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Phytoremediation potential of indigenous plants from Thai Nguyen province, Vietnam

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Abstract

This study was focused on determining Arsenic (As), Lead (Pb), Cadmium (Cd) and Zinc (Zn) in 33 indigenous plants and 12 soil *in-situ* plant samples in Thai Nguyen Province, Vietnam. The results showed that the soils of surveyed mining areas contained 181.2- 6754.3 mg kg^{-1} As, 235.5-4337.2 mg kg^{-1} Pb, 0.8- 419 mg kg^{-1} Cd and 361.8-17565.1 mg kg^{-1} Zn depending on the characteristics of each mining site. These values are much higher than those typical for normal soil. The heavy metal uptake into shoots and roots of 33 indigenous plant species was also determined. Two species of the plants investigated, *Pteris vittata* L. and *Pityrogramma calomelanos* L. were As hyperaccumulators, containing more than 0.1% heavy metals in their shoots. *Eleusine indica* L., *Cynodon dactylon* L., *Cyperus rotundus* L. and *Equisetum ramosissimum* (Vauch) accumulate very high Pb (0.15-0.65%) and Zn (0.22-1.56%) concentration in their roots. Additional experiments to clarify the potential of six these plants as good candidates for phytoremediation of heavy metal pollution soil are being carried out in our laboratory.

Key words

Heavy metal, Soil pollution, Hyperaccumulator, Indigenous plants, Phytoremediation

Introduction

Large areas of mining land were contaminated by heavy metals (Jung and Thornton, 1996; Cheng, 2003; Kim *et al.*, 2004). This threatens the ecology safety and human health. How to control and remediate the heavy metal contamination is one of the major problems (Cuihua Chen *et al.*, 2006). There are many methods used for remediating this pollution but only phytoremediation is a cost effective, environmental friendly, aesthetically pleasing approach most suitable for developing countries (Ghosh *et al.*, 2005).

Heavy metal contaminated soils at mining areas in Vietnam are a major ecological concern. Contaminated soils reduce the quality of both soil and ground water in many areas subjected to mining activities. Heavy metal contamination such as Ni, Cr, Pb, Cu, Se, Hg, Cd requires treatment as soon as possible (Nguyen Anh, 2005). Up to now, results of geological surveys in Vietnam have identified 5000 mines and ore points, of which about 90 metal mines are currently active. The area of inactive mines accounts for 3749 ha. The land area used in Sn exploitation is over 300 ha, of which the soil area after restoration is only 55.8 ha (nearly 20%). However, the quality of soil after restoration is very low and does not meet cultivation conditions (Dang Van Bat *et al.*, 2005).

Rice is cultivated on land in Sn mining areas in Son Duong, Tuyen Quang, with As and Cu levels of 642 mg kg^{-1} and 235 mg kg^{-1}, respectively, well above the Vietnamese standards of 12 mg kg^{-1} and 50 mg kg^{-1}, respectively (Nguyen Anh, 2005). The study on the distribution of As, Pb, Bi, Sn, Cu, Cd, Fe, and W in Sn mining areas in Son Duong, Tuyen Quang indicated that their contents were higher than permitted standards (Nguyen Van Binh *et al.*, 2000). Currently, Thai Nguyen has been identified as a province rich in ore points and mines including limestone, clay, coal, Fe, Ti, W, Pb, Au and Sn. Areas of concentrated contaminants include Dai Tu, Dong Hy, Phu Luong and Vo Nhai districts. Due to inadequate technology, e.g. sites lacking a treatment system or only having a preliminary treatment option, these sites have caused a serious environmental pollution problem, especially for soil and water (TBL,2004; TNPPC,2004).

Studies of heavy metal contaminated soil are sparse in Vietnam, and have focused on traditional handicraft settlements and sites influenced by chemical and paint industries. This study to evaluate the current levels of heavy metal (As, Pb, Cd and Zn) contamination in soil in specific mining areas of Thai Nguyen province as well as to identify indigenous plants with potential for phytoremediation. This is first detailed investigation in Vietnam of mine site soil contamination and the potential to develop phytoremediation as a treatment option.

Materials and Methods

Sampling site: The survey areas are located at Dong Hy and Dai Tu districts, Thai Nguyen province in North of Vietnam (Fig. 1). The areas are located in the monsoon tropical climate zone with two distinct seasons. The rainy season is from May to October with an annual average temperature of 27-29°C, and the dry season is from November to April with an annual average temperature of 16-20°C (Kien Chu Ngoc et al, 2009). The Tan Long (Zn/Pb mine) and Trai Cau (Fe mine) areas of Dong Hy and the Ha Thuong (Ti/Sn mine) and Yen Lang (coal mine) areas of Dai Tu district were studied. A total of 33 plant samples and 12 soil *in-situ* plant samples (plants growing in the same place where 12 soil samples are taken) were collected. The soil characteristics of four areas were taken from results of Le Duc *et al.*, 2008 (Table 1). It should be noted that the studied soils were taken at the same place where the species were collected. At the Tan Long and Ha Thuong mining area, the soils had relatively sandy texture while those at the Trai Cau and Yen Lang had a silted texture.

Soil analysis: Approximately 150-200 g soil around the 12 plant species were collected with a clean shovel, placed in plastic bags, and transported to the laboratory in Ha Noi. Soil samples were air-dried, crushed to pass through a 1 mm sieve and stored at 4°C in dark plastic bags until being analysed. Digestion of heavy metals was conducted using US EPA 3051 method, a weighed amount of dried sample (1 g±1 mg) was placed into digestion vessels. Concentrated HNO_3 65% (2.35 ml) and HCl 37% (7 ml) were added and shaken the mixture carefully. The vessels were placed on a microwave-accelerated reaction system (DAP-100+, Berghof Products Instruments, Germany). The sample digestion was conducted with 8 min ramping to 140°C, continuously holding this temperature for 15 min. After cooling to room temperature, the content of the vessel was transferred into acid-washed plastic bottles and was diluted to 10 ml with ultra-pure water. Concentrations of As, Pb, Cd and Zn in acid digests were quantified with an atomic absorption spectroscopy (AAS; AA-6800, Shimadzu, Japan) and on inductively coupled plasma-mass spectroscopy (ICP-MS, ELAN 9000, Perkin Elmer, USA).

Plant analysis: Each plant sample included a mixture of 3 plants of a species to analyze heavy metal concentration in roots and shoots. The plant samples were washed with tap water to remove soils and dust, rinsed with deionized water, and oven dried at 60°C for 3-5 days. Digestion of heavy metals in the plant samples was conducted using US EPA 3051 method with some modifications. Plant shoot and root were harvested separately. A weighed amount of dried sample (400 mg) was placed into digestion vessel and add 5 ml of HNO_3 (65%) and 3 ml H_2O_2 (30%). Shake the mixture carefully and wait at least 20 min before vessel is closed. Heat the vessels in microwave oven. After digestion, the plant solutions were cooled to room temperature, diluted to 50 ml with ultra-pure water and transferred into acid-washed plastic bottles. The heavy metal concentration were measured by an atomic absorption spectroscopy (AAS; AA-6800, Shimadzu, Japan) and on inductively coupled plasma-mass spectroscopy (ICP-MS, ELAN 9000, Perkin Elmer, USA).

Reagent blanks with reference material standard from Canadian National Research Council (NRC) (TORT-2) were used to verify the precision of the digestion procedure and the subsequent analysis.

Data analysis and statistical analysis: The bioconcentration factor (BF) of each plant species was determined by dividing the heavy metal content in plant shoots by the heavy metal concentration in the soil where the plant is growing. All the data in mean and standard deviation were performed using Microsoft excel for window program.

Results and Discussion

Heavy metal concentration in plants: A total of 33 different plant species samples were collected from four areas to identify the heavy metal concentration in their roots and shoots. The collected plant species can grow at the mine tailings or in the soils affected by mining waste. All results were presented in Table 2 are average of 3 replications and all mean are presented as a values ± 1 standard deviation. The results showed that 2 ferns, *Pteris vittata* L. and *Pytirogramma calomelanos* L. were capable of accumulating high arsenic concentrations. As concentration in shoot and root of *Pteris vittata* L. were 5876.5±99.6 and 2642.5±72.3 mg kg^{-1}, respectively while these figures of *Pytirogramma calomelanos* L. were 2426.3±104.5 and 2256±123.4 mg kg^{-1}. Remarkably, a large amount of As from roots of these ferns transposed to shoot, facilitating the removal of As from of Pb accumulation to hyperaccumulator levels, *i.e.* 1000 mg kg^{-1}. None of the plant species, had high Cd accumulating ability.

The Zn accumulating ability in some investigated plant species was quite high, *e.g. Equisetum ramosissimum* (Vauch), *Cyperus rotundus* L. and *Eleusine indica* L. with Zn accumulating in shoots at 1346.2±130.2, 1201.4±147.3 and 4346.8±157.9 mg kg^{-1}, respectively and in the roots at 3756.9±145.7, 2194.4±155.7 and 3108.7±213.5 mg kg^{-1} Zn, respectively. Plants containing more than 1% DW of Zn in its leaves are called as Zn hyperaccumulators, irrespective of the metal concentration in the soil (Baker and Walker, 1990). Zn concentration in some plants was quite high in the roots and shoots but according to Baker and Walker, they were not Zn hyperaccumulators. Nevertheless, they are indigent plants so they can easily adapt to the local conditions. The Zn accumulation mentioned-above plant species are very remarkable. Combining data from Pb and Zn accumulation of 33 species, we define that *Eleusine indica* L., *Cynodon dactylon* L., *Cyperus rotundus* L. and

Table - 1: Soil characteristic of four mining areas

Areas	pH (KCl)	OM (%)[a]	CEC ($cmol_c kg^{-1}$)[b]
Tan Long, Dong Hy	7.1-8.9	0.85-3.35	5.0-17.5
Trai Cau, Dong Hy	3.5-5.1	0.46-1.24	1.3-6.3
Ha Thuong, Dai Tu	1.9-3.4	0.24-3.29	2.5-16.5
Yen Lang, Dai Tu	3.4-6.0	1.40-4.20	10.0-11.3

[a]OM = Organic matter, [b]CEC = Cation exchangeable capacity

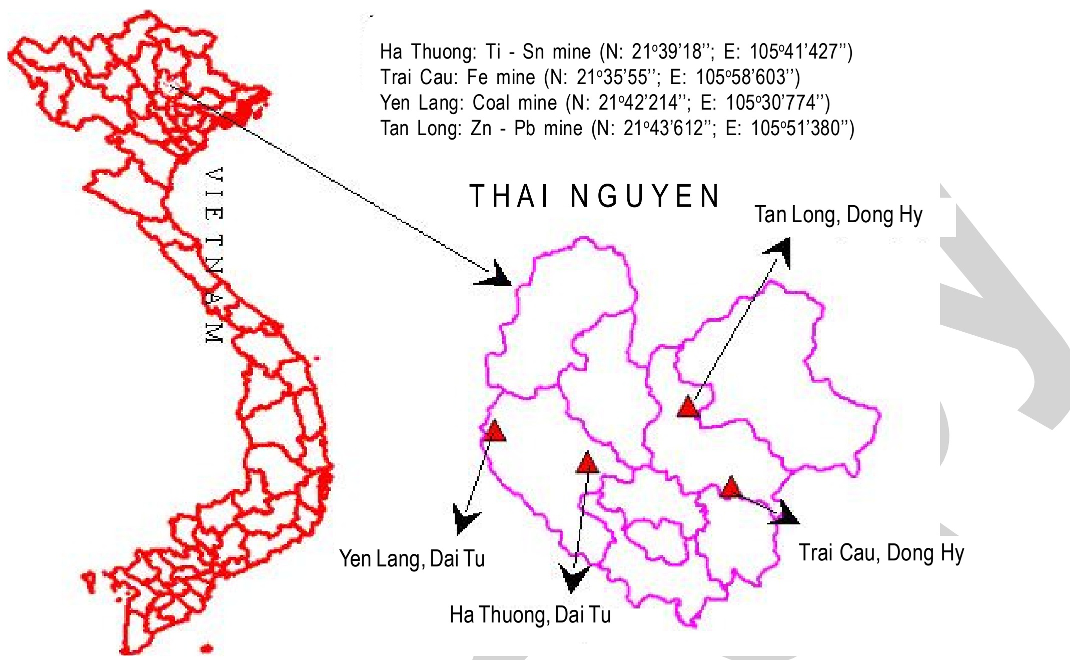

Fig. 1: Location of survey areas in Thai Nguyen province

Equisetum ramosissimum (Vauch) are suitable for Pb and Zn treatment in the soil of Thai Nguyen province.

In many ways, living plants can be compared to solar driven pumps, which can simultaneously extract and concentrate several elements from their environment. Most plants have the ability to accumulate metals/metalloids from soil and water, especially elements essential for growth and development. Phytoremediation, a technology using plants to remove or immobilize contaminants in soil or water, has been intensively studied during the past decade due to its potential cost-effectiveness and environmental harmonies (Reeves and Baker, 2000; Kramer, 2005). According to Reeves and Baker (2000), hyperaccumulators are plants that containing more than 0.1% of Ni, Co, Cu, Cr, As or Pb or 1% of Zn in its shoots on dry weight, irrespective of the metal concentration in the soil. In these studies, we identified indigenous plants with good potential for phytoremediation applications in Thai Nguyen province (Table 2). The results demonstrated that *Pteris vittata* L. (Chinese brake fern) and *Pityrogramma calomelanos* L. (silver fern) could uptake and accumulate As in their shoots up to 5876.5±99.6 and 2426.3±104.5 $mgkg^{-1}$ dry weight, respectively, and meet the criteria for arsenic hyperaccumulators. The results are the same in comparison with data of Ma *et al.*, 2001. The fern *Pteris vittata* L. was identified as an arsenic hyperaccumulator (Ma *et al.*, 2001; Wei and Chen, 2001; Chen *et al.*, 2002) and *Pityrogramma calomelanos* L. was also been discovered as an arsenic hyperaccumulator in Thailand (Jirarut Wongkongkatep *et al.*, 2003). The two ferns showed great potential in the phytoremediation of arsenic contaminated soils (Francesconi *et al.*, 2002; Chen *et al.*, 2002). However, these two ferns had some different characteristics compared with data of the published studies. *Pteris vittata* was collected at the highly polluted area also by Pb and Zn while *Pityrogramma calomelanos* can grow in the wet soil with very low pH (1.9-3.4). Normal plant growth can be achieved in the pH of 5-7 (P. Rotkittikhun *et al.*, 2006). We also screened four pioneer species suitable for Pb and Zn pollution treatment in the soil of the mining areas. They are *Eleusine indica* L., *Cynodon dactylon* L., *Cyperus rotundus* L. and *Equisetum ramosissimum* (Vauch). Currently, the published data on heavy metal treatment capacity of *Cynodon dactylon* L. and *Cyperus rotundus* L. is very rare. No information is available concerning Pb and Zn accumulation of *Eleusine indica* L. and *Equisetum ramosissimum* Vauch. in the literature. Our research indicated that *Equisetum ramosissimum* Vauch. and *Eleusine indica* L. could grow well at the Pb-Zn mine tailings of Tan Long, Dong Hy district and accumulated Pb and Zn much more than 0.3% in their roots.

As our above - mentioned results indicated that 33 different plant species samples were collected from four areas to identify the heavy metal concentration in their roots and shoots. For second phase we have selected only 7 more potential plant species (Table 3) belonging to those 33 plant species, which are grown well in Tan Long and Ha Thuong mining areas. These plants have good heavy metal uptake and are rather popular in the two areas. 5 other species growing on the soil affected by mining wastewater also have been selected in the same areas for evaluation. Parallel to analysing heavy metal content in 12 plant shoots and roots samples, heavy metal concentration of 12 soil samples around these plants were also analyzed. The relationship between the content of a heavy metal in soil and that in the plant growing in that soil indicates the accumulating ability of the plant to uptake that heavy metal. The purpose of this evaluation was identifying a ratio or Bioaccumulation Factor (BF) (the ratio of heavy metal content in shoots to total heavy metal content in soil). For *Eleusine indica* L., *Cynodon dactylon* L., *Cyperus rotundus* L. and *Equisetum ramosissimum* (Vauch), although Pb and Zn accumulation in shoots was quite high but the BF was low. However, total concentrations of Pb and Zn were removed from the mining soils

Table - 2: Heavy metal concentration in shoots and roots of 33 indegenous plant species of Thai Nguyen province

Area	Plant species	As (mg kg^{-1})		Pb (mg kg^{-1})		Cd (mg kg^{-1})		Zn (mg kg^{-1})	
		Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
Tan Long, Dong Hy	*Pteris vittata* L.	**5876.5±99.6**	**2642.5±72.3**	9.4±1.4	10.2±1.7	0.4±0.1	1.3±0.3	152.3±12.7	220.5±23.5
	Pteris linearis Poir.	3.9±1.1	4.1±1.3	153.9±10.2	139.5±9.7	2.7±0.5	5.6±0.8	310.5±35.8	512.6±40.6
	Hypericum japoniocum (Thunb)	36.9±2.2	43.3±3.4	715.1±20.4	523.3±32.4	67.8±5.7	115.2±10.8	450.6±40.3	623.5±42.8
	Saccharum spontaneum L.	3.3±0.9	9.8±1.5	7.2±1.3	117.8±20.3	0.2±0.1	0.4±0.1	321.2±21.2	456.5±35.6
	Cynodon dactylon L.	44.1±3.5	765.5±23.2	538.5±25.2	**4579.6±88.5**	4.4±0.7	34.6±4.8	**912.8±42.5**	15.6±3.8
	Chrysopogon aciculatus (Retz.)	14.5±1.9	32.5±2.6	507.5±30.2	577.5±28.4	4.1±1.2	12.7±3.5	80.2±12.1	112.3±18.4
	Amaranthus lividus L.	3.8±0.8	2.6±0.6	24.7±4.3	11.9±2.6	69.5±11.5	6.7±2.3	75.6±10.3	56.3±8.5
	Echinochloa frumentacea (Roxb.)	0.5±0.2	1.3±0.3	4.6±0.5	14.5±2.5	0.2±0.1	1.3±0.3	126.3±11.7	138.6±15.8
	Eupatorium odoratum L.	1.3±0.4	2.68±0.5	9.9±1.2	21.3±2.7	1.2±0.4	2.5±0.8	123.5±12.6	153.9±15.8
	Eleusine indica L.	25.2±2.8	236.0±15.1	664.5±45	**4638.2±210.4**	9.3±1.3	26.5±2.5	**4346.8±157.9**	**3108.7±213.5**
	Equisetum ramosissimum (Vauch)	28.2±2.6	34.3±4.1	455.2±32.6	**1025.7±65.8**	9.2±1.5	29.0±3.6	**1346.2±130.2**	**3756.9±145.7**
	Cyperus rotundus L.	19.9±1.7	37.7±3.6	**941.3±35.2**	**1560.2±113.5**	7.2±2.1	9.5±2.4	**1201.4±147.3**	**2194.4±155.7**
Trai Cau, Dong Hy	*Agrostis micrantha* Steud.	10.0±1.2	2.0±0.2	0.6±0.1	17.0±3.4	4.3±1.1	19.8±3.2	89.6±10.1	63.5±9.7
	Blechnum orientale L.	10.1±1.3	6.3±0.7	14.4±3.7	257.5±7.5	0.3±0.1	0.5±0.2	70.6±1.5	112.5±10.5
	Trema orientalis L.	2.4±0.3	1.6±0.2	5.0±1.2	3.1±1.3	0.4±0.2	0.2±0.1	80.2±9.4	56.3±10.3
	Eupatorium odoratum L.	1.3±0.3	2.7±0.6	9.9±2.3	21.3±3.2	1.2±0.4	2.5±0.5	132.5±8.9	115.2±7.5
	Pennisetum purpureum (Schum)	18.2±1.5	22.0±2.3	433.2±12.8	360.5±24.5	3.9±0.8	2.7±0.6	648.5±13.5	745.3±50.1
Ha Thuong, Dai Tu	*Scirpus mucronatus* L.	5.8±1.2	10.6±1.7	1.9±0.2	3.4±0.8	0.1±0.1	0.1±0.1	345.3±12.8	251.3±14.5
	Melastoma sp.	14.8±1.3	15.2±1.5	4.6±1.1	5.3±0.9	0.2±0.1	1.2±0.2	256.5±17.4	310.5±18.5
	Pityrogramma calomelanos L.	**2426.3±104.5**	**2256.0±123.4**	49.9±5.6	85.4±7.4	1.0±0.3	1.1±0.5	368.6±15.7	230.8±24.6
	Leptochloa chinensis (Nees)	39.9±3.5	42.5±5.1	793.8±27.4	812.3±32.7	25.2±2.1	31.2±3.8	274.5±21.4	312.5±32.8
	Blechnum orientale L.	20.2±2.6	31.2±3.7	4.5±1.1	6.4±1.2	0.6±0.2	1.4±0.7	323.6±34.8	402.9±38.0
Yen Lang, Dai Tu	*Blechnum orientale* L.	46.7±3.4	52.3±4.2	14.6±1.5	16.4±2.4	0.2±0.1	0.6±0.2	123.6±12.5	213.8±30.4
	Scirpus mucronatus L.	350.0±7.5	410.2±10.2	60.8±4.6	83.5±5.3	0.8±0.3	3.2±0.5	326.8±12.3	412.4±14.8
	Cyperus halpan L.	27.0±2.1	32.5±4.2	6.4±1.3	7.3±0.9	7.2±1.3	9.2±1.6	312.9±10.9	436.2±24.6
	Paspalum orbiculare Forst.	25.8±2.3	42.6±5.2	5.9±1.1	8.5±2.1	2.4±0.4	6.3±1.1	523.4±30.6	613.5±29.5
	Imperata cylindrica (Beaurs)	25.5±3.2	35.4±4.3	2.3±0.7	9.3±1.5	0.2±0.1	3.1±1.0	213.8±12.3	286.4±13.8
	Elephantopus scaber L.	2.3±0.4	0.8±0.2	9.1±1.2	2.4±0.3	5.9±1.2	2.1±0.8	332.8±15.8	436.7±19.4
	Fimbristylis acuminate Vahl	21.3±2.1	156.9±7.3	728.5±25.7	816.3±30.8	44.7±3.4	48.9±4.6	316.4±13.2	422.5±12.7
	Eleocharis dulcis (Burm.f.)	16.8±2.4	25.6±4.2	20.7±3.1	3.5±0.2	0.4±0.2	0.2±0.1	66.1±9.2	37.3±5.3
	Cyperus imbricatus Retz.	3.7±0.7	1.6±0.3	99.8±16.3	44.8±3.2	2.3±0.6	1.0±0.3	236.8±13.9	438.7±15.7
	Pteris cadieri H. Christ	850.0±24.5	127.8±22.4	182.4±34.5	**1878.1±89.5**	2.0±0.4	21.8±2.8	419.3±10.6	**4439.0±247**
	Polygonum hydropiper L.	5.6±1.3	8.2±2.6	179.8±25.7	1444.3±75.8	1.0±0.3	1.1±0.2	312.6±26.8	653.4±41.5

Values are mean ± standard deviation of 3 replicates

Table - 3: Heavy metal concentration in 12 soils and *in-situ* plants samples of Thai Nguyen province

Area	Plant species	As ($mgkg^{-1}$)				Pb ($mgkg^{-1}$)				Cd ($mgkg^{-1}$)				Zn ($mgkg^{-1}$)			
		Soil	Plant		BF	Soil	Plant		BF	Soil	Plant		BF	Soil	Plant		BF
			Shoot	Root			Shoot	Root			Shoot	Root			Shoot	Root	
Tan Long,	*Cynodon dactylon* L.	584.8	44.1	765.5	0.075	4316.9	538.5	6579.6	0.12	67.4	4.4	34.6	0.07	16741.0	912.8	15,617	0.05
Dong Hy	*Cyperus rotundus* L.	750.2	19.9	37.7	0.027	3733.1	941.3	1560.1	0.25	80.9	7.2	9.5	0.09	17565.1	1201.4	2194.4	0.07
	Eleusine indica L.	612.8	25.2	236.1	0.041	4337.2	664.4	4638.2	0.15	69.2	9.3	26.5	0.13	15231.1	3108.7	4346.7	0.2
	Equisetum ramosissimum (Vauch)	174.7	28.2	34.3	0.16	1849.3	455.2	3025.7	0.25	229.0	9.2	29.0	0.02	7876.1	1346.1	3756.9	0.17
	Pennisetum purpureum Schum	592.3	18.3	21.9	0.03	4160.6	433.1	360.5	0.10	71.4	3.9	2.7	0.05	15326.0	648.5	745.3	0.04
	Pteris vittata L.	181.2	1528.0	724.0	8.43	1559.2	183.4	3878.1	0.12	419	2.1	21.8	0.01	7123.7	491.3	4439.0	0.07
Ha Thuong,	*Blechnum orientale* L.	3268.4	940.3	376.4	0.28	541.9	49.9	85.4	0.10	4.0	1.0	1.1	0.25	17565.1	368.6	230.8	0.02
Dai Tu.	*Eleocharis dulcis* (Burm.f.)	4346.2	16.8	25.6	0.004	235.5	20.7	3.5	0.09	0.8	0.4	0.2	0.5	361.8	66.1	37.3	0.18
	Fimbristylis acuminate Vahl	6754.3	43.6	8526.6	0.006	283.3	17.6	432.4	0.06	2.3	0.4	7.6	0.17	602.1	77.7	154.1	0.13
	Cynodon dactylon L.	6514.3	72.3	156.1	0.01	293.1	24.1	41.4	0.08	2.9	0.3	0.8	0.10	598.3	103.8	104.8	0.17
	Pityrogramma calomelanos L.	3102.5	3740.0	3450.0	1.21	513.2	85.4	49.9	0.17	1.8	1.0	1.1	0.56	10315.1	368.6	230.8	0.04
	Saccharum spontaneum L.	6531.2	38.4	216.5	0.006	312.2	34.9	10.2	0.11	3.2	0.3	0.4	0.09	567.4	63.7	41.2	0.11

Determination of BF for the investigated heavy metals. Values are mean of 3 replicates, BF = Bioconcentration factor of 4 species are very high so we can use them for heavy metal treatment in the soil. The same result was seen with Cd, the BF in selected plants for this metal was very low. As concentration in Ha Thuong, Dai Tu dist. was very high. *Pteris vittata* L. and *Pytirogramma calomelanos* L. growing on the soils had the BF by 8.43 and 1.2, respectively. This is a high ratio compared to those of other plants. Furthermore, the high BF indicated its potential in phytoremediation under field conditions. Arsenic hyperaccumulators usually have ability to uptake large concentration of arsenic, even at very low arsenic concentration in soils, illustrating efficient bioaccumulation, which is an important factor for phytoremediation (Tu *et al.*, 2002; Chen *et al.*, 2005). These plant species (hyperaccumulators) can concentrate metals in their above-ground tissues to level far exceeding those present in the soil or in the non-accumulating species growing nearby.

We have observed highly variable heavy metal concentrations; *i.e.* high in some soils, but not for others? Even soil from different sites in the same area had different results of heavy metal concentration (Wei Jiang *et al.*, 2005). One of the reasons is that the 12 soils samples have very different physiochemical properties and heavy metal concentration depending on mining properties. The obtained results about heavy metal concentrations in soil at the 2 investigated mining areas showed that Ha Thuong, Dai Tu district is area with the highest As pollution (3102.5-6754.5 mg kg^{1}) while at Tan Long, Dong Hy, Thai Nguyen Pb, Cd and Zn concentration levels were very high (4337.2 mg kg^{-1} for Pb, 419 mg kg^{-1} for Cd and 17565.1 mg kg^{-1} for Zn). The standard values permitted in soil are As = 12 ppm, Cd=5 ppm, Pb=120 ppm and Zn= 200 ppm

There are many advantages in using indigenous plant for phytoremediation because the impact of other soil properties and climatic conditions is very important. Our finding indicates that two fern *Pteris vittata* L. and *Pytirogramma calomelanos* L. suitable for As treatment in the mining soil of Ha Thuong, Dai Tu, dist. Four grasses *Eleusine indica* L., *Cynodon dactylon* L., *Cyperus rotundus* L. and *Equisetum ramosissimum* (Vauch) are the best at keeping Pb, Zn concentration in their root. Phytostabilization is defined as immobilization of a contaminant in soil through absorption and accumulation by roots, adsorption onto roots, or precipitation within the root zone of plants (US-EPA, 2000). So we can use these grasses for phytostabilization of Pb and Zn in Tan Long, Dong Hy, dist.

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