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Tungsten (W) and lead (Pb) leaching behavior in firing range soils

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Tungsten (W)-based munitions have been proposed as a more environmental friendly alternative to lead (Pb) and depleted uranium (DU) munitions. The potential environmental impacts of W on Pb leaching were examined, where the mass loading of W was on the order of 1 wt%, making it comparable to Pb loading at small firing ranges. The general acid neutralization capacity (GANC) test was performed to evaluate W impacts on Pb leaching in four firing range soils with significantly different Pb concentrations and geoenvironmental characteristics. A series of soil parameter and mineralogical studies (X-Ray Powder Diffraction: XRPD) were applied to interpret Pb and W speciation and their leaching behavior under different conditions. Although it is widely believed that W is insoluble, W concentrations were measured in excess of 100 mg/L in firing range soil-water systems at 30 days, for less than 0.2 equivalents acid/kg soil. Water-extractable W concentrations were as high as 40 mg/L after 14 days equilibration. As W leached, the pH of the Pb-contaminated firing range soils decreased by 1.5 to 2.5 pH units, and Pb leaching increased by 100x in poorly-buffered soils, whereas it was lowered by a factor of 2x in well-buffered soils. Once soluble, W (as WO_4^{2-}) also reacted with Pb^{2+} to form insoluble Pb-W precipitates ($PbWO_4$), depending on the soil conditions. Overall, W-induced increases in Pb solubility occurred at pH$<$6. Above pH 6, Pb was present as hydrocerussite ($Pb_3(CO_3)_2(OH)_2$), cerussite ($PbCO_3$) and stolzite ($PbWO_4$) with the overall fate of Pb and W remaining complex. Accordingly, this paper examines the observed W and Pb leaching phenomena as a function of six main factors: soil composition, reaction time, soil buffering capacity, pH, the Pb:W ratio, and the potential formation of insoluble minerals (i.e., $PbWO_4$).