MECHANISMS AND PERMANENCE OF SEQUESTERED PB AND AS IN SOILS: IMPACT ON MOBILITY AND BIOAVAILABILITY

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Keywords: Arsenic, bioaccessibility, bioavailability, lead, soil remediation

Introduction

Soil Pb and As are the primary human health risk drivers at many DoD, DOE, and USEPA sites. We conducted a multidisciplinary study to determine fundamental understanding of the relationship between Pb or As species in soil and their bioavailability to humans. The specific objective of the study were (1) to extend As in vitro bioaccessibility (IVBA) methods to predict relative bioavailable (RBA As) As for use in human health risk assessment (HHRA) and (2) to evaluate the permanence of in situ remediation of Pb contaminated soils using phosphate soil amendment.

Methods

The technical approach of the project consists of two components: Objective 1 focused on IVBA methods to predict RBA As (Figure 1) and objective 2 focused on evaluation of the permanence of in situ remediation of Pb contaminated soils (Figure 2).

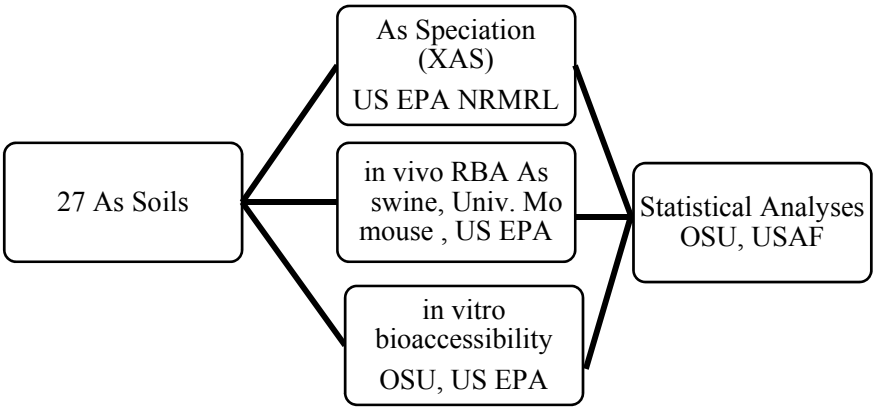

Figure 1. Technical approach of the project for objective 1

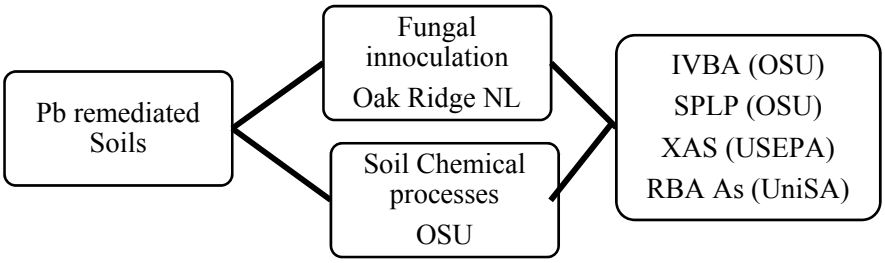

Figure 2. Technical approach of the project for objective 2

Twenty-seven As containing soils from a wide variety of As sources were selected for objective 1. A comprehensive evaluation of 5 international published IVBA methods to predict animal RBA As was determined. The IVBA methods included; the Solubility Bioaccessibility Research consortium assay (SBRC), the Unified Barge Method (UBM), the Physiologically Based Extraction Test (PBET), the OSU In Vitro Gastrointestinal Method (OSU), and the California Bioavailability method (CAB). RBA As was determined using both the juvenile swine and adult mouse models. In vitro in vivo correlation was performed by linear regression of IVBA As vs. RBA As was fitted using linear regression for each method. Solid phase speciation of As was determined using X-Ray Absorption Spectroscopy (XAS). Contaminated Pb soils from two locations that were remediated by phosphate-containing soil amendment addition were used in Objective 2. The temporal effect of key biological (e.g., organic acid excreting fungi) and chemical processes (e.g., soil pH) on the long-term permanence of Pb and its bioavailability to humans was evaluated. The effect of chemical and biological processes on sequestered Pb in remediated soil was assessed using XAS, leachability testing including USEPA Method 1312 SPLP, IVBA Pb methods, and animal dosing to determine RBA Pb.

Results

Arsenic bioaccessibility was determined using five different international in vitro methods and ranged from <1 to >90%. All of the IVBA methods met the criteria for IVIVC and linear regression could be used to predict RBA As of the study soils. In situ P-containing soil amendments resulted in a significant ($P<0.01$) reductions in Pb mobility (i.e. SPLP Pb), IVBA Pb, and RBA Pb for soils from both study sites. Speciation with XAS shows the reduction was due to formation of Pb pyromorphite. Incubation of Pb remediated soil with organic acid excreting fungus had no effect on Pb mobility, IVBA Pb, RBA Pb, or Pb speciation by XAS. In general, Pb solubility increased when soil pH was < 4. For both study sites, the effect of P treatment is apparent at low pH. A sharp increase in soluble Pb occurred at pH < 4 for the control soils and pH < 3 for the P-treated soil. The P-treatment extended the insolubility and stability of sequestered Pb from pH 4 to pH 3.

Conclusions

In vitro bioaccessibility methods have the ability to accurately predict in vivo RBA As. The methods that most resemble human physiology are better predictors for RBA. Phosphorus treatment of Pb contaminated soil resulted in a stable reduction in soluble Pb and Pb human bioavailability over a long period of time (>10 y). Fungal treatments did not affect sequestered Pb stability, bioavailability or speciation.