Title
The use of NTA and EDTA for lead phytoextraction from soil from a battery recycling site

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Introduction

Lead ranks second among the most hazardous metals in the Priority List of the US environmental Protection Agency (ATSDR, 2009). Some of the potentially Pb most contaminating activities are lead mining, lead smelting and battery recycling. Areas near Pb recycling facilities may be enriched by atmospheric fallout and wastes disposal. Thus, soil pollution, metal leaching and contamination of animals and locally grown vegetables can occur owing to enrichment of soil with lead. A battery recycling site is a location where spent lead-based batteries, used mainly in automobiles, are processed to recover reusable lead compounds. Some sites consist of battery-breaking/lead-recovery operations only while others add secondary smelting/refining. Waste-acid and battery-casing commonly disposed of on site can contaminate the soil if strict environmental controls are not established (Nedwed and Clifford, 1998). Phytoextraction is a soil remediation technique involving plants that concentrate heavy metals in their shoots, which may be removed from the area by harvest (Nascimento and Xing, 2006). The present work aimed to evaluate the use of a biodegradable (NTA) and a non-degradable chelant (EDTA) for Pb phytoextraction from a soil contaminated by battery-casing disposal.

Materials and Methods

The experiment used a soil collected near an automobile battery recycling facility. The soil was collected from 0-20 cm depth. Soil was air-dried and homogenized (2 mm-mesh) and acidity was corrected for pH between 6.0 and 6.2 using calcium carbonate and magnesium oxide (3:1 molar ratio). Two maize plants were grown in plastic pots with 2 dm$^3$ soil. Pots were daily irrigated with distilled water maintaining soils at approximately 80% of water holding capacity. For assisting Pb phytoextraction, two synthetic chelant agents (EDTA and NTA) were applied to soil in the concentrations: 0, 2, 5, 10, and 20 mmol kg$^{-1}$ at the 30th day after planting. Plants were harvested 8 days after chelants application. Phytoextraction efficiency was evaluated by Pb net removal: Removal = Pb$_{shoots}$ x DM / 1000 where, Pb$_{shoots}$ = Pb Shoot concentration (mg kg$^{-1}$) and DM = dry matter production (g pot$^{-1}$).

Experimental design was delineated as random blocks, factorial scheme, using two synthetic chelants and five concentrations with three replicates. Data obtained were submitted to analyses of variance. Regression equations were chosen to evaluate the chelant doses effect based on the significance of parameters and higher $R^2$.

Results and Discussion

Both EDTA and NTA significantly increased the Pb concentration in shoots and roots of the maize plants. EDTA was significantly more efficient than NTA in increasing metal concentration in shoots (Figure 1). EDTA addition is regarded as the most effective technique for enhancing Pb phytoextraction (Nascimento et al. 2006, Vaxevanidou et al. 2008).
NTA doses increased in 9, 19, 22, and 32 times the Pb concentration in the maize shoots biomass. The 5 mmol kg$^{-1}$ EDTA concentration was the only one efficient on Pb translocation once the shoot/root ratio was superior to 1, increasing to 1.1% the metal accumulation in the shoot. The application of 5 mmol kg$^{-1}$ of NTA and EDTA removed roughly 50 and 100 mg Pb pot$^{-1}$, respectively. This result indicates that 20 and 10 successive cultivations, respectively, would be necessary to remove all the Pb from the soil pot. Taking into account that there are four maize growing seasons per year in the field, the time required to completely clean up the site would be 5 years using NTA. Given the guidelines for Pb concentration in agricultural soils used in Brazil (72 mg kg$^{-1}$), the time necessary to phytoremediate the site by using 5 mmol kg$^{-1}$ NTA could be less than five years.

Phytoextraction efficiency must be seen as a combination of high enough metal concentration in the shoots and high biomass. This implies a high net metal removal from soil. The EDTA and NTA doses promoted linear increase on the net removal of Pb from soil (Figure 2). EDTA and NTA increased the Pb removal up to 229 and 99 mg pot$^{-1}$, respectively. EDTA poses a higher stability constant for Pb (log $K_s = 17.88$) than NTA (log $K_s = 12.27$) (Quartacci et al. 2007). This fact, along with the high ability of EDTA to boost the root-to-shoot Pb transfer, can explain the success of EDTA in enhancing Pb phytoextraction (Blaylock et al. 1997). However, the use of EDTA in field conditions has been severely criticized due to the inherent risk of metal leaching (Meers et al. 2005).

Conclusions

The use of synthetic chelants EDTA and NTA was effective for enhancing the Pb phytoextraction from a battery recycling site soil. For this reason, results of the study indicate that phytoremediation of the Pb contaminated soil using 5 mmol kg$^{-1}$ of NTA could be feasible in less than a 5-year period.
Figure 2. Pb net removal by maize shoots in a soil treated with crescent doses of EDTA and NTA chelants ( ◆ Pb-EDTA ■ Pb-NTA).

References


