Lead Particle Size and its Association with Firing Conditions and Range Maintenance: Implications for Treatment

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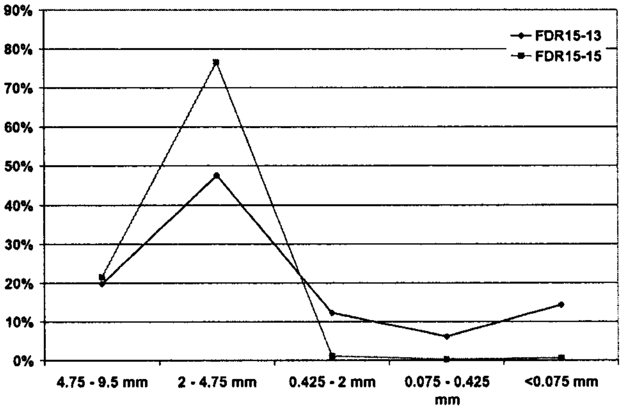
ABSTRACT

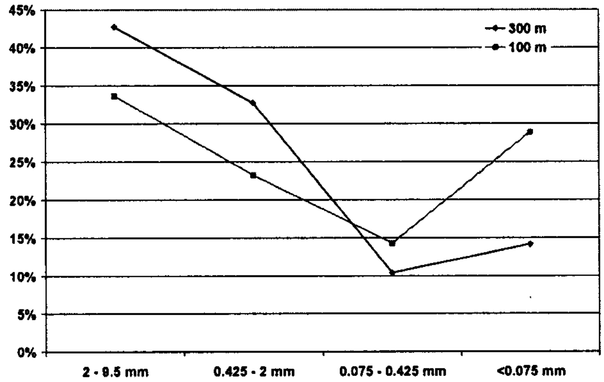
Firing range soils are the second largest contributor of lead (Pb) to the environment, as Pb is used in ammunition due to its favorable physical properties. The toxicity of Pb is a well established fact, so that Pb-contaminated firing range soils constitute a hazard for the human health and the environment and are subject to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), which regulates contaminated site treatment in the United States. There are several alternatives to treat Pb-contaminated soils, such as physical extraction, chemical washing and stabilization/solidification (S/S). The Pb concentration, speciation and particle size, i.e. its association with a soil fraction, are the predominant factors that determine the type of treatment to be applied, with particle size being the controlling factor in determining whether a soil can be subject to physical or chemical extraction. The advantage of these extraction methods when compared to S/S is that Pb can be eventually recovered in its metallic form and that the clean soil can be potentially reused.

The present study explores the particle size distribution of Pb in different firing range soils in order to elucidate the factors that ultimately determine its association with the soil particle size fractions. Seven firing range soils were analyzed, representing different environments, firing conditions and maintenance practices. The particle size distribution and Pb concentration in each fraction were determined for samples obtained from the surface of the backstop berms in the direction of firing. The soils used to construct these berms were sandy in most of the cases, with the exception of one range, in which 90% of the particles were in the silt and clay fraction. For this fine-grained soil firing range site Pb was, consequently, found in the fine fraction in that soil.

The type of weapon predominantly used in the firing ranges was found to significantly affect the particle size of Pb deposited in the soil berms. The use of low-velocity pistols correlated with the accumulation of Pb in the coarse sand and gravel fractions, as bullets did not fragment considerably upon impact. Conversely, in the ranges, where high-velocity

rifles were the predominant weapon fired, lead fragmented considerably and accumulated in the fine sand and silt/clay fractions. The use of high-velocity weapons did not only affect the Pb particle size, but also the soil grain size distribution. It lead to significant pulverization of the dredge sand used in one of the ranges and exacerbated the





accumulation of Pb in the fines fraction, which was practically zero prior to pulverization, as evidenced by comparison with unaffected soil. Figures 1a and b show examples of lead distribution in ranges firing low-velocity pistols and high-velocity rifles, respectively.
Figures 1a and b: Lead distribution in the soil fractions in a firing range using pistols (a) and rifles (b)

The conditions of firing were also shown to affect the particle size of Pb. The use of deflectors prior to impact with the berm reduced the velocity of pistol bullets significantly, leaving them almost intact. Lead was mostly present as metallic particles in this soil, rendering its separation a relatively easy task. The firing distance was also found to contribute to Pb fragmentation, i.e. longer distances correlated to lower velocities and thus lower degree of fragmentation.

The range maintenance practices may also exacerbate lead fragmentation and speciation, depending on the prevailing environmental conditions. The use of water spray to suppress fugitive dust resulted to accelerated corrosion of metallic Pb in one firing range, as the increased humidity in the berm favored carbonation reactions and lead carbonate formation, which accumulated in the fine fraction.

More importantly, Pb particle size is the controlling factor that will dictate its leachability. The isolation and separation of Pb is easier when Pb is predominately present in the coarse soil fraction and thus will facilitate a physical particle separation treatment approach with low cost and labor. Conversely, Pb in the finer fractions is subject to chemical transformation and sorption reactions and is more difficult to physically and/or chemically extract. The only cost-effective treatment option in this case is S/S treatment, which does not physically remove Pb from the soil and is more resource-consuming.

In conclusion, the type of weapons used, the firing conditions and the range maintenance practices are crucial factors that have to be considered by range owners, in order to minimize Pb introduction into the environment and thus reduce remediation costs.