Risk Assessments at Closed Small Arms Shooting Ranges Need to Consider Lead in Soil and in Lead Bullet and Shot Sources

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OBJECTIVE

To develop an efficient procedure for more accurately evaluating risk/hazards of total lead in fine soil fraction and munition debris at closed shooting ranges.

INTRODUCTION

Small arms shooting ranges often contain levels of lead in the fine soil fraction that greatly exceed screening levels for human and ecological health. Additionally, bullets/fragments/shot are sources of lead contamination and even more lead remains in these lead munitions debris (MD) at shooting ranges. These lead MD also continue to weather to more soluble lead corrosion products over time (1, 2). The rate of lead weathering and release is site-specific ranging from 0.3 to 9% per year, depending on the soil moisture, pH, organic material, plant canopy, microbial populations and soil tillage (2,9,10-13). Several lead corrosion products, including lead carbonates, readily dissolve and leach soluble lead under both acidic and alkaline conditions (2,3,14). Once lead is released from bullets or shot, it shows a bioavailability of about 100% (15) and poses an ingestion risk to humans, wildlife and livestock (11,16,17).

Measuring contaminants in the ingestible fine soil fraction is adequate for estimating current exposures of human receptors (18). However, conventional soil sampling approaches overlook future weathering and release of a large amount of lead from lead MDs into the ingestible fine soil fraction, thereby generating exposure estimates that are biased low (Fig. 1).

Common Problems with quantitating lead MD sources:

- Each .30 Cal bullet initially contains about 8g lead (range of 7 to 14 g). The complete release and mixing of lead from one .30 Cal bullet could raise over 100 kg of soil to the 80 mg/kg lead screening level for residential use in California. However, there is only about a 1 in 100,000 chance the bullet would be captured using conventional grab sampling because EPA Method 3050B/6010B only requires digestion of 1 g soil.
- Each No. 7.5 shot contains about 80 mg lead. The complete dissolution of 1 lead shot could raise one kg of soil to the screening level of 80 mg/kg for residential use. However, there is only about a 1 in 1,000 chance the shot would be captured using conventional grab sampling methods.
- Thus, conventional sampling methods are not sufficient to assess risk of future use on small arms range sites, since at least 99.9% of the samples would miss the particulate contaminants in bullet or shot sources and underestimate total lead and future exposures to lead (3).

Thus, different sampling procedures are needed to estimate exposures of future human and ecological receptors to completely weathered lead MDs at shooting ranges.

We developed a screening-level sampling approach that allows a metal detector to rapidly screen the top 6" of soil for density of lead bullets that would exceed 80 or 400 mg/kg total lead, assuming complete bullet dissolution in soil (See Table 1 and Table 2). We also developed alternative methods for measuring total lead in fine soil fraction and lead MD that should provide more accurate estimates of future exposures.

ACCEPTABLE DENSITY OF LEAD MD is the maximum number of lead MD per unit volume/mass of soil so as to not exceed applicable screening levels for total lead, assuming complete release and mixing, and is calculated by summing lead in each lead MD, and lead in fine soil (MC) (See Table 2). The 2003 ITRC guidelines on evaluation of shooting ranges recommends samples be collected based on the current and historical range layout, at locations where lead bullets or shot are most concentrated and over the vertical and horizontal limits of the area where bullets/shot are present (3). Assuming background soil concentration of 20 mg/kg lead:

For lead shot

Only need 5-6 shot pellets per square foot in the top 2" (or 1.3 kg soil) to reach the Cal-Modified RSL of 80 mg/kg lead for residential use in California, once all the lead in the shot is released to soil.

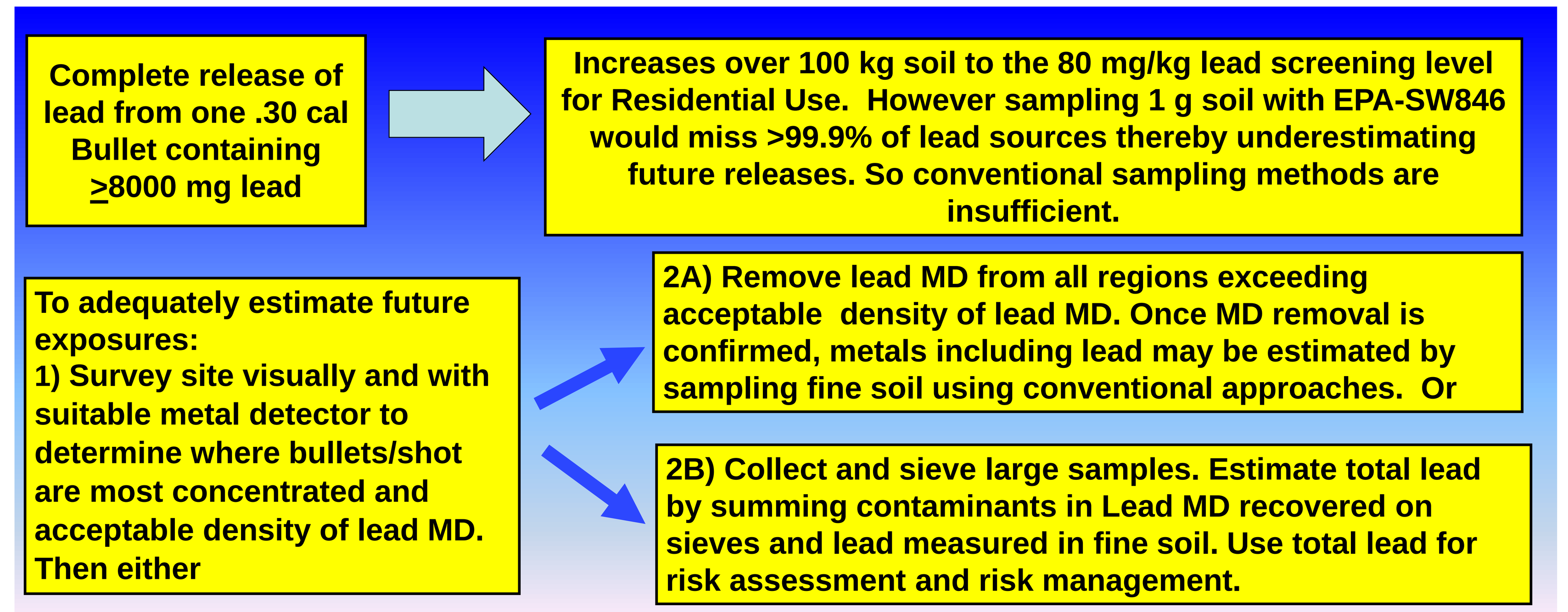

Figure 1. Estimating Future Exposures at Shooting Ranges Requires Different Approaches to Measure Total Contaminants in Soil and in Lead Bullets/Shot.

Table 1. Metal Detector Sensitivity: Maximum Distance (in inches) a Lead Shot or Bullet can be Detected.

Detector Model	Detect No. 9 Shot at	Detect .30 Cal Bullet at	Detect .45 Cal Bullet at	Detect .50 Cal Bullet at
White's GMT (48 kHz)	2"	7.3"	10"	8.8"
White's MXT (14 kHz)	non-detect	8.2"	9.5"	10"
TDI SL w 6 x 10" Coil	non-detect	6.2"	7.7"	7.6"
Weight of lead MD (g)	0.05 g	9.4 g	14.8 g	44.7 g

Note: (1) Detectors must be ground balanced, adjusted to be free from interference and confirmed to be capable of detecting lead MD fired on the site. (2) All measurements are based on a single MD, and will differ with gain and ground balance settings. (3) MXT was tested in Prospector mode. (4) Other detector makes/models capable of detecting lead MD released on a site may also be acceptable. (5) Disclaimer: Citation of specific models of metal detectors is not a recommendation or endorsement of these products.

For lead bullets

- Only need one .30 Cal bullet (150 grains with 8 grams lead) per 7.2 square foot in the top 6" (or ~148 kg soil) to reach the Cal-Modified RSL of 80 mg/kg lead in soil, once all the lead in the bullet is released to soil.
- Under random sampling, very large sample volumes would be needed to account for future lead releases from lead MD (see Table 2).
- Sample volumes can be smaller if samples are collected at locations where bullets are most concentrated and lead MD is collected with the sample (see below).

Sensitivity of Metal Detectors. Several metal detectors were tested to determine the soil depth that lead bullets and shot could be detected (Table 1). While some detectors were not suitable (not shown), we anticipate that other brands and models of high quality metal detectors may also be suitable. Users should confirm that a detector is suitable for detecting bullets/fragments/shot present at a range.

White's GMT Detector (Very Low Frequency (VLF) Type):

- Most sensitive detector tested and could detect a No. 9 shot at a distance of 2". Generally, higher frequency VLF detectors are more sensitive to small lead bullets and shot.

White's TDI SL Detector (Pulse Induction Type):

- Less affected by ground mineralization and was sufficient for screening pistol/rifle/machine gun ranges for bullets and fragments, but may not be suitable for small lead fragments and shot.

Case Study/Validation – Pistol/Rifle/Machine Gun Ranges

- A White's TDI SL metal detector was used to survey for lead bullets/fragments on several small arms shooting ranges that had been closed for 40 to 70 years.
- Lead bullets were not visible, but were easily detected in the top 6 inches of soil with this detector.
- Confirmation digs showed 100% of the lead bullet-like signals tested were lead bullets/fragments.
- The TDI SL detector rapidly and easily identified several locations with a high density of lead bullets and well over 10,000 mg/kg total lead that had been previously missed by gridded sampling for lead using X-ray fluorescence (XRF).
- These and other observations show that particulate lead MD sources containing high concentrations of total lead can be missed by conventional SW-846 gridded sampling methods, but were easily detected by screening with a metal detector.

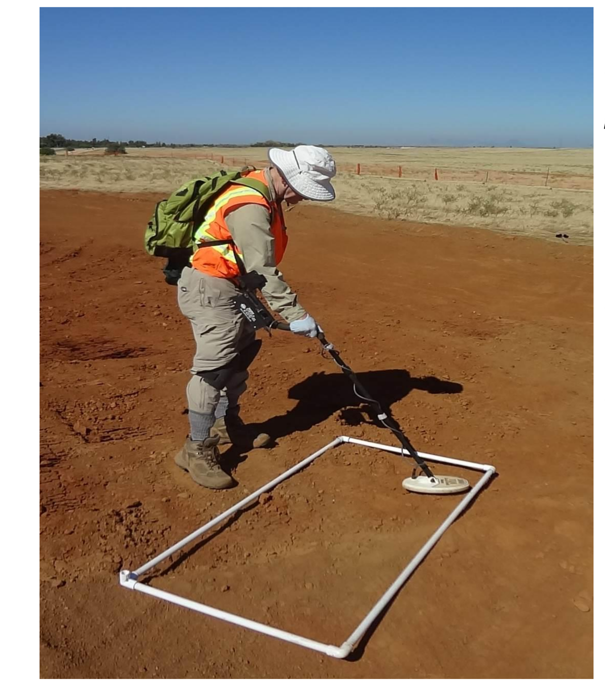

Figure 2. *A suitable pulse induction metal detector is used to screen for the concentration of lead bullets and fragments within 6 inches of the surface in a 10 square foot template.*

Table 2. Maximum Number of Lead MDs (shot or bullet) to not Exceed Soil Screening Levels (i.e. Acceptable Density of Lead MD).

Type of Lead MD Present	Desired Human or Ecological Health Screening Level in Soil (mg/kg)	Volume (and Mass) of Soil brought up to corresponding Screening Level by each Lead MD, assuming complete release & mixing *	Acceptable Number of Lead MD per square foot surface Area ** (Number/sq ft)	Therefore: If lead MD is not removed before sampling, Minimum mass (kg) of soil per sample needed to measure total lead using random sampling ** , ***
No. 7.5 Shot	56	0.054 cu ft (2.2 kg)	3.1	2.2 kg
No. 7.5 Shot	80	0.033 cu ft (1.3 kg)	5.5	1.3 kg
No. 7.5 Shot	320	0.0065 cu ft (0.27 kg)	26	0.27 kg
No. 7.5 Shot	400	0.0051 cu ft (0.21 kg)	23	0.21 kg
.30 Cal bullet	56	6.0 cu ft (246 kg)	0.083	246 kg
.30 Cal bullet	80	3.6 cu ft (148 kg)	0.14	148 kg
.30 Cal bullet	320	0.72 cu ft (30 kg)	0.70	30 kg
.30 Cal bullet	400	0.57 cu ft (23 kg)	0.88	23 kg

* Assumes background soil concentration of 20 mg/kg lead, but changes with lead concentration in fine soil.
** Cu. Ft. soil surface per Lead MD is based on top 2" soil for shot and top 6" soil for bullets.
*** If lead MD is removed, and removal confirmed, conventional sampling approaches for lead may suffice.

AN APPROACH TO SCREEN AND SAMPLE CLOSED SHOOTING RANGES

1. Characterize the extent of lead MDs

- Survey range features, including impact berm, target area, firing line, and surface danger zone visually and with a suitable metal detector and identify sampling locations where lead MD is most concentrated.
- Perform rapid screen to determine extent and greatest density of lead MD at a slow walk by moving detector coil back and forth in a 1 meter arc just above the soil. Flag with markers and record coordinates with greatest density of lead MD.
- For rifle/pistol ranges - estimate the concentration of lead MD per square foot surface area using a defined template (see Figure 2 and Table 2).

2. Address Lead MD and Munition Constituents (MC) on the site.

Scenario 1: If lead MDs have already been removed before sampling:
Removal of lead MD from all areas where the acceptable density of lead MD exceeds screening levels (see Table 2) may allow the use of conventional methods on moderate-size, soil samples collected at locations with the highest density of lead MD. This approach is consistent with EPA (2003) which recommends that sampling be performed after removal of lead MD (18). Removal of lead MD should also be confirmed with a metal detector and by sieving 1 - 2 kg samples as described below.

Scenario 2: If lead MDs have not been removed before sampling:
This scenario requires collecting large samples shown in Table 2 using random sampling, or collecting high-biased samples in the example described below.

Step 1. Collect Samples

At skeet/trap ranges: Include top 2" of soil over 0.5 sq. ft. or pool 1-2 kg core samples.

At pistol/rifle/machine gun ranges:
Collect the top 2 to 6" of soil over 0.25 sq. ft. or pool 2 kg core samples collected with sampler with a diameter at least 3 times the length of bullets. Confirm the collection of lead MD.

Step 2. Process Samples through a Series of Sieves.

At skeet/trap ranges:
Weigh and sieve entire sample through a US Standard No. 4 sieve underlain by a No.16 sieve and solid collection pan. Weigh and count the number of lead shot.

At pistol/rifle/machine gun ranges:
Weigh and sieve entire sample through a No. 4 sieve underlain by a No.10 sieve and solid collection pan. Recover, weigh and save all lead MD captured on sieves

Step 3. Quantitate Metals in Lead MDs Using Gravimetric Analysis.

- Estimate metals, including lead, antimony, arsenic and copper gravimetrically based on the weight of pooled lead MD from each sample.

Step 4. Quantitate Metals, including Lead in Fine Soil Fraction.

- Determine MC metals, including lead, antimony, arsenic and copper in sieved soil passing through the finest sieve using EPA Method 3050B/6010B.
- Alternatively, analyze MC samples for lead, antimony and copper by XRF using EPA Method 6200, provided ≥ 5% of the samples are also analyzed with 3050B/6010B and show a high correlation with the two methods.

Step 5. Sum Contaminants in Lead MD and Fine Soil Fraction in Each Sample.

- Calculate total metals, including lead, arsenic, antimony and copper as their respective sums in lead MD and in fine soil MC.
- Cleanup and risk management decisions regarding future site use should be based on total metals in combined lead MD and fine soil fraction.

Special Case – Risk Assessment based on Future Residential Scenario

- Divide sites into 50' x 50' grid cells and screen ~20% of each grid cell for density of lead MD with suitable metal detector. Within each grid cell, sample two locations with greatest density of lead MD.
- Calculate Exposure Point Concentration for each 5,000 sq. ft. residential exposure unit.
- Address hot spots for residential and industrial receptors.

Evaluation of Lead Shot from Bird Ingestion: The lead shot ingestion pathway is critically important to birds because it is acutely poisonous. Consider the risk of shot ingestion, as well as exposure to lead released from lead MD into the environment in the ecological risk assessment (19).

DISCUSSION AND CONCLUSIONS

- Gridded sampling and analysis of soil at small arms shooting ranges with conventional SW-846 methods was not sufficient for risk assessment purposes because high concentrations of metals, including lead in lead MD were missed and thus not accounted for.
- Consequently, future exposures would be underestimated and may not be health protective.
- Our suggested approach is as follows:
  - Closed small arms ranges are screened visually, as well as with a suitable metal detector and large-volume samples collected at locations where bullets/fragments/shot are most concentrated.
  - If lead MD is removed from all areas where acceptable density of Lead MD exceeds screening levels, metals may be estimated by conventional gridded sampling of MC in fine soil fraction.
  - If lead MD is not removed from the entire site before sampling, then:
    - Collect large samples (See Table 2), or biased samples (See Scenario 2), sieve entire sample, recover lead bullets and shot and quantitate lead MD gravimetrically.
    - Contaminants in the fine soil fraction is determined and totaled with contaminants in lead MD.
    - Total contaminant concentration in fine soil fraction and in lead MD should be used for risk assessment purposes and incorporated into making risk management decisions regarding future use.

SELECTED REFERENCES

(3) ITRC, 2003. Characterization and Remediation of Soils at Closed Small Arms Firing Ranges, January 2003; Interstate Technology and Regulatory Council.
(18) EPA, 2003. TRW Recommendations for performing human health risk analysis on small arms shooting ranges, US EPA, OSWER, March 2003.

For a complete list of references please go to https://munitionsdebris.wordpress.com/2015/03/12/reference-section-closed-small-arms-shooting-ranges or scan the QR code to the right