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GROWTH AND ABSORBANCE OF HEAVY METALS OF REED PLANTS (*Phragmites australis)* IN SOIL AFTER MINERAL MINING IN THAI NGUYEN PROVINCE OF VIETNAM

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ABSTRACT

Reed plant (*Phragmites australis*) is an indigenous and wild plant species which was found as a pioneer plant appearing in many places after mineral mining in Thai Nguyen province of Vietnam. This plant has the capacity to uptake heavy metals in soil so that it is considered to be a good biological control method in contaminated soils. The study was conducted to survey five (5) different places after mineral mining in Thai Nguyen such as Trại Cau iron mine, Lang Hich lead-zinc mine, Muoi Nac lead-zinc mine, Cay Cham titanium mine 1 and Cay Cham titanium mine 2. The results showed that reed is a pioneer plant and appears in different topographical conditions from catchment areas to slope shoulder. However, dense plant populations were found in lower places with high soil moisture contents. Due to long mineral mining process, the topsoil has been shuffled, causing effects on the growth and the population distribution of plants. High contents of heavy metals were accummulated in reed plant body as follows: Zn 1154.66 mg/kg, Pb 243.92 mg/kg, Cd 35.84 mg/kg, and As 199.02 mg/kg. The accumulation of heavy metals in reed plant is proportional with the contents of heavy metals in soil and inversedly correlational with pH and organic carbon content in the soil. It is recognized that reed plants play an enormous role in absorbing heavy metals and in keeping the soil free from pollutants after mining.

Keywords: reed plant (*Phragmites australis*), soil pollution after mineral mining, heavy metal, Pb, Zn, Cd, As and bio-control method.

INTRODUCTION

Soil pollution of heavy metals from mineral mining has been a crucial problem and with a tendency to increase in Vietnam (Dang V. M., *et al*., 2011a). There are many methods to process heavy metals in soil such as: soil cleaning, and heavy metals fixing by chemical method. However, these have not been applicable due to high cost and the possibilities to produce new pollutants, which is not suitable in Vietnam. In view of this, biomethod has been considered a relevant method to polluted soil by heavy metals after mineral mining in Thai Nguyen province, Vietnam (Dang V. M., *et al*. 2011b). Among the indigenous plants with high capacity to absorb heavy metals appearing in these areas (Dang D. K., *et al*., 2011), the reed plant (*Phragmites australis)* has not received much attention yet although this is a popular plant appearing in the areas after mineral mining, particularly in places of low grounds which are hollow and humid.

According to previous researches, reed plants have been used to process heavy metals of enormous absorbance within its biomass. In the middle regions of India, reed plants have eliminated 70% As and 58-65% Pb in wetlands through its roots (Nadia A. A., *et al*., 2004). Another research about absorbance of heavy metals in reed plant body has shown a content of Cd oscillates from 675 to 1193 mg/kg in its roots, from 45 to 85 mg/kg in its leaves; Zn from 42 to 106 mg/kg, from 166 to 915 mg/kg, respectively (George.E.R. and David J. L., 2011). Reed plants have the capacity to gather heavy metals so that it is considered to be an important biological control method for contaminated areas in Vietnam (Dang V. M., *et al*., 2011b).

The objectives of this study were to assess the growth of reed plants and its absorbance of heavy metals contained in soil after mineral mining in Thái Nguyên, and to identify the role of native reed plant species among indigenous plants which is used to rehabilitate contaminated soil after mineral mining in Vietnam in general and in Thai Nguyen in particular.

RESEARCH METHODOLOGY

This research was implemented in five (5) areas of metal mines of iron, zinc and titanium in Thai Nguyen which have been disused after exploitation for years. These are the areas of severe pollution of heavy metals after mining with abundant growth of native reed plant which is one of the pioneer plants appearing in these areas (Dang V. M., *et al*., 2011b).

The research was carried out in the period of 2000-2012. The main contents of the research were as follows: (1) to assess the growth of plants and its population in areas of post-exploitation, (2) to study the relationship between the contents of heavy metals in soil and the absorbance of plants, and (3) to analyze the soil factors such as soil OM and pH affecting this absorbance.

The growth of plants has been assessed on the criteria of height and length of leaves. Moreover, its absorbance of heavy metals has been assessed based on the analysis of heavy metals contents in its roots, trunks and leaves.

Soil and plant samples were taken from the standardized plots of 1000 square meters (50 x 20 m), representating different types of topographies: low wetland, flat land, hillsides and hilltops of the mine areas which were studied. A number of reed plants in each plot

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were observed and monitored. The height and trunk diameters were measured, and dried biomass was identified. Soil samples were taken separately from the different parts of the plants: the trunks, the roots and the leaves. Plant samples were cleaned by using processed water and submerged in distilled water before being dried at 60^oC, then they were grilled into yarns of 1 mm for analysis.

Soil samples were taken from the depth range of 0 to 20 centimeters at the same point of reed plant sample-taken. Soil samples were taken under the method of mixture of sub-samples before being mixed into one sample for analysis. Thereafter, the soil samples were parched by air and extruded from rocks before being sifted into yarns at 2 millimeters.

Table-1. Locations of plant and soil samples within the research area.

#	Sample	UTM coordinates	Absolute high above sea level	Location
I	**Lead/ Zinc mine Cuoi Nac at Yen Do commune, Phu Luong district**			
1	Đ1	x = 576509 y = 2411939	64 m	Valley and catchment
2	Đ2	x = 576430 y = 2411831	75 m	Hillside
3	Đ3	x = 576328 y = 2411902	119 m	Hilltop
II	**Titan mine Cay Cham 1 at Dong Dat commune, Phu Luong district**			
4	Đ4	x = 570819 y = 2404192	72 m	Hillside
5	Đ5	x = 570699 y = 2404067	98 m	Hilltop
6	Đ6	x = 570763 y = 2404139	67 m	Valley
7	Đ7	x = 571839 y = 2404138	20 m	Waste area
III	**Iron mine Trai Cau, Dong Hy district**			
8	Đ8	x = 598506 y = 2388346	26 m	Waste soil from mining
9	Đ9	x = 598509 y = 2388350	31 m	Hillside
10	Đ10	x = 598513 y = 2388353	38 m	Hilltop
IV	**Titan mine Cay Cham 2 at Dong Dat commune, Phu Luong district**			
11	Đ11	x = 0416614 y = 2405168	54 m	Valley (along stream)
12	Đ12	x = 0416639 y = 2405224	57 m	Hillside
13	Đ13	x = 0416696 y = 2405263	63 m	Upper hillside
IV	**Lead/ Zinc mine Lang Hich at Tan Long commune, Dong Hy district**			
14	Đ14	x = 0433254 y = 2404223	80 m	Waterstream side Flat area along sewage
15	Đ15	x = 0433285 y = 2404198	86 m	Hillside Waterstream side
16	Đ16	x = 0433409 y = 2404363	93 m	Flat area along sewage

The analysis of heavy metals (Pb, Zn, Cd, As) contents in soil and plants used the Atomic Absorption Spectro method (George. E. Rayment and David J. lynsi, 2011). Three grams of homogenous samples were scaled to Kjeldahl, followed by the addition of 20 ml of HNO_3: HCl under the ratio of 1:3. Then, the samples were heated under the temperature from 90^oC to 110^oC, and maintained the oxygen condition in the jar during the process by carefully adding small amounts of acid nitric until the mixture turned white. This showed that the heavy metal contents have been noticeably extruded. The color of final solution turned colorless or bright yellow. Then, they were cooled, and placed in jars of 100 ml. Samples were analyzed based on the AAS system of Thermo M6 AAS.

Soil pH was measured by KCl 1N on 1:2.5 soil: water suspensions, and then measured by using a standard pH meter. Soil organic matter was measured by method chiurin.

RESULTS AND DISCUSSIONS

The growth of reed plants after mining

Table-2. The growth of reed plants in research areas.

Mine	Location	Number of clusters / plot	Number of plants / plot	Tree height (cm)	Root deep (cm)	Ground dry biomass (kg)
Lead/ Zinc mine Cuoi Nac	Valley	37	333	161	34.5	6.605
	Hillside	34	408	135	23.5	9.953
	Hilltop	27	324	130	22.5	5.443
Titan mine Cay Cham 1	Hillside	27	513	150	26.5	14.389
	Hilltop	34	442	115	35.0	14.361
	Valley	57	567	150	27.5	9.355
	Waste area	30	401	110	30.0	12.569
Iron mine Trại Cau	Waste area	175	3675	180	30.0	66.885
	Hillside	87	1458	179	31.0	52.541
	Hilltop	77	2387	189	26.5	33.108
Titan mine Cay Cham 2	Waterstream side	55	501	120	29.5	13.565
	Hill side	30	419	110	29.0	13.981
	Hill top	29	580	145	35.0	9.433
Lead/ Zinc mine Lang Hich	Waterstream side	175	1575	175	30.5	58.377
	Flat area along sewage	494	2964	140	30.0	21.972
	Hillside	121	968	120	27.5	17.298

It is evident that reed plants were found to be pioneer native species growing in all soil types under study area after mineral mining in Thai Nguyen province. However, plant growth and population distribution were different depending on topographical places and time after mining.

As Trai Cau Iron and Lang Hich Zinc mines have long been existent in the disposal sites. The population of the plant in this area is large with 175 clusters/plot in Trai Cau and 494 clusters/plot in Lang Hich. In mines of Cay Cham Titanium and Cuoi Nac zinc, the high disorder of topsoil has reduced the population of the plants due to land damage (Table-2).

The soil revival time of post-exploitation has a big impact on the population and growth, as well as the development of reeds. At sites of long revival such as Trai Cau and Lang Hich, reed plants are found to be densely populated and completely grown. In Cay Tram and Cuoi Nac mines, the disorder of the topsoil has reduced the population of plants due to incessant land depletion and damage.

Topographies have obviously affected the development of reed plants. Study showed that at low topograpghy areas with short distance to waterstream and high soil humidity, reed plants grow better. It is evident that reeds grow better at the sites of waste and drainage system of mines than other locations.

In the site surveyed, the biomass of the reed plants varied. In Trai Cau Iron mine, the plants were highly populated with absolute growth and development. The plant biomass of each plot was high (33.108 to 66.885 kg/plot). Lang Hich Zinc mine had a distribution of dry biomass of 17.298 to 58.377 kg/plot, Cay Tram mine of 9.355 to 14.389 kg/plot and Cuoi Nac mine of 5.443 to 9.953 kg/plot.

Within the mining area, the quantity of plant biomass was also larger at low topography areas or places nearby waterstream where soils had higher humidity and more healthy condition.

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Heavy metal content in soil

Soil pH of Cuoi Nac, Trai Cau, Cay Cham 1 and 2 and Lang Hich mines ranged from 5, 6 to 7, while its CEC was relatively low with less than 10 Me/100g of soil. Soil organic carbon ranged from low content in hillsides to higher content in the flat and valley areas (Table-3).

Heavy metal contents in soil in the mining areas were high, mostly exceeding the standard level in Vietnam (reference at QCVN 03:2008/BTNMT). Particularly, the Zn content in Cuoi Nac mine ranged from 8.2 times to 11.5 times higher than the approved QCVN 03:2008/BTNMT.

Heavy metal contents in soil varied within one mine. The contents of heavy metals in upper hillside areas were mostly found lower than that in foothills and valley areas.

Table-3. Soil chemical properties in the research area

Mine	Topography	pH	CEC (me/100g)	OM (%)	Zn (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	As (mg/kg)
Lead/ Zinc mine Cuoi Nac	Valley	6.58	6.8	2.86	2311.36	321.98	34.38	185.49
	Hillside	6.49	6.6	2.5	2011.52	342.80	32.82	176.70
	Hilltop	6.72	7.8	2.31	1640.80	291.24	21.18	250.31
Titan mine Cay Cham 1	Hillside	4.16	7.6	2.01	1871.12	340.56	24.96	114.39
	Hilltop	3.12	8.8	0.72	1284.80	189.92	18.24	141.75
	Valley	3.6	8.2	1.55	1137.12	351.68	30.48	256.12
	Waste area	6.98	8.6	1.56	1802.72	225.98	26.34	220.94
Iron mine Trại Cau	Waste area	6.59	7.7	1.81	1632.96	375.68	37.14	269.64
	Hillside	6.06	8.1	2.27	2222.72	357.12	35.22	182.35
	Hilltop	5.99	8.7	1.13	2038.72	174.84	31.44	404.01
Titan mine Cay Cham 2	Waterstream side	5.77	8.8	2.84	1147.22	1566.89	6.81	53.64
	Hill side	6.16	7.7	2.48	1510.87	718.23	2.99	154.80
	Hill top	6.84	6.9	2.43	1757.73	1810.52	5.69	121.05
Lead/ Zinc mine Lang Hich	Waterstream side	6.98	6.1	2.86	1432.98	1293.62	4.64	61.20
	Flat area along sewage	7.24	6.7	2.39	1085.40	1016.24	5.76	122.40
	Hillside	6.06	7.9	2.03	2203.71	1137.93	2.79	130.05

Remarks: Standard level of heavy metal content in soil in Vietnam (reference at QCVN 03:2008/BTNMT): Zn = 200 mg/kg, Pb = 70mg/kg, Cd = 2 mg/kg, AS = 12mg/kg

Uptake of heavy metals by reed plants

Data in Table-4 indicated that Zn, Pb, Cd and As were found in trunk, leaves and roots of reed plants. Results showed that reed plants absorbed these metal elements from the soils. The contents of heavy metals were found much higher in roots than in trunk and leaves. Zn content found in the roots was approximately 2 to 4 times higher than that in the leaves; Pb content was from 1 to 4 times higher, Cd from 2 to 5 times higher, and particularly As from 5 to 13 times higher.

In comparison to other plants of heavy metal absorption such as pern (*Pteridophyta Cyatheaceae*), vetiver grass (*vetiveria zizanioides* L.), the absorption capacity of reed was lower (Dang Van Minh *et al*., 2011; Bùi Thị Kim Anh, 2012). However, its larger biomass, especially in humidity, had led to a remarkable total of accumulated heavy metals in the plant body.

Table-4. Heavy metal contents of the different parts of reed plants Unit: mg/kg.

Mine	Stems and leaves				Roots			
	Zn	Pb	Cd	As	Zn	Pb	Cd	As
Cuoi Nac lead and zinc mine	204.70	26.47	6.74	22.52	657.77	97.63	20.06	173.35
Cay Cham 1 titan mine	348.53	49.70	7.69	24.45	630.59	101.78	27.01	197.97
Trai Cau iron mine	355.97	33.46	8.49	32.43	798.69	103.05	27.35	226.52
Cay Cham 2 titan mine	186.70	70.88	2.21	18.80	654.37	173.04	5.07	77.78
Lang Hich lead and zinc mine	234.17	74.82	3.71	12.48	582.72	141.31	3.74	108.22

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Factors affecting absorption capacity of heavy metals by reed plants

Content of heavy metal in soil

In order to understand the factors affecting absorption of these heavy metals by plants, correlation of heavy metals between the soil and the plant is presented in Figure-1.

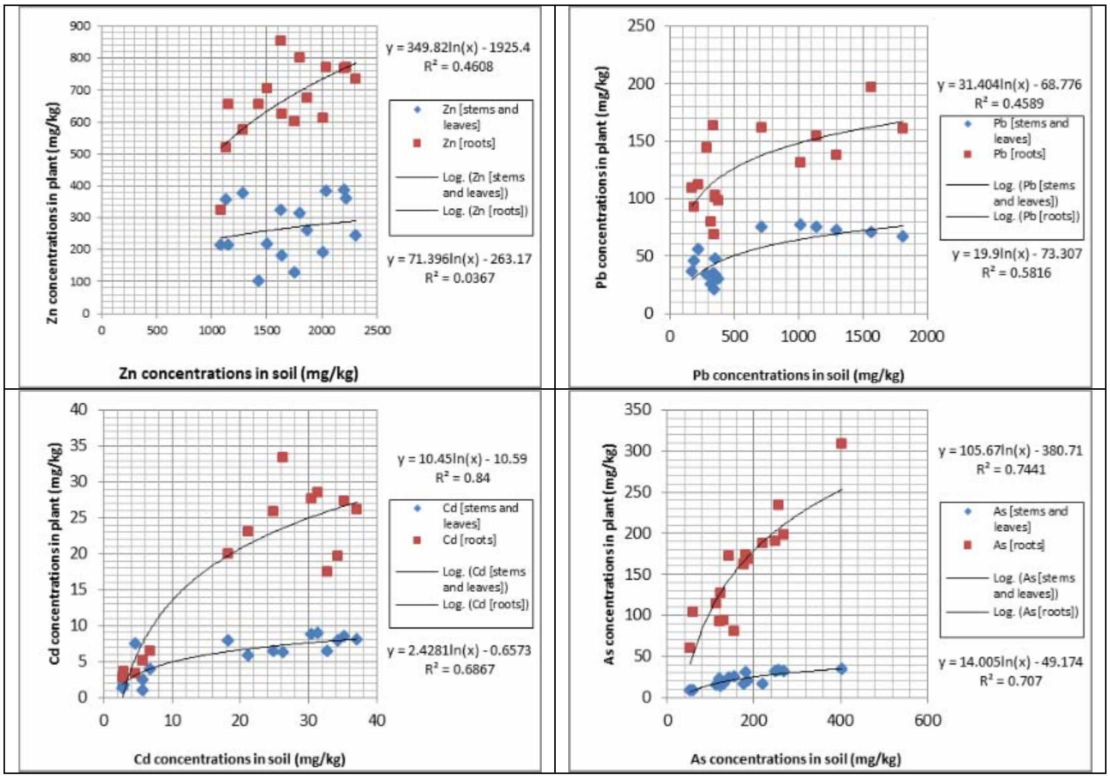

Figure-1. Correlation between heavy metal content in soil and heavy metal content in reed plant.

It is apparent that the correlation between heavy metal in-soil content and the accumulation of those metals in plant roots, trunks and leaves is proportional (Figure-1), among which the strongest element of correlation was As (R^2 is from 0.7441 to 0.707), followed by Cd ($R^2 = 0.6867$ to 0.8437), Pb ($R^2 = 0.4589$ to 0.5816) and finally Zn ($R^2 =$ 0.0367 to 0.4608). Data indicated that As, Zn, Pb, Cd content in the roots, trunks and leaves increased when in-soil, As content increased from 0 to 121.05 mg/kg; and Zn from 0 to 1300 mg/kg, Pb from 0 to 225.98 mg/kg, and Cd from 0 to 18.24 mg/kg; otherwise, the capacity of heavy metals accumulation will gradually level off.

Soil pH

Table-5. The correlation equation between the content of heavy metals absorbed in plants and the content of heavy metals in soil and pH soil.

Heavy metal	Correlation equation	Coefficient (R^2)
Zn	Yr = 323.78 + 0.21 Soil Zn - 1.52 pH	0.416
Zn	Ys = 386.51 + 0.09 Soil Zn - 45.08 pH	0.388
Pb	Yr = 121.69 + 0.05 Soil Pb - 4.89 pH	0.498
Pb	Ys = 37.98 + 0.03 Soil Pb - 1.21 pH	0.569
Cd	Yr = 11.01 + 0.71 Soil Cd - 1.35 pH	0.802
Cd	Ys = 5.34 + 0.17 Soil Cd - 0.48 pH	0.701
As	Yr = 81.90 + 0.67 Soil As - 7.97 pH	0.876
As	Ys = 16.19 + 0.08 Soil As - 1.48 pH	0.704

Remarks: Yr is dependent variable - content of heavy metals contained in root plants in mg/kg
Ys is depemdent variable- content of heavy metals contained in stems and leaves in mg/kg

The correlation equation between the heavy metal content accumulated in the plant bodies (roots and trunk and leaves), with the content of 4 in-soil heavy metals of Zn, Pb, Cd, As and pH are present under the form of: y = α + ax_1 - bx_2, where y is heavy metal gathered up by plants, x_1 is heavy metal content in soil, and x_2 is soil pH.

The accumulation of heavy metals in reed plant was proportional to the in-soil content of heavy metals; and inversely correlational to the pH concentration. The correlation ratio of heavy metal absorption capacity between in-body and in-soil and the pH concentration varied. The correlation between the accumulated As and Cd in the plant bodies and in soil with pH was quite strong (R^2_{As} = 0.7043 to 0.8763) và (R^2_{Cd} = 0.7001 to 0.802), followed by Pb on average (R^2_{Pb} = 0.498 to 0.569), and Zn at low (R^2_{Zn} = 0.388 - 0.416) (Table-5). Possibly, when soil pH increases, heavy metals in soil tends to shift from mobility form into less mobility form, hence, resulting to reduce the plant absorption capacity of heavy metals from soil.

Soil organic matter

Table-6. The correlation equation between the content of heavy metals absorbed in plants to the content of heavy metals in soil and the organic matter in soil.

Heavy metal	**Correlation equation**	**Coefficient** (R^2)
Zn	Yr = 372.54 + 0.21 Soil Zn - 29.24 OM	0.4373
Zn	Ys = 400.64 + 0.07 Soil Zn - 116.61 OM	0.6556
Pb	Yr = 99.74 + 0.05 Soil Pb - 2.49 OM	0.4753
Pb	Ys = 46.71 + 0.03 Soil Pb - 9.07 OM	0.6187
Cd	Yr = 16.21 + 0.64 Soil Cd - 5.63 OM	0.8598
Cd	Ys = 3.85 + 0.16 Soil Cd - 0.63 OM	0.6740
As	Yr = 85.37 + 0.60 Soil As - 18.27 OM	0.8743
As	Ys = 11.19 + 0.08 Soil As - 1.37 OM	0.6671

Remarks: Yr is dependent variable - content of heavy metals contained in root plants in mg/kg
Ys is dependent variable- content of heavy metals contained in stems and leaves in mg/kg

Similar to soil pH, the accumulation of heavy metals in plant was proportionate to heavy metal content in the soil and inversely correlational to the organic matter in soil (Table-6). Results showed that the higher organic matter in soil, the absorption capacity in soil increases, thus, leading to a decrease in the accumulation of heavy metals by the plant. This is attributed to the fact that heavy metals by in-soil organic matter under the form of absorption, generates continuous organic chelate. This also means that, the higher organic content in soil leads to a limited mobilization of heavy metal element.

CONCLUSIONS

The reed plant is found to be a pioneer plant appearing in all five (5) study places after mineral mining in Thai Nguyen province of Vietnam. This plant has the capacity to gather heavy metals in soil so that it is considered to be a good biological control method in contaminated soils. Reed appears in the whole areas after mining. However, dense plant populations were found in lower places with high soil moisture. The content of heavy metals in the soil is commonly proportionate with its content in the plant bodies. The accumulation of heavy metals in reed plant is comparative with the content of heavy metals in the soil and inversedly correlational with pH and organic carbon content in the soil. It is recognized that reed plays an enormous role in absorbing heavy metals and in keeping the soil free from pollutants after mining.

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