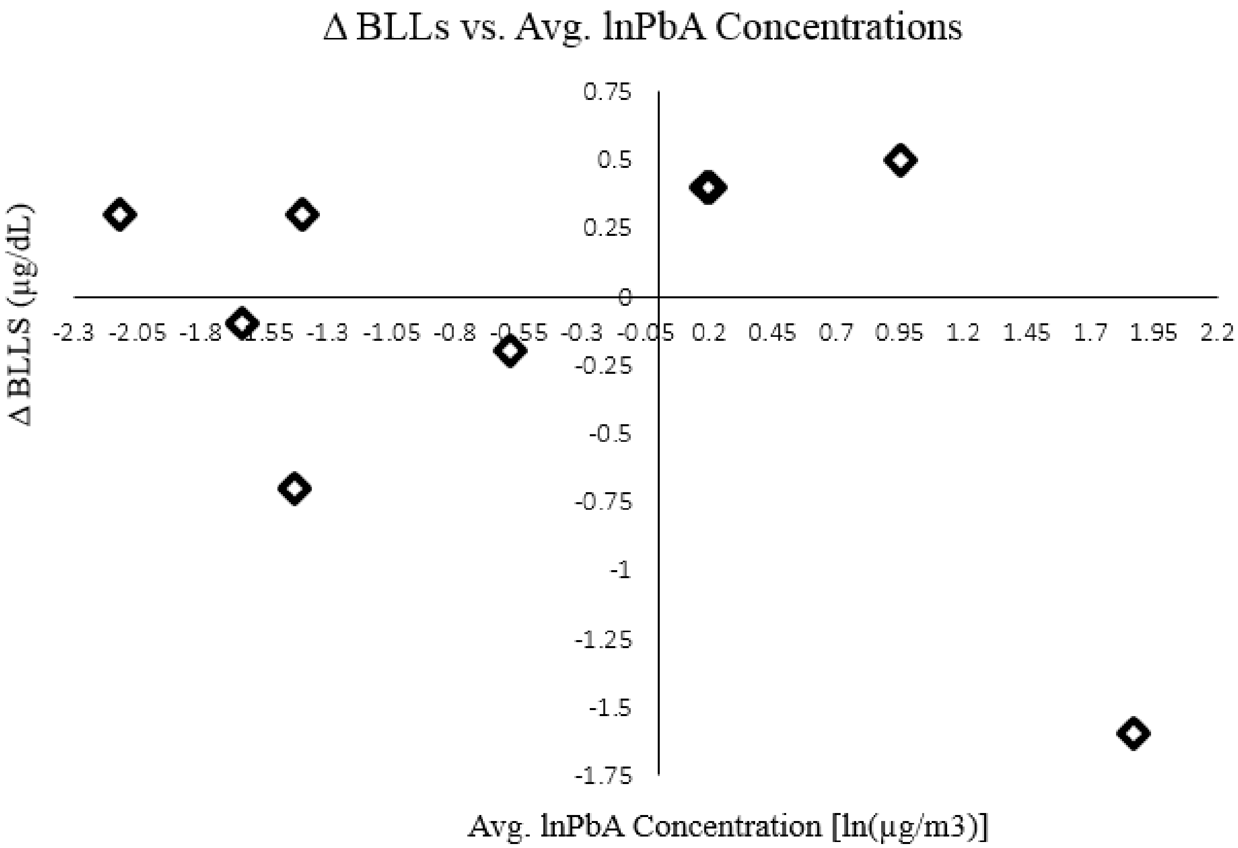


Figure 24 Δ BLLs vs. Avg. LN PbA Concentrations Scatterplot.

Δ BLLs vs. Total Lead/Full Metal Jacket (FMJ) Rounds

To test the hypothesis that the type and number of rounds fired while on the range can influence the blood lead level (hypothesis #3), we plotted graphs to investigate these relationships (Figures 25 and 26). Again, it can be seen that there is no association between Δ BLLs and the type or number of rounds.

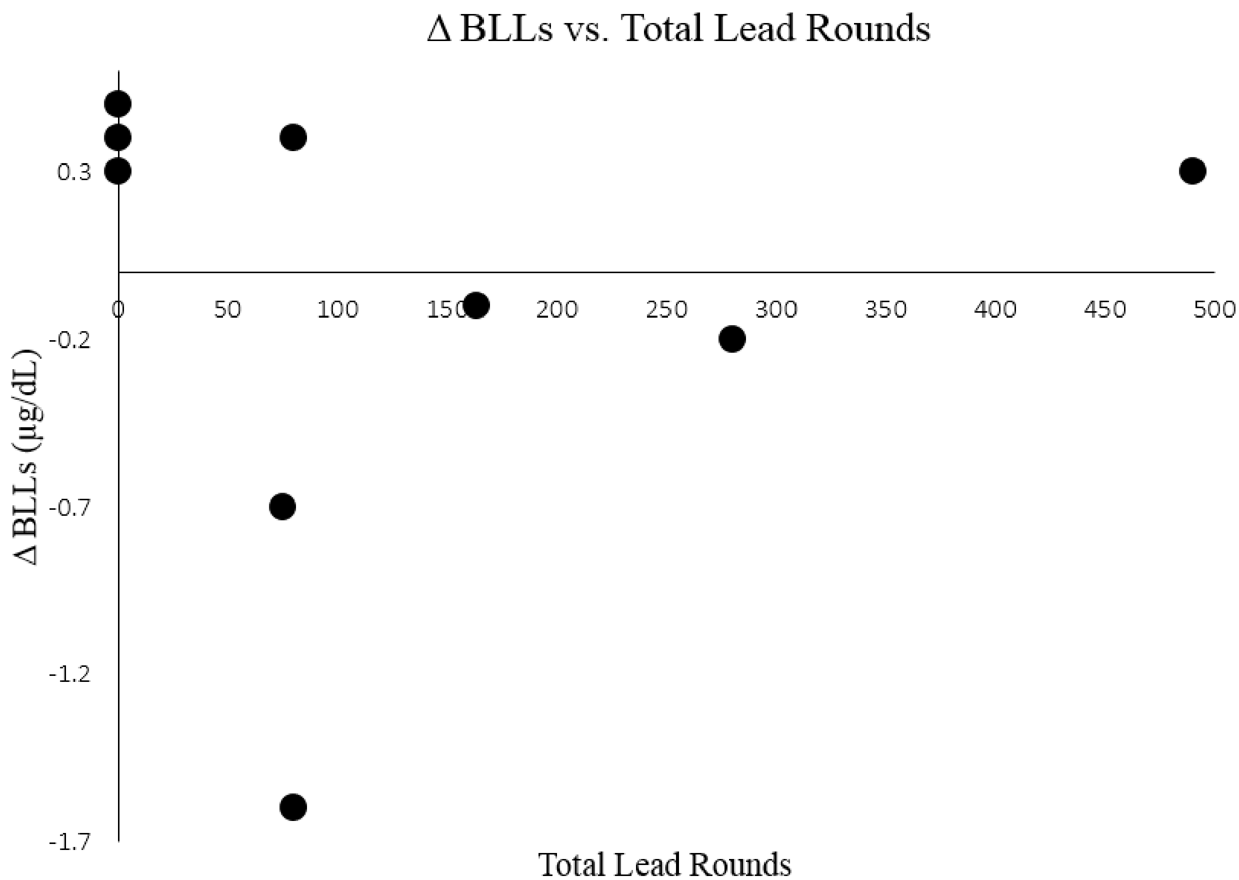


Figure 25 Δ BLLs vs. Total Lead Rounds Scatterplot.

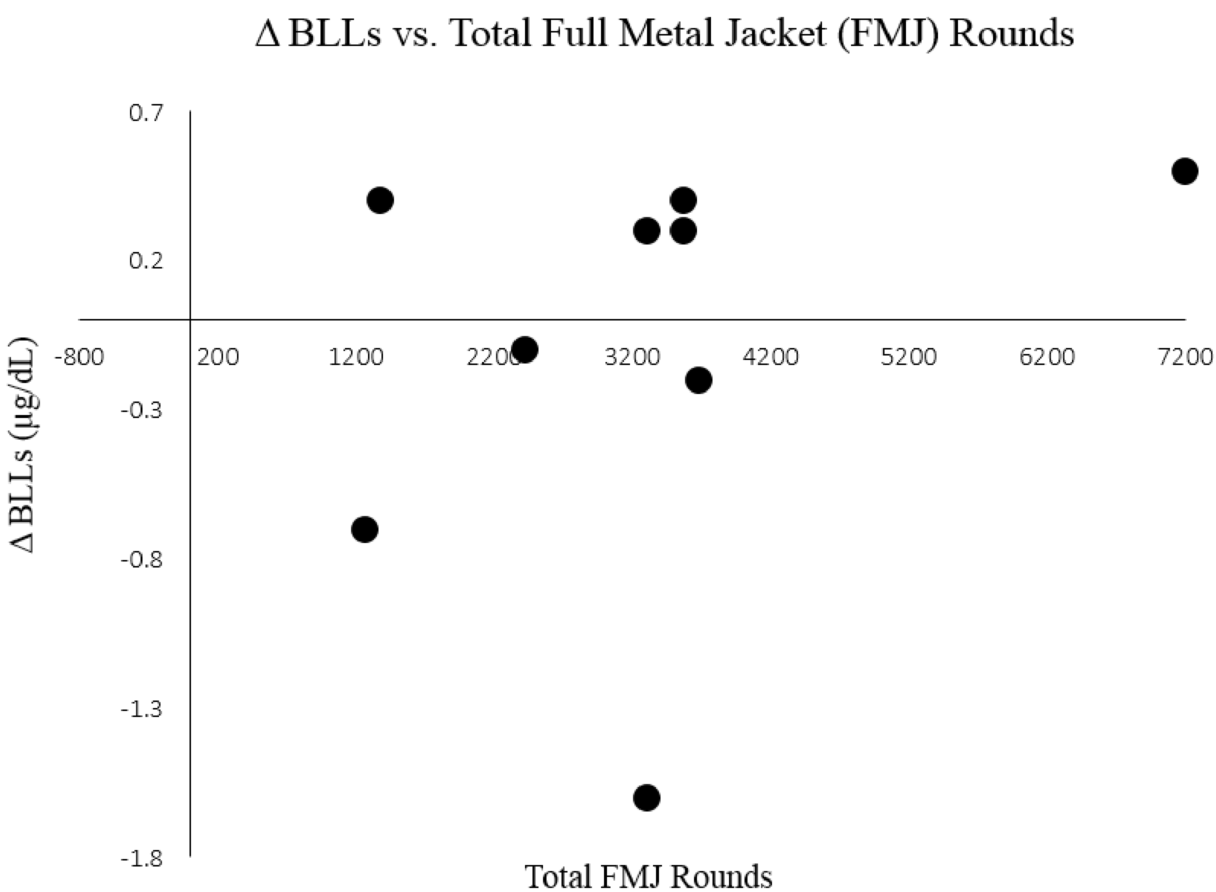


Figure 26 Δ BLLs vs. Total Full Metal Jacket (FMJ) Rounds Scatterplot.

Post vs. Pre Surface Wipe Sampling

Wipe sampling was conducted to evaluate the effectiveness of weekly and monthly cleaning protocols. Weekly cleaning is generally done the first three Fridays of the month and involves the retrieval of ammunition casings/slugs with a dry squeegee, the use of a HEPA vacuum cleaner, and "tidying up the place" for users the following week. Monthly cleaning is generally conducted on the last Friday of the month and covers the same as the weekly cleaning, but adds the cleaning of the bullet trap and mopping the floor of the range. The workers conducting both the weekly and monthly cleaning wear full Tyvek suits, gloves, safety glasses, and half-mask respirator with a P100 HEPA filters.

In order to evaluate the two cleaning practices, we first evaluated the homogeneity of the surface contamination. Sixty side-by-side paired surface wipe samples (30 weekly, 30 monthly) were taken from the floor of the indoor firing range over a 4-month period. The pairs were evaluated using a paired t-test. No statistical differences were found between the side-by-side samples ($p > 0.05$). This allowed us to compare the pre-and post-cleaning samples and assume that they would be similar if cleaning hadn't taken place.

To evaluate both cleaning methods statistically, we used paired t-tests to measure the post- to pre-cleaning differences for both weekly and monthly cleaning practices, where negative values indicate that cleaning removed lead. Statistically significant differences were found for both, weekly and monthly cleaning procedures ($p<0.012$ and $p<0.016$, respectively). Interestingly, the weekly cleaning had lower surface concentrations after cleaning than before cleaning (Table 10 and Figure 27), while the monthly cleaning had higher concentrations after cleaning than before (Table 10 and Figure 28).

Figures 27 and 28 show how surface lead concentrations increased over time, which is indicative of poor cleaning practices. Then, we compared weekly from monthly data to determine which cleaning practice is better than the other. Figure 28 shows that during the first month of sampling, the cleaning maintains low a level of surface lead; however, the surface lead on the second month almost doubles after cleaning and increasing gradually on the third month. This finding indicates that the monthly cleaning procedure is not eliminating the surface lead but rather spreading it around the firing range floor. Figure 27shows that weekly cleaning, although not eliminating surface lead completely, allows the level of surface lead to increase slightly over time. Although weekly cleaning seems to be removing surface lead better than monthly cleaning, it's still not reducing the quantity over time. Like shown with BLLs, another comparison between surface lead concentrations before and after cleaning is by plotting all the values including a symmetry (1:1) line. Figures 29 and 30 show post vs. pre lead surface wipe concentrations for weekly and monthly cleaning practices, respectively. Values observed above the symmetry (1:1) line are post lead surface concentrations and values observed below the symmetry (1:1) line are pre lead surface concentrations. We can observe that most of the weekly data (Figure 29) falls below the symmetry (1:1) line. On the contrary, most of the monthly data (Figure 30) falls above the symmetry (1:1) line; a clear indication that monthly cleaning is less efficient than weekly cleaning. Additionally, when the differences were investigated by cleaning procedure and date (Figures 31 and 32), we find that on one day, the weekly cleaning procedure reduced the lead level in a statistically significant manner, whereas the monthly cleaning procedure increased the lead level on two of the days in a significant manner.

Table 10 Pre/Post Avg. and Delta (Δ) Surface Wipe Concentrations (μg/100 cm^2).

Date	**Cleaning protocol**	**Average Pre-cleaning (SD)**	**Average Post Cleaning (SD)**	**Average Delta (SD)**
1/24/14	Weekly	0.40 (0.13)	0.42 (0.15)	.006 (0.13)
2/14/14	Weekly	0.64 (0.15)	0.30 (0.07)	-0.34 (0.18)
2/28/14	Weekly	0.70 (0.31)	0.45 (0.09)	-0.23 (0.27)
	Overall Weekly	0.58 (0.16)	0.39 (0.08)	-0.19 (0.18)
1/31/14	Monthly	0.28 (0.05)	0.44 (0.06)	0.17 (0.07)
2/21/14	Monthly	0.73 (0.51)	1.44 (0.32)	0.76 (0.57)
4/4/14	Monthly	1.01 (0.89)	2.35 (1.07)	1.35 (1.62)
	Overall Monthly	0.67 (0.37)	1.41 (0.78)	0.76 (0.59)

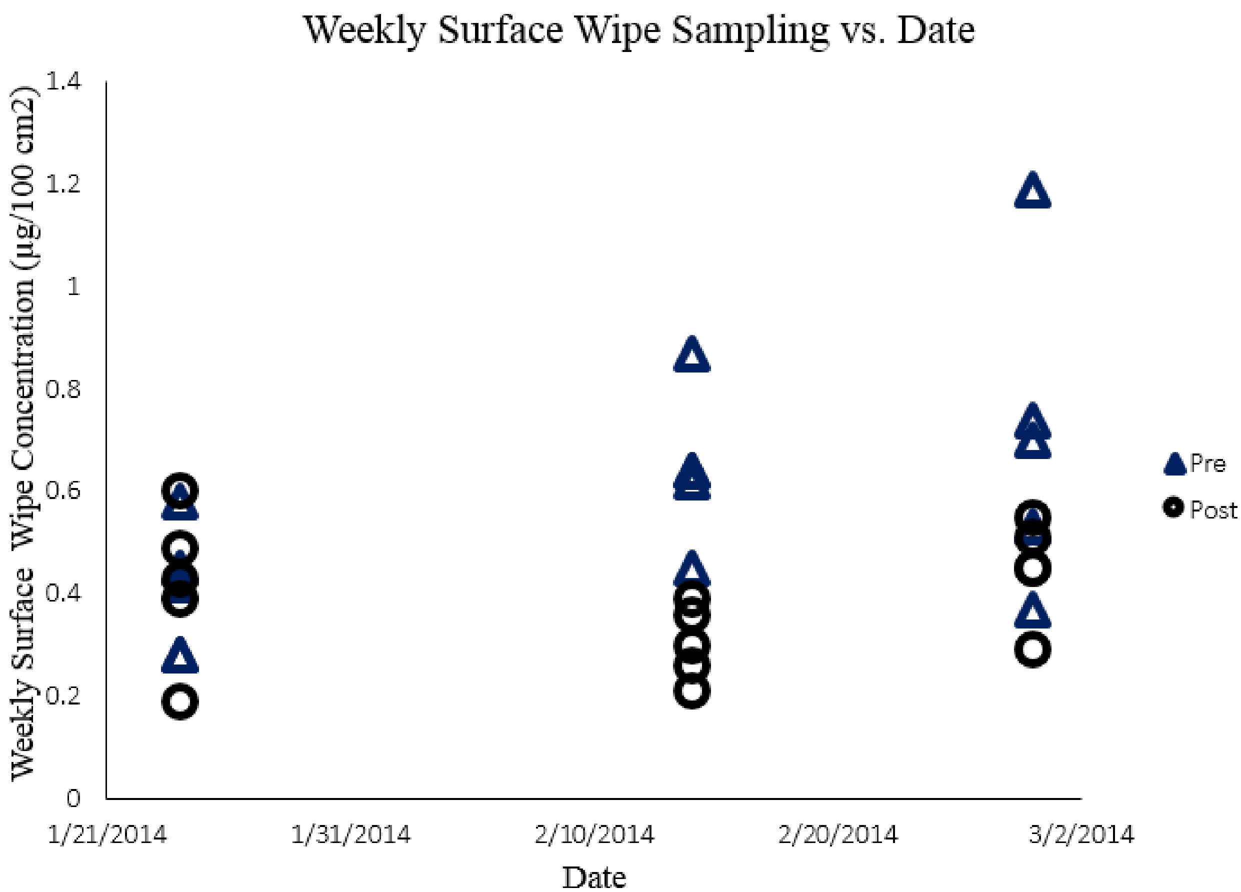


Figure 27 Weekly Surface Wipe Sampling vs. Date Scatterplot.

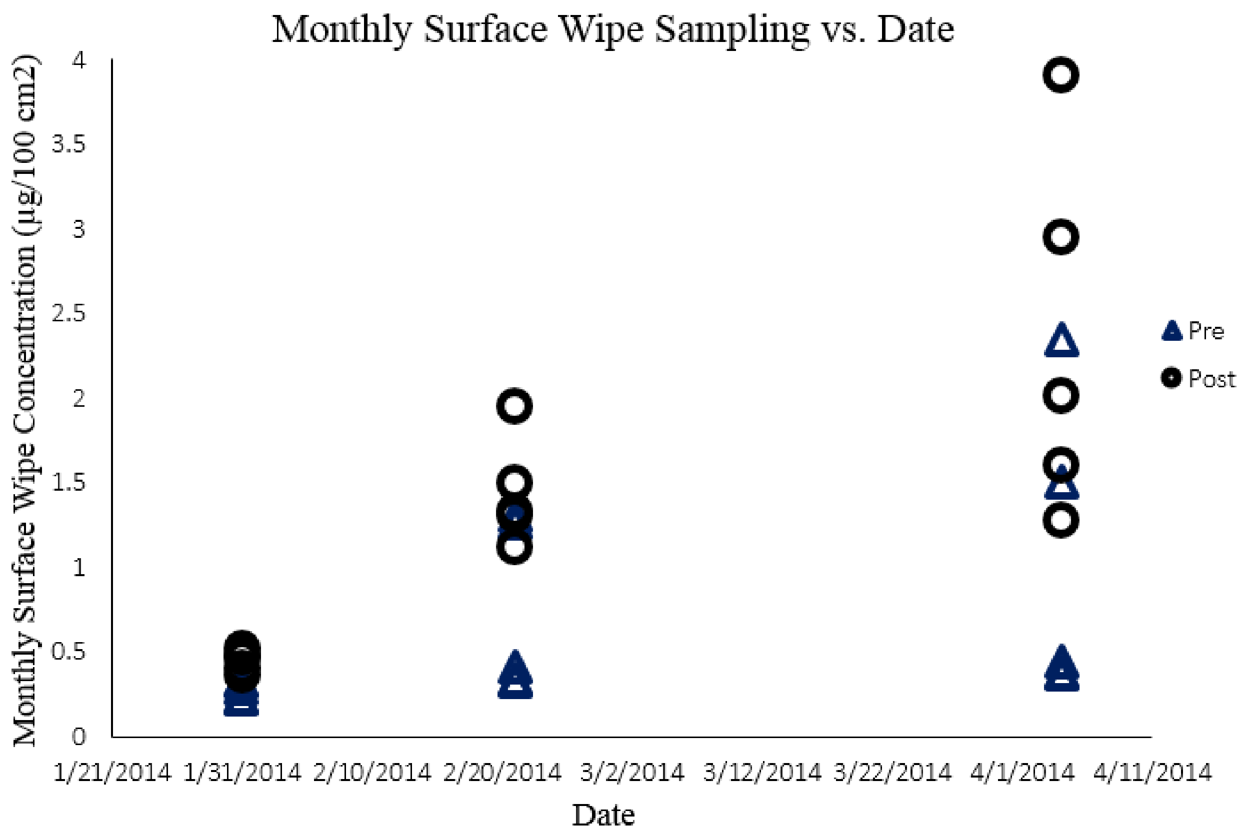


Figure 28 Monthly Surface Wipe Sampling vs. Date Scatterplot.

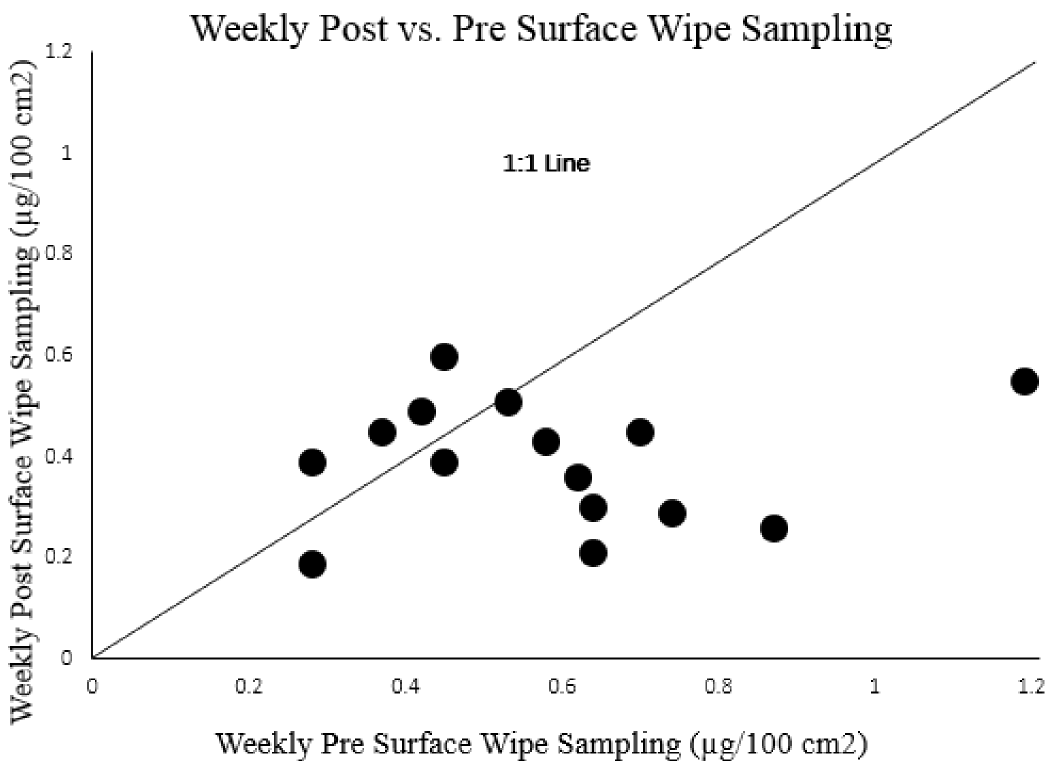


Figure 29 Weekly Post vs. Pre Surface Wipe Sampling Scatterplot.

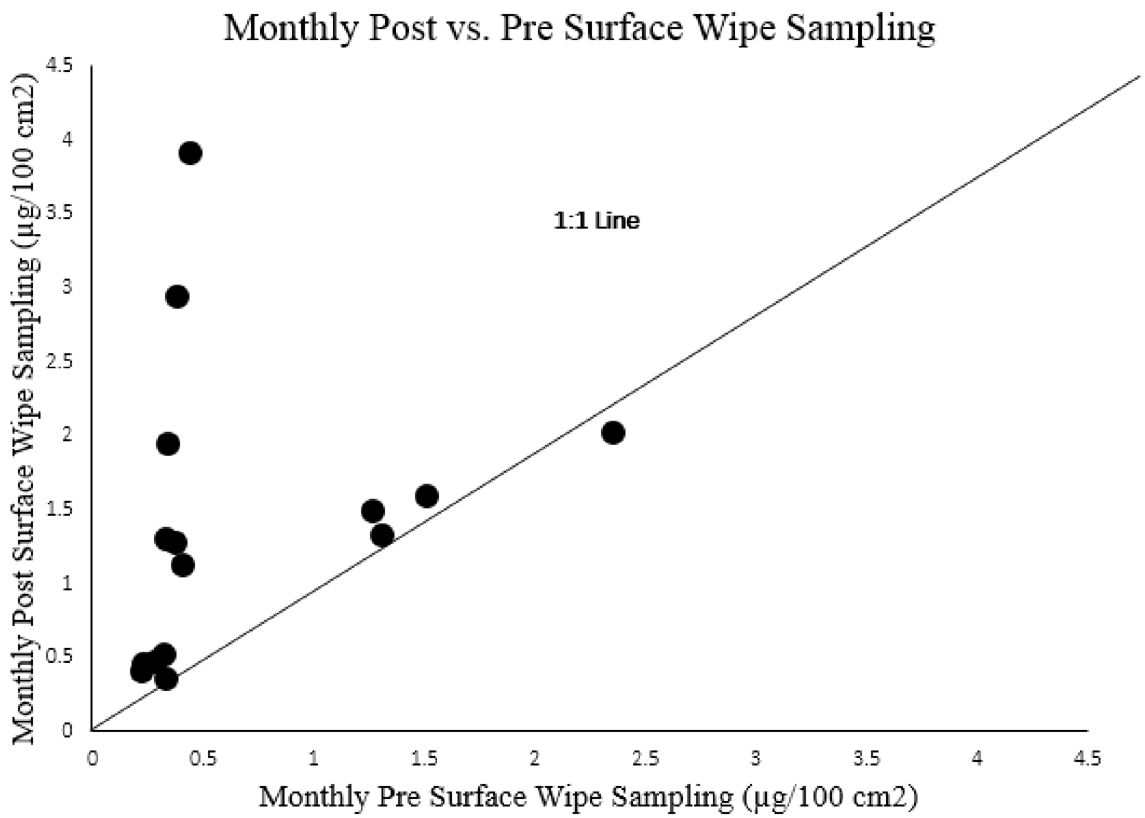


Figure 30 Monthly Post vs. Pre Surface Wipe Sampling Scatterplot.

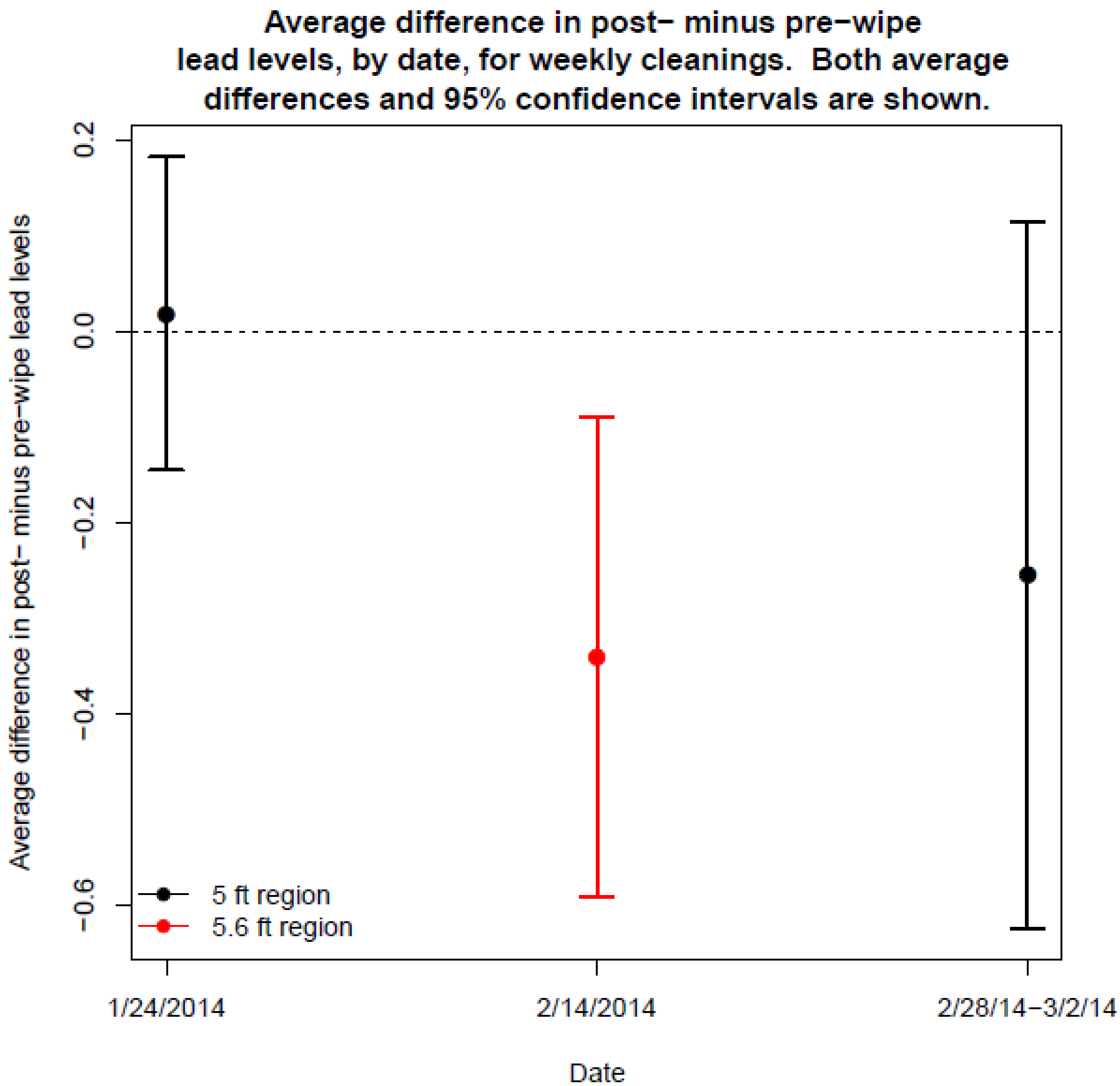


Figure 31 Avg. Difference (Δ) in Weekly Surface Wipe Sampling vs. Date (Figure by S Bergen).

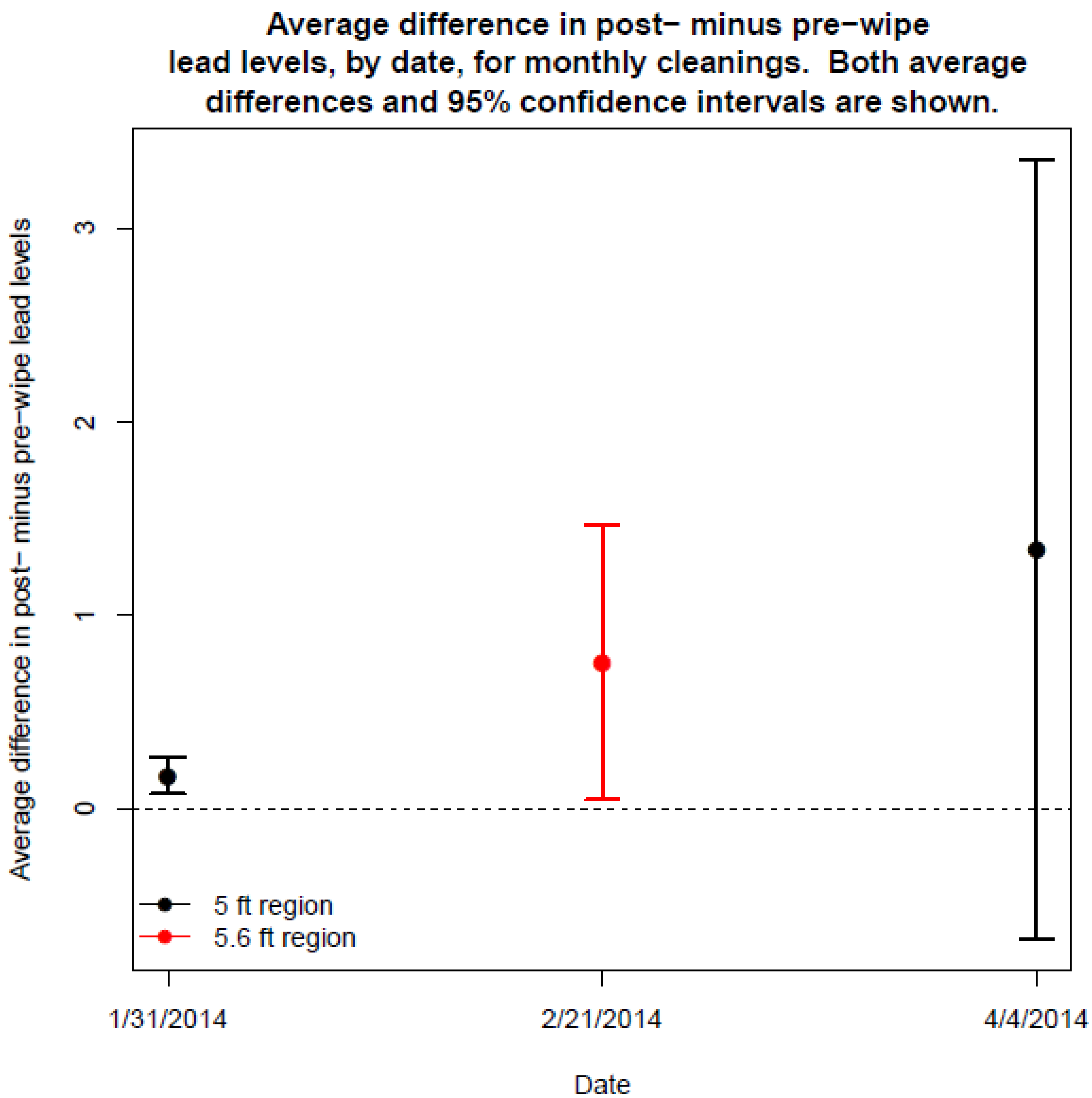


Figure 32 Avg. Difference (Δ) in Monthly Surface Wipe Sampling vs. Date (Figure by S Bergen).

Quality Control

Several procedures of quality control were utilized throughout the study to identify potential issues with the data collected at the firing range (MCE filters and Ghost Wipes™). Field blank Ghost Wipes were found to be almost negligible in lead content (highest concentration was 0.03 µg/100 cm^2). Field blank MCE filters were almost negligible for lead content. The highest concentration for personal air sampling was 0.07 µg/m^3 and for surface wipe sampling was 0.03 µg/100 cm^2. Thus, the values were within 5 % of air sampling and surface wipe sampling's limit of detection (0.03 µg/m^3 and 1 µg/100 cm^2, respectively).

The laboratory spiked both MCE filters and Ghost Wipes™ and found recovery rates at 104.3% and 99.1%, respectively.

Discussion

Biomonitoring Outcomes

Blood lead levels (BLLs) measured for all nine subjects were within normal limits. The highest average BLL was 2.4 µg/dL, which is 20 times lower than OSHA's standard of 40 µg/dL. Although the rate of elimination of lead from the body is variable, depending on the individual's metabolism, age, diet, etc., our study shows that the lead exposure generated at the indoor firing range does not seem to be a threat to the health of the FAIs. The combination of controls, using copper jacketed bullets instead of lead (substitution) and a well-functioning ventilation system (engineering control) kept blood lead levels relatively low. Gulson et al., (2002) agreed with this finding and suggested that to reduce the uptake of lead even further, non-lead primers should be used. However, as mentioned previously, studies have shown that low BLLs can dramatically affect glomerular and tubular renal function (Rossi, 2008). That is why the already established annual medical monitoring program (i.e., OMSEP) needs to be consistent and closely followed for FAIs and other personnel.

Airborne Lead Exposures

Air samples from personal breathing zones (PBZs) from all nine subjects were within normal limits. The highest average air lead exposure was 10.5 µg/m^3, which is 5 times lower than OSHA's standard of 50 µg/m3. Although there are many variables that could influence FAIs exposure to lead (i.e., type of ammunition, number of rounds fired, personal hygiene practices), our study showed that the lead exposure generated in the indoor firing range did not greatly impact the airborne lead exposures of the FAIs. Again, a combination of controls, using copper jacketed bullets instead of lead (substitution) and a well-functioning ventilation system (engineering control) kept airborne lead exposures low.

Relationships Between Variables

Our study could not find any relationships between airborne lead and BLLs, ammunition (lead or full metal jacket), or FAI activity (work-related or extracurricular). Likewise, no relationship was drawn between BLLs and type of ammunition or FAI personal activity.

It is very important to reiterate our findings with subjects #10 and #14 (Figures 21 and 22) which yielded airborne lead exposures of 20.5 µg/m^3 and 8.5 µg/m^3, respectively. After interviewing the FAIs regarding this event, it was established that they fired weapons during the session, though it is not a common practice due to internal accountability issues. Although our 4-week study could not find any relationship between airborne lead and BLLs, ammunition or FAI activity, it may not necessarily represent the exposure that could occur over a longer period of time (i.e., six months, 12 months, or 18 months).

Valway et al., (1989) assessed the effect of using jacketed ammunition instead of leaded bullets, by having shooters fire 60 rounds in approximately 10 minutes. The types of bullets used were copper-jacketed bullets, nylon-clad bullets and leaded bullets. Although the results of air sampling showed 97% reduction using copper-jacketed bullets, the minimal airborne lead exposure in this part of Valway's study was 27.8 $\mu g/m^3$ (very close to OSHA's action limit of 30 $\mu g/m^3$), potentially placing the shooters at risk of lead poisoning if exposed to airborne lead over long periods of time.

Our study did find some discrepancies with the weekly and monthly cleaning procedures that take place inside the indoor firing range. Weekly cleaning, which is conducted by active duty U.S. Coast Guard personnel, had lower surface concentrations after cleaning than before cleaning. However, monthly cleaning, which is conducted by civilian contracted personnel, had higher concentrations after cleaning than before. It is possible that the mop used to clean the floor on a monthly basis is simply moving the lead around the floor, instead of removing it. This allows the surface lead concentrations to accumulate as time passes. This finding is an indication that poor monthly cleaning practices are being used inside the firing range.

Limitations

Our study has several limitations. Our goal was to recruit at least 15 subjects and we only acquired nine. A larger sample size could have given us a better representation of the population we were studying (i.e., FAIs.) and increase our power to demonstrate statistically significant effects.

Another limitation was that the duration of the study was relatively short. With a longer study, we may have been able to collect more replicate samples, which could have reduced the variance of our measures and given us more accurate measures (Nieuwenhuijsen, 2003).

In order to get a "better picture" of what takes place in other U.S Coast Guard indoor firing ranges, our study would have benefited with inclusion of more than one location. Possible variations (or differences) in the use of weaponry, ammunition, engineering controls, hygiene practices, etc., would have been captured, compared, and new lessons learned.

Conclusions

One of our concerns driving this study was the fact that DoD budget cuts could close down nearby federal indoor ranges and more military personnel (i.e., Navy, Army, and Air Force) would start visiting U.S. Coast Guard Base Seattle's indoor firing range. This could increase lead exposures for the FAIs. So far, that concern has not been realized. However, if a combination of controls (i.e., jacketed ammunition, properly maintained ventilation system and an effective surface cleaning protocol) is well sustained, exposures to lead should be kept below the AL and PEL.

In sum, our results show that a combination of controls, using copper jacketed bullets instead of lead and a well-functioning ventilation system, can be used to keep air and blood lead levels low. One concern was the fact that firing lane #1 yielded several high air velocities (> 100 fpm) above NIOSH recommendations of 40-75 fpm. This could be considered a flaw in the ventilation system's design or maintenance and should be further investigated. Having high velocities inside an indoor firing range could create eddies or turbulence (as in Figure 2) and possibly place firing range users at risk for lead exposure.

Using the hierarchy of controls has enabled working personnel's mean BLLs and airborne lead exposure to be maintained at less than 20 times OSHA's standards (more than 20 times below 40 µg/dL and 50 $\mu g/m^3$, respectively). However, it is clear that although OSHA's surface contamination recommendation of 21.5 $\mu g/100\ cm^2$ was not exceeded (highest value was 4.4 $\mu g/100\ cm^2$) anywhere inside the firing range, we found that the weekly cleaning procedure is more effective than the monthly procedure at removing lead from the floor. A more robust cleaning procedure needs to be implemented in order to improve the removal of lead contamination from the range. The possibility of spreading surface lead outside the firing range via different means (i.e., lead-contaminated working boots, clothing, and hands or hair) is present and could affect other personnel or a more sensitive population (i.e., pregnant women, children).

When interviewing the civilian cleaning crew that conducts the monthly cleaning, we discovered that their employer does not have a “set in stone” procedure to clean the firing range. The use of good engineering controls can be circumvented if housekeeping is lacking, as found by Scott (Scott, 2012). Additionally, some studies mentioned that ranges’ walls, structures, tables (i.e., classroom), chairs, partitions, and nearby classrooms should also be regularly cleaned and have washable surfaces to improve cleaning operations (Gelberg, 2009). These were not investigated in this study, but it is part of the U.S. Coast Guard Base Seattle indoor firing range’s cleaning and maintenance standard operating procedure.

Future Work

During the course of this study, the noise level created outside of the firing range was sometimes extremely loud. Future studies may investigate noise controls to reduce exposures outside of the range. If the noise levels outside of the range were greater than 90 dBA, averaged over an 8 hr time period, the OSHA Hearing Conservation Standard comes into play. Another possible venue for investigation would be to further investigate the effectiveness of the cleaning procedures. As mentioned earlier, our study showed that both weekly and monthly cleaning procedures are not properly eliminating surface lead; it’s acumulating over time and spreading around the indoor firing range. A possible solution would be to request a consultation with another hazardous materials cleaning company or OSHA to conduct an assessment of the present procedure with thoughts to add, correct, or eliminate steps to allow for proper elimination of surface lead.

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Bibliography

Abadin, H. (2007). *Toxicological profile for lead.* Atlanta: Agency for Toxic Substances and Disease Registry.

Agency for Toxic Substances & Disease Registry (2005). *Public Health Statement for Lead.* Atlanta: U.S. Department of Health and Human Services.

Agency for Toxic Substances & Disease Registry (2007). *Toxicological Profile for Lead.* Cincinnati: U. S. Department of Health and Human Services.

Altaise, O. I. (2010). Lead exposure: A contributing cause of the current breast cancer epidemic in Nigerian women. *Biol Trace Elem Res*, 127-139.

Altera, B. (2004). Lead-based paint activities in military family housing. *The Air Force Law Review*, 101-129.

American Conference of Governmental Industrial Hygienists (2004). *Industrial Ventilation: A manual of recommended practice, 25th edition.* Cincinnati: Signature Publications.

American Conference of Governmental Industrial Hygienists (2013). *TLVs and BEIs based on the documentation of the threshold limit values for chemical substances and physical agents & biological exposure indices.* Cincinnati: Signature Publications.

Anania, T. L. (1975). *Lead Exposure and Design Considerations for Indoor Firing Ranges.* Cincinnati: National Institute for Occupational Safety and Health (NIOSH) .

Anderson, K. E. (1977). Plumbism from airborne lead in firing range. *The American Journal of Medicine* , 306-312.

Anttila, A. (1995). Excess lung cancer among workers exposed to lead. *Scandinavian Journal of Work, Environment & Health* , 460-469.

Bagci, C. (2004). Blood lead levels of the battery and exhaust workers and their pulmonary function tests. *Int J Clin Pract*, 568-572.

Barry, P. S. (1975). A comparison of concentrations of lead in human tissue. *Br J Ind Med*, 119-139.

Bergen, S. (2014, May 17). Avg. Difference in Monthly Surface Wipe Sampling vs. Date. Seattle, WA.

Bergen, S. (2014, May 17). Avg. Difference in Weekly Surface Wipe Sampling vs. Date. Seattle, WA.

Bevan, J. (2006). *Targeting Ammunition: A Primer.* Switzerland: Small Arms Survey.

Bomar, J. (1996). *Gunner's Mate 1 & C (NAVEDTRA 14110).* Pensacola: Naval Education and Training Command.

Bress, W. C. (1991). Percutaneous in vivo and in vitro absorption of lead. *Vet Hum Toxicol*, 212-214.

Brookhaven National Laboratory (2014). *Surface Wipe Sampling Procedure.* Ridge: Safety & Health Services Division - Industrial Hygiene Group.

Bureau of Medicine and Surgery (2002). *Indoor Firing Ranges Industrial Hygiene Technical Guide.* Portsmouth: Navy Environmental Health Center.

Burham, A. (1996). Lead exposure in indoor firing ranges: Environmental impact and health risks to the range users. *International Journal of Occupational Medicine and Environmental Health*, 323-329.

Casarett, L. J. (1996). *The Basic Science of Poisons.* New York: McGraw-Hill.

Centers for Disease, Control and Prevention (CDC) (1983). Reducing exposures to airborne lead in indoor firing ranges--United States. *Morbidity and Mortality Weekly Report (MMWR)*, 483-489.

Centers for Disease, Control and Prevention (CDC) (2011). Adult blood lead epidemiology and surveillance - United States, 2008-2009. *MMWR*, 841-845.Contra Costa Health Services Project (2014, April 05). *Questions and Answers About Lead in Ceramic Tableware.* Retrieved from Contra Costa Health Services: http://cchealth.org/services/

Costa de Almeida, G. R. (2009). Lead in saliva from lead-exposed and unexposed children. *Science of the Total Environment*, 1547-1550.

Craig, P. J. (1980). The Natural Environment and the Biogeochemical Cycles. *Springer-Verlag*, 185-197.

Croghan, C. W. (2003). Methods of dealing with values below the limit of detection using SAS. *U.S Environmental Protection Agency (EPA)*, 1-5.

Crouch, K. G. (1991). Ventilation control of lead in indoor firing ranges: Inlet configuration and booth and fluctuating flow contributions. *American Industrial Hygiene Association Journal*, 81-91.

Demmeler, M. (2009). High blood lead levels in recreational indoor-shooters. *Int Arch Occup Environ Health*, 539-542.

Department of Housing and Urban Development (HUD), 2. C. (2000). *Requirements for notification, evaluation, and reduction of lead-based paint hazardsin in federally owned residential property and housing receiving assistance; final rule.* Washington, D. C.: Government Printing Office.

Di Lorenzo, L. (2010). Lead exposure in firearms instructors of the Italian State Police. *Med Lav*, 30-37.

Dolbow, J. (2010). *The Coast Guardsman's Manual.* Annapolis: U. S. Naval Institute.

Dolbow, J. (2013). *The Coast Guardsman's Manual.* Annapolis: U. S. Naval Institute.

Donovan, B. A. (1994). *Health Hazard Evaluation Report No. 92-0029 (Kessler Studios).* Cincinnati: National Institute for Occupational Safety and Health (NIOSH).

Dorman, D. C. (2013). *Potential health risks to DOD firing-range personnel from recurrent lead exposure.* Washington, D. C.: The National Academies Press.

Encylopedia Britannica (2014, April 28). *Lead (Pb).* Retrieved from Encyclopaedia Britannica Online: http://www.britannica.com/EBchecked/topic/333514/lead

Englyst, V. (2001). Lung cancer risks among lead smelter workers also exposed to arsenic. *The Science of the Total Environment*, 77-82.

Environmental Protection Agency (2010). *Calibration Curves: Program Use/Needs.* Washington, D. C.: U. S. Environmental Protection Agency (USEPA).

Ettinger, A. S. (2004). Effect of breast milk lead on infant blood lead levels at 1 month of age. *Environmental Health Perspectives*, 1381-1385.

European Lung Foundation (2013, September 9). *Fumes from military small arms lead to decline in lung function.* Retrieved from Sciency Daily: http://www.sciencedaily.com

Fischbein, A. (1979). Exposure to lead in firing ranges. *Journal of Occupational Medicine*, 1141-1144.

Fischbein, A. (1980). Comparative lead emissions from conventional and jacketed ammunition. *American Industrial Hygiene Association Journal*, 525-527.

Fisher, E. (2013, May 14). *Bellevue gun shop cited for exposing workers to lead*. Retrieved from Washington State Department of Labor and Industries (L & I): http://lni.wa.gov

Fleming, D. E. (1997). Accumulated body burden and endogenous release of lead in employees of a lead smelter. *Environ Health Perspect*, 224-233.

Freeman, E. J. (2012). Trends in notifiable blood lead levels in NSW, 1998-2008. *NSW Public Health Bulletin*, 11-12.

Froines, J. R. (1990). Characterization of the airborne concentration of lead in U.S. industry. *American Journal of Medicine*, 1-17.

Gaddis, M. L. (1990). Introduction to biostatistics: Part 6, correlation and regression. *Ann Emerg Med*, 1462-1468.

Gelberg, K. H. (2009). Lead exposure among target shooters. *Archives of Environmental & Occupational Health*, 115-119.

Gilbert, S. (2012). *A small dose of Toxicology.* Seattle: Healthy World Press.

Gilfillan, S. C. (1965). Lead poisoning and the fall of Rome. *Journal of Occupational Medicine*, 53-60.

Gracia, R. C. (2007). Lead toxicity and chelation therapy. *Am J Health-Syst Pharm*, 45-53.

Griffin, T. B. (1975). Clinical studies on men continuously exposed to airborne particulate lead. *Georg Thieme Publisher*, 221-240.

Gross, S. B. (1975). Lead in human tissues. *Toxicol Appl Pharmacol*, 638-651.

Gulson, B. L. (2002). Changes in blood lead of a recreational shooter. *The Science of the Total Environment*, 143-150.

Gulson, B. L. (1996). Nails: Concern over their use in lead exposure assessment. *The Science of the Total Environment*, 323-327.

Heard, M. J. (1979). Human uptake and metabolism of tetra ethyl and tetramethyl lead vapour labelled with 203Pb. *International Conference on Management and Control of Heavy Metals in the Environment*, 103-108.

Heard, M. J. (1982). Effect of minerals and food on uptake of lead from the gastrointestinal tract in humans. *Hum Toxicol*, 441-445.

Houlihan, J. (2001, 04 30). *Lead Pollution at Outdoor Firing Ranges.* Retrieved from Environmental Working Group: http://www.ewg.org

Hursh, J. B. (1989). Percutaneous absorption of mercury vapor by man. *Arch Environ Health*, 120-127.

International Agency for Research on Cancer (2006). *Volume 87, Inorganic and Organic Lead Compounds: Summary of Data Reported and Evaluation.* Lyon: World Health Organization.

Jacobs, D. E. (2002). The prevalence of lead-based paint hazards in U.S. housing. *Environmental Health Prespectives*, A599-606.

James, A. C. (1994). Deposition of inhaled particles. *Annual International Commision of Radiological Protection*, 231-299.

King, M. (2005, March 18). *Lead and lead alloys.* Retrieved from Wiley Online Library: http://onlinelibrary.wiley.com

Klein, M. (2014, April 10). *Technical Track: Indoor Range Design, Retrofitting Your Indoor Firing Range.* Retrieved from National Shooting Sports Foundation: http://nssf.org

Landrigan, P. J. (1975). Chronic lead absorption. Result of poor ventilation in an indoor pistol range. *JAMA*, 394-397.

Larese, F. (2006). Skin absorption of inorganic lead (PbO) and the effect of skin cleansers. *J Occup Environ Med*, 692-699.

Lawrence Berkely National Laboratory (2010, December 09). *Safe Soldering Work Practices.* Retrieved from Berkeley Lab: http://www.lbl.gov

Lilley, S. G. (1988). The use of sweat to monitor lead absorption through the skin. *The Science of the Total Environment* , 267-278.

Lynn, T. (2005). Lead exposure for indoor firing ranges among students on shooting teams. *MMWR*, 577-579.

MMWR. (1991). Effectiveness in Disease and Injury Prevention Control of Excessive Lead Exposure in Radiator Repair Workers. *Centers for Disease Control & Prevention*, 139-141.

MMWR. (2005). *Blood lead levels - United States, 1999-2002.* Atlanta: Centers for Disease Control and Prevention.

Morgenthaler, A. B. (2002). Indoor shooting range. *American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Journal*, 44-46.

Morley, J. C. (1997). *Immigration and Naturalization Service.* San Ysidro: National Institute for Occupational Safety and Health (NIOSH).

Morose, G. (2013). *Industrial uses of lead.* Lowell: Toxics Use Reduction Institute.

National Institute for Occupational Safety and Health (NIOSH) (1991). *Health Hazard Evaluation and Technical Assistance Report: FBI Academy, Quantico, VA.* Cincinnati: Department of Health and Human Services.

National Institute for Occupational Safety and Health (NIOSH) (1992). *Request for Assistance in Preventing Lead Poisoning in Construction Workers.* Atlanta: National Institute for Occupational Safety and Health (NIOSH).

National Institute for Occupational Safety and Health (NIOSH) (1997). *Protecting Workers Exposed to Lead-Based Paint Hazards: A Report to Congress.* Atlanta: National Institute for Occupational Safety and Health (NIOSH).

National Institute for Occupational Safety and Health (NIOSH) (2009). *NIOSH Alert: Preventing Occupational Exposures to Lead and Noise at Indoor Firing Ranges.* Cincinnati: Department of Health and Human Services.

National Institute for Occupational Safety and Health (NIOSH) (2010, June 25). *Hierarchy of Controls*. Retrieved from Centers for Disease Control and Prevention: http://www.cdc.gov/niosh/topics/engcontrols/

National Institute for Occupational Safety and Health (NIOSH) (2011). *Noise and Lead Exposures at an Outdoor Firing Range - California.* Atlanta: National Institute for Occupational Safety and Health (NIOSH).

National Institute for Occupational Safety and Health (NIOSH) (2012). *NIOSH Pocket Guide to Chemical Hazards.* Cincinnati: Department of Health and Human Services.

National Institute for Occupational Safety and Health (NIOSH) (2013, September 30). *Lead*. Retrieved from Center for Disease Control and Prevention: http://www.cdc.gov/niosh/topics/lead/

National Science Foundation (1977). *Physical and chemical characteristics of environmental lead.* Arlington: In Lead in the Environment.

National Shooting Sports Foundation (1997). *Environmental Aspects of Construction and Management of Outdoor Ranges.* Newtown: National Shooting Sports Foundation.

National Shooting Sports Foundation (2013). *Firearms and Ammunition Industry Economic Impact Report.* Newtown: National Shooting Sports Foundation .

Navy Facilities Engineering Command (1992). *Military Handbook: Range Facilities and Miscellaneous Training Facilities Other Than Buildings.* Washington, D. C.: Government Printing Office.

Nevada Mining Association (2008). *Industrial Hygiene Sampling Manual.* Reno: Nevada Mining Association.

Nieuwenhuijsen, M. J. (2003). *Exposure Assessment in Occupational and Environmental Epidemiology.* New York: Oxford University Press.

Occupational Safety and Health Administration (1993, December 13). *29 CFR 1910.1025, Lead (General Industry)*. Retrieved from United States Department of Labor: http://osha.gov

Occupational Safety and Health Administration (1993, December 13). *29 CFR 1926.62, Lead (Construction)*. Retrieved from U. S. Department of Labor: http://www.osha.gov

Occupational Safety and Health Administration (2006, April 03). *29 CFR 1910.1000 (Air contaminants)*. Retrieved from United States Department of Labor: http://www.osha.gov

O'Flaherty, E. J. (1995). Physiologically based models for bone-seeking elements. V Lead absorption and disposition in childhood. *Toxicol Appl Pharmacol*, 297-308.

Olmez, I. (1985). Airborne lead and trace elements in an indoor shooting range: A study of the DC National Guard Armory Pistol Range. *Environmental Toxicology and Chemistry* , 447-452.

Onarlioglu, B. (1999). The effect of lead inhalation on rat lung morphology. *Turkish Journal of Medical Sciences*, 617-622.

National Toxicology Program (2003). *Report on Carcinogens Background Document for Lead and Lead Compounds.* Cincinnati: U.S. Department of Health and Human Services.

National Toxicology Program (2011). *Lead and lead compounds.* Washington, D. C.: Government Printing Office.

Rabinowitz, M. B. (1976). Kinetic analysis of lead metabolism in healthy humans. *J Clin Invest*, 260-270.

Riutta, A. L. (2012). *Range lead and ventilation investigation.* Norfolk: USCG Health, Safety & Work-Life Service Center (HSWL SC) Environmental Health & Industrial Hygiene Branch (se-eh).

Riutta, A. L. (2013). *Range lead and ventilation investigation.* Norfolk: USCG Health, Safety & Work-Life Service Center (HSWL SC) Environmental Health & Industrial Hygiene Branch (se-eh).

Ross, C. R. (1960). Survey of lead hazard in indoor firing ranges. *Industrial Hygiene Journal*, 256-260.

Rossi, E. (2008). Low level environmental lead exposure – A continuing challenge. *Clin Biochem Rev*, 63-70.

Scott, E. E. (2012). Impact of housekeeping on lead exposure in indoor law enforcement shooting ranges. *Journal of Occupational and Environmental Hygiene*, D45-D51.

Sapp, B. (2006, 10 22). *Ammunition & Ballistics Analysis.* Retrieved from Teaching Forensics: http://bsapp.com/teachingforensics/

Savage Range Systems, Inc. (2011). *Bullet Traps and Clearing Stations*. Retrieved from Savage Range Systems, Inc.: http://savagerangesystems.com/bullettraps/

Schaeffer, D. J. (1990). Indoor firing range air quality: Results of a facility design survey. *American Industrial Hygiene Association*, 84-89.

Schrauzer, G. N. (2008). Effects of selenium and low levels of lead in on mammary tumor development and growth in MMTV-infected female mice. *Biol Trace Elem Res*, 268-275.

Thermo Scientific (2011). *Matrix Spiking – Why Spike and How to Do It.* Waltham: Thermo Scientific.

Skerfving, S. (1983). Metabolism of inorganic lead in occupational exposed humans. *Arh. hig. rada. toksikol.*, 341-350.

Small Arms Survey (2011, April 07). *Estimating Civilian Owned Firearms.* Geneva: The Graduate Institute of Geneva. Retrieved from Small Arms Survey: http://www.smallarmssurvey.gov

Spyratos, D. (2013). Occupational exposure and lung cancer. *J Thorac Dis*, 440-445.

Steenland, K. (2000). Lead and cancer in humans: Where are we now? *American Journal of Industrial Medicine*, 295-299.

Succop, P. A. (2004). Imputation of data values that are less than a detection limit. *Journal of Occupational and Environmental Hygiene*, 436-441.

Sun, C. C. (2002). Percutaneous absorption of inorganic lead compounds. *American Industrial Hygiene Association Journal*, 641-646.

Sun, H. W. (2009). Lead distribution in blood and organs of mice exposed to lead by vein injection. *Environmental Technology*, 1051-1057.

Tak, S. (2008). Characteristics of US workers whose blood lead trigger the medical removal protection provision, and conformity with biological monitoring requirements, 2003-2005. *American Journal of Industrial Medicine* , 691-700.

Target, A. (2011). *Indoor Shooting Range Development.* Retrieved from Action Target: http://www.actiontarget.com

Texas Commission of Environmental Quality (2014, April 08). *Air Pollution from Lead*. Retrieved from Texas Commission of Environmental Quality: http://www.tceq.texas.gov/airquality/sip/criteria-pollutants/sip-lead

United Nations Envrionment Programme (2014, April 08). *Lead Exposure and Human Health.* Retrieved from United Nations Environment Programme, Environment for Development: http://www.unep.org/

Universities Occupational Safety and Health Educational Resource Center (2003). *NIOSH spirometry training guide.* Washington, D. C.: Government Printing Office.

U.S. Army Corps of Engineers (1990). *USACE Design Manual for Indoor Firing Range.* Washington, D. C.: National Institute of Building Sciences

U. S. Coast Guard (2011, April 29). Coast Guard Medical Manual (COMDTINST M6000.1E). Washington, D.C., USA.

U. S. Coast Guard (2013). *Coast Guard Range Training Handbook.* Washington, D. C.: Government Printing Office.

U. S. Coast Guard (2013). *The Ordnance Manual, COMDTINST M8000.2D.* Washington, D. C.: Government Printing Office.

U.S. Congress Office of Technology Assessment (1985). *Preventing Illness and Injury in the Workplace.* Washington, D. C.: Government Printing Office.

U.S. Department of Defense (2012). *Defense budget priorities and choices.* Washington, D.C.: Government Priting Office.

U.S. Department of Housing and Urban Development (2014, April 06). *The Lead Disclosure Rule*. Retrieved from U. S. Department of Housing and Urban Development (HUD): http://portal.hud.gov

USCG Health, Safety & Worklife Service Center (HSWL SC) (2012). *USCG Safety & Environmental Health: Indoor Firing Range Evaluation Guide.* Norfolk: Environmental Health & Industrial Hygiene Branch (se-eh).

U. S. Coast Guard Training Quota Management Center (2013, December 30). *Fire Arms Instructor (FAI) Course*. Retrieved from Training Quota Management Center: http://www.uscg.mil/hq/tqc/

Valway, S. E. (1989). Lead absorption in indoor firing range users. *American Journal of Public Health*, 1029-1032.

Verbrugge, L. A. (2009). Human exposure to lead from ammunition in the circumpolar north. *Alaska Department of Health and Social Services, Division of Public Health, Section of Epidemiology*, 126-136.

Waldron, H. A. (1973). Lead poisoning in the ancient world. *Medical History*, 391-399.

Washington Department of Labor & Industries (L & I) (2014, March 29). *About OSHA, WISHA, and DOSH*. Retrieved from Washington State Department of Labor and Industries : http://lni.wa.gov

Washington Department of Labor & Industries (L & I) (2014, May 12). *How Washington State ABLES Protects Workers and Families*. Retrieved from Washington Department of Labor & Industries (L & I): http://www.lni.wa.gov/Safety/Research/OccHealth/Lead/Ables/default.asp

Washington State Department of Labor & Industries, T. S. (1999). *Occupational Lead Exposure: An Alert for Workers.* Olympia: Washington State Department of Labor & Industries.

Weis, C. P. (1991). Characteristics to consider when choosing an animal model for the study of lead bioavailability. *Chem Speciat Bioavail*, 113-119.

Wells, A. C. (1975). Deposition in the lung and uptake to blood of motor exhaust labelled with 203Pb. Inhaled Particles IV. *Pergamon Press*, 175-189.

Williams, M. K. (1975). Justification for NIOSH recommended air standard. *J Occup Med* , 93-96.

Workers' Compensation Insurance for Oregon (2010, July). *Lead.* Retrieved from SAIF Corporation: http://www.saif.com/employer

Ziegler, E. E. (1978). Absorption and retention of lead by infants. *Pediatr Res*, 29-34.

Appendices

Appendix A - UW IRB Approval Letter

UNIVERSITY *of* WASHINGTON
HUMAN SUBJECTS DIVISION

Date: November 7th, 2013

PI: LT Melvin Torres
Graduate Student
DEOHS

CC: Martin Cohen, Sc.D

RE: Human Subjects Application #46101, "Characterizing Lead Exposure at a Coast Guard Firing Range"

Dear Leiutenant Torres,

Human Subjects application #46101, "Characterizing Lead Exposure at a Coast Guard Firing Range" has been approved by the University of Washington IRB in Subcommittee EJ under Expedited Categories 7, 5, and 2. The Subcommittee has determined that this research meets all the requirements for approval outlined in 45 CFR 46.111.

The approval is valid from 11/7/2013 through 11/6/2014. If you have completed the study, including all data analysis, by 11/6/2014 you will need to close out the application. If you have not completed the project by that date, you will need to submit a Status Report requesting continuing approval six weeks before the expiration date. The Status Report to renew or close your study can be found on the HSD website.

If at anytime during your study an adverse event occurs, contact HSD immediately.

Note that HSD policy requires that you use copies of the stamped approved consent materials with subjects. You will find the stamped form at the back of your approval packet. If use of stamped copies is not applicable to your study because you have been approved to obtain oral or electronic consent, you must use the exact script that has been approved.

Please use the IRB application number listed above on any forms submitted which relate to this research, or on any correspondence with the HSD office.

If we can be of further assistance, please contact us at (206) 543-0098 or via email at hsdinfo@uw.edu. Thank you for your cooperation, and good luck in your research.

Sincerely,

Blair Maman
Administrator for IRB J
Human Subjects Division
(206) 543-0919
uwvibro@uw.edu

4333 Brooklyn Ave. NE, Box 359470 Seattle, WA 98195-9470

main 206.543.0098 fax 206.543.9218 hsdinfo@u.washington.edu www.washington.edu/research/hsd

Appendix B - USCG IRB Approval Letter

U.S. Department of Homeland Security

United States Coast Guard

Commandant
United States Coast Guard

2703 Martin Luther King Jr. Ave. SE
STOP 7907
Washington, DC 20593-7907
Staff Symbol: CG-113
Phone: (202) 475-5182
Fax: (202) 475-5909

6500
05 Dec 2013

MEMORANDUM

COMPERATORE.
CARLOS.A.1272010524

From: Carlos A. Comperatore, Ph.D.
Chair, Coast Guard Institutional Review Board

Reply to
Attn of:
LTJG Ryan Reynolds
202.475.5162

To: Melvin Torres, LT
University of Washington Graduate Student

Subj: COAST GUARD INSTITUTIONAL REVIEW BOARD (CG IRB) APPROVAL OF CHARACTERIZING LEAD EXPOSURE AT A COAST GUARD FIRING RANGE

Ref: (a) Coast Guard Human Research Protection Program, COMDTISNT M6500.1 (Series)

1. The Coast Guard Institutional Review Board (CG IRB) reviewed the subject submittal using reference (a) and in accordance with CFR 45 part 46. For the purposes of the CG IRB this protocol is deemed minimal risk.

2. The CG IRB recognizes the authority of the University of Washington Human Subjects Review Committee (UW HSRC) as having primary oversight of this study.

3. Exemption from further CG IRB oversight is granted with the understanding that no further changes or additions will be made to the study procedures, data collection instruments and/or Principle Investigators involved in the conduct of this research. Any changes shall be submitted to the CG IRB for review and approval prior to beginning or continuation of data collection, in addition to any requirements that the UW HSRC may have.

4. Any unanticipated problems related to your use of human subjects in this study must be promptly reported to the CG IRB through its coordinator, LTJG Ryan Reynolds, in addition to meeting any stipulations required by the UW HSRC.

5. Please notify the CG IRB coordinator upon completion of your study. Should you have any questions or concerns, do not hesitate to contact LTJG Ryan Reynolds at the provided phone number or via email at ryan.p.reynolds@uscg.mil.

#

Appendix C - Study Participant Consent Form

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Human Subjects Division

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UNIVERSITY OF WASHINGTON

STUDY PARTICIPATION CONSENT FORM

CHARACTERIZING LEAD EXPOSURE AT A COAST GUARD FIRING RANGE

Researchers:
Melvin A. Torres, LT, U.S. Coast Guard
Phone: 832-226-2540
Martin A. Cohen, ScD, School of Public Health, University of WA
Phone: 206-616-1905
Noah S. Seixas, PhD, School of Public Health, University of WA
Phone: 206-685-7189
Michael S. Morgan, ScD, School of Public Health, University of WA
Phone: 206-685-3221

RESEARCHER'S STATEMENT

We are asking you to join in a research study. The purpose of this consent form is to give you the information you will need to help you decide whether to be in this study. Please read this form carefully. You may ask questions about what we will ask you to do, the risks, the benefits, your rights as a volunteer, or anything else about the research or this form that is not clear. When all of your questions have been answered, you can decide if you want to be in this study or not. This process is called "informed consent." We will give you a copy of this form for your records; we will keep the original as part of our records retention.

PURPOSE

Military personnel as well as other federal and state agencies are required to maintain weaponry qualifications as part of their service to our country. However, without proper controls, maintenance and hygiene procedures, and medical monitoring, users of firing ranges may be exposed to elevated levels of airborne and surface lead contamination. The purpose of our 12-week-long study is to evaluate lead exposures to users of the indoor firing range at the U.S. Coast Guard Base in Seattle, WA. We will also evaluate factors that affect air lead exposures and subsequent blood lead levels.

PROCEDURES

At the beginning of the study, each participant will fill out two questionnaires: The first will gather your demographic information and the second will ask questions about job tasks, your work routine, past firing range experience, and hobbies and other activities that could affect your exposure to lead. The second questionnaire will be used again approximately 30 days later.

The first will be regarding personal habits, demographics, past firing range experience, etc. The second, will be distributed 30 days after the first questionnaire to obtain changes (if any) in work routine, additional job tasks or hobbies, and/or unusual activities that would increase or decrease

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Review Committee

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occupational (lead) exposure. Each questionnaire should take approximately 10 minutes to complete.

As part of the study, we will be taking approximately 10 milliliters of blood from a vein in your arm at two different times: at the beginning of the study and the other approximately 30 days after the first blood draw. If you agree, the blood will be drawn by certified phlebotomists from the Medical Clinic at the U.S. Coast Guard Base in Seattle, WA. After collection, the samples will be sent to a certified contracted laboratory for lead analysis.

Between the first and second blood draws, you will do your typical work as an FAI. When you are on the range, we would like to measure your personal lead exposure at least once but not more than twice during the study. This entails wearing a small air sampling pump on your belt with a tube running to a filter in a small plastic cassette that would be clipped to your collar. To help us interpret our data, we will collect your shooting log that you normally keep for the range.

We also request permission to be given your blood lead levels for the previous two years if you are in the occupational monitoring surveillance evaluation program (OMSEP). This information will assist our study in determining possible exposures to lead.

Your name will be recorded with your demographic information, but we will code the rest of the study data that you or the clinic provides to us. We will keep the link between your name and the code in a separate, secured location no later than 01 January 2015. After that date, we will destroy the link. If we publish the results of this study, we will not use your name. All personal information will be maintained in a confidential manner and stored in locked cabinet in a locked office.

There are some limits to this protection. We will voluntarily provide the information to:

- a member of the federal government who needs it in order to audit or evaluate the research; or
- individuals at the University of Washington, the U.S. Coast Guard, and other groups involved in the research, if they need the information to make sure the research is being done correctly.

BENEFITS

Participants in this study will benefit from learning about their airborne lead exposure and blood lead level during weaponry qualification sessions. Additionally, the information gained from this study could benefit the U.S. Coast Guard in determining if the indoor firing range is in fact maintaining safe levels of airborne lead.

THINGS TO THINK ABOUT

We will label your samples and the information about you with a number, not your name. We will keep your name and other information that might identify you separate from your sample. The record that links the number with your name will be kept by the UW researchers.

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One of the risks of allowing us to keep the samples is that information about you might be released accidentally.

OTHER INFORMATION

The blood samples will be kept until it is used up or destroyed. The samples will be used only for research. As previously stated, the purpose of our study is to evaluate lead exposure of the indoor firing range; the results may help improve safety protocols for range users.

Even if you decide now that your samples can be used for research, you can change your mind later. Just let us know that you do not want us to use your sample for our research.

Your name will not be used in any published reports about this study.

If you decide to cease participation in the research, you may do so at any time without penalty.

IMPORTANT STEPS TO TAKE IF BLOOD LEAD LEVELS ARE FOUND TO BE ABNORMAL

If your blood lead level is found to be above 50 ug/mL, we will remove you from the study. We will make sure that you receive follow up consultation with a physician.

QUESTIONS

If you have questions about this research or about this study, please contact one of the people listed on this form. If you have questions about your rights as a research donor, please contact the University of Washington Human Subjects Division at (206) 543-0098).

________________________________ ______________
Signature of person obtaining consent date

________________________________ ______________
Printed name of person obtaining consent date

SUBJECT'S STATEMENT

The study described above has been explained to me, and I voluntarily consent to participate. I had the opportunity to ask questions and understand that future questions I may have about the study or about my rights as a subject will be answered by any of the University of Washington researchers listed above this form.

________________________________ ______________
Your signature Date

________________________________ ______________
Your printed name Date

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Review Committee

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Appendix D - HIPAA Authorization Consent Form

UNIVERSITY of WASHINGTON
HUMAN SUBJECTS DIVISION

HIPAA Authorization

For the Use of Patient Health Information for Research

Research Title: Characterizing lead exposure at a Coast Guard Firing Range

Lead researcher: Melvin A. Torres
Institution of lead researcher: University of Washington

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OCT 01 2013
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A. Purpose of this form

The purpose of this form is to give your permission to the research team to obtain and use your patient health information. Your patient information will be used to do the research named above.

State and federal privacy laws protect your patient information. These laws say that, in most cases, your health care provider can release your identifiable patient information to the research team only if you give permission by signing this form.

You do not have to sign this permission form. If you do not, you will still be allowed to join the research study. Your decision to not sign this permission will not affect any other treatment, health care, enrollment in health plans or eligibility for benefits.

B. The patient information that will be obtained and used

"Patient information" means the health information in your medical or other healthcare records. It also includes information in your records that can identify you. For example, it can include your name, address, phone number, birthdate, and medical record number.

1. Location of patient information

By signing this form you are giving permission to the following organization(s) to disclose your patient information for this research:

- University of Washington, Department of Environmental & Occupational Health Science

Name of health care organization(s) or provider(s):

U.S. Coast Guard Medical Clinic, Seattle, WA.

2. Patient information that will be released for research use

This permission is for the health care provided to you during the following time period: October 1, 2011 through July 01, 2014

The specific information that will be released and used for this research is described below:

- Blood Lead Level Laboratory Results

CG IRB Approved DEC 05 2013

APPROVED
NOV 07 2013
UW Human Subjects Review Committee

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C. How your patient information will be used

The researcher will use your patient information only in the ways that are described in the research consent form that you sign and as described here.

The research consent form describes who will have access to your information. It also describes how your information will be protected. You can ask questions about what the research team will do with your information and how they will protect it.

The privacy laws do not always require the receiver of your information to keep your information confidential. After your information has been given to others, there is a risk that it could be shared without your permission.

D. Expiration

This permission for the researchers to obtain your patient information on July 1, 2014.

E. Canceling your permission

You may change your mind at any time. To take back your permission, you must send your **written** request to:

Martin A. Cohen, Sc. D
University of Washington
Box: 354695
4225 Roosevelt Way NE.
Seattle, WA 98105-6099

If you take back your permission, the research team may still keep and use any patient information about you that they already have. But they can't obtain more health information about you for this research unless it is required by a federal agency that is monitoring the research.

If you take back your permission, you will not need to leave the research study.

F. Giving permission

You give your permission to release your information by signing this form.

Printed Name of Research Subject Birthdate

Signature of Research Subject Date of signature

You will receive a copy of this signed form. Please keep it with your personal records.

Appendix E - FAI Demographics Questionnaire

Date: ___/___/____ Participant ID: ____________

Survey: Demographics Researcher: ____________

USCG Indoor Firing Range Study: FAI Demographics

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Human Subjects Divis
NOV 07 2013
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Instructions: As participant of the study, we are requesting that you provide us with the information below. Please don't hesitate to ask any questions that you may have. Our points of contacts are:

LT Melvin Torres 832-226-2540

1. First Name: ____________________
2. Last Name: ____________________
3. Rank: __________________________
4. Position/job (i.e., Gunner's Mate, Boatswain's Mate, Machinery Technician):
   ____
5. Briefly, what activities do you do for your job? __________________________________
   ____
6. Nationality: _________________________________
7. Country of Birth: ________________________________
8. Current Age: ___________
9. Gender: Male ☐ Female ☐
10. How long have you been a Fire Arms Instructor (FAI)?

    ________ years months days (circle one)

11. On average, how often are you an FAI at the US Coast Guard range in Seattle?
    - ☐ Never, if this response please
    - ☐ 1 time a month?
    - ☐ 2 -3 times a month?
    - ☐ once a week?
    - ☐ 2 – 3 times a week?
    - ☐ 4 -5 times a week?

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Appendix F - Appendix F: Pre/Post Firing Session Questionnaire for Fire Arms Instructors (FAIs)

Date: ___/___/___ Participant ID: __________

Survey: Pre / Post Researcher: __________

USCG Indoor Firing Range Study: Firing Session Questionnaire for Fire Arms Instructors (FAIs)

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Instructions: As participant of the study, we are requesting that you provide us with the information below. Please don't hesitate to ask any questions that you may have. Our points of contacts are:

LT Melvin Torres 832-226-2540

1. On average, how often do you clean the Const Guard firing range?
   - ☐ Never, if this response please **GO TO Question # 5**
   - ☐ 1 time a month?
   - ☐ 2 -3 times a month?
   - ☐ 4 or more times a month?
2. While cleaning the range, what kind of respirator do you use?
   - ☐ None
   - ☐ Disposable dust mask (N95 style)
   - ☐ Rubber half facepiece with filter cartridges
   - ☐ Powered air-purifying respirator
3. Have you been fit tested for the respirator?
   ☐ Yes ☐ No, but I have a respirator ☐ Don't know ☐ No, don't have a respirator
4. Have you received training to use the respirator?
   ☐ Yes ☐ No, but I have a respirator ☐ Don't know ☐ No, don't have a respirator
5. Do you eat or drink in the range?
   ☐ Yes ☐ No
6. In the last year, have you ever drank water (including coffee and tea) from the base's drinking fountain or taps?
   ☐ Yes ☐ No
7. If yes, how often do you drink water from the base's drinking fountain or taps?
   - ☐ multiple times a day
   - ☐ once a day
   - ☐ once a week
   - ☐ once a month
   - ☐ less than once a month

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8. Do you smoke in the range?
   ☐ Yes ☐ No

9. After working or shooting on the range, do you wash your hands before eating or smoking?
   ☐ Yes ☐ No

10. Do you wear your work clothes home after working or shooting on the range?
   ☐ Yes ☐ No

11. Have you ever done any of the below job tasks in the past year (check the one that applies)?

Job task	Yes	No	Don't Know
a. Cutting or burning iron work with a torch			
b. Welding painted surfaces or lead-containing scrap metal			
c. Soldering with lead-based solder			
d. Rolling or brushing lead paint*			
e. Spray painting with lead paint*			
f. Applied lead paint* as a powder			
g. Erecting or removing barriers containing lead paint*			
h. Lead paint* removal by dry scraping			
i. Lead paint * removal using chemicals			
j. Lead paint * removal by power sanding			
k. Lead paint * removal by burning			
l. Lead paint * removal by abrasive blasting			
m. Cleanup of leaded material			
n. Sweeping of leaded materials			
o. Cleaning lead with a standard vacuum			

* By paint, we mean paint or primer.

11/5/13

- 12. Have you ever worked in any of the below industries?

Industry	Yes	No	Don't Know
a. Battery manufacturing			
b. Battery recycling			
c. Lead soldering			
d. Lead smelting			
e. Foundry			
f. Radiator repair			
g. Metal machining or grinding			
h. Wire or cable manufacture			
i. Plastics or PVC manufacturing			
j. Scrap metal recycling			
k. Ammunition manufacture			
l. Demolition			

m. Other lead work not already mentioned (please write the type of job done):

____

13. Have you ever engaged in any of the following activities?

Activity	Yes	No	Don't Know
a. Leadlighting or stained glass			
b. Pottery or ceramics with lead glaze			
c. Making bullets or shot			
d. Making fishing sinkers			
e. Home or other building renovation			
f. Furniture or mirror renovation			
g. Burning painted wood			
h. Home car maintenance			
i. Home auto paint renovation			
j. Regular use of hair color restorer or other leaded cosmetics			
k. Do you hunt for game?			
l. If yes, do you eat you eat your game?			

14. Have you recently taken any of the following folk medicines?

Medicine	Yes	No	Don't Know
a. Ayurvedic (ancient Hindu) medicine			
b. Chinese herbal medicine			
c. Other folk remedies (if yes, please list)			

15. Have you ever received a gunshot wound?
☐ Yes ☐ No ☐ Don't know

16. If yes, do you still have lead in your body?
☐ Yes ☐ No ☐ Don't know

17. Have you ever been "medically removed" from work due to lead exposure?
☐ Yes ☐ No ☐ Don't know

Firing Range Information

18. Do you shoot at the firing range at USCG Base in Seattle? ☐ Yes ☐ No

19. If yes, in the last month, on average how much time did you spend firing rounds?

_____ hrs per day week month (circle one)

20. Do you shoot at other firing ranges?
☐ Yes ☐ No

21. If yes, in the last month, on average how much time did you spend firing rounds?

_____ hrs per day week month (circle one)

22. On average, about how many rounds do you fire while at the range?

_____ bullets per event

23. What kind of bullet do you typically fire? (List the percentage of each type)

Standard lead _______%

Full metal jacket _______%

Frangible _______%

11/5/13

Other green product ________%

Appendix G: - Range Data Collection Form

Range Data Collection Form

FORCECOM ARMORY SEATTLE							
Unit Name	DATE	FAI NAME	NALC	Rds Fired	#SHOOTERS	TIME STARTED	TIME ENDED
EX: USCGC P.SEA	02JAN09	GM2 MORALES	A059	550	10	0800	1500
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							

Appendix H: - UW Field Research and Consultation Group Field Data Sheet

FIELD RESEARCH AND CONSULTATION GROUP FIELD DATA SHEET

INDUSTRIAL HYGIENIST:
PROJECT:
ANALYSES:
Media:

FRCG NO:
SAMPLING DATE:
SUBMISSION DATE:

Summary:

Sample ID	Pump ID	Requested Analyses	Activity Description	Sampling Rate (l/min) Initial	Final	Avg.	Sampling Time Start	Stop	Total	Sample Vol (m^3)	Tare Weight	Gross Weight	Sample Weight	Conc. (mg/m^3)	Comments
						#DIV/0!			0	#DIV/0!			0.000	#DIV/0!	
						#DIV/0!			0	#DIV/0!			0.000	#DIV/0!	
						#DIV/0!			0	#DIV/0!			0.000	#DIV/0!	
						#DIV/0!			0	#DIV/0!			0.000	#DIV/0!	
						#DIV/0!			0	#DIV/0!			0.000	#DIV/0!	
						#DIV/0!			0	#DIV/0!			0.000	#DIV/0!	
						#DIV/0!			0	#DIV/0!			0.000	#DIV/0!	
						#DIV/0!			0	#DIV/0!			0.000	#DIV/0!	
						#DIV/0!			0	#DIV/0!			0.000	#DIV/0!	
						#DIV/0!			0	#DIV/0!			0.000	#DIV/0!	
						#DIV/0!			0	#DIV/0!			0.000	#DIV/0!	
						#DIV/0!			0	#DIV/0!			0.000	#DIV/0!	
						#DIV/0!			0	#DIV/0!			0.000	#DIV/0!	

FRCG_frm.xls

Appendix I: - Surface Wipe Sampling Form

Melvin's Surface Wipe Sampling Form ™

Date: ____________________

Location: ____________________

Location	ID	Pre	Post

Appendix J: - Personal Air Sampling Analysis Reports

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

2/13/2014

To Dr. Marty Cohen Melvin Torres
FRCG
DEOHS
BOX 354695
University of Washington
Seattle, WA

From Catherine Sigourney

Subject ANALYSIS REPORT
EHL Reference Client Reference Sampling Site
11400041 2013-053 USCG Firing Range

	Sampling	Receipt	Preparation	Analysis
Dates	12/17/13 -> 1/28/14	1/30/2010	2/6/2010	2/10/2010

Method EHLSOP -11 Microwave Sample Preparation for IH Filter for Metal Analysis
EHLSOP - 07 Instrumental Analysis Of Elements by ICP-MS (Based On EPA 6020a I

Media MCE filter

Results

Sample ID	Cu (µg/sample)	Zn (µg/sample)	Sn (µg/sample)	Sb (µg/sample)	Pb (µg/sample)
1	< 0.02	0.07	0.23	< 0.02	0.10
2	< 0.02	0.07	< 0.02	0.08	1.05
3	0.42	0.08	< 0.02	< 0.02	0.11
4	< 0.02	0.08	< 0.02	< 0.02	0.21
9	< 0.02	0.17	< 0.02	< 0.02	0.05
11	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
10	0.12	0.03	< 0.02	< 0.02	0.06
12	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
13	< 0.02	0.08	< 0.02	< 0.02	0.20
14	0.04	0.10	< 0.02	0.03	0.32
15	< 0.02	< 0.02	< 0.02	< 0.02	0.08
16	< 0.02	0.10	< 0.02	< 0.02	0.23
17	< 0.02	0.04	< 0.02	< 0.02	0.07
18	< 0.02	0.06	< 0.02	0.04	0.50
19	< 0.02	< 0.02	0.03	< 0.02	< 0.02
20	< 0.02	0.05	< 0.02	< 0.02	0.03
21	< 0.02	< 0.02	0.03	< 0.02	< 0.02
22	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
23	0.03	0.08	< 0.02	< 0.02	0.18
24	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
25	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
26	< 0.02	< 0.02	< 0.02	< 0.02	0.04
27	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
28	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
102	< 0.02	0.07	0.04	0.06	0.24
103	< 0.02	0.05	0.04	< 0.02	0.03
104	< 0.02	0.04	0.03	< 0.02	0.08
105	< 0.02	0.04	0.04	< 0.02	< 0.02
106	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
107	0.19	0.09	< 0.02	0.24	1.61
108	0.41	0.17	< 0.02	1.48	3.87
109	< 0.02	< 0.02	< 0.02	< 0.02	0.08
110	< 0.02	< 0.02	< 0.02	< 0.02	0.07
111	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

Sample ID	Units	Cu	Zn	Sn	Sb	Pb
1	mg/m3	< 0.00005	0.00014	0.00045	< 0.00005	0.0002
2	mg/m3	< 0.00005	0.00013	< 0.00005	0.00016	0.00205
3	mg/m3	0.00079	0.00015	< 0.00005	< 0.00005	0.0002
4	mg/m3	< 0.00005	0.00015	< 0.00005	< 0.00005	0.0004
9	mg/m3	< 0.00005	0.00038	< 0.00005	< 0.00005	0.00011
11	mg/m3	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005
10	mg/m3	0.00024	0.00006	< 0.00005	< 0.00005	0.00012
12	mg/m3	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005
13	mg/m3	< 0.00005	0.00017	< 0.00005	< 0.00005	0.00041
14	mg/m3	0.00009	0.0002	< 0.00005	0.00006	0.00065
15	mg/m3	< 0.00005	< 0.00005	< 0.00005	< 0.00005	0.00015
16	mg/m3	< 0.00005	0.00021	< 0.00005	< 0.00005	0.00046
17	mg/m3	< 0.00007	0.00011	< 0.00007	< 0.00007	0.00018
18	mg/m3	< 0.00007	0.00018	< 0.00007	0.00011	0.0014
19	mg/m3	< 0.00007	< 0.00007	0.00008	< 0.00007	< 0.00007
20	mg/m3	< 0.00007	0.00014	< 0.00007	< 0.00007	0.00009
21	mg/m3	< 0.00007	< 0.00007	0.00008	< 0.00007	< 0.00007
22	mg/m3	< 0.00007	< 0.00007	< 0.00007	< 0.00007	< 0.00007
23	mg/m3	0.00006	0.00014	< 0.00004	< 0.00004	0.00031
24	mg/m3	< 0.00006	< 0.00006	< 0.00006	< 0.00006	< 0.00006
25	mg/m3	< 0.00004	< 0.00004	< 0.00004	< 0.00004	< 0.00004
26	mg/m3	< 0.00004	< 0.00004	< 0.00004	< 0.00004	0.00007
27	mg/m3	< 0.00004	< 0.00004	< 0.00004	< 0.00004	< 0.00004
28	mg/m3	< 0.00004	< 0.00004	< 0.00004	< 0.00004	< 0.00004
102	mg/m3	< 0.00004	0.0001	0.00008	0.00009	0.00015
103	mg/m3	< 0.00004	0.00009	0.00007	< 0.00004	0.00004
104	mg/m3	< 0.00004	0.00007	0.00004	< 0.00004	0.00013
105	mg/m3	< 0.00004	0.00007	0.00007	< 0.00004	< 0.00004
106	mg/m3	< 0.00004	< 0.00004	< 0.00004	< 0.00004	< 0.00004
107	mg/m3	0.001	0.0005	< 0.0001	0.0013	0.0085
108	mg/m3	0.0022	0.0009	< 0.0001	0.0078	0.0205
109	mg/m3	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0004
110	mg/m3	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0004
111	mg/m3	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Quality Assurance

Parameter	Cu	Zn	Sn	Sb	Pb
R^2, Calibration	0.9999	0.9999	0.9999	0.9997	0.9999
Reporting Limit, (ug)	0.02	0.02	0.02	0.02	0.02
SR Efficiency	99.1%	105.7%	102.3%	99.7%	103.9%

Notes
Results were not corrected for spike recovery efficiency.
Results were corrected for matrix blank values.

Field blanks, when submitted, are analyzed and reported as samples; no corrections are made for field bla
It is solely the submitter's decision on how to utilize the field blank values.
Results apply only to the samples tested.
Unless otherwise noted, the conditions of the samples as received were satisfactory.

Analyst Comments

Reviewed by

Susan Tao, Ph.D. QAC Date
206-221-4646

Russell Dills, Ph.D. EHL D
206-543-3263

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

4/8/14

To Dr. Marty Cohen — Melvin Torres
FRCG
DEOHS
BOX 354695
University of Washington
Seattle, WA

From Rebecca Christ — Catherine Signorelly

Subject ANALYSIS REPORT

EHL Reference	Client Reference	Sampling Site
11403018	2013-053	USCG Firing Range

Dates

Sampling	Receipt	Preparation	Analysis
2/10-03/6/14	3/13/14	3/26-4/2/2014	4/3 - 4/4/14

Method EHLSOP -11 Microwave Sample Preparation for IH Filter for Metal Analysis
EHLSOP - 07 Instrumental Analysis Of Elements by ICP-MS (Based On EPA 6020a Rev.1 2007)

Media MCE Filters

Results

Sample ID	Cu (µg/sample)	Zn (µg/sample)	Sn (µg/sample)	Sb (µg/sample)	Pb (µg/sample)
200	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
201	< 0.03	< 0.1	< 0.03	< 0.03	0.08
202	< 0.03	< 0.1	< 0.03	< 0.03	0.06
203	< 0.03	< 0.1	< 0.03	< 0.03	0.05
204	< 0.03	< 0.1	< 0.03	< 0.03	0.08
205	1.72	0.8	< 0.03	0.97	4.29
206	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
207	< 0.03	< 0.1	< 0.03	< 0.03	0.08
208	< 0.03	< 0.1	< 0.03	0.06	0.12
209	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
210	< 0.03	< 0.1	< 0.03	< 0.03	0.04
211	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
212	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
213	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
214	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
225	0.03	< 0.1	< 0.03	< 0.03	0.08
226	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
227	< 0.03	< 0.1	< 0.03	< 0.03	0.09
228	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
229	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
230	< 0.03	< 0.1	< 0.03	0.05	0.21
231	< 0.03	< 0.1	< 0.03	< 0.03	0.06
232	< 0.03	< 0.1	< 0.03	< 0.03	0.13
233	< 0.03	< 0.1	< 0.03	< 0.03	0.05
234	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
235	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
236	< 0.03	< 0.1	< 0.03	0.08	0.94
237	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03

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University of Washington

Sample ID	Cu (µg/sample)	Zn (µg/sample)	Sn (µg/sample)	Sb (µg/sample)	Pb (µg/sample)
238	< 0.03	< 0.1	< 0.03	< 0.03	0.04
239	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
240	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
241	0.38	< 0.1	< 0.03	0.04	0.24
242	0.06	< 0.1	< 0.03	< 0.03	0.06
243	< 0.03	< 0.1	< 0.03	< 0.03	0.11
244	< 0.03	< 0.1	< 0.03	< 0.03	0.05
245	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
246	< 0.03	< 0.1	< 0.03	< 0.03	0.11
247	< 0.03	< 0.1	< 0.03	< 0.03	0.04
248	< 0.03	< 0.1	< 0.03	< 0.03	0.06
249	0.12	< 0.1	< 0.03	< 0.03	0.06
250	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
251	0.04	< 0.1	< 0.03	0.47	1.23
252	< 0.03	< 0.1	< 0.03	< 0.03	0.05
253	< 0.03	< 0.1	< 0.03	< 0.03	0.05
254	< 0.03	< 0.1	< 0.03	< 0.03	0.04
255	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
256	< 0.03	< 0.1	< 0.03	< 0.03	0.03
257	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
258	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
259	< 0.03	< 0.1	< 0.03	< 0.03	0.03
260	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03

Sample ID	Sample Size	Cu	Zn	Sn	Sb	Pb
	m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3
200	0.66434	< 0.04	< 0.2	< 0.04	< 0.04	< 0.04
201	0.66434	< 0.04	< 0.2	< 0.04	< 0.04	0.120
202	0.67938	< 0.04	< 0.2	< 0.04	< 0.04	0.0894
203	0.67635	< 0.04	< 0.2	< 0.04	< 0.04	0.0695
204	0.66389	< 0.04	< 0.2	< 0.04	< 0.04	0.122
205	0.54464	3.15	1.47	< 0.05	1.79	7.87
206	0.57570	< 0.04	< 0.2	< 0.04	< 0.04	< 0.04
207	0.56017	< 0.04	< 0.2	< 0.04	< 0.04	0.140
208	0.56252	< 0.04	< 0.2	< 0.04	0.0991	0.216
209	0.54464	< 0.05	< 0.2	< 0.05	< 0.05	< 0.05
210	0.21492	< 0.1	< 0.6	< 0.1	< 0.1	0.183
211	0.21909	< 0.1	< 0.6	< 0.1	< 0.1	< 0.1
212	0.22533	< 0.1	< 0.6	< 0.1	< 0.1	< 0.1
213	0.21364	< 0.1	< 0.6	< 0.1	< 0.1	< 0.1
214	0.21909	< 0.1	< 0.6	< 0.1	< 0.1	< 0.1
225	0.40602	0.0844	< 0.3	< 0.06	< 0.06	0.198
226	0.40401	< 0.06	< 0.3	< 0.06	< 0.06	< 0.06
227	0.41006	< 0.06	< 0.3	< 0.06	< 0.06	0.228
228	0.39992	< 0.06	< 0.3	< 0.06	< 0.06	< 0.06
229	0.41006	< 0.06	< 0.3	< 0.06	< 0.06	< 0.06
230	0.78948	< 0.03	< 0.2	< 0.03	0.0583	0.269
231	0.76720	< 0.03	< 0.2	< 0.03	< 0.03	0.0808
232	0.76591	< 0.03	< 0.2	< 0.03	< 0.03	0.165
233	0.77695	< 0.03	< 0.2	< 0.03	< 0.03	0.0621
234	0.77737	< 0.03	< 0.2	< 0.03	< 0.03	< 0.03

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University of Washington

Sample ID	Sample Size	Cu	Zn	Sn	Sb	Pb
	m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3
235	0.18360	< 0.1	< 0.7	< 0.1	< 0.1	< 0.1
236	0.18768	< 0.1	< 0.7	< 0.1	0.428	4.99
237	0.17908	< 0.1	< 0.7	< 0.1	< 0.1	< 0.1
238	0.18045	< 0.1	< 0.7	< 0.1	< 0.1	0.213
239	0.18040	< 0.1	< 0.7	< 0.1	< 0.1	< 0.1
240	0.18360	< 0.1	< 0.7	< 0.1	< 0.1	< 0.1
241	0.49776	0.758	< 0.3	< 0.05	0.0839	0.491
242	0.51486	0.115	< 0.2	< 0.05	< 0.05	0.122
243	0.49925	< 0.05	< 0.3	< 0.05	< 0.05	0.220
244	0.50635	< 0.05	< 0.2	< 0.05	< 0.05	0.0918
245	0.49776	< 0.05	< 0.3	< 0.05	< 0.05	< 0.05
246	0.70962	< 0.04	< 0.2	< 0.04	< 0.04	0.160
247	0.71022	< 0.04	< 0.2	< 0.04	< 0.04	0.0514
248	0.68571	< 0.04	< 0.2	< 0.04	< 0.04	0.0875
249	0.71955	0.167	< 0.2	< 0.03	< 0.03	0.0764
250	0.71022	< 0.04	< 0.2	< 0.04	< 0.04	< 0.04
251	0.61404	0.0696	< 0.2	< 0.04	0.766	2.00
252	0.61864	< 0.04	< 0.2	< 0.04	< 0.04	0.0796
253	0.60150	< 0.04	< 0.2	< 0.04	< 0.04	0.0748
254	0.62320	< 0.04	< 0.2	< 0.04	< 0.04	0.0638
255	0.61864	< 0.04	< 0.2	< 0.04	< 0.04	< 0.04
256	0.24846	< 0.1	< 0.5	< 0.1	< 0.1	0.115
257	0.25048	< 0.1	< 0.5	< 0.1	< 0.1	< 0.1
258	0.25031	< 0.1	< 0.5	< 0.1	< 0.1	< 0.1
259	0.25234	< 0.1	< 0.5	< 0.1	< 0.1	0.117
260	0.24846	< 0.1	< 0.5	< 0.1	< 0.1	< 0.1

Quality Assurance

Parameter	Cu	Zn	Sn	Sb	Pb
R^2, Calibration	1.0000	0.9998	1.0000	1.0000	1.0000
Reporting Limit, (µg)	0.03	0.1	0.03	0.03	0.03
SR Efficiency	105.1%	101.9%	97.8%	103.5%	104.3%

Notes: Results were not corrected for spike recovery efficiency.
Results were corrected for matrix blank values.

Field blanks, when submitted, are analyzed and reported as samples; no corrections are made for field blank values.
It is solely the submitter's decision on how to utilize the field blank values.
Results apply only to the samples tested.
Unless otherwise noted, the conditions of the samples as received were satisfactory.

Analyst Comments

Reviewed by 4/9/14

Susan Tao, Ph.D. QAC — Date
206-221-4568

4/8/14
Russell Dills, Ph.D. EHL Director — Date
206-543-3263

 3/3

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

Sample ID	Cu (μg/sample)	Zn (μg/sample)	Sn (μg/sample)	Sb (μg/sample)	Pb (μg/sample)
238	< 0.03	< 0.1	< 0.03	< 0.03	0.04
239	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
240	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
241	0.38	< 0.1	< 0.03	0.04	0.24
242	0.06	< 0.1	< 0.03	< 0.03	0.06
243	< 0.03	< 0.1	< 0.03	< 0.03	0.11
244	< 0.03	< 0.1	< 0.03	< 0.03	0.05
245	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
246	< 0.03	< 0.1	< 0.03	< 0.03	0.11
247	< 0.03	< 0.1	< 0.03	< 0.03	0.04
248	< 0.03	< 0.1	< 0.03	< 0.03	0.06
249	0.12	< 0.1	< 0.03	< 0.03	0.06
250	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
251	0.04	< 0.1	< 0.03	0.47	1.23
252	< 0.03	< 0.1	< 0.03	< 0.03	0.05
253	< 0.03	< 0.1	< 0.03	< 0.03	0.05
254	< 0.03	< 0.1	< 0.03	< 0.03	0.04
255	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
256	< 0.03	< 0.1	< 0.03	< 0.03	0.03
257	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
258	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
259	< 0.03	< 0.1	< 0.03	< 0.03	0.03
260	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03

Sample ID	Sample Size m3	Cu μg/m3	Zn μg/m3	Sn μg/m3	Sb μg/m3	Pb μg/m3
200	0.66434	< 0.04	< 0.2	< 0.04	< 0.04	< 0.04
201	0.66434	< 0.04	< 0.2	< 0.04	< 0.04	0.120
202	0.67938	< 0.04	< 0.2	< 0.04	< 0.04	0.0894
203	0.67635	< 0.04	< 0.2	< 0.04	< 0.04	0.0695
204	0.66389	< 0.04	< 0.2	< 0.04	< 0.04	0.122
205	0.54464	3.15	1.47	< 0.05	1.79	7.87
206	0.57570	< 0.04	< 0.2	< 0.04	< 0.04	< 0.04
207	0.56017	< 0.04	< 0.2	< 0.04	< 0.04	0.140
208	0.56252	< 0.04	< 0.2	< 0.04	0.0991	0.216
209	0.54464	< 0.05	< 0.2	< 0.05	< 0.05	< 0.05
210	0.21492	< 0.1	< 0.6	< 0.1	< 0.1	0.183
211	0.21909	< 0.1	< 0.6	< 0.1	< 0.1	< 0.1
212	0.22533	< 0.1	< 0.6	< 0.1	< 0.1	< 0.1
213	0.21364	< 0.1	< 0.6	< 0.1	< 0.1	< 0.1
214	0.21909	< 0.1	< 0.6	< 0.1	< 0.1	< 0.1
225	0.40602	0.0844	< 0.3	< 0.06	< 0.06	0.198
226	0.40401	< 0.06	< 0.3	< 0.06	< 0.06	< 0.06
227	0.41006	< 0.06	< 0.3	< 0.06	< 0.06	0.228
228	0.39592	< 0.06	< 0.3	< 0.06	< 0.06	< 0.06
229	0.41006	< 0.06	< 0.3	< 0.06	< 0.06	< 0.06
230	0.78948	< 0.03	< 0.2	< 0.03	0.0583	0.269
231	0.76720	< 0.03	< 0.2	< 0.03	< 0.03	0.0808
232	0.76591	< 0.03	< 0.2	< 0.03	< 0.03	0.165
233	0.77695	< 0.03	< 0.2	< 0.03	< 0.03	0.0621
234	0.77737	< 0.03	< 0.2	< 0.03	< 0.03	< 0.03

Environmental Health Laboratory
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Sample ID	Cu (µg/sample)	Zn (µg/sample)	Sn (µg/sample)	Sb (µg/sample)	Pb (µg/sample)
238	< 0.03	< 0.1	< 0.03	< 0.03	0.04
239	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
240	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
241	0.38	< 0.1	< 0.03	0.04	0.24
242	0.06	< 0.1	< 0.03	< 0.03	0.06
243	< 0.03	< 0.1	< 0.03	< 0.03	0.11
244	< 0.03	< 0.1	< 0.03	< 0.03	0.05
245	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
246	< 0.03	< 0.1	< 0.03	< 0.03	0.11
247	< 0.03	< 0.1	< 0.03	< 0.03	0.04
248	< 0.03	< 0.1	< 0.03	< 0.03	0.06
249	0.12	< 0.1	< 0.03	< 0.03	0.06
250	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
251	0.04	< 0.1	< 0.03	0.47	1.23
252	< 0.03	< 0.1	< 0.03	< 0.03	0.05
253	< 0.03	< 0.1	< 0.03	< 0.03	0.05
254	< 0.03	< 0.1	< 0.03	< 0.03	0.04
255	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
256	< 0.03	< 0.1	< 0.03	< 0.03	0.03
257	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
258	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03
259	< 0.03	< 0.1	< 0.03	< 0.03	0.03
260	< 0.03	< 0.1	< 0.03	< 0.03	< 0.03

Sample ID	Sample Size	Cu	Zn	Sn	Sb	Pb
	m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3
200	0.66434	< 0.04	< 0.2	< 0.04	< 0.04	< 0.04
201	0.66434	< 0.04	< 0.2	< 0.04	< 0.04	0.120
202	0.67938	< 0.04	< 0.2	< 0.04	< 0.04	0.0894
203	0.67635	< 0.04	< 0.2	< 0.04	< 0.04	0.0695
204	0.66389	< 0.04	< 0.2	< 0.04	< 0.04	0.122
205	0.54464	3.15	1.47	< 0.05	1.79	7.87
206	0.57570	< 0.04	< 0.2	< 0.04	< 0.04	< 0.04
207	0.56017	< 0.04	< 0.2	< 0.04	< 0.04	0.140
208	0.56252	< 0.04	< 0.2	< 0.04	0.0991	0.216
209	0.54464	< 0.05	< 0.2	< 0.05	< 0.05	< 0.05
210	0.21492	< 0.1	< 0.6	< 0.1	< 0.1	0.183
211	0.21909	< 0.1	< 0.6	< 0.1	< 0.1	< 0.1
212	0.22533	< 0.1	< 0.6	< 0.1	< 0.1	< 0.1
213	0.21364	< 0.1	< 0.6	< 0.1	< 0.1	< 0.1
214	0.21909	< 0.1	< 0.6	< 0.1	< 0.1	< 0.1
225	0.40602	0.0844	< 0.3	< 0.06	< 0.06	0.198
226	0.40401	< 0.06	< 0.3	< 0.06	< 0.06	< 0.06
227	0.41006	< 0.06	< 0.3	< 0.06	< 0.06	0.228
228	0.39592	< 0.06	< 0.3	< 0.06	< 0.06	< 0.06
229	0.41006	< 0.06	< 0.3	< 0.06	< 0.06	< 0.06
230	0.78948	< 0.03	< 0.2	< 0.03	0.0583	0.269
231	0.76720	< 0.03	< 0.2	< 0.03	< 0.03	0.0808
232	0.76591	< 0.03	< 0.2	< 0.03	< 0.03	0.165
233	0.77695	< 0.03	< 0.2	< 0.03	< 0.03	0.0621
234	0.77737	< 0.03	< 0.2	< 0.03	< 0.03	< 0.03

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Sample ID	Sample Size	Cu	Zn	Sn	Sb	Pb
	m3	µg/m3	µg/m3	µg/m3	µg/m3	µg/m3
235	0.18360	< 0.1	< 0.7	< 0.1	< 0.1	< 0.1
236	0.18768	< 0.1	< 0.7	< 0.1	0.428	4.99
237	0.17908	< 0.1	< 0.7	< 0.1	< 0.1	< 0.1
238	0.18045	< 0.1	< 0.7	< 0.1	< 0.1	0.213
239	0.18040	< 0.1	< 0.7	< 0.1	< 0.1	< 0.1
240	0.18360	< 0.1	< 0.7	< 0.1	< 0.1	< 0.1
241	0.49776	0.758	< 0.3	< 0.05	0.0839	0.491
242	0.51486	0.115	< 0.2	< 0.05	< 0.05	0.122
243	0.49925	< 0.05	< 0.3	< 0.05	< 0.05	0.220
244	0.50635	< 0.05	< 0.2	< 0.05	< 0.05	0.0918
245	0.49776	< 0.05	< 0.3	< 0.05	< 0.05	< 0.05
246	0.70962	< 0.04	< 0.2	< 0.04	< 0.04	0.160
247	0.71022	< 0.04	< 0.2	< 0.04	< 0.04	0.0514
248	0.68571	< 0.04	< 0.2	< 0.04	< 0.04	0.0875
249	0.71955	0.167	< 0.2	< 0.03	< 0.03	0.0764
250	0.71022	< 0.04	< 0.2	< 0.04	< 0.04	< 0.04
251	0.61404	0.0696	< 0.2	< 0.04	0.766	2.00
252	0.61864	< 0.04	< 0.2	< 0.04	< 0.04	0.0796
253	0.60150	< 0.04	< 0.2	< 0.04	< 0.04	0.0748
254	0.62320	< 0.04	< 0.2	< 0.04	< 0.04	0.0638
255	0.61864	< 0.04	< 0.2	< 0.04	< 0.04	< 0.04
256	0.24846	< 0.1	< 0.5	< 0.1	< 0.1	0.115
257	0.25048	< 0.1	< 0.5	< 0.1	< 0.1	< 0.1
258	0.25031	< 0.1	< 0.5	< 0.1	< 0.1	< 0.1
259	0.25234	< 0.1	< 0.5	< 0.1	< 0.1	0.117
260	0.24846	< 0.1	< 0.5	< 0.1	< 0.1	< 0.1

Quality Assurance

Parameter	Cu	Zn	Sn	Sb	Pb
R^2, Calibration	1.0000	0.9998	1.0000	1.0000	1.0000
Reporting Limit, (ug)	0.03	0.1	0.03	0.03	0.03
SR Efficiency	105.1%	101.9%	97.8%	103.5%	104.3%

Notes: Results were not corrected for spike recovery efficiency.
Results were corrected for matrix blank values.

Field blanks, when submitted, are analyzed and reported as samples; no corrections are made for field blank values.
It is solely the submitter's decision on how to utilize the field blank values.
Results apply only to the samples tested.
Unless otherwise noted, the conditions of the samples as received were satisfactory.

Analyst Comments

Reviewed by

Susan Tao, Ph.D. QAC — Date
206-221-4568

Russell Dills, Ph.D. EHL Director — Date
206-543-3263

Appendix K: - Surface Wipe Sampling Analysis Reports

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

2/11/2014

To Dr. Marty Cohen Melvin Torres
FSCCG
DEOHS
BOX 354695
University of Washington
Seattle, WA

From Catherine Sigourney

Subject ANALYSIS REPORT
EHL Reference Client Reference Sampling Site
13-0204 2014-031 UWCG Firing range

	Sampling	Receipt	Preparation	Analysis
Dates	1/26/14 & 1/27/14	1/30/2014	2/6/2014	2/10/2014

Method EHL SOP # 12 Optimized Microwave Sample Digestion of Surface Wipes
EHL SOP # 07 Instrumental Analysis Of Elements by ICP-MS (Based On EPA 6020a)

Media Ghost wipe

Results

Sample ID	Cu (µg/sample)	Zn (µg/sample)	Sn (µg/sample)	Sb (µg/sample)	Pb (µg/sample)
1.1 POST	3	< 40	0.24	2.7	17.4
1.1 PRE	10	70	0.40	3.4	23.2
1.2 POST	4	< 40	0.13	4.3	20.3
1.2 PRE	9	60	0.25	6.9	30.2
2.1 POST	8	< 40	0.12	6.0	31.4
2.1 PRE	13	80	0.22	6.3	26.4
2.2 POST	10	< 40	0.11	6.1	47.3
2.2 PRE	14	< 40	0.16	8.6	29.7
3.1 POST	29	< 40	0.10	7.3	41.0
3.1 PRE	9	< 40	0.09	13.6	34.9
3.2 POST	28	< 40	0.11	6.9	44.0
3.2 PRE	26	< 40	0.16	22.3	61.9
4.1 POST	14	< 40	0.11	10.4	33.4
4.1 PRE	27	< 40	0.14	18.3	38.9
4.2 POST	13	< 40	0.10	9.1	48.3
4.2 PRE	10	< 40	0.10	17.3	44.9
5.1 POST	10	< 40	0.07	6.2	34.3
5.1 PRE	10	< 40	0.21	17.3	40.0
5.2 POST	10	< 40	0.11	6.7	84.7
5.2 PRE	12	< 40	0.10	14.6	41.6
6.1	< 2	< 40	< 0.05	< 0.2	0.1
1	21	< 40	0.29	8.8	147
2	9	< 40	0.15	2.7	33.2
3	26	< 40	0.21	3.1	29.6
4	< 2	< 40	< 0.05	< 0.2	0.3

Quality Assurance

Parameter	Cu	Zn	Sn	Sb	Pb
R^2 Coefficient	0.9999	0.9998	0.9999	0.9997	0.9999
Reporting Limit (µg)	2	39	0.05	0.2	0.1
SS Efficiency	108.7%	139.3% *	92.7%	101.2%	98.7%

Notes Results were not corrected for spike recovery efficiency.
Results were corrected for matrix blank values.
Samples were corrected for Tb recovery.
4.2 PRE Tb was not added (example) values were not corrected for Tb recovery.

Field blanks, when submitted, are analyzed and reported as samples, no corrections are made for field blank v
It is solely the submitter's decision on how to utilize the field blank values.
Results apply only to the samples tested.
Unless otherwise noted, the condition of the samples as received was satisfactory.

Analyst Comments * Recovery exceeds acceptance criteria because of high matrix background of Zn.

Reviewed by ______________________

Susan Tian, Ph.D. QAC Date
206.221.4946

Russell Dills, Ph.D. EHL D
206.543.1263

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

4/8/14

To Gerry Croteau — Melvin Torres
FRCG
DEOHS
BOX 354695
University of Washington
Seattle, WA

From Rebecca Christ — Catherine Signoretty

Subject ANALYSIS REPORT

EHL Reference	Client Reference	Sampling Site
11403017	2013-053	USCG Firing Range

Dates

Sampling	Receipt	Preparation	Analysis
1/24/14-3/2/14	3/13/14	3/26-4/2/2014	4/3 - 4/4/14

Method
EHLSOP -12 Microwave Sample Preparation for IH Wipes for Metal Analysis
EHLSOP - 07 Instrumental Analysis Of Elements by ICP-MS (Based On EPA 6020a Rev.1 2007)

Media Ghost Wipes

Results

Sample ID	Cu (µg/sample)	Zn (µg/sample)	Sn (µg/sample)	Sb (µg/sample)	Pb (µg/sample)
0.1	225	95.3	1.31	51.5	430
0.2	52.1	56.8	0.60	16.9	144
0.3	26.9	44.0	0.38	10.7	86.6
3.1	51.1	46.0	0.38	14.2	173
3.2	13.6	39.2	0.13	4.5	32.8
3.3	16.9	37.4	0.25	4.9	38.1
5	11.5	45.4	0.14	2.3	34.3
6	145	66.9	0.29	5.0	86.0
7	10.3	46.9	0.31	3.0	57.5
7.1	35.3	47.1	0.19	13.3	125
7.2	8.23	37.8	0.06	4.0	23.7
7.3	4.43	35.8	< 0.05	1.6	12.0
12.1	107	52.2	0.46	28.1	403
12.2	6.09	33.5	0.07	2.6	24.4
12.3	10.2	36.1	< 0.05	2.0	27.8
15.1	115	57.7	0.39	35.3	394
15.2	12.2	38.8	0.09	4.7	57.8
15.3	6.64	38.0	< 0.05	2.1	21.2
17.1	101	63.4	0.53	39.5	447
17.2	23.2	40.6	0.32	8.0	96.1
17.3	16.5	38.8	0.26	5.0	53.6
1.1 PRE	12.3	28.7	0.16	4.6	43.7
1.2 PRE	7.67	19.0	0.12	5.4	20.9
2.1 PRE	14.8	57.5	0.24	3.8	32.3
2.2 PRE	6.74	19.1	0.26	2.9	32.8
3.1 PRE	6.63	21.3	0.18	2.5	25.3
3.2 PRE	8.80	20.5	0.16	2.9	20.7
4.1 PRE	9.04	19.4	0.31	5.4	30.1
4.2 PRE	6.09	15.9	0.16	2.9	26.2
5.1 PRE	18.5	29.7	0.13	3.7	25.9

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Sample ID	Cu (µg/sample)	Zn (µg/sample)	Sn (µg/sample)	Sb (µg/sample)	Pb (µg/sample)
5.2 PRE	10.1	25.7	0.10	3.0	17.5
11.1 PRE	23.1	61.4	0.21	15.1	61.3
11.2 PRE	15.6	56.9	0.15	12.2	67.3
12.1 PRE	30.3	58.7	0.11	8.7	33.5
12.2 PRE	18.0	53.7	0.18	12.8	140
13.1 PRE	52.9	67.7	0.18	27.5	83.5
13.2 PRE	21.6	51.1	0.12	13.2	45.2
14.1 PRE	21.3	63.1	0.12	21.5	58.2
14.2 PRE	113	76.1	0.18	21.2	65.3
15.1 PRE	26.8	59.8	0.10	18.5	47.1
15.2 PRE	31.9	56.4	0.22	16.5	43.5
16.1 PRE	56.8	82.8	0.59	14.0	156
16.2 PRE	25.3	56.3	0.29	6.1	105
17.1 PRE	14.9	49.8	0.27	4.9	54.4
17.2 PRE	11.7	47.8	0.25	7.3	199
18.1 PRE	19.7	55.0	0.35	3.6	33.0
18.2 PRE	6.90	46.1	0.19	4.0	34.9
19.1 PRE	217	39.9	0.14	5.4	36.7
19.2 PRE	14.1	87.9	0.22	2.6	29.5
20.1 PRE	7.66	48.0	0.12	4.3	38.2
20.2 PRE	7.31	44.5	0.14	6.2	43.4
30.1 PRE	8.90	41.7	0.13	7.4	108
30.2 PRE	16.5	52.8	0.12	5.7	39.2
31.1 PRE	11.3	51.8	0.13	6.9	38.6
31.2 PRE	7.39	49.7	0.11	4.1	34.6
32.1 PRE	14.0	48.4	0.20	4.8	51.3
32.2 PRE	27.7	51.8	0.30	6.1	88.3
33.1 PRE	27.7	57.4	0.15	5.8	45.8
33.2 PRE	29.1	54.4	0.18	4.4	60.1
34.1 PRE	25.3	58.0	0.19	7.6	50.8
34.2 PRE	9.82	49.6	0.19	6.9	188
1.1 POST	9.44	23.9	0.19	4.6	53.6
1.2 POST	10.6	48.1	0.16	4.4	51.2
2.1 POST	7.04	21.9	0.10	3.2	32.0
2.2 POST	15.7	24.5	0.14	3.6	40.6
3.1 POST	9.49	24.8	0.14	3.9	45.8
3.2 POST	14.8	46.1	0.14	4.2	46.9
4.1 POST	31.2	59.5	0.12	3.5	42.3
4.2 POST	10.9	20.9	0.13	4.7	52.7
5.1 POST	9.31	47.4	0.11	4.2	43.3
5.2 POST	9.99	43.9	0.10	3.4	37.9
11.1 POST	13.1	48.6	0.07	4.9	23.5
11.2 POST	6.37	40.1	0.06	3.5	18.5
12.1 POST	19.0	48.8	0.08	4.8	28.9
12.2 POST	11.6	44.1	0.08	4.5	23.6
13.1 POST	13.2	51.1	0.13	5.4	31.9
13.2 POST	16.8	46.2	0.08	5.2	27.1
14.1 POST	15.5	51.7	0.07	5.4	34.5
14.2 POST	17.6	55.3	0.09	7.5	38.3
15.1 POST	55.0	54.6	0.15	8.6	40.7
15.2 POST	35.1	46.6	0.08	8.6	37.6
16.1 POST	18.2	48.5	0.37	8.1	134
16.2 POST	18.1	50.0	0.39	7.4	132

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Sample ID	Cu (µg/sample)	Zn (µg/sample)	Sn (µg/sample)	Sb (µg/sample)	Pb (µg/sample)
17.1 POST	144	70.2	0.41	7.1	137
17.2 POST	16.3	50.6	0.45	9.4	163
18.1 POST	19.4	48.5	0.46	9.4	170
18.2 POST	20.7	46.6	0.44	12.0	221
19.1 POST	17.8	103.0	0.31	7.0	133
19.2 POST	14.5	56.2	0.48	7.2	128
20.1 POST	16.1	52.3	0.38	6.1	105
20.2 POST	24.9	40.5	0.42	6.3	120
30.1 POST	8.29	46.0	0.15	3.4	32.7
30.2 POST	10.6	45.1	0.09	3.3	25.3
31.1 POST	22.2	49.1	0.14	7.4	42.6
31.2 POST	12.6	46.1	0.17	7.5	47.2
32.1 POST	16.9	45.7	0.15	8.3	52.1
32.2 POST	17.1	45.5	0.15	6.3	38.6
33.1 POST	15.9	45.7	0.09	6.8	49.6
33.2 POST	17.0	40.4	0.16	7.4	51.6
34.1 POST	16.9	47.5	0.13	6.5	48.3
34.2 POST	67.0	52.8	0.20	9.4	62.0
0.1 (FB)	0.69	11.9	< 0.05	< 0.6	0.11
.15 (FB)	0.84	13.2	< 0.05	< 0.6	0.10
0.2 (FB)	1.35	34.0	< 0.05	< 0.6	< 0.05
0.3 (FB)	0.63	10.0	< 0.05	< 0.6	0.16
0.4 (FB)	1.79	42.5	< 0.05	< 0.6	0.07
8 (FB)	0.74	13.0	< 0.05	< 0.6	0.07

Quality Assurance

Parameter	Cu	Zn	Sn	Sb	Pb
R^2 Calibration	1.0000	0.9998	1.0000	1.0000	1.0000
Reporting Limit, (µg)	0.05	0.3	0.05	0.6	0.05
SR Efficiency	113.8%	89.5%	94.5%	106.4%	99.1%

Matrix Blank Results	Cu	Zn	Sn	Sb	Pb
(µg/sample)	1.6	36.22	0.003	0.2	0.02

Notes

Results were not corrected for spike recovery efficiency.
Results were corrected for process blank values.
Spike recovery experiment used matrix blank subtraction to determine efficiency.
Matrix blank results are being provided due to the variability in background levels in Cu & Zn from FB samples and matrix blank provided to the lab.

Field blanks, when submitted, are analyzed and reported as samples; no corrections are made for field blank values.
It is solely the submitter's decision on how to utilize the field blank values.
Results apply only to the samples tested.
Unless otherwise noted, the conditions of the samples as received were satisfactory.

Analyst Comments

Reviewed by [signature] 4/8/14

Susan Tao, Ph.D. QAC — Date
206-221-4548

[signature] 4/8/14

Russell Dills, Ph.D. EHL Director — Date
206-543-3263

