POTENTIAL VALUE OF SYNTHETIC AND NATURAL PHOSPHATE COMPOUNDS IN ENHANCING IMMOBILIZATION AND REDUCING BIOAVAILABILITY OF MIXED HEAVY METAL CONTAMINANTS

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Introduction

Metal mining and smelting activities, and indiscriminate disposal of agricultural and industrial wastes have resulted in the contamination of soil and water resources with heavy metal contaminants (Raicevic et al., 2009; Sun et al., 2010). For example, shooting ranges and base-metal tailings are a major source of mixed-contamination (co-contamination) of heavy metals including cadmium (Cd), copper (Cu), lead (Pb), antimony (Sb), and zinc (Zn) (Lafond et al., 2013; Sanderson et al., 2012). Phosphate (P) compounds are used to immobilize these metals, thereby reducing their bioavailability (Bolan et al., 2003; 2014). However, only few studies have examined the relative value of soluble and insoluble P compounds in the immobilization of co-contaminants, which is critical in determining the overall effectiveness of *in situ* stabilization techniques in the sustainable remediation of mixed heavy metal contaminated soils. This study was conducted to examine the immobilization and subsequent mobility and bioavailability of Cd, Pb, and Zn in a contaminated soil from shooting range. This study also reports on the results of an extended long-term (3 years) stability of Cd, Zn, and Pb immobilization by both synthetic and natural P compounds

Methods

Soluble P fertilizer (diammonium phosphate; DAP) and reactive (Sechura; SPR) and unreactive (Christmas Island; CPR) phosphate rocks (PR) were tested for Cd, Pb, and Zn immobilization and their subsequent mobility and bioavailability in a contaminated soil from shooting range. Phosphate-induced immobilization of Cd, Pb, and Zn was calculated based on the reduction in ammonium nitrate (NH_4NO_3)-extractable metal concentration. The mobility of Cd, Pb, and Zn as affected by P application was examined using leaching experiments and the mobility was expressed as percentage of mass leached with respect to the total metal mass in soil. The bioavailability of Cd, Pb, and Zn was expressed as percentage of metal mass taken up by earthworms or plants with respect to the total mass in soil. Metal bioaccessibility was expressed as a percentage of metal mass extracted by simple bioavailability extraction test (SBET) with respect to the total mass in soil.

Results

The addition of P compounds resulted in the immobilization of Cd, Pb, and Zn by 1.56-76.2%, 3.21-83.56%, and 2.31-74.6%, respectively, as measured by NH_4NO_3-extractable concentrations. The reactive SPR significantly reduced Cd, Pb, and Zn leaching while soluble DAP increased their concentrations in the leachate. The SPR reduced Cd, Pb, and Zn bioaccumulation in earthworms by 7.13-23.4% and 14.3-54.6% compared to earthworms in the DAP and control treatment, respectively. Bioaccessible Cd, Pb, and Zn concentrations as measured by SBET showed higher long-term stability of P-immobilized Pb and Zn than Cd.

Conclusion

The differential effect of P-induced immobilization between P compounds and metals is attributed to the difference in the solubility of P compounds and the nature of metal phosphate compounds formed, respectively. Therefore, Pb and Zn immobilization by P compounds is an effective long-term remediation strategy for mixed heavy metal contaminated soils.

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