Chemical Stabilization of Polluted Soils With Heavy Metals

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Abstract

In situ chemical immobilization is a remediation technique that involves addition of chemicals to contaminated soil to reduce the solubility of metals. Diammonium Phosphate (DAP) is considered effective in metal immobilization. For these analyses DAP was added in a proportion 1P:15 M_{tot}, in three soil concentrations: maximum, middling and minimum; repacked in columns and saturated with water. The DAP treatments were analyzed for total and soluble metals concentrations, for maximum point concentration diminished 70% for total metals content and 98% for soluble metal content. In middling and minimum points there was an irregular behavior, which was attributed to low added DAP concentrations. Results suggest that DAP amendment was viable for the point of higher heavy metals concentration in a smelting site.

Introduction

The zones that have been subject to mining activities, present diverse heavy metal pollution levels, being a potential risk for exposed population (Higueras *et al.*, 2005). Remediation of polluted soils with metals and metalloids is important because these do not degrade and are environmental persist (Quartacci *et al.*, 2005). Heavy metals immobilization involves addition of chemical products to the soil that react with heavy metals, forming highly insoluble compounds; such in that form they are not available for alive beings. The heavy metals continue in the soil, but in a least harmful form (McGowen *et al.*, 2001). Given it´s commercially available, DAP could prove to be an economical and effective treatment for metal immobilization like Pb, Cd and Zn (Cotter-Howells *et al.*, 1996). McGowen and collaborators (2001) mention that DAP provides an effective heavy metal immobilization treatment in smelter-contaminated soil, being the best proportion 1:15 P with M_{tot} ($M_{tot} = \sum$ total Cd, Pb and Zn).

Materials and Methods

DAP treatments were evaluated using solute transport experiments with repacked soil columns similar to methods described by Selim and Amacher (1996). Reagent grade DAP, $(NH_4)_2HPO_4$ (23% P), was added as an amendment to the contaminated soils based on the total metal molarity of Cd, Pb, and Zn in the soil. The proportion selected for the present experiment was 1(P): 15 (M_{tot}), chosen according to the results obtained by McGowen (2001).

The contaminated soil used in the present study was collected next to tailings damps on a mining site in Chihuahua, Chih, Mexico, and characterized based in its metal content. The proportion 1:15 was considered for three different heavy metal soil concentrations of the characterized site: maximum, middling, and minimum concentration. They were uniformly mixed 500g of soil with the corresponding amount of DAP amendment for each one of the soil samples, according to Table1.

Table 1. Background soil concentrations and DAP added amount

Sample	Initial soil concentrations (mg/kg)				g DAP/500 g soil
	Pb	Cd	Zn	As	
Maximum	18,201.16	322.14	35,756.65	2,525.29	11.97
Middling	3,266.33	68.53	3,411.19	210.99	1.29
Minimum	103.80	5.60	215.60	16.80	0.07

Afterward were repacking into acrylic transport columns of 6.30 cm diameter and 13 cm long. Soils were saturated with distilled water in a continuous upward flow using a piston pump until saturation and allowed to equilibrate for 48 h prior to further leaching. After the equilibration period, a saturated flow regime was resumed and soil solution fractions were manually collected through 32 bottles of 50 mL by each sample. Sample effluent pH was immediately measured after collection. Remaining effluent (40 mL by fraction) was acidified with trace metal grade HNO_3 (pH < 2) and microwave digested for metal and metalloid analysis (As, Cd, Pb, Zn) by atomic absorption spectrometer.

Obtained soil samples after treatment were dried and analyzed for total and soluble metal and metalloids determination (obtained by PECT method); also soil samples were taken for their reading by SEM (Scanning Electron Microscope).

Results and Discussion

In the three contaminated soil samples, pH increased a point above background value; this variation for Ph values can be attributed to the soil tested capacity, because the composition analysis made previously of this soil indicate that it is constituted by gypsum (Ca SO_4 $2H_2O$). The results coincide with the obtained by Cotter-Howells (1996) in where, it mentions that DAP did not increase soil acidification and metals remobilization, although, in this study limestone had been added to contaminated soil, he concludes like McGowen (2001) that this can be necessary to compensate the potential soil acidification by the nonalkaline soil ammonium fertilizer use, which in our study was not realize due to study soil constitution. The results of organic matter of treated samples were smaller than background levels; nevertheless, they still in the same classification of little organic matter. The cationic change capacity increases with treatment, changing the classification of these samples from very low to low fertility.

Total metals concentrations of As, Pb, Cd and Zn, for maximum point were diminished above of 70%, nevertheless these concentrations still exceeding regulatory levels. In middling and minimum points, did not display diminution in its background concentrations.

Heavy metals solubility (As, Pb, Cd and Zn) decreased enough, being more recognized in maximum point were diminished above 98%, final concentrations with exception of Zinc and Arsenic in the midpoint, were below regulatory levels.

Basta *et al.* (2004) and Cao *et al.* (2002) mention that metal absorption depends on pH. Effective in situ immobilization of lead require heightened Pb solubility, inducing by acid conditions, doing necessary soil acidification before P addition being added H_3PO_4 or other acids. Soil pH reduction would facilitate the Pb and P dissolution in soil heightens Pyromorphite formation. Chen *et al.* (2003) and Cao *et al.* (2003) conclude that the investigated treatments above 10 g of DAP kg^{-1} were most effective to heavy metals immobilization. All the previous one coincide with the analysis results obtained, in where the maximum point which has acid pH and in addition received a 11g amendment of DAP g 500 g^{-1} was the one that removed more metals and better perform.

Basta *et al.* (2004) and Yoon *et al.* (2007) mention that added phosphorus amount for effective immobilization of Pb is an important factor. Considered that, treatments of midpoint (1.29 g DAP 500 g^{-1}) and minimum point (0.07 g DAP 500 g^{-1}) development were less efficient due to the little amount of added DAP.

According to analysis made by SEM, just in maximum point case, the morphology was similar to a Pyromorphite (Figure 1), in addition on mapped lecture appeared in the same bar P, Pb, Cd, which indicate the elements in these compound.

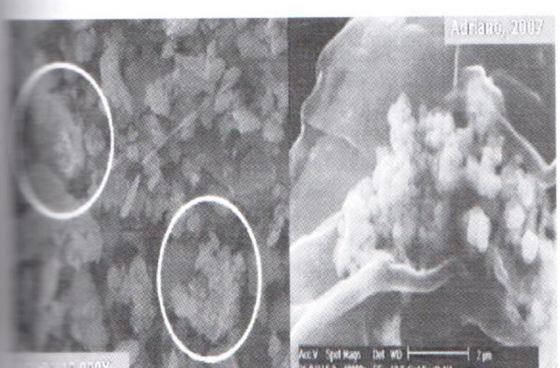

Figure 1. Maximum point sample in SEM analysis and reference compare.

The optimal proportion of P-Mtotal of 1:15 in soil, used in this study, can fluctuate with different concentrations from reagent metals in other contaminated soils. Phosphates formed by DAP treatment in contaminated soils, must provide long term reductions in solubility and metal transport (Cotter-Howell *et al.*, 1996).

Conclusions

DAP amendment for soils provide effective heavy metals immobilization for the point of greater metal concentration, this corresponds to three optimal conditions development: 1). Acid soil pH, 2). High metal concentrations, so relation 1 P: 15 M_{total}, allowed an addition above 10 g of DAP/kg, 3). Soil damping capacity, because this sample is constituted mainly by gypsum.

Analyzed and multicontaminated soil needs an economic remediation alternative easy to apply. The results of this study show that chemical stabilization is an excellent option for this site, specifying that exists the necessity of realize more laboratory tests before field taking.

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