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Phytoremediation of Cadmium and Lead contaminated soil types by Vetiver grass

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Abstract. Phytoremediation is an alternative technology to remove heavy metals in contaminated soil. Vetiver grass (*Vetiveria zizanioides* (Linn.) Nash) was used for Cadmium (Cd) and Lead (Pb) removal experiments in 4 various soil types: (S1) sandy soil with abundant organic matter; (S2) sandy soil with poor organic matter; (S3) clay soil with abundant organic matter; (S4) clay soil with poor organic matter. Plants were grown for 30 days before transferring to experimental pots. $Pb(NO_3)_2$ solution was added to the soil types in each experimental pot at 0, 100, 300 and 700ppm; similarly $CdCl_2$: 0, 10, 30 and 60ppm. Plants were observed for their growth and harvested after 3 months. Cd and Pb accumulation in roots and shoots was analyzed. The results showed that Vetiver grass grew in 4 various soil types. The statistical analysis indicated that vetiver's uptake ability of Cd and Pb increase as the level of Pb, Cd in various soil types increase. Cd accumulation rates between shoots and roots of vetiver grass were fairly low (<13.32%); on the contrary, the accumulation rates of Pb shoot/ root is very high (9.72%-88.14%). Therefore, vetiver grass can use to phytoextration of Pb and phytostabilization of Cd.

Keywords: Phytoremediation; Vetiver; Cadmium; Lead; Contaminated soil.

1. Introduction

Heavy metal contamination is caused by various sources, such as industrial processes, manufacturing, disposal of industrial and domestic refuse, and agricultural practices. Phytoremediation is considered an innovative, economical, and environmentally compatible solution for remediating some of heavy metal contaminated sites [3,4]. The main factors controlling the ability of phytoremediation are plant species, metal availability to plant roots, metal uptake by roots, metal translocation from roots to shoots and plant tolerance to toxic metals. There are many types of plants currently used in phytoremediation, such as *Thlaspi carerulescens, Alyssum murale, A. lesbiacum, and A. tenium*. However, the remediation potential may be limited due to the slow growth and low biomass of these plants.

Recently phytoremediation researchers have discovered that vetiver grass (*Vetiveria zizanioides* (Linn.) Nash) can accumulate high levels of metals. The metal accumulating ability of this plant, coupled with metal tolerance and high shoot biomass, makes this plant ideal for

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phytoextraction (Randloff et al., 1995; Knoll, 1997; Truong and Baker, 1998; Chen, 2000) [2, 5-7]. Vetiver grass has been widely known for it effectiveness in erosion and sediment control (Truong et al., 1995). In Australia, vetiver grass was used to stabilize landfill and industrial waste sites contaminated with heavy metals such as As, Cd, Cr, Ni, Cu, Pb and Hg (Truong and Baker, 1998). In China, vetiver grass was planted in a large scale for pollution control and mine tail stabilization (Chen, 2000) [2].

In Vietnam, vetiver grass has been successfully for erosion control and slope stabilization. However, to the best of our knowledge, the study on phytoextraction of heavy metal by vetiver grass is still lacking. Hence, the objectives of this research were to investigate phytoremediation of Cd and Pb in various soil types.

2. Materials and methods

2.1. Soil and Plant Preparation

Soil samples were collected from top soils. It was air-dried and thoroughly mixed before use. Physical and chemical properties (*i.e.*, soil texture, soil pH, organic matter, total nitrogen, total phosphorus and potassium) were analyzed (Table 1). Initial Cd and Pb content in the soil were analyzed prior to the experiment. Four soil types were used in the experiment: (S1) the sandy soil with abundant organic matter; (S2) the sandy soil with poor organic matter; (S3) the clay soil with poor organic matter; and (S4) the clay soil with abundant organic matter.

(a) S1: Garden soil adding muck was sampled in the No. 10 Hoa Minh ward, Lien Chieu district, Danag city.

(b) S2: Garden soil without muck was sampled in the No. 10 Hoa Minh ward, Lien Chieu district, Danag city.

(c) S3: Hill soil was sampled in the North of Hoa Khanh ward, Lien Chieu district, Danag city.

(d) S4: Ricefield soil was sampled in Dien Hoa commune, Dien Ban district, Quang Nam province.

The experiment was conducted in greenhouse at Bio-experimental House, the faculty of Biology & Environmental Science, The University of Education – Danang University. The experimental pot was plastic with 25 cm upper diameter, 20 cm lower diameter and 35 cm height. The experimental pots were set up by adding 10 kg of soil sample into each pot. Further culling was done to obtain 5 plants in each pot. The vetiver grass were planted in 4 different Pb concentrations (0, 100, 300 and 700 ppm) and 4 different Cd concentrations (0, 10, 30 and 60ppm). After 1 month of growth, lead nitrate ($Pb(NO_3)_2$) and Cadmium chlorinate ($CdCl_2$) solutions were added and 3 replicates were done for each composition. The experimental pots were arranged in a way that a Completely Randomized Block Design could be conducted. Physical changes of plants in each pot were observed daily.

Table 1. The physical and chemical properties of soil studied

Parameters	Unit	Soil types			
		S1	*S2*	*S3*	*S4*
Total Nitrogen	%	0.033	0.003	0.075	0.004
Total phosphorus	%	0.025	0.021	0.065	0.037
K_2O_5	%	0.382	0.214	0.964	0.999
pH		5.360	4.760	6.280	4.417
CHC	%	6.90	0.60	3.59	0.39
Pb	ppm	2.625	3.400	6.775	5.675
Cd	ppm	0.069	0.071	0.191	0.08

2.2. Pb, Cd analyzation in plants and soils

Plants were harvested after 3 moths of plantation. Each plant was rinsed, cut, and group selected into shoots and roots. Each part was dried in an oven at 65^{o}C for 72 hours. Both wet and dry weights were recorded. All dried parts were ground using mortar, mixed thoroughly, and digested with HNO_3. Sample solutions were analyzed for Cd and Pb by flame atomic absorption on a Spectrophotometer. The soil was air-dried and digested with HNO_3. Analysis of Cd and Pb was conducted by the same procedure described above [1].

2.3. The Efficiency of Pb, Cd Removal

The Efficiency of Pb, Cd Removal was calculated using the equation below:

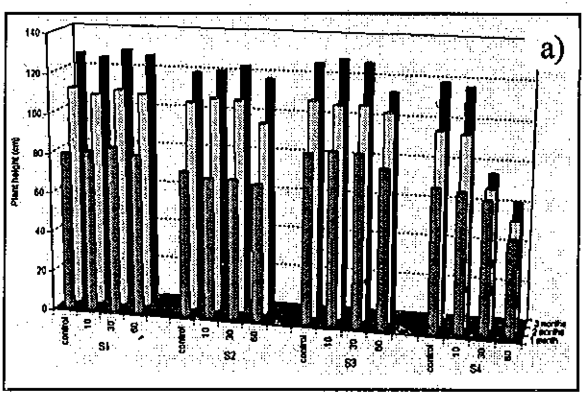
$$\text{Efficiency of Pb, Cd removal (\%)} = \frac{\text{(Pb /Cd in shoots + Pb/Cd in roots) (mg) x100}}{\text{Total Pb/Cd in pot (mg)}}$$

Then, data were statistically analyzed using analysis of variance and Duncan's multiple range tests for mean comparison. A probability level of $P<0.05$ was considered for significant difference.

3. Results and discussion

3.1. Growth observation

During the experimental period, all vetiver grass survied under all conditions of Pb, Cd concentration in soils. There was an increase in plant height until harvest at three months after Pb, Cd were added (Fig. 1).



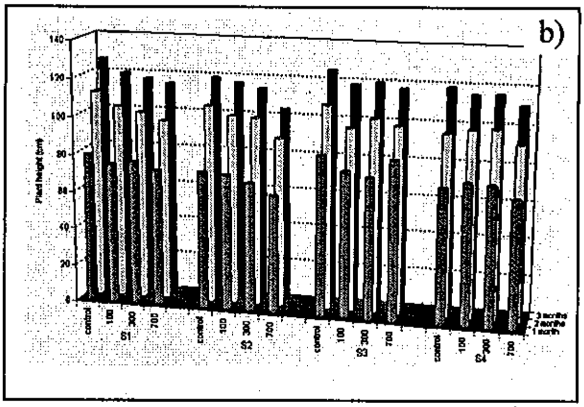


Fig. 1. Height (cm) of vetiver grass planted in soil types contaminated with Cd/Pb added in 4 levels, taken at 1, 2 and 3 months after application.

In addition, the vetiver grass grew best in the sand soil with abundant organic matter (S1) and worst in the clay soil with poor organic matter (S4).

From statistical analysis, it was found that the vetiver grass could grow well even on soils contaminated with Cd and Pb. It might be concluded that Pb/Cd in soil even at the level above critical value to plant growth has no negative effect on vetiver growth. This finding is similar to the results of Truong (1999), Roongtanakiat and Chairoj (2001). It was confirmed that vetiver grasses are highly tolerant, and thus could grow in highly Pb-contaminated soils.

3.2. Cd and Pb accumulation in plant

The results showed that a vetiver could take up more amounts of Cd and Pb when there are plenty of Cd and Pb in 4 soil types (Table 2 and Fig. 2). There was significant difference among soil types regarding Vetiver's accumulation of Cd and Pb. Vetiver's accumulation ability of Cd and Pb in shoot and root in various soil types descending S1>S2>S3>S4. Surprisingly, the S3 gave high growth but lowest Cd and Pb accumulation compared to those of the other three soil types. These finding suggested that the soil type could cause the difference in Cd and Pb accumulation in vetiver plants. Alloway (1997), Baker and Senft (1997) reported that plant species as well as cultivars differ widely in their uptake ability and accumulation of heavy metals.

The average highest heavy metal concentrations in shoot of vetiver grass for Cd and Pb were 2.95ppm and 74.65ppm, respectively. They were lower than the toxic threshold levels (Truong, 1999). In vetiver roots, vetiver grass could accumulate the highest amount of Cd and Pb at the highest Cd and Pb level in soil group S1 and S4. The average highest Cd and Pb concentrations in roots of vetiver grass were 43.24ppm and 85.71ppm, respectively.

Comparing the distribution of Cd and Pb concentration in the parts of vetiver grass, Cd and Pb was found to accumulate more in roots than in shoots. However, Pb was translocated more to shoot (the accumulation rate in shoot/root is from 9.92% to 87.94%) while Cd was accumulated more in root (the accumulation rate in shoot/root is form 1.85% to 13.32%).This finding is similar to the results of Truong (1999) and Roongtanakiat et. al. (2002) [5, 8]. They found that a small amount of Cd and a moderate proportion of Pb were translocated to the shoot.

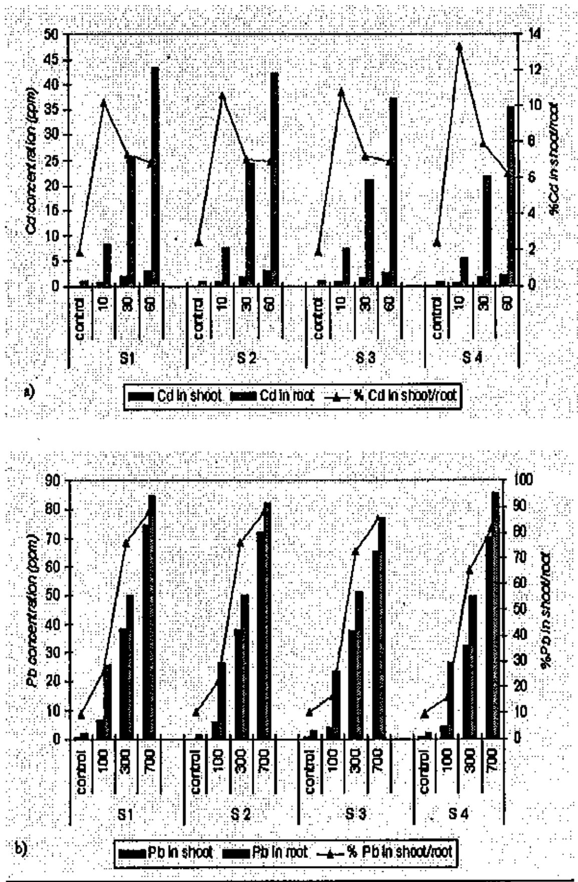


Fig. 2. Concentration of Cd (a) and Pb (b) in shoot and root of vetiver planted in soil types contaminated with Pb, Cd added in 4 levels

Table 2. Concentrations of Cd and Pb in the shoots and roots of vetiver grass planted in 4 various soil types with Pb, Cd in 4 levels

Heavy metal	Soil types	Cd/Pb levels (ppm)	Cd/Pb in shoot (ppm)		Cd/Pb in root (ppm)		% Cd/Pb in shoot /root
			M	±Sd	M	±Sd	
Cd	S1	control	0.02	±0.003[a]	1.08	±0.005[a]	1.85
		10	0.87	±0.019[b]	8.54	±0.040[b]	10.19
		30	1.87	±0.010[c]	25.59	±0.625[c]	7.31
		60	2.95	±0.006[d]	43.24	±1.034[d]	6.82
	S 2	control	0.02	±0.003[a]	0.81	±0.019[a]	2.47
		10	0.8	±0.009[b]	7.56	±0.065[b]	10.58
		30	1.71	±0.014[c]	24.35	±0.571[c]	7.02
		60	2.93	±0.025[d]	42.34	±0.482[d]	6.92
	S 3	control	0.02	±0.005[a]	1.07	±0.014[a]	1.87
		10	0.79	±0.003[b]	7.31	±0.157[b]	10.81
		30	1.52	±0.020[c]	21.09	±0.920[c]	7.21
		60	2.58	±0.011[d]	37.24	±1.519[d]	6.93
	S 4	control	0.02	±0.002[a]	0.82	±0.013[a]	2.44
		10	0.71	±0.013[b]	5.33	±0.068[b]	13.32
		30	1.7	±0.011[c]	21.62	±0.836[c]	7.86
		60	2.2	±0.007[d]	35.31	±1.826[d]	6.23
Pb	S1	control	0.2	±0.01[a]	2.04	±0.16[a]	9.80
		100	6.55	±0.14[b]	25.52	±1.19[b]	25.67
		300	38.23	±0.73[c]	50.29	±0.97[c]	76.02
		700	74.65	±0.68[d]	84.69	±1.17[d]	88.14
	S 2	control	0.13	±0.01[a]	1.31	±0.30[a]	9.92
		100	5.93	±0.09[b]	26.32	±2.05[b]	22.53
		300	38.02	±0.47[c]	50.11	±0.54[c]	75.87
		700	72.27	±0.89[d]	82.18	±2.88[d]	87.94
	S 3	control	0.26	±0.03[a]	2.59	±0.22[a]	10.04
		100	3.93	±0.09[b]	23.30	±1.20[b]	16.87
		300	37.46	±1.52[c]	51.51	±1.43[c]	72.72
		700	65.64	±1.33[d]	76.96	±1.48[d]	85.29
	S 4	control	0.21	±0.02[a]	2.16	±0.08[a]	9.72
		100	4.32	±0.33[b]	26.32	±0.97[b]	16.41
		300	32.48	±1.02[c]	49.78	±1.02[c]	65.25
		700	70.08	±0.30[d]	85.71	±0.81[d]	81.76

Note: The same letters on the same corner means that there is no significant difference at 95% confidence level.

3.3. The Efficiency of Cd and Pb Removal

In general, the removal of Cd and Pb from contaminated soil was correlated with more Cd and Pb accumulation by roots and shoots of plants (*Table 3*). The present study indicated that the Pb removal efficiency of Vetiver grass was very low (the highest efficiency was 0.26%). On the contrary, the Cd removal efficiency of Vetiver grass was quite high (the highest efficiency was 0.72%). The highest efficiency of Cd and Pb removal of vetiver grass were at 100ppm in soil group S1 (table 2). The Cd and Pb removal efficiency of Vetiver grass in 4 various soil types descending S1>S2>S3>S4. These finding suggested that the soil type could cause the difference in Cd and Pb distribution in vetiver grass as well as the removal efficiency.

Table 3. Efficiency of Cd and Pb removal of Vetiver grass planted in soil types contaminated with Pb, Cd added in 3 levels

Heavy metal	Cd/Pb levels (ppm)	Soil types S1	S2	S3	S4
Cd	10	0.72	0.62	0.60	0.44
	30	0.69	0.64	0.56	0.53
	60	0.58	0.54	0.44	0.39
Pb	100	0.26	0.24	0.19	0.22
	300	0.23	0.22	0.21	0.19
	700	0.18	0.16	0.14	0.15

4. Conclusion

The vetiver grass had a high tolerance to Cd and Pb. It can grow in various soil types (sand and clay; abundant and poor organic matter) with high Cd and Pb levels in soil (Cd: 10 - 60ppm, over Vietnam's standard -TCVN 7209-2002- from 5 to 30 times; Pb: 100 – 700ppm, over Vietnam's standard -TCVN 7209-2002- from 1.5 to 10 times). The heavy metal accumulation between shoots and roots of Vetiver grass for Pb was quite high (9.92 – 87.94%); in contrary, for Cd was very low (<13.32%). Therefore, the important implication of these findings is that vetiver can be used for phytoextraction of Pb and phytostabilization of Cd on sites contaminated with high levels of heavy metals.

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