Effects of EDTA on solubility of cadmium, zinc, and lead and their uptake by rainbow pink and vetiver grass

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Abstract

Rainbow pink (*Dianthus chinensis*), a potential phytoextraction plant, can accumulate high concentrations of Cd from contaminated soils. Vetiver grass (*Vetiver zizanioides*) has strong and long root tissues and is a potential phytostabilization plant since it can tolerate and grow well in soils contaminated with multiple heavy metals. Soil was moderately artificially contaminated by cadmium (20 mg/kg), zinc (500 mg/kg), and lead (1000 mg/kg) in pot experiments. Three concentrations of Na₂-EDTA solution (0, 5, and 10 mmol/kg soil) were added to the contaminated soils to study the influence of EDTA solution on phytoextraction by rainbow pink or phytostabilization by vetiver grass. The results showed that the concentrations of Cd, Zn, and Pb in a soil solution of rainbow pink significantly increased following the addition of EDTA ($p < 0.05$). The concentrations of Cd and Pb in the shoots of rainbow pink also significantly increased after EDTA solution was applied ($p < 0.05$), but the increase for Zn was insignificant. EDTA treatment significantly increased the total uptake of Pb in the shoot, over that obtained with the control treatment ($p < 0.001$), but it did not significantly increase the total uptake of Cd and Zn. The concentrations of Zn and Pb in the shoots of rainbow pink are significantly correlated with those in the soil solution, but no relationship exists with concentrations in vetiver grass. The toxicity of highly contaminating metals did not affect the growth of vetiver grass, which was found to grow very well in this study. Results of this study indicate that rainbow pink can be considered to be a potential phytoextraction plant for removing Cd or Zn from metal-contaminated soils, and that vetiver grass can be regarded as a potential phytostabilization plant that can be grown in a site contaminated with multiple heavy metals.
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1. Introduction

Phytoremediation is the use of plants to remediate organic, inorganic or nuclear pollutants in contaminated sites. Phytoremediation techniques include phytoextraction, phytostabilization, phytovolatilization, phytodegradation and phytofiltration (Salt et al., 1995; Chaney et al., 1997; Lombi et al., 1998; Wenzel et al., 1999; Garbisu and Alkorta, 2001). Of these techniques,

phytoextraction and phytostabilization are used to remediate inorganic-contaminated soil, especially soil contaminated by heavy metals. Phytoextraction accumulates toxic metals from contaminated soil into the aboveground tissue of higher plants, which are then harvested and incinerated and/or buried (Kumar et al., 1995; Chaney et al., 1997; Wenzel et al., 1999; Garbisu and Alkorta, 2001). Phytostabilization uses the dense root system of the plant to physically stabilize the contaminated soil, protecting against erosion by wind and water, thereby reducing the risk to the environment by the leaching of pollutants into groundwater (Salt et al., 1995; Chaney et al., 1997; Garbisu and Alkorta, 2001; Pulford and Watson, 2003).

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Over 400 plant species of hyperaccumulators from all over the world can accumulate high concentrations of metals at contaminated sites (Baker et al., 2000), but many of them have a low growth rate and very low biomass; they therefore need much time to remove contaminants from soils. Two strategies, one involving chelating agents and the other involving genetic engineering, are being developed to increase the phytoextraction of metals with higher biomass or by transgenic plants. Synthesized chelating agents, such as ethylenedinitrilotetraacetic acid (EDTA), diethylenetrinitriropentaacetic acid (DTPA), hydroxyethylenediaminetriacetic acid (HEDTA), trans-1,2-cyclohexylenedinitrilotetraacetic acid (CDTA), and ethylenebis(oxyethylenetrinitrilo)tetraacetic acid (EGTA), were applied to metal-contaminated soil to increase the mobility and bioavailability of the metal in the soils and also to increase the amount of heavy metals accumulated in the upper parts of plants (Huang and Cunningham, 1996; Blaylock et al., 1997; Huang et al., 1997; Ebbs and Kochian, 1998; Wu et al., 1999). These results revealed that adding synthetic chelating agents can increase both the solubility of metal in soil solution and the concentration of metal in the shoots of plants. However, in soils contaminated with multiple metals, the application of synthetic chelating agents can reduce both the biomass of the plant and the total amount of metal removed because the high concentrations of other metals in the soil solution are toxic to the plant (Chen and Cutright, 2001; Lombi et al., 2001). Synthetic chelating agents at high concentrations can also be toxic to plants (Cooper et al., 1999). Applying synthetic chelating agents to soils contaminated by multiple metals represents another challenge for chemical enhancement of the phytoextraction by plants grown on contaminated sites.

Using garden plants to remove metals from contaminated soils is a popular and satisfactory strategy, because it recovers the contaminated sites to their natural condition and also generates economic value if appropriate flower species are cultivated. Chen and Lee (1997) reported that when rainbow pink was grown in a contaminated site in northern Taiwan for five weeks, the Cd concentration in the shoot of the plant increased from 1.56 (under the control treatment) to 115 mg/kg, and the total Cd total uptake was about 100 g/ha/yr. These findings showed that this plant can accumulate a high concentration of Cd. Moreover, the accumulated Cd concentration can reach the threshold (100 mg Cd/kg) of a hyperaccumulator of Cd (Baker et al., 2000).

Vetiver grass (*Vetiver zizanioides*) is a fast-growing plant that tolerates various environments, including soil pH values between 3.0 and 10.5 and temperatures from 14 to 55 °C. It also effectively controls erosion of soil by water (NRC, 1993; Truong et al., 1995). In soils contaminated with multiple elements, high concentrations of heavy metals do not affect the plant's growth

(Roongtanakiat and Chairaj, 2002). In previous study, from 250 to 750 mg Pb/kg accumulated in the shoots of vetiver grass when the grass was grown in Pb-contaminated sandy loam soil, but a high concentration of Pb reduced the growth, biomass, and total chlorophyll content of the plant (Chantachon et al., 2002).

The objectives of this study are (i) to identify the effects of adding EDTA on the concentration of heavy metals in soil solution when rainbow pink and vetiver grass are grown in artificially polluted soils contaminated with Cd, Zn, and Pb in the soils of northern Taiwan, and (ii) to evaluate the effect of adding EDTA on the phytoextraction of rainbow pink and on the phytostabilization of vetiver grass.

2. Materials and methods

2.1. Characteristics of pot-tested soils

A rural soil, artificially contaminated by Cd, Zn, and Pb, was used in the pot experiments. The soil's pH value was determined using glass electrodes in a soil to water ratio of 1:1 (McLean, 1982). The soil particle size distribution was analyzed using the pipette method (Gee and Bauder, 1986). Organic carbon content was determined by the Walkley–Black wet combustion method (Nelson and Sommers, 1982). Cation exchange capacity (CEC) was determined using the ammonium acetate method (Rhoades, 1982; Thomas, 1982). The total concentration of Cd, Zn, and Pb in soils were digested by aqua regia and determined by atomic absorption spectrometry (Hitachi 180-30 type) (EPA/ROC, 2002).

2.2. Pre-treatment of the soil

The soil used in this study was collected from a Cd-contaminated site in northern Taiwan. The surface soil (0–20 cm) of the contaminated site was sampled, air-dried, and ground to pass through a 2 mm sieve. It was stored in large plastic bottles for laboratory analysis and pot experiments. Three salt solutions, $\text{Cd}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$, ZnO, and $\text{Pb}(\text{NO}_3)_2$, were added to the air-dried soil to control the total concentration (as individual element concentration) of the three metals at 20 mg Cd/kg, 500 mg Zn/kg, and 1000 mg Pb/kg. The treated soils were wetted for two weeks by adding deionized water to maintain water content of 60% of the total water-holding capacity to enable the added heavy metal salts to reach a steady-state. Then, the soils were dried at room temperature for approximately four weeks. The artificially contaminated soil was subjected to three cycles of wet and dry processes before pot experiments were conducted (Blaylock et al., 1997).

2.3. Pot experiments and laboratory analysis

Each pot contained 3.5 kg (dry weight) of artificially contaminated soil. Two rhizon soil moisture samplers (RSMS) were put in each pot at a depth of around 10 cm below the surface of the soil. Two seedlings of rainbow pink (*Dianthus chinensis*) or ten seedlings of vetiver grass (*Vetiver zizanioides*) were planted in each pot. The pot experiments were conducted in a greenhouse using a randomized complete block design (RCBD) with a number of treatments and three replicates. The soil moisture content was maintained at 60% of the water-holding capacity, by weighing and adding deionized water every two days.

Three concentrations of Na₂-EDTA solution (0, 5, and 10 mmol/kg soil) were added to the contaminated soils after seven days of planting. The growth conditions and observed symptoms of toxicity, displayed by the plants, were also recorded. Tested plants were harvested seven days after the EDTA solution was first added to the pot. The harvested plants were oven-dried at 60 °C for 72 h, weighed, and ground to 0.5 mm for analysis. Then, 0.2 g of the plants were digested by the H₂SO₄/H₂O₂ digestion method (Jones and Case, 1990). The digested solutions were filtered through Whatman No. 42 filter paper, and then diluted with deionized water to a volume of 50 ml in a flask. The Cd, Zn, and Pb concentrations were determined by atomic absorption spectrometry (Hitachi 180-30 type).

Soil solutions were also collected directly by an RSMS before harvesting. The bioavailable concentrations of Cd, Zn, and Pb in contaminated soils were evaluated from the concentrations of heavy metals in the soil solution, which were determined by inductively coupled plasma optical emission spectrometry (ICP-OES) (Perkin–Elmer 2000 DV).

2.4. Statistics

The variance and significance of the differences among concentrations of Cd, Zn, and Pb in the soil solutions and the plants were analyzed by ANOVA. Statistical significance was defined as $p = 0.05$.

3. Results and discussion

3.1. Soil characteristics

Table 1 shows the physical and chemical characteristics of the studied soil. The studied soil texture was silty clay with a moderate cation exchange capacity of 13.9 cmol₍₊₎/kg soil. The original total concentrations of the metals in the contaminated soil, digested by aqua regia, were 2.58 ± 0.08 mg Cd/kg, 80.0 ± 5.32 mg Zn/kg and 31.3 ± 2.09 mg Pb/kg, respectively. After the soil was spiked with salts of heavy metals, the final total concentrations of the elements were 19.0 ± 1.74 mg Cd/kg, 503 ± 44.1 mg Zn/kg, and 931 ± 54.7 mg Pb/kg, respectively.

3.2. Concentrations of metals in soil solution in pot experiments

The results indicated that the Cd, Zn, and especially the Pb concentrations in the soil solution collected from rainbow pink (*Dianthus chinensis*) were simultaneously and significantly increased ($p < 0.05$) by adding 5 or 10 mmol/kg EDTA solution, except for Cd in 10 mmol/kg EDTA treatment (Fig. 1). In previous studies, the application of EDTA solution efficiently increased the soluble or exchangeable fraction of metals which was available to plants (Blaylock et al., 1997; Barona et al., 2001; Chen and Cutright, 2001). The results of this study were similar to those of previous studies. Cd concentrations in the soil solutions did not significantly increase when 10 mmol EDTA/kg soil was applied, perhaps because the high variation of Cd concentrations in the soil solutions after 10 mmol EDTA/kg soils was added. The Pb concentration in the soil solution significantly increased from 5.93 ± 1.27 (in the control treatment) to 90.4 ± 12.5 mg Pb/l (15-fold) and also from 5.93 ± 1.27 to 252 ± 182 mg Pb/l (42-fold) when 5 and 10 mmol of EDTA/kg soils were added, respectively ($p < 0.001$) (Fig. 1c). After 10 mmol EDTA/kg soils had been added for 21 days, Zn and Pb concentrations in the soil solution were approximately double and 30 times those of the control (data not shown). EDTA solution can

Table 1
The physical and chemical properties of studied soil

pH (H ₂ O)	O.C. (g/kg) ^a	Texture	CEC (cmol ₍₊₎ /kg soil) ^b	Metal concentration (mg/kg) ^c		
				Cd	Zn	Pb
4.9	16.9	Silty clay ^d	13.9	2.58 ± 0.08	80.0 ± 5.32	31.3 ± 2.09

^a O.C.: organic carbon.

^b CEC: cation exchangeable capacity.

^c The total content of Cd, Zn, and Pb in the original soil was digested by aqua regia.

^d Sand 14.2%, silt 46.2%, and clay 39.6%.

Fig. 1. The concentrations of: (a) Cd; (b) Zn and (c) Pb in the soil solution of rainbow pink, which was sampled at the 0 day and 14th day after planting with the different concentrations of EDTA treatments. The probability level of significant difference is at $p = 0.05$ ($n = 3$).

remain in the soil for a long period. Lombi et al. (2001) found that EDTA can be found in the soil pore water five months after EDTA solution is applied. This study, however, finds that the three heavy metals can remain in soil solution for more than 21 days after 10 mmol/kg of EDTA is added, showing also that EDTA treatment can increase the mobility of metals in the contaminated soils. This finding also implies a potential risk of polluting groundwater when EDTA is used to mobilize metals in contaminated sites.

Fig. 2. The concentrations of: (a) Cd; (b) Zn, and (c) Pb in the soil solution of vetiver grass, which was sampled at the 0 day and 14th day after planting with the different concentrations of EDTA treatments. The probability level of significant difference is at $p = 0.05$. Replicates (n) = 3.

The vetiver grass (*Vetiver zizanioides*) exhibits the same trends as those obtained in the rainbow pink pot experiments. Adding 5 or 10 mmol EDTA/kg soils can significantly increase the concentration of Cd and Zn in soil solution, and especially that of Pb ($p < 0.05$) (Fig. 2). The concentration of Pb in the soil solution was significantly increased from 5.79 ± 1.34 (in the control treatment) to 322 ± 81.7 mg Pb/l (56-fold) and to 725 ± 160 mg Pb/l (125-fold) when 5 and 10 mmol/kg soil of EDTA solution were added, respectively ($p < 0.05$).

(Fig. 2c). These results indicate that the EDTA solution effectively increased the concentration of metal, especially for Pb, in the soil solution. The findings are consistent with those obtained following the application of EDTA treatments in other studies of contaminated soils (Blaylock et al., 1997; Huang et al., 1997; Wu et al., 1999; Luo et al., 2000; Chen and Cutright, 2001; Lombi et al., 2001). The differences of the chelating effects between EDTA and metals are reflected by the formation constant ($K_f = 19.0$) of the Pb–ligand complexes, which exceeds those of the Cd–ligand complexes ($K_f = 17.4$) and the Zn–ligand complexes ($K_f = 17.5$) (Martell and Smith, 1974, 1982).

3.3. Effects of EDTA treatments on uptake of metals by rainbow pink

The concentration of Cd in the shoots of rainbow pink was significantly increased after 10 mmol/kg of EDTA solution was added ($p < 0.05$) (Fig. 3a). The Zn concentration in the shoots of plants also increased from around 700 ± 132 mg/kg to 1200 ± 369 mg/kg ($p > 0.05$) (Fig. 3b). The Pb concentration in the plants was not detectable (ND, below detection limit) when no EDTA treatment was applied. However, seven days after 5 or 10 mmol/kg of EDTA solution was added, the Pb concentration in the shoots of rainbow pink had increased significantly from ND to 243 ± 61.3 or 348 ± 101 mg/kg, respectively ($p < 0.05$) (Fig. 3c). Lead appears to form the Pb–EDTA complex, which is available for uptake by plants after EDTA is applied (Vassil et al., 1998). Barona et al. (2001) also pointed out that Pb remained weakly adsorbed to soil components after EDTA solution was applied. Because of the high value of formation constant ($K_f = 19.0$) of the Pb–ligand complexes (Martell and Smith, 1974, 1982), the Pb–EDTA complex more easily formed after EDTA solution is applied, so the uptake of Pb by rainbow pink is enhanced. The results of this study indicate that EDTA solution enhances the removal of Pb from contaminated soil and also the accumulation of Pb in the shoots, which results are consistent with those of previous studies (Blaylock et al., 1997; Huang et al., 1997; Wu et al., 1999; Chen and Cutright, 2001; Jarvis and Leung, 2001; Lombi et al., 2001; Jarvis and Leung, 2002).

After 5 or 10 mmol/kg of EDTA solution was applied, no significant influence on the biomass of rainbow pink was observed ($p > 0.05$). The mean dry biomasses of rainbow pink following 0, 5, and 10 mmol/kg EDTA treatment were 4.91 ± 0.93 , 5.35 ± 0.56 , and 4.08 ± 0.70 g/plant, respectively. With respect to the enhancement of phytoextraction by rainbow pink in metal-contaminated soils, adding 5 or 10 mmol/kg of EDTA solution did not significantly increase the total removal of Cd and Zn from the contaminated soil ($p > 0.05$) (Fig. 4a and b); however, the increase was significant for the removal of

Fig. 3. The concentrations of (a) Cd, (b) Zn, and (c) Pb in the shoots of rainbow pink, which was harvested at the 14th day after planting with the different concentrations of EDTA treatments. The probability level of significant difference is at $p = 0.05$. Replicates (n) = 3.

Pb ($p < 0.001$) (Fig. 4c). The total removal of Pb by the rainbow pink obtained by adding 5 mmol/kg of EDTA solution did not differ significantly from that obtained by adding 10 mmol/kg of EDTA solution (Fig. 4c). We propose that rainbow pink is a potential phytoextraction plant for removing Cd or Zn from metal-contaminated soil without applying any amendment. The amount removed per harvest is around 0.13 ± 0.05 mg Cd/plant, 3.49 ± 1.37 mg Zn/plant, and trace Pb/plant (Fig. 4). We also propose that Pb in contaminated soil is not

Fig. 4. The total uptake of: (a) Cd; (b) Zn and (c) Pb in the shoots of rainbow pink, which was harvested at the 14th day after planting with the different concentrations of EDTA treatments. The probability level of significant difference is at $p = 0.05$. Replicates (n) = 3.

available to rainbow pink, but adding 5 mmol/kg of EDTA solution significantly increases the bioavailability of Pb in contaminated soil. Treatment with 5 or 10 mmol/kg of EDTA solution can promote the removal of Pb by rainbow pink, far in excess of that obtained from the control treatment in this study. Therefore, further study must be undertaken to identify the critical concentration of EDTA solution between 0 to 5 mmol/kg, to remove a significant amount of Pb from the contaminated soil.

Fig. 5. The concentrations of: (a) Cd and (b) Zn in the shoots of vetiver grass, which was harvested at the 14th day after planting with the different concentrations of EDTA treatments. The concentration of Pb in the shoot is not detectable (ND). The probability level of significant difference is at $p = 0.05$. Replicates (n) = 3.

3.4. Effects of EDTA treatments on metal uptake by vetiver grass

Although the concentrations of Cd, Zn, and Pb in a solution, in which vetiver grass was planted, changed greatly after EDTA solution was added (Fig. 2), the concentration of Cd in the shoots of the vetiver grass did not significantly increase, ranging from 20 to 30 mg/kg (Fig. 5a). The concentration of Zn in the shoot, ranging from 390 to 520 mg/kg, was significantly increased only by adding 5 mmol/kg of EDTA solution ($p < 0.05$) (Fig. 5b). Adding 10 mmol/kg EDTA solution did not increase the Zn concentration in the shoots of vetiver grass, and the biomass of the vetiver grass decreased from 0.91 ± 0.04 g/plant (0 mmol/kg of EDTA added) to 0.73 ± 0.10 g/plant (10 mmol/kg of EDTA added) ($p > 0.05$). We proposed that the toxicity of metals, resulting from their increased concentration in the soil solution, reduced the concentration of Zn in the shoots of vetiver grass, but no significant symptoms of toxicity were observed in the pot experiments. Vetiver grass did

not take up lead in the soil solution, even though the concentration of Pb in the soil solution increased greatly after EDTA solution was added. The concentration of Pb in the shoots of vetiver grass was undetectable (ND, under the detection level) following any treatment (data not shown in Fig. 5). We suppose that this species of vetiver grass cannot take up or accumulate the Pb in its shoot although the concentration of Pb in soil is as high as 1000 mg/kg. This result also indicates that the growth of vetiver grass is unaffected by the toxicity of the three contaminant metals in the soil in this case study because no symptoms of phytotoxicity were observed. Applying 0, 5, and 10 mmol/kg of EDTA solution only slightly decreased the biomass of vetiver grass from 0.91 ± 0.04 g/plant to 0.80 ± 0.20 and 0.73 ± 0.10 g/plant, respectively ($p > 0.05$). The total removal of heavy metals from the contaminated soils was only around 0.015 mg Cd/plant and around 0.30 mg Zn/plant after different concentrations of EDTA were added ($p > 0.05$) (Fig. 6).

3.5. Relationships between metal concentrations in plants and those in soil solution

The concentrations of heavy metals in the soil solution extracted by different extractors or directly sampled by RSMS can predict the concentrations in the shoot of plants (Kabata-Pendias et al., 1993; Parkpian et al., 2002). The analysis of data in this study yields correlation coefficients (R^2) between the concentrations of three metals in the soil solution and those in the shoots of rainbow pink of 0.23 (Cd, $p > 0.05$), 0.50 (Zn, $p < 0.01$) and 0.91 (Pb, $p < 0.001$) (Fig. 7). These results indicate that significant relationships exist between the concentrations of Zn and Pb in the soil solution and those in the shoots of rainbow pink. For vetiver grass, even though the concentrations of Cd and Zn in soil solution increased dramatically after the EDTA solution was added, the concentrations of Cd and Zn taken up by the shoot were not changed, ranged from 20 to 30 mg Cd/kg and ranged from 390 to 520 mg Zn/kg, respectively ($p > 0.05$) (Fig. 8). Roongtanakiat and Chairroj (2002) found that vetiver grass could take up 2.9 mg Cd/kg soil and 253.8 mg Zn/kg soil when it was planted in metal-contaminated soil. The concentrations of Cd and Zn taken up in this study were much higher than those obtained by Roongtanakiat and Chairroj (2002), implying that this species of vetiver grass is resilient to Cd and Zn.

4. Conclusion

EDTA solution is considered to be a chelating agent that promotes the solubility of metals in contaminated sites. The application of EDTA solution can significantly increase concentrations of Cd, Zn, and especially

Fig. 6. The total uptake of (a) Cd and (b) Zn in the shoots of vetiver grass, which was harvested at the 14th day after planting with the different concentration of EDTA treatments. The concentration of Pb in the shoot is not detectable (ND). The probability level of significant difference is at $p = 0.05$. Replicates (n) = 3.

Pb in soil solution moderately contaminated by these three metals ($p < 0.05$). Except in the case of the high variation of Cd concentration in the soil solution of rainbow pink after 10 mmol/kg of EDTA solution is added, applying EDTA solution at a high concentration (10 mmol/kg) increases the concentration of the metals in the soil solution more than is obtained by applying EDTA at a lower concentration (5 mmol/kg), but the EDTA solution may contribute to the pollution of the groundwater.

Adding EDTA solution efficiently and significantly increases the concentrations of Cd and Pb in the shoots of rainbow pink. Treatment with 5 mmol/kg of EDTA solution significantly increases the concentration of Zn only in the shoots of the vetiver grass ($p < 0.05$). Adding EDTA solution also significantly increases the total removal of Pb by rainbow pink ($p < 0.001$), but did not affect the total removal of Cd, Zn, and Pb by vetiver grass.

The results of this study indicate that the concentrations of Zn and Pb in soil solution are significantly related

Fig. 7. The relationship between the concentrations of: (a) Cd; (b) Zn and (c) Pb in the soil solution and in the shoot of rainbow pink, which was harvested at the 14th days after planting.

to those in the shoots of rainbow pink after treatment with EDTA solution. For vetiver grass, even though the concentrations of Cd, Zn, and Pb in the soil solution increased, the concentrations of the metals in the shoots did not change, except for that of Zn, following treatment with 5 mmol/kg of EDTA solution. Because the concentrations of Cd and Zn in the shoot were not significantly changed in both 5 and 10 mmol/kg of EDTA treatments expected for Zn in the 5 mmol/kg EDTA treatment, and the concentration of Pb was not detected among all the treatments. Therefore, the concentrations of Cd, Zn, and Pb in soil solution could not predict the concentrations of metals in the shoots of vetiver grass in this study.

Rainbow pink can accumulate high concentrations of Cd and Zn in its shoot naturally even when no EDTA solution is added. However, in this study, the accumulated concentrations of the metals in the shoots are not as high as those reported in a previous study (Chen and Lee, 1997) because of the short period of growth (14 days). Treatment with EDTA solution specifically promoted the uptake of Pb in the contaminated soil in this

Fig. 8. The relationship between the concentrations of: (a) Cd and (b) Zn in soil solution and in the shoot of vetiver grass, which was harvested at the 14th day after planting. The concentration of Pb in the shoot is not detectable (ND).

study. Further studies must be conducted to increase the period of growth of rainbow pink before EDTA treatment and also to increase the concentrations of metals accumulated.

The results of this study indicate that rainbow pink is a potential phytoaccumulator of Cd and Zn from metal-contaminated soil. We suggest that Pb is not accumulated in rainbow pink, but that adding EDTA solution can significantly increase the concentration of the Pb in the soil solution and thus its bioavailability in contaminated soil. This study demonstrates that vetiver grass is a potential phytostabilization plant at sites contaminated with several metals.

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