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BC Wildlife Federation:

Standards and Best Practices for Lead Management

An assessment of approaches to lead management for outdoor shooting ranges

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1.0 Executive Summary

Over the past several decades, public and regulatory concern towards lead has dramatically increased. As stated by US Environmental Protection Agency (EPA), the firing of lead shot has the potential to contaminate site soil, but it can also leach off-site into the air, steams, and drinking water. There is minimal risk of lead for people using the range, but the liability lies in lead's ability to migrate off site. In the recent case involving the Salt Spring Island Rod and Gun Club, the Ministry of the Environment has ordered a site investigation, leading to the club's potential closure.

To be able to fully comprehend the issue of lead in the environment, it is first important to consider how lead transported throughout the environment. Lead is most likely to create a problem when it is taken off-site. There are four ways in which this can happen:

1) lead can be dissolved in storm runoff water,
2) transportation of lead particles along with soil in storm runoff,
3) dissolving into groundwater, and
4) wind-driven through dust particles.

Physical characteristics that could make a range more likely to be susceptible to lead pollution include range size, soil chemistry, topography, vegetation, annual precipitation, level of use, and accessibility. Most outdoor shooting ranges will not experience significant adverse effects of lead pollution, however it is crucial to identify your range's specific lead mobility characteristics, and be proactive in evaluating the mobility potential.

It is common for general liability policies to exclude coverage for pollution, meaning clubs and their directors could face significant financial losses from cleaning up/remediating lead pollution on their outdoor shooting ranges.

Lead standard across various jurisdictions are very consistent, meaning there is a solid structure and guidelines to base goals on moving forward.

Determining site contamination is a very complicated process and it is recommended that the range owner obtain a detailed site investigation to help determine areas of risk and best management practices to be applied. Certain options may be suitable depending on range location, layout, and facilities. Solutions proposed also vary greatly in price outlay. The shooting ranges that want to be sustainable in the long-term will evaluate the assessments and recommendations contained in this document, and determine the most feasible and effective methods for their needs.

In regards to developing an environmental stewardship plan, it should be implemented in four steps.

1) Control and contain the lead.
2) Prevent lead migration.
3) Reclamation of lead.
4) Record keeping and documentation.

The best way to manage potential issues is to develop and implement a site-specific environmental stewardship plan based on a completed site investigation.

It is important that the range managers be able to clearly communicate to the public their plans for dealing with lead, and also their status in regards to meeting regulations.

When addressing allegations, utmost caution should be taken. It is important that the range manager address allegations professionally, respectfully and with care for the concerns of the complainant. Facts should be stated regarding the allegations, and if something addressed is unknown of by the club, it is important that the complainant is provided clear communication that addressing a potential issue is a top priority for the club.

2.0 Introduction

Public and regulatory concern about the potential effects of lead in the environment has dramatically increased over the years. Potential risks associated with environmental and human exposure to lead in air, paint, drinking water, surface waters, soils and sediments are potentially significant, and shooting ranges are under increasing scrutiny. At least one club with a shooting range has had legal action taken against it regarding allegations of lead pollution by a neighbour wanting to close down their range.

According to the US Environmental Protection Agency, "*firing ranges can damage the environment and contaminate the soil, and possibly the groundwater, with lead from the bird-shot, bullets and bullet fragments, as well as produce airborne lead dust. The impacts of lead in firing ranges is long lasting, and when bullets are left in shooting ranges, the lead oxidizes in exposure to air and acidic soil conditions. These lead bullets, bullet particles, or dissolved lead can be moved off site by storm water runoff. Dissolved lead can then migrate through soils to groundwater, leading to contamination of soil in the area*." In addition, shotgun ranges area of particular concern due to the small size of the projectiles and the wide area of dispersion. "

The issue of lead pollution at outdoor shooting ranges is a very real operational issue that gun clubs are going to have to deal with. If BCWF affiliated clubs are found to be polluting the environment, it could damage the credibility of the BCWF as a whole, and adversely affect our ability to promote environmental stewardship and conservation goals. The presence and allegations of a contaminated site could also present significant financial costs that could bankrupt the club, leading to its demise.

For example: As a result of a complaint by a neighbor, The Ministry of Environment ordered the Salt Spring Island Rod and Gun Club (SSIRG), to carry out a site investigation, despite the fact they were found not to be a pollution nuisance in an earlier proceeding. It would appear as though shooting ranges are vulnerable to allegations of lead pollution, and a club is required to prove they are not polluting. Proving innocence can become expensive if allegations are made, as a ministry required “site investigation report” and “summary site conditions report” cost can cost $75,000 and $17,500, respectively (or more).

Unlike in the US, there are currently no Canadian standards for lead management and remediation of outdoor shooting ranges. This lack of prescribed standards could result in clubs with outdoor shooting ranges contributing to lead pollution inadvertently.

The purpose of this document is to outline preliminary standards and best practices for lead management and provide actionable best management practises that can be implemented at ranges, as to be proactive, manage risk in regards to possible allegations, and maintain positive community goodwill.

3.0 Lead in the Environment

3.1 Physical Transport of Lead at Shooting Ranges

There are four primary mechanisms in which lead is transported off-site; including:

- **Dissolved in storm runoff** - Lead shot or bullet fragments in the field may chemically change over time into more water-soluble compounds (Section 3) and subsequently be transported into surface waters. Factors influencing the amount of dissolved lead in storm water runoff may include annual precipitation rate, pH (i.e. level of acidity) of rain and surface water, contact time, soil cover, and the chemical forms of lead present.

- **Lead particles or lead on soil particles in storm runoff** - Lead present as shot or bullet fragments may be physically transported by storm runoff in surface waters. This pathway is dependent on rainfall intensity, topographic slope, soil type, velocity of runoff, and presence of vegetative cover or man-made structures. Lead fragments are dense and would not be as subject to transport by runoff as would lead absorbed to soil particles.

- **Dissolved in ground water** - Water-soluble forms of lead may be transported to groundwater under certain conditions that may be found at some ranges and can be influenced by annual precipitation rate, soil type, soil chemistry, depth to groundwater and pH of groundwater.

- **Wind-driven lead dust or lead associated with wind driven soil particles** – Smal amounts of airborne lead dust can be generated during the firing process and upon bullet impact with a berm. Such dust production is influenced by bullet construction and velocity, soil type and soil moisture.

3.2 Site Characteristics to Consider in Assessment

This section identifies the physical characteristics that must be considered when evaluating your range. A summary of common physical characteristics at ranges is also presented in Appendix 4.

Range Size

Shotgun range design and type affects the ease of lead shot collection. Larger ranges typically tend to have lead shot that is dispersed over a wider area, while smaller ranges tend to concentrate lead shot in a smaller area. Reducing the area of the shot fall zone will concentrate the shot within a smaller area, allowing for easier and more cost effective cleanup and reclamation. Best Management Practices (BMP) for reducing the shortfall zone at trap and skeet ranges, as well as sporting clay ranges, are discussed in section 5.1.3.

Soil Characteristics

Spent lead bullets and shot are most often deposited directly on and into soil during shooting. When lead is exposed to air and water, it may oxidize and form one of several compounds. The specific compounds created, and their rate of migration, are greatly influenced by soil characteristics, such as pH and soil types. Knowing the soil characteristics of an existing range site is a key component to developing an effective lead management plan. Soil acidity is measured as pH on a scale between 1 (most acidic) and 14 (most alkaline, or basic), where 7 is termed neutral. Ideal soil pH for shooting ranges is 6.5 to 8.5. Although other factors influence solubility of lead in water, a good rule of thumb is that lead will precipitate out of solution when the pH or alkalinity of water is greater then about 7.5. But, lead dissolved in acid groundwater may travel many miles without change.

Soil Physical Characteristics

The migration rate of specific lead compounds is affected by the physical characteristics of soil. For example, dense soils, consisting of heavy clays, will prevent the lead compound from moving quickly through the subsurface. Any “free” lead ions become attached to clay particles, with this bond helping to prevent migration. However, with denser soils, the amount of surface runoff increases.

Although clay soils inhibit migration, lead reclamation by contemporary removal machinery tends to be more difficult in clayey conditions. Clayey soils tend to clog the screens and “bind” with shot and bullets. This situation may require additional traditional screening, or perhaps screening using water to enhance separation.

In contrast, sandy soils or gravel may not impede migration because the open pores of these soils allow lead compounds to percolate quickly. Fortunately, lead reclamation activities are more easily conducted in sandy soils. With this in mind, ranges located in sandy soils should consider removing lead more frequently.

Annual Precipitation

One of the most important factors that influences lead degradation (i.e., chemical reactions) and migration is precipitation. Water, most often in the form of rain, provides the means by which lead is transported. In general, ranges located in areas with high annual/seasonal rainfall will have a higher risk of lead migration than those located in arid regions. This is especially true of outdoor ranges using "Steel Bullet Traps."

Steel bullet traps build up a layer of lead residue; these particles are extremely small and more easily transported by rain/water. Also, the smaller the particle, the quicker it will degrade. A bullet trap needs to have a means to collect contact water, or be covered to prevent water from reaching it, and to minimize releases and degradation.

Topography/Runoff Directions

The topography of your range impacts both the ease of lead reclamation and the mobility of the lead. For example, lead reclamation is more successful at ranges where the shortfall zone is relatively flat, since many lead reclamation companies use heavy machinery that cannot operate on slopes or steep hills.

Another important characteristic is the direction in which your range topography slopes. During and after periods of rain, storm water runoff may wash lead particles or lead compounds off the range. If there are surface water bodies such as lakes, rivers, or wetlands downgradient, the potential for lead to adversely affect the surrounding environment is even greater. Therefore, it is important to identify and where appropriate, consider controlling the direction of surface water runoff at your range.

Groundwater

Groundwater depth should be considered when developing a lead management plan since the closer the groundwater is to the surface, the greater the potential for dissolved lead to reach it.

Vegetation

Vegetative ground covers can impact the mobility of lead and lead compounds. Vegetation absorbs rainwater, thereby reducing the time that the lead is in contact with water. Vegetation also slows down surface water runoff, preventing the lead from migrating off-site. However, excessively wooded areas (such as those often used for sporting clay ranges) inhibit lead reclamation by making the soils inaccessible to some large, lead-removal machinery.

Understanding the type, concentration and variety of vegetation on your range is necessary for developing your lead management program and implementing BMPs at your range.

Accessibility

Accessibility to shortfall zones and backstops is extremely important for lead reclamation activities. A range that is not accessible to reclamation equipment will have difficulty implementing lead reclamation practices

3.3 Conclusion

Based on increased public scrutiny of the potential environmental impacts of outdoor shooting ranges, potential for exposure to and the toxicity of lead in the environment, processes and factors affecting the mobility of lead in the environment, and potential preventive and remedial options, the following general conclusions may be drawn:

1. Increased attention to the impacts of lead warrants that shooting range managers evaluate whether such impacts exist at their range;
2. The basic geochemical processes (outlined in appendix 1) controlling lead mobility at outdoor shooting ranges are well known; however, range-specific interactions of factors may need to be assessed;
3. Range-specific lead mobility can be estimated if certain site characteristics are known and appropriate site-specific evaluations are performed;
4. Most outdoor shooting ranges probably do not have adverse environmental impacts caused by lead; however, conditions may exist that could result in such impacts; and
5. Outdoor shooting ranges can be proactive in evaluating the potential for adverse lead impacts and can minimize or prevent such impacts.

4.0 Lead Standards

Lead can be an issue at any outdoor shooting range for humans, wildlife, and plant-life. Ensuring that lead concentrations are within their legal limits is of the utmost importance because there are large social and economic costs associated with lead exceeding these standards.

4.1 Measurement of Lead Levels

Lead levels are measured in two different ways. The first way in which lead is measured is by calculation of the mg/kg of lead in a certain sample. The second standard in which lead mobility is measured is through the TCLP (toxicity characteristic leaching procedure) method. This method is specified by the BC Ministry of Environment (MoE) Hazardous Waste Regulation (HWR), in order to determine whether a material leaches concentrations that would classify it as a hazardous waste. Since the TCLP method does not simulate the natural environment, samples should also be analyzed with using the Synthetic Precipitation Leaching Procedure (SPLP), which better simulates the conditions of the natural environment.

Soil standards are divided into categories based on land use. Agricultural land use (AL), urban park land use (PL), wild-lands land use (WL), residential land use (RL); commercial land use (CL), and industrial land use (IL) were each considered, to determine their applicability to the Site.

4.2 Regulations

	Lead Concentration (mg/kg)	TCLP (mg/L)
British Columbia Soil Standards	400	5

This table provides a simple introduction to general standards in BC for most shooting ranges. A majority of shooting ranges will be zoned under urban park (PL) and residential (RL), so these standards will apply in most cases. For a more in-depth table comparing different land use zones and geographical variables in regards to lead concentration standards, refer to Appendix 5. For a standards comparison between individual provinces and countries, refer to Appendix 7.

As shown in Appendix 3, BC, Ontario, USA, Sweden, and Germany all employ very similar standards for both lead concentration and TCLP.

These standards will need to be met under and site investigation order by the MoE upon request. For further information, visit section 4.1 for a brief on potential liabilities and consideration when dealing with the MoE.

4.3 Assessment

To determine range specifics regarding lead standards, it is recommended that British Columbia approved contaminated sites professional be brought in to conduct a preliminary site investigation and detailed site investigation. During this process, various samples and data will be analyzed to determine if environmental standards have been violated and the likeliness of an environmental concern in the future.

Concurrently, this will help communicate to the ministry that you are aware of the potential problem, and taking proactive measures to help mitigate any future concerns. Hiring a firm to perform a site investigation could potentially be an expensive process, but would yield invaluable knowledge for site planning and future litigation.

If this option is not economically feasible for your range, then there are some steps that range owners can go through to determine their site's risk of exceeding environmental standards. pH is an important factor when considering potential for lead to leach into the environment, so it would be advantageous to take periodic pH samples around the site every 6 months. pH meters can be purchased from most home and garden shops and they will give the range owner an idea of the potential problem. pH ranges from 6-8 indicate that it is unlikely lead will oxidize and leach off the property. A good rule of thumb is that lead will be very immobile when pH is greater than 7.5, but lead dissolved in acidic (less than 6) groundwater and soil may be very mobile.

The owner must also consider the geographical landscape of their site. For a brief summary of site factors and their impact on lead mobility, please refer to Appendix 4. Among many site considerations, the most important is proximity to bodies of water. It should also be noted that the only way to reduce concentration of lead on site is to physically remove it, so consideration should be given for budgeting of lead removal and possibly lead containment traps for future use.

4.4 Liability

This section will provide a brief overview of the legal environment and the contaminated site standards enforced by the provincial government of British Columbia. The information that will be discussed is located in full form under chapter 53, part 4 of the BC's Environmental Management Act.

It is important to note that a Ministry director may order an owner or operator of a site, at the owner's expense, to undertake a preliminary site investigation or detailed site investigation and to prepare a report of the investigation in accordance with the regulations. A report can be requested if the director has a reasonable suspicion that the site is either contaminated, or contains substances that may threaten or cause adverse effects on human health or the environment. Also, the owner or operator is liable for any of the costs incurred by the site investigations, meaning that the shooting range will bear all of these costs. In the Salt Spring Island Gun Club case, the club was required to have a detailed site investigation done, costing $75,000 plus $17,500 for the MoE review.

If the site turns out to be a "contaminated site" under provincial lead standards, then it will be necessary to establish who is responsible for the cost of remediation. Under Division 3 of chapter 53 in The Environmental Management Act, persons responsible for remediation simply put are those who currently or historically owned or operated a contaminated site that produced the substance and caused the site to become contaminated.

If the contamination migrates on to another's property, similar rules apply where the owner or operator of the contaminated property is liable for the remediation and cleanup of any contamination that is directly caused by on-site activities. However, it should be noted that the purchaser is not liable for remediation if the site was already contaminated and the person had no knowledge or reason to suspect that it could be contaminated, and took all appropriate inquiries into the previous ownership.

In short, the person or organization that is responsible for the pollution is responsible for the costs of remediation. In the case of leased land, the polluter is still responsible for the costs of remediation, unless there is a clause in the contract for this issue.

Outlined in Section 9.0, is a summary of a recent case in which the Salt Spring Island Rod and Gun Club has dealt with a neighbor who made allegations to the ministry regarding lead pollution leaching on to his neighboring property.

5.0 Lead Management Best Practices (BMP)

The information on the various alternatives presented below were collected from The US Environmental Protection Agency (EPA)'s "Best Practices for Lead at Outdoor Shooting Ranges", The NSSF's "Environmental Aspects of Construction and Management of Outdoor Shooting Ranges", related case studies, and a variety of scholarly articles.

To operate an outdoor range that is environmentally protective requires implementing an integrated lead management program, which incorporates a variety of appropriate best management practices (BMPs). These BMPs create a four step approach to lead management:

Step 1 - Control and contain lead bullets and bullet fragments.
Step 2 - Prevent migration of lead to the subsurface and surrounding surface water bodies.
Step 3 - Remove the lead from the range and recycle.
Step 4 - Documenting activities and keeping records.

An effective lead management plan will require implementing and evaluating BMPs from each of the 4 steps. It should be noted that steps 1-2 do not negate the need for removal of lead, but are practices that should be completed between lead reclamation events. It's also important to note that cost and complexity of practises vary greatly, and it is your ranges individual characteristics that will determine which should be implemented. Refer to Appendix 5 for a full list of potential BMPs applicable to both shotgun ranges ad rifle/pistol ranges.

5.1 Step 1 - Control and Contain Lead Bullet

Knowing where spent lead will allow the appropriate BMP to be used. The single most effective BMP for managing lead in these areas is by bullet containment. Owners/operators should employ a containment system that allows for the maximum containment of lead on-site. The BMPs listed in this section are only for reference because the applications needed for different site conditions vary greatly.

5.1.1 Earthen Berms and Sand Traps

The earthen backstop is the most common bullet containment mechanism for rifle and pistol ranges. The earthen backstop is generally between 15-20 feet high with a recommended slope as steep as possible. In many instances backstops are naturally occurring hillsides. With the earthen berm, the operator must ensure the berm is free of large rock and debris because these materials will increase chance of fragmentation, making lead reclamation activities more difficult.

A variation of the earthen backstop is the sand trap. The sand trap is normally a mound of soil between 15-20 feet high located directly behind the bullet target, serving as a tool for controlling lead and contact water. Like the earthen berm, periodic maintenance is required to ensure safety. The uppermost layer (to a depth of 1 to 2 feet) must be free of large rocks and other debris to reduce ricochet and bullet fragmentation, and to facilitate reclamation efforts. There may also be an impermeable layer (e.g., clay or liner) under the sand to prevent lead from contacting the soil underlying the trap.

While both options are sufficient for short term control of lead, sand traps are the better option due to the lower lead concentration present because of sand's lower field capacity, organic matter, and a higher pH compared to soil (Liu 2012). Replacing a soil berm with sand would be a viable practice in reducing bullet weathering at a low cost. For existing earthen berms, a layer of ballistic sand (2-4 ft.) should be added to reduce the ability for lead to weather and leach into soil. Lime and phosphates should be mixed in with sand to raise pH and decrease the mobility of lead.

5.1.3 Containment Solutions for Shotgun Ranges

Unlike rifle and pistol ranges, the area impacted by lead shot fired at trap, skeet and sporting clay ranges is spread out and remains primarily on the surface. Knowing where spent lead is allowing for appropriate BMPs to be used. The most effective practice for management of lead at a trap and skeet range is reducing the shot fall zone. It is possible to concentrate the lead shot in a smaller area by modifying the shooting direction into a smaller, more condensed area to make the reclamation process simpler and more effective.

Trap Fields

One way to reduce the shot fall zone at trap fields is to build the fields at an angle to one another. This will make the shape of the shooting dispersal pattern smaller and more concentrated. However, if you do decide to choose this option, be aware of safety issues when designing the overlapping shortfall zones.

For a range with only one trap field, one way to minimize the shot fall zone is to keep trap machines set in as few holes as possible (e.g., the number two or three hole setting). This reduces the area of lead concentration by limiting the angles for pigeon (clay) throwing, and therefore the area for lead shot fall. However, when two or more trap fields are positioned side by side, the shot fall zone will be continuous regardless of the "hole" setting.

Shot Curtains and Ground Covering

Another method to consider for concentrating lead shot is the use of a shot curtain. This device is emerging as a potentially effective tool to keep lead shot out of selected areas of the range, thereby, reducing the size of the shot fall zone and corresponding cost of reclamation. Different designs and material have been utilized in shot curtains and a number are in operation.

An untested option would be to a have permeable layer of cloth, rubber, or polyester covering the ground of the shot fall zone. This permeable layer would allow water to pass through, but would catch lead and allow for easy reclamation. Lead could be collected routinely as to not pose an environmental risk through the weathering of lead. More research should be done on this, including viable materials, costs, and implementation, but in theory it has the potential to substantially contribute to addressing the issue of lead deposits at shotgun ranges.

5.2 Step 2 – Best Management Practices to Prevent Lead Migration

5.2.1 Lime Addition

The best management practice for monitoring and adjusting soil pH is an important range program that can effect lead migration. Of high concern are soils with low pH values, because lead mobility increases in acidic soil conditions since the lead is more likely to break down. The ideal soil value for shooting ranges is between 6.5 and 8.5.

For this BMP there is an actionable step that owners/operators can take. To determine the pH of your soil, you can purchase a pH meter at any lawn and garden center. They are inexpensive and will allow you to have more control over the lead migration at your particular site. According to the US EPA, if pH is **less than 6**, it is recommended that pH should be raised by **spreading lime**. If pH **greater than 8,** do not add lime because this could increase mobility of lead. pH should be **checked annually**. Heavily wooded areas on sporting clay sites should be checked **semi-annually.** Multiple samples around the site should be taken.

Lime spreading should occur around earthen backstops, sand traps, trap and skeet shortfall zones, sporting clays courses and any other areas where the bullets/shots or lead fragments/dust accumulate. Spreading lime over the shot fall zone will help to raise the pH of the very top soil layer to a pH closer to ideal levels and reduce the migration potential of lead. This is an easy, low cost method. Spreading lime neutralizes the acidic soils, thus minimizing the potential for the lead to degrade.

Spreading bags of 50 pounds per 1000 square feet of range will raise pH approximately one pH unit for a period between one and fours years (US EPA). The market price of lime in either the granular or pelletized form commonly ranges from approximately $2.00 to $4.00 per fifty-pound bag (2016). Bags of lime can be purchased from most garden and lawn centers. It is important to measure pH at least once a year after application of lime because its effectiveness will decrease after time. If the site has a regular acidic pH, routine yearly applications will be necessary.

5.2.2 Phosphate Addition

In addition to lime spreading, another way to control lead migration is phosphate spreading. This method is recommended where lead is widely dispersed in range soils, a range is closing, or there is a high potential for vertical lead transport to groundwater (e.g., low soil pH, shallow water table). Unlike lime spreading, the main purpose of phosphate spreading is not to adjust soil pH but to bind the lead particles. This process also decreases the potential amount of lead that can migrate off-site or into the subsurface. Phosphate spreading can be done either separately or in conjunction with lime spreading. Generally, 15 to 20 pounds of phosphate per 1,000 square feet will effectively control the lead.

Phosphate spreading is especially recommended for sporting clays ranges and those parts of ranges not easily accessible by reclamation equipment. Phosphate spreading should be repeated frequently during the range's lifetime. Phosphate can be bought in its pure form, or as phosphate rock, or as lawn fertilizer. The average 40 lb bag of fertilizer costs around $10 and contains 25% phosphate. This is a very cost effective options for controlling lead. One study found that phosphate amendment is most effective in immobilizing lead in many kinds of shooting range soils and it will bring TCLP concentration below the required standard (Cao 2008). Therefore, phosphate is more effective than lime spreading at controlling lead, however both practices should be used. Like lime spreading, phosphate should be reapplied on a yearly basis.

5.2.3 Controlling Runoff

The BMPs for controlling soil erosion and surface water runoff are important to preventing lead from migrating off-site. There are two factors that influence the amount of lead transported off-site by surface water runoff: the amount of lead fragments left on the range and the velocity of the runoff.

Vegetative Ground Cover

Planting vegetative ground cover (such as grass) is an easy erosion control method. Vegetation provides several benefits by minimizing the amount of lead that will run off the land surface during heavy rainfall. Ground cover absorbs rainwater, which reduces the amount of water the lead is in contact with, as well as the time that the lead is in contact with the water. Furthermore, the ground cover will divert and slow down surface water runoff, thus helping to prevent lead from migrating offsite. Grasses yield the greatest benefit at rifle and pistol ranges where the bullet impact areas are sloped, and water runoff and soil erosion may be more likely.

- Utilize quick growing turf grass (such as fescue and rye grass)
- Avoid vegetation that attracts bird or other animals

- Use grass to direct runoff water away from problem areas (e.g., planting them at the top of the backstop or sand-trap

Grass does a great job at slowing down the rate of flow and reducing the amount of lead entering the soil via rainwater. However, it does require periodic maintenance to maintain its effectiveness and aesthetic appeal.

Surface Covers

For outdoor rifle and pistol ranges, impact backstops and target areas can also be covered with roofed covers or other permanent covers to prevent rainwater from contacting berms. However, this method may be less desirable because of the cost to install the roof, which must be carefully designed to avoid safety issues with ricochets, etc.

Engineered Runoff Controls

At shotgun ranges, dams and dikes can also be used to reduce the velocity of surface water runoff. Dams and dikes must be positioned perpendicular to the direction of runoff to slow the flow of surface water runoff. To accomplish this, determine the direction of the range's surface water runoff. This will be particularly obvious at ranges with sloped terrain. The dams or dikes should be constructed using mounds of dirt that are approximately a foot high. These mounds should transect the entire range, perpendicular to the storm water runoff direction.

These runoff controls are most important at ranges at which off-site runoff is a potential problem, such as ranges where the lead accumulation areas are located up-gradient of a surface water body or an adjacent property. Since lead particles are heavier than most other suspended particles, slowing the velocity of surface water runoff can reduce the amount of lead transported in runoff.

5.3 Lead Removal and Recycling

To successfully minimize lead migration, the most important BMP for lead management is lead reclamation. Implementing a regular reclamation program will allow you to avoid expensive remediation and potential litigation costs. Ranges in regions with high precipitation and/or with acidic soil conditions may require more frequent lead recovery since the potential for lead migration is greater.

5.3.1 Hand Raking and Sifting

A simple BMP that can be done by club members, particularly at small ranges, is raking and/or sifting bullet fragments from the soil. Sifting and raking activities should be concentrated at the surface layer. This is a low technology and low-cost management alternative for lead reclamation.

At trap and skeet ranges, conducting sifting and raking activities in the shot fall zone (approximately 125 - 150 yards from the shooting stations) will yield the most lead. For sporting clay ranges, these activities should be conducted around tree bases, where lead shot tends to collect. Basically, the process consists of raking with a yard rake the topsoil in the shot fall areas into piles, as if you were raking leaves, removing any large debris (e.g., rocks, twigs, leaves, etc.), and then sifting the soil using screens.

Once the soil has been raked and collected, pass it through a standard 3/16-inch screen to remove the large particles. This process will allow the lead shot sized particles to pass through the screen. The sifted material (those not captured by the 3/16-inch screen) should be passed through a 5/100-inch screen to capture the lead and lead fragments. Screens can be purchased at many local hardware stores.

Raking and sifting can be performed by club members on a volunteer basis. It is recommended that the club provides incentives for participation, such as reduced fees, or special events. Ranges have been known to hire high school and college students in the summer. This technique may be a cost effective strategy for small scale ranges, but larger ranges may not benefit.

5.3.2 Hiring a Professional Reclamation Company

Another option for lead removal is to hire a professional reclamation company. Lead reclamation companies claim to recover 75%-95% of the lead in the soils. Generally, with reclamation companies there is no minimum range size requirement for lead reclamation. Concentration of lead is more important than quantity spread over a field, especially if it is a difficult range for reclamation (e.g., hilly, rocky, a lot of clay in the soil). Many Ranges may even find lead reclamation to be a profitable endeavour due to the high value of lead.

These companies are often in high demand, and it may take over a year for the company to start at your club. It would be wise to plan ahead and make the call as soon as possible.

Some reclamation companies require a site visit to view the topography, the soil composition, and amount of lead observed on the ground. During the visit, some companies may even do a site analysis to determine whether or not it is feasible to reclaim. This analysis identifies the location of lead, the expected recovery amount, and the depth lead reaches into the soils. It is recommended by reclamation companies that lead be reclaimed every 5-10 years depending on site condition and range usage. Some ranges may break even, or possibly profit off of lead reclamation activities.

5.4 Documenting Activities and Record Keeping

Documenting activities and keeping good records is of paramount importance for an effective lead management program at a range. Owners/operators should document all activities done at the range with respect to BMPs and recycling of lead. Records should be kept on when services were provided and who provided them.

The records should be kept for the life of the range. Records may be used to show that owners/operators are doing their part to help prevent lead migration off-site, and that they are doing their part to be stewards of the environment.

5.4.1 Shot Counting and Lead Estimation

The easiest way ranges can determine the amount of lead at their shooting range is by keeping track of how many clays that have been thrown at the shotgun range. According to the NSSF, a 12-guage shot contains 1/12th pounds of lead. This means that the range operator could assume that 1/12th a pound of lead is being deposited within the shortfall zone of the range per clay. With informed estimates of reclaimable lead, the range operator has a greater ability to consult with a reclamation company to perform reclamation activities at the point when there is enough lead for it to be profitable. According to MT2, a U.S. company specializing in lead reclamation and soil remediation, a range with average use can reclaim their lead profitably between 5-10 years.

5.5 Non-Lead Alternatives

Another method of preventing lead contamination at pistol, rifle, trap, skeet, or sporting clays ranges is to use less toxic or non-lead ammunition. While non-lead alternatives may not be the most ideal best management practise currently, it presents the best opportunity for the long-term sustainability of sport shooting.

Currently, steel (soft iron) shot is being recommended by the ISSF to replace lead shot in the Olympics. The push for lead based shotgun ammunition is based on the enormous volume of cartridges fired by competitors, parity with prices for lead cartridges, the suitability of steel shot to be used in trap and skeet events, and the ease of substitution for lead shot in conventional 12 and 20-gauge shotgun cartridges. Given the lower density of steel shot versus lead shot, it is necessary to use steel shot of a larger diameter than the lead equivalent, coupled with an increase in shot velocity, to achieve the same ballistic efficiency and effective range (Thomas, 2013).

Detractors from the use of steel shot cartridges argue that damage to the choke of barrels could occur. That is a possibility with heavy magnum steel cartridge loads with large diameter shot ([3.6 mm) fired through barrels with abrupt large choke constrictions (i.e., full and extra full choke).

A switch to steel shot for shotgun disciplines could effectively eliminate a large amount of lead pellets currently being deposited into the environment and many ranges, but will not address that deposited by other shooting sports.

6.0 Issues Management

6.1. Be Proactive

Under all the laws and regulations, the province puts forth, the range is responsible for knowing the requirements and the meeting them. Ranges that are alleged to be in violation face at very least an uphill expensive, and uncertain legal/regulatory battle and public relations battle to put an end to the allegations in some way.

The most fundamental encouragement for ranges is to develop an environmental stewardship plan. Once a legal or regulatory environmental action is triggered, specific legal/regulatory processes come into play. These often result in actions selected by persons other than range managers with objectives different from those range managers and therefore could threaten wellbeing of the range. Pro-active development and implementation of a site-specific lead and noise management plans allows range managers to identify and address issues within their budget and schedules in a way consistent with long-term range operation.

Another way to stay ahead of potential allegations is to maintain a proactive and continuous public relations effort. Completely eradicating the potential for lead to end up on a neighbor's property may not be possible. Therefore, proactively maintaining good relationships with your neighbors, municipality, regional district, and local media is extremely important, and can greatly assist in preventing lead pollution complaints.

For public relations it is essential that your range communicate to the public that you have an environmental stewardship plan for dealing with lead. Outline what you are doing to problems from occurring. This will help create goodwill and trust amongst those worried about the issue of lead pollution. Provide your environmental stewardship plan on your club or range website to show that you are indeed meeting your responsibilities. The key is being open and honest with the public about what you are doing to ensure you are doing your part.

6.2. Dealing with Allegations/Complaints

When dealing with potential allegations or complaints, it is crucial that they are taken seriously and responded to with utmost professionalism.

Since the Ministry of Environment may consider allegations made with minimal or no substantial evidence, it is crucial that the range be in a position to refute the possibility of the lead contamination with a site investigation report that has timely data. It is important to show empathy and legitimate concern for the complainant's issue, but the facts are necessary to prove that in fact, you are either aware of potential contamination, or there is substantial evidence that the range operations comply with government regulations.

- Please heed the following considerations and questions should your range receive a sound complaint: Who is the complainant?
- What is the basis for the concerns?
- Can the concerns be addressed? How?
- Is the club in violation of any regulations?
- Has a site investigation been conducted? Need to be conducted?
- What were the results?
- What needs to be done?

7.0 Conclusion

A variety of lead management alternatives have been assessed in regards to addressing the issue of lead management at outdoor shooting ranges in Canada. Certain alternatives may be better suited for specific ranges based on soil characteristics, annual precipitation, range size, topography, etc. Shooting ranges should consider having a site investigation done at their range to determine the true risk of lead contamination on their property, and the potential for mobility on to neighboring properties and waterways. At a minimum, the range operator should conduct a pH test at several locations yearly. Physical characteristics of the site should also be evaluated to determine the likeliness of lead particles being transported off site.

While lead must eventually be removed from the soil, measures can be taken to reduce the ability for it move off site. Range operators and club members can spread lime and phosphate in between lead reclamation cycles to reduce to the amount of lead that will be transported off site. This is an effective measure that anyone can take, and the effects can last up to 5 years

Traditional reclamation using a front-end loader at a shotgun range is significantly more expensive than rifle/pistol. For rifle/pistol ranges, sand should be used as the 1st layer on berms. For future ranges, bullet traps should be carefully considered because there is no need for reclamation, and lead can be easily and efficiently reclaimed and sold, providing an additional stream of revenue for the club.

The bottom line is that lead needs to be carefully managed at outdoor shooting ranges. It is recommended every range conduct a detailed site investigation to assess potential risks before allegations are made unexpectedly, and there is little time to assess or redress the situation.

While there are mid-term steps that can be taken to reduce risk, soil remediation is inevitable. In addition, those who caused the pollution are responsible for making sure the organisation meets required regulation. Remember, with the Ministry of the Environment, it is the ranges' job to prove its innocence, so it is crucial that the range take all allegations seriously and be proactive in creating and following an environmental stewardship plan to prove compliance and consideration for all stakeholders involved.

8.0 Appendices

Appendix 1 - Glossary

Adsorption/desorption - Adsorption is a process by which dissolved lead or other ions are chemically bound to the surface of particles in contact with the solution (e.g., clay particles in suspension in water). Desorption is the reverse of adsorption, and is the process by which adsorbed lead or other ions are released into solution. In natural waters adsorption and desorption both go on continuously, and factors such as pH determine which predominates.

Adsorption/desorption processes are controlled by several complex and interactive parameters. The parameters that give rise to the adsorption of lead include acidic pH, high concentration of lead, concentration of competing ions, and the amount of lead or competing ions already adsorbed. Generally, lead is found to strongly adsorb to sediments and is not mobile under most conditions.

Bioavailability - Presence in a chemical and physical form that can enter the physiological processes of organisms. Lead dissolved in water is bioavailable, while metallic lead is not. As lead changes forms (e.g., metallic lead oxidizes into lead compounds that are more soluble) its bioavailability changes. If metallic lead is ingested (e.g., by waterfowl) the portion that dissolves while passing through the digestive tract becomes bioavailable.

Eh - A measure of the oxidation condition (or oxidizing ability) of a mixture. Large positive values indicate highly oxidized conditions, while large negative values indicate highly reduced (anoxic) conditions.

Equilibrium - Stable conditions under which there is no net transformation of material from one form to another.

Geochemical - Chemical processes taking place in, or involving components of, soil or sediment. Kinetic - Involving motion or time. Kinetic considerations deal with conditions at a point in time or during a finite time period, recognizing that conditions may be different at other times.

Mobility - In this document mobility refers to lead entering and remaining in solution in surface or ground water, and in the water trapped in the spaces between soil and sediment particles. It includes the dissolution of lead as well as processes that determine whether the lead remains in solution.

Oxidation/reduction - Oxidation originally referred to combining with oxygen, as in iron combining with oxygen and oxidizing into iron oxide (rust). Chemically this involves the loss of electrons by the iron, and the term oxidation has evolved to refer to any process involving the loss of electrons, such as the conversion of metallic lead into lead ions. Reduction is the reverse of oxidation, or the gain of electrons, such as converting lead ions to metallic lead. Oxidation and reduction are usually described together as oxidation/reduction or redox processes.

Rates affecting the oxidation/reduction processes include dissolved oxygen levels, organic carbon content, and biological activity. These processes can vary dramatically and can be estimated from site-specific observations or determine analytically through direct measurements. Potential oxidation is also largely related to the pH of the soil. Oxidations rates are generally expected to be faster under higher infiltration rates, acidic or and other conditions that would increase the transportation of oxygen to other reactive chemicals to metallic lead. Oxidation/reduction is a slow process, and the rate of corrosion has been estimated in only a few cases and has been reported as approximately 0.3 to .01 percent per year.

pH - A standard scale for measuring acidity, on which values from 7 down to 0 are progressively more acidic and values from 7 to 14 are progressively more basic or alkaline. A pH of 7 is neutral. Most surface water is slightly acidic to slightly basic, and typically has a pH somewhere between about 5.5 and 8.0.

Precipitation/dissolution - Precipitation is a process in which dissolved constituents combine to form a relatively insoluble compound (e.g., dissolved lead and dissolved sulfate can combine to form the relatively insoluble precipitate lead sulfate). Dissolution is the reverse of this process in which solids dissolve as their individual soluble components. Site-specific conditions such as pH determine whether precipitation or dissolution will be the dominant process.

Appendix 2 – BC Lead Standards

Lead (Chemical Abstract Service # 7439-92-1)

COLUMN I	**COLUMN II**	**COLUMN III**	**COLUMN IV**	**COLUMN V**	**COLUMN VI**	**Note**
Site-specific Factor	**SOIL STANDARD FOR PROTECTION OF SITE-SPECIFIC FACTOR**					
	Agricultural (AL)	**Urban Park (PL)**	**Residential (RL)**	**Commercial (CL)**	**Industrial (IL)**	**2**
HUMAN HEALTH PROTECTION						
Intake of contaminated soil	400	400	400	700	4 000	3,4
Groundwater used for drinking water						
pH < 6.0	100	100	100	100	100	5,6
pH 6.0 — < 6.5	250	250	250	250	250	5,6
pH ≥ 6.5	4 000	4 000	4 000	4 000	4 000	5,6
ENVIRONMENTAL PROTECTION						
Toxicity to soil invertebrates and plants	1 000	1 000	1 000	2 000	2 000	

Livestock ingesting soil and fodder	350					
Major microbial functional impairment	NS					7
Groundwater flow to surface water used by aquatic life						
pH < 5.5	150	150	150	150	150	5,6
pH 5.5 — < 6.0	250	250	250	250	250	5,6
pH 6.0 — < 6.5	2 000	2 000	2 000	2 000	2 000	5,6
pH ≥ 6.5	40 000	40 000	40 000	40 000	40 000	5,6
Groundwater used for livestock watering						
pH < 5.5	150					5,6
pH 5.5 — < 6.0	250					5,6
pH 6.0 — < 6.5	1 500					5,6
pH ≥ 6.5	30 000					5,6
Groundwater used for irrigation						
pH < 5.5	150	150	150			5,6
pH 5.5 — < 6.0	400	400	400			5,6
pH 6.0 — < 6.5	3 500	3 500	3 500			5,6

pH ≥ 6.5	100 000	100 000	100 000			5,6

Notes

1. All values in µg/g unless otherwise stated. Substances must be analyzed using methods specified in a director's protocol or alternate methods acceptable to the director.
2. The site-specific factors of human intake of contaminated soil and toxicity to soil invertebrates and plants specified in this matrix apply at all sites.
3. Intake pathway of exposure modeled is inadvertent ingestion of soil.
4. Standards have been derived based on results of clinical studies at sites. Standards represent the rounded sum of the toxicologically-based value plus the applicable soil ingestion clinical study factor, if one is available. For AL, PL and RL, the soil ingestion clinical study factor is 385 µg/g. For CL, the soil ingestion clinical study factor is 650 µg/g. For IL, no soil ingestion clinical study factor is available, therefore the IL standard was set equal to the toxicologically-based value.
5. The pH is the pH of the soil at a site.
6. Standard has been adjusted based on a reference provincial background soil concentration. Standard represents the rounded sum of the toxicologically-based value plus the reference provincial background soil concentration. For all land uses, the reference provincial background soil concentration is 108.6 µg/g.
7. NS — no standard. Insufficient acceptable scientific data exists, so no standard is calculated.

BC Ministry of Environment (BC MoE). 2014. Contaminated Sites Regulation, Schedule 9: Generic Numerical Sediment Criteria (includes amendments up to B.C. Reg. 4/2014, January 31, 2014). B.C. Reg. 375/96. O.C. 1480/96 and M271/2004. Effective April 1, 1997. Victoria, B

Appendix 3 - Soil Standards Comparison for Parks and Residential

	Lead Concentration mg/Kg	TCLP mg/L
British Columbia	400	5
Ontario	120	5
USA	400	5
Germany	1000	5
Sweden	300	5

Citations for standards in order:
http://www.tervita.com/solutions/challenge/waste-management-and-disposal/~/media/c5c48115175d40ab8a06aabc7838d40e.ashx
https://www.epa.gov/lead/hazard-standards-lead-paint-dust-and-soil-tsca-section-403
http://www.mah.gov.on.ca/AssetFactory.aspx?did=8996
http://www.bmub.bund.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/soilreport.pdf
https://www.naturvardsverket.se/Documents/publikationer/620-5053-2.pdf

Appendix 4 – Summary of Geographical Characteristics Affecting Lead Mobility

	Benefits	Risk
Clayey Soil	- May impede percolation of water through contaminated soil - acts as barrier between contamination and ground water - Finds free lead ions - May benefit growth of vegetative covers	- May increase runoff - Difficult to reclaim lead via sifting and raking because lead binds to clay
Sandy Soil	- Easy to reclaim lead through sifting and raking	- Contaminated rainwater can easily percolate through soil and groundwater
Steep Rolling Terrain	- Increases effectiveness of filter bed management methods	- Promotes off-site drainage - Can impede reclamation of expended shot via raking
Wooded Area	- Vegetation may slow runoff of metallic lead	- Impedes lead reclamation activities making equipment difficult to maneuver - May introduce lead into ecosystem through wildlife, increasing exposure
On-site or contiguous surface water bodies	None	- Highest risk! - Water increased risk of oxidation and dissolution into environment - Not an option for locations looking to operate long-term
Vegetation	- Ground covers slow down surface water run-off	- Lead may be absorbed into grasses, other

	- Some vegetation can extract lead ions from soils	wildlife food sources
Acidic pH <7	None	- Acidic soil contribute to lead dissolution - Increased potential for contamination

Appendix 5 - Summary of Potential Best Management Practices for Lead Management

	Shotgun Ranges	Rifle/Pistol Ranges
Potential Operational Approaches	• Shot recovery and recycling • Target recovery • Alternative shot materials • Lime and phosphate application	• Bullet recovery and recycling • Lime and phosphate application
Potential Engineering Approaches	• Range siting • Clay layer/mixing • Physical barriers to shot distribution • Shortfall zones designed to be outside of surface water bodies • Ranges designed to maximize overlap of shortfall zones, while maintain shooter safety • Elimination of depressions that may hold water • Storm water management/erosion control	• Range siting • Clay layers/mixing • Bullet containment • Baffles/tube ranges • Berm Construction and maintenance • Bullet traps • Runoff controls • Storm water management/erosion control

9.0 Cases

SSIRG Case Summary V. Salt Spring Island Rod and Gun Club, 2014 BCSC 1088.

In a recent case involving The Salt Spring Island Rod and Gun Club (SSIRGC), a Real Estate Investor who had purchased adjacent land then sued SSIRGC for noise nuisance, lead pollution and being a safety hazard. This neighbour also made a subsequent complaint to the Ministry of Environment (MOE) re: lead pollution, and has filed another lawsuit against the SSIRGC. The cost to the SSIRGC of meeting MOE requirements for engineering studies was approximately $105,000 ($75,000 + $35,000) and $32,500 ($17,500 + $15,000) for the ministry to review the engineering reports.

The cost of fighting/defending these allegations is beyond what many small club can deal with.

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Burnaby Gun Club, Burnaby, BC. Profiles On Remediation Projects. BC Ministry of Environment

The City of Burnaby made the decision to end the gun club lease and sought to return the ranges to park use. Burnaby had the three target areas checked for contaminants. Site investigations showed that a 1.8-hectare area contained lead, zinc, copper, and antimony, with concentrations high enough to be designated hazardous waste under British Columbia's Hazardous Waste Regulation. Keystone Environmental was retained by the City of Burnaby to develop a solution for the closure of the rifle ranges and the area's conversion to park use. Keystone concluded that the best solution lay not in removing materials but in coalescing them and retaining them on site. Under the Contaminated Sites Regulation, the Ministry of Environment can certify compliance with the regulations if the remediation plan showed that the contaminants, following implementation of mitigation and management strategies, no longer posed an unacceptable risk to human health and/or the environment. Once separated, the hazardous waste material was treated and combined with cement powder and sealed within a vault built beneath the proposed parking lot. In the range areas materials remain that exceed park Contaminated Sites Regulation standards, but are not hazardous wastes. These materials have been capped using a barrier of limestone to prevent leaching of the metals by rainwater, and to keep out the roots of the surrounding trees. Keystone's design and onsite management completed the project at a cost approximately $1 million dollars less than other solutions considered by the City prior to Keystone Environmental's engagement. With sustainability now at the forefront of urban design, the revitalization of contaminated sites is frequently a part of redevelopment. Compared with the 'dig and dump' approach, the innovative remediation strategies used by Keystone Environmental reduced risks more effectively and much more economically.

10.0 References

EA Engineering, Science, and Technology, Inc. (1996): Lead Mobility at Shooting Ranges. Sporting Arms and Ammunition Manufacturer' Institute Inc.

This review of scientific literature was conducted to summarize the current understanding of the environmental mobility of lead in surface or ground water, sediment, and soil, and the factors controlling lead mobility.

(2005): Best Management Practices at Outdoor Shooting Ranges (4th). Environmental Protection Agency Region 2. EPA-902-B-01-001.

This manual by the US EPA helps illustrate and promote an understanding of why lead is an environment, public, and regulatory concern, the benefits of applying good management practices, what can be done to successfully manage lead, and why implementing an environmental stewardship plan is essential to the long-term sustainability of your range.

Ministry of the Environment. (2016). Environmental Management Act: Contaminated Site Remediation. Ch. 43, Part 4. (2003), Victoria BC, Canada.

This document will provide a detailed overview of the legal environment and the contaminated site standards enforced by the provincial government of British Columbia.

Thomas V, Guitart R (2013): Transition to Non-toxic Gunshot Use in Olympic Shooting: Policy Implications for IOC and UNEP in Resolving an Environmental Problem.

Thousands of tons of lead shot which pose toxic risks to animals and may pollute both surface and ground waters. Non-toxic steel shot is an acceptable and effective substitute, but International Shooting Sports Federation (ISSF) rules prevent its adoption. This document considers some of the implications when switching to non-lead ammunition.

Cao X, Dermatas D (2008): Evaluating the Applicability of Regulatory Leaching Tests for Assessing Lead Leachability in Contaminated Shooting Range Soil. Environ Monit Assess 139:1–13

This study determined Pb leach ability in the range soils using TCLP and another US-EPA regulatory leaching method, synthetic precipitation leaching procedure (SPLP). The standard one-point TCLP test would either over- or under-estimate Pb leach ability in shooting range soils. Lead concentration in the SPLP leachates ranged from 0.021 to 2.6 mg l^{-1}, with all soils above the USEPA regulatory limit of 0.015 mg l^{-1}. In contrast to TCLP, SPLP leaching had reached equilibrium, with regard to both pH and Pb concentrations, within the standard 18 h leaching period, and the analytical SPLP results were in good agreement with those derived

from modeling. Thus, we concluded that SPLP is a more appropriate alternative than TCLP for assessing lead leachability in range soils.

Cao X, Dermatas D, Xu X, Shen G (2008): Immobilization of Lead in Shooting Range Soils by Means of Cement, Quicklime, and Phosphate Amendments. Env Sci Pollut Res 15 (2) 120–127

This study investigates the stabilization of Pb in shooting range soils treated with cement, quickline, and phosphate. Two soils were used and collected from two shooting ranges, referred to as SR1 and SR2. The treatment additives were applied to the soils at rates from 2.5% to 10% (w/w). The effectiveness of each treatment was evaluated by Pb leach ability, measured by the Toxicity Characteristic Leaching Procedure (TCLP). The possible mechanisms for Pb immobilization were elucidated using X-ray powder diffraction. Cement and quicklime treatments were effective in immobilizing Pb in SR1 soil, with reduction of Pb concentration in TCLP leachate to below US EPA standards. Cement and quicklime were less effective in SR2 soils, leaving TCLP levels higher than standard. Phosphate application was most effective in reducing Pb leaching in both soils. This study reveals that immobilizing Pb can be one of the best management practices for Pb contamination at shooting range sites and phosphate amendment is the most effective in immobilizing lead.

Liu R, Gress J, GAO J, Ma L. (2012): Impacts of two best management practices on Pb weathering and leach ability in shooting range soils. Environ Monit Assess 185:6477-6484.

This study investigates the impacts of two best management practices recommended by the US EPA agency on Pb weathering and leach ability in shooting range soils. The two BMPs included replacing soil berm with sand berm and periodically removing bullets or shot from a berm. Samples of lead were mixed with soil/sand, or placing bullet on the surface of sand/soil, then incubated for a 16-18-week period under high or low rainfall simulations. After this period, it was found that total Pb concentration in sand were lower than that in soil. Total leachable Pb in sand was also lower than in soil and when bullets were mixed with sand/soil, however they were comparable when bullets were placed on the sand/soil surface. While replacing a soil berm with sand berm can slow down Pb weathering, it may increase Pb leach ability in the long term. Removal of Pb bullets and Pb shot can be effective, but caution needs to be exercised to minimize the adverse impacts. Removing lead from trap/skeet via mechanical sieving and pneumatic separation effectively removed lead from source.