Applying diversity index and dominant species in research and selection of some indigenous plant species to absorb Pb, Zn

Ứng dụng chỉ số đa dạng và ưu thế loài trong nghiên cứu và lựa chọn một số loài thực vật bản địa có khả năng hấp thụ Pb, Zn

Research article

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The study was carried out at Dai Dong and Chi Dao communes, Van Lam District, Hung Yen Province. The biological diversity indexes and dominance index of species were used to identify native plant species which have the ability to absorb Pb and Zn. The results were verified by applying methods such as plant classification, quadrat cell counting, biological indicators and chemical analysis. Results showed that there are five species of plants with the highest dominant index calculated due to number of individuals in the study area including *Bidens pilosa* L (33.03%), *Acroceras munroanum* (8.14%), *Commelina coelestis* (7.83%), *Carex capillacea* (5.41%), *Ipomoea aquatic* (5.26%). Verified results showed that *Bidens pilosa* L, *Acroceras munroanum*, *Commelina coelestis*, *Ipomoea aquatic* can be used to treat Pb with the absorption concentration of 380 mg/kg, 288 mg/kg, 270 mg/kg, 223 mg/kg, respectively. Only *Commelina coelestis* can absorb Zn with the highest concentration of 73mg/kg. In summary, Pb absorption of dominant species in the study area is higher than the absorption of Zn.

Nghiên cứu được thực hiện tại hai xã Đại Đồng và xã Chi Đạo, huyện Văn Lâm, tỉnh Hưng Yên nhằm xác định một số loài thực vật bản địa có khả năng hấp thụ Pb, Zn bằng cách sử dụng chỉ số đa dạng sinh học và chỉ số ưu thế loài. Kết quả được kiểm chứng bằng các phương pháp như phân loại thực vật, đếm ô quadrat, sử dụng chỉ số sinh học và phân tích hóa học. Kết quả cho thấy có năm loài thực vật có chỉ số ưu thế cao nhất tính theo số lượng cá thể trong khu vực nghiên cứu là: Đơn buốt (33,03 %), Cỏ lá tre (8,14 %), Thái lài (7,83 %), Kiết tóc (5,41 %), Rau muống (5,26 %). Kết quả phân tích kiểm chứng thấy Đơn buốt, Cỏ lá tre, Thái lài, Rau muống có khả năng xử lý Pb với giá trị lần lượt là 380 mg/kg, 288 mg/kg, 270 mg/kg, 223 mg/kg. Trong khi đó chỉ có Thái lài là có khả năng hấp thụ Zn với giá trị cao nhất là 73 mg/kg. Nhìn chung khả năng hấp thụ Pb của các loài ưu thế tại khu vực nghiên cứu cao hơn so với khả năng hấp thụ Zn.

Keywords: heavy metals, spend some diversity, species dominance index

1. Introduction

Studies on the heavy metal absorption ability on soil of plant were done by many national and foreign authors and provided meaningful results. Identification of the native plants that have capable to treat heavy metals usually bases on the general principle that is to identify polluted areas. Currently, two approaches used in the selection of plant species are based on the heavy metal content accumulated in plants and tolerance to effects of pollutants. With the

first method, the plants will be collected from the contaminated areas. Then the contents of heavy metal in all parts of the plants are analyzed and combined with selection criteria of plant species suitable for initial purpose. To verify the heavy metal treatment ability, we need to optimize growth conditions for plants. This method has high-precision but high cost for chemical analysis. With the second method, contaminated areas, information on the diversity and dominance of the study area must be determined by assesment of changes in diversity and dominance of plants before and after they are affected by the

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wastesource. In the polluted environmental conditions, if any plants are still living, adaptive and are the dominant species, their resistance to contaminants is very high. To verify the heavy metal absorption ability, accumulated levels in the plants will be analyzed. This method is high efficient because it requires low cost by less sample analysis experiments but could select plants with high heavy metal absorption ability.

2. Materials and methods

2.1. Study area

Dai Dong and Chi Dao communes were chosen for study because both of communes have many households working on metal recycling which discharged Pb and Zn for long time. The climatic and soil conditions are represented for Red river delta and suitable for the growth of crops as well as weeds. In this study, we take samples in canals, rice fields and disposal sites receiving waste sources.

Figure 1: Map of study area (GoogleEarth)

2.2. Soil and plant sampling method

Soil samples were taken by specialized tools and same locations with plant samples. Soil samples are taken at the surface (0-15 cm) at 7 different areas. Two kinds of soil samples include 3 dry samples at the landfill (KV1, KV6, KV7) and 4 semi-submerged samples collected at rice fields and canals (KV2, KV3, KV4, KV5). While, the vegetable cells were taken from the east - west - south - north - center. In the wetland areas (canals), the plants were taken at every 2 meters in the distance from upstream to downstream. Based on current conditions and the sampling

location, we selected 38 plant samples at the study areas. The detail of sampling locations is shown in the Table 1.

2.3. Biodiversity survey method

* Botanical classification method

Collected plants at study sites were identified through the references combined with expert advice.

* Vegetation survey method

Vegetation survey was conducted based on standard cell counting methods (O quadrat) with dimensions of 120 × 80 cm of each cell.

* Biostatistics method

In this method, the biological indicators applied include: Shannon & Weiner index:

$$H' = - \sum_{i=1}^s pi \ln pi$$

Simpson index:

$$Cd = \sum_{i=1}^s \left(\frac{ni}{N} \right)^2$$

Where pi : Percentage of individuals in the i^{th} species
 $pi = ni/N$
 ni : Total individual of i species
 N : Total individual of all species

2.4. Analysis method

* Soil samples: organic carbon was analyzed by Walkley - Black, pH by pH meter, total Pb and Zn by Asano – Kato method, 1997.

* Plant samples: heavy metal concentrations were analyzed by Asano Kato method.

3. Results and discussion

3.1. Diversity and dominance of plant

3.1.1 The list of plants appearing on the study area

The study results showed that 37 plant species belonging to 17 families appeared in the study area (Table 2).

Table 1. Soil and plant sampling location

Location symbol	Soil sample	Sampling location
KV1	Đ1	Landfill - Chi Dao commune
KV2	Đ2	Rice filed and Landfill – Chi Dao commune
KV3	Đ3, B3	Canals - Chi Dao commune
KV4	Đ4	Rice field - Chi Dao commune
KV5	Đ5, B5	Canals - Chi Dao commune
KV6	Đ6, B6	Ma Chuc, Long Thung, Dai Dong
KV7	Đ7	Dai Tu, Dai Dong

Note: KV- Location; Đ – Soil

Table 2. The list of plants appearing on the study area

No	Family	Latin name	Vietnamese name
1	Asteraceae	<i>Bidens pilosa</i> L.	Don buot
2		<i>Artemisia vulgaris</i> L..	Ngai cuu
3		<i>Sp1</i>	Cai dong
4		<i>Eclipta prostrata</i> (L.)	Nho noi
5		<i>Torenia asiatica</i> L.	Ngo dai
6		<i>Grangea maderaspanata</i> (L.)	Cai dong
7		<i>Gynura divaricata</i> L.	Bầu đất
8		<i>Acroceras munroanum</i>	Co la tre
9		<i>Eleusine indica</i> (L.)	Co man trau
10		<i>Cynodon dactylon</i>	Co ga
11		<i>Panicum paludosum</i>	Ke nuoc
12		<i>Echinochloa crus – galli</i> (L.)	Co long vuc nuoc
13		<i>Sp1</i>	Co
14		<i>Sp2</i>	Co
15		<i>Sp3</i>	Co
16	Commelinaceae	<i>Commelina coelestis</i>	Thai lai
17	Cyperaceae	<i>Carex capillacea</i>	Kiet toc
18		<i>Cyperus serotinus</i> Rottb	Co ba canh
19		<i>Cyperus rotundus</i> L..	Co gau
20	Convolvulaceae	<i>Ipomoea aquatic</i>	Rau muong
21	Urticaceae	<i>Parietaria debilis</i>	Tuong anh
22	Solanaceae	<i>Physalis angulata</i>	Tam bop
23		<i>Solanum americanum</i>	Lulu duc
24	Onagraceae	<i>Ludwigia adscendens</i> (L.)	Dua nuoc
25		<i>Ludwigia octovalvis</i>	Rau muong
26	Amaranthaceae	<i>Alternanthera sessilis</i>	Rau deu
27	Marsileaceae	<i>Marsilea quadrifolia</i> L.	Co bo
28	Polygonaceae	<i>Polygonum hydropiper</i> L..	Nghe nuoc
29		<i>Polygonum hydropiper</i> L.	Nghe ram
30		<i>Rumex chinensis</i> Campd	Chut chit
31	Verbenaceae	<i>Lantana camara</i> L.	Ngu sac
32	Araceae	<i>Coloscasia esculenta</i> L.	Khoai nuoc than trang
33		<i>Coloscasia</i> Black	Khoai nuoc than tim
34	Pontederiaceae	<i>Eichhornia crassipes</i>	Beo tay
35	Mackinlayoideae	<i>Centello asiatica</i>	Rau ma
36	Gleicheniaceae	<i>Dicranopteris dichotoma</i>	Guot
37	Pteridaceae	<i>Pteris vittata</i> L.	Duong xi

3.1.2 Diversity and dominance of plants

Table 3 and 4 showed that in 7 study areas, KV1 had the lowest diversity but dominant value was the highest, while KV3 was opposite.

Diversity and dominance of plant species were homologous at all study areas based on the number of individual, fresh and dry weight. If diversity value was calculated only based on the number of individuals at the dry land areas (KV1, KV6, KV7), KV6 had the highest diversity with the presence of 15 species. This is the agricultural area so that many species appear there than in other locations. At the low field locations, KV4 was more diverse than KV2 with three analysis methods, while semi-submerged area, the diversity at the KV3 was higher than KV5. If calculated on the entire 7 reaserch areas, KV3 had

the highest diversity beacause there are many canals at this location.

If the diversity was calculated due to the fresh weight, the results were 3.03; 2.93; 3.54 at dry land KV6, low field KV4, canals KV3, respectively. These locations had the highest diversity value. The dry weight based diversity values were also same with the above results.

Dominant values calculated according to individual were 0.84; 0.18; 0.16 at dry land KV1, low field KV4, canals KV5, respectively. If due to the fresh weight, the dominant values at the dry land KV7, low field KV2, canals KV5 were, respectively, 0.45; 0.21; 0.18. These areas also had the greatest values. It was the same value in the case of the fresh weight.

Table 3. Diversity value of the research areas

Kind of land	Location	Total of species	Diversity (H)		
			Individual	Fresh weight	Dry weight
Dry land	KV1	6	0.38	1.73	1.83
	KV6	15	2.13	3.03	2.98
	KV7	7	1.31	1.53	1.49
Low field	KV2	8	1.91	2.41	2.33
	KV4	14	1.99	2.93	2.74
Canal	KV3	21	2.42	3.54	3.57
	KV5	14	2.05	2.74	2.68

Table 4. Dominant values of the research areas

Kind of land	Location	Total of species	Dominance (Cd)		
			Individual	Fresh weight	Dry weight
Dry land	KV1	6	0.84	0.36	0.33
	KV6	15	0.16	0.17	0.17
	KV7	7	0.34	0.45	0.46
Low field	KV2	8	0.16	0.21	0.24
	KV4	14	0.18	0.15	0.19
Canal	KV3	21	0.10	0.10	0.10
	KV5	14	0.16	0.18	0.19

3.2. The relationship between Pb and Zn concentrations in soil with diversity and dominance of plant at the study area

Analytical results showed that all soil at the study areas were polluted by Pb and Zn except KV5 and KV6 that had Zn concentration lower than QCVN 03: 2015/BTNMT. At dry land locations (KV1, KV7, KV6), Pb and Zn concentrations in soil were higher than in other locations. In particular, at KV1 the values of Pb and Zn in soil were highest

that reached to 23426mg/kg and 237mg/kg, respectively. This may because there were many Pb recycling households operating in this area for a long time. At semi-submerged lands including low field (KV2, KV4) and canals (KV3, KV5), Pb and Zn concentrations in soil were high because of receiving polluted wastewater from landfills at the high terrain. In these locations, the KV2 and KV3 had high Pb and Zn concentrations in soil. The Pb content was 131,778 mg/kg and Zn was 1559 mg/kg at KV2, while Pb was 102,762 mg/kg and Zn was 366 mg/kg at KV3 (Table 5).

Table 5. Pb and Zn concentrations in soil and the diversity and dominance values

Kind of land	Location	Pb (mg/kg)	Zn (mg/kg)	Diversity (H)	Dominance (Cd)
Dry land	KV1	23426	237	0.38	0.84
	KV7	134	213	1.31	0.34
	KV6	164	117	2.13	0.16
Low field	KV2	131778	1559	1.91	0.16
	KV4	1822	260	1.99	0.18
	KV3	102762	366	2.42	0.1
	KV5	7321	142	2.05	0.16
QCVN 03:2015/BTNMT		70	200		

3.2.1 The relationship between the Pb and Zn concentrations in soil and the diversity

Each plant species has the resistance differently with different heavy metal contents in soil. Figure 2 and 3 shows that the trend of the diversity fluctuations at dry land, low field and canals is different. At the dry land (KV1, KV7, KV6), when the Pb and Zn concentrations in soil increase from KV6 (164 mg/kg Pb; 117 mg/kg Zn) to KV1 (23,436 mg/kg Pb; 237 mg/kg Zn), the diversity decreases from KV6 (2.13) to KV1 (0.38). This pointed out that the Pb, Zn affected on the flora in these areas. The similar results were found at the low field areas. Concentrations of Pb and Zn in soil at KV4 were 1,822 mg/kg and 260 mg/kg Zn, respectively and increased to KV2 (131,778 mg/kg Pb; 1,559 mg/kg Zn), the diversity decreased from KV4 (1.99) to KV2 (1.91). At the canals, the trend was reverse when

Pb concentration increased, the diversity also increased, KV5 (7,321 mg/kg Pb; 142 mg/kg Zn) increased to KV3 (102,762 mg/kg Pb; 366 mg/kg Zn), the diversity increased from KV5 (2.05) to KV3 (2.42). Both areas (KV3, KV5) were high plant diversity values, it showed that these plant species in these locations had good resistance with heavy metal infected conditions.

3.2.2. The relationship between the Pb and Zn concentration in soil and the dominance

Figure 4 and 5 show the relationship between the concentrations of Pb and Zn in soil in all study locations and the dominance at the study areas.

At the dry land areas (KV1, KV7, KV6), when the Pb, Zn concentrations in soil increased from KV6 (164 mg/kg Pb; 117 mg/kg Zn) to KV1 (23,426 mg/kg Pb; 237 mg/kg Zn), the dominant values increased from KV6 (0.16) to KV1 (0.84). It means that the potential appearance of the dominant species was highest at KV1 because of the high levels of heavy metal contamination in soil, only some species can withstand and then become the dominant species.

In the wetland areas (low fields and canals), the trend was opposite with the dry areas. At the low field location, when the Pb, Zn concentration in soil increased from KV4 (1822 mg/kg Pb; 260 mg/kg Zn) to KV2 (131,778 mg/kg Pb; 1,559 mg/kg Zn), the dominant values decreased from KV4 (0.18) to KV2 (0.16), and similar to the canal area. This may be that the flora at the submerged areas had high uniformity.

Figure 2. The relationship between the Pb concentration in soil and the diversity

Figure 3. The relationship between the Zn concentration in soil and the diversity

Figure 4. The relationship between the Pb concentration in soil and the dominance

Figure 5. The relationship between the Zn concentration in soil and the dominance

3.3. Determination of the dominant species in the study area

Figure 5 and Table 6 showed that if the dominant values calculated by individual species, there were five dominant species including *Bidens pilosa* L. (33.03%), *Acroceras munroanum* 8.14%), *Commelina coelestis* (7.83%), *Carex capillacea* (5.41%), *Ipomoea aquatic* (5.26%) (Table 6).

If taking into account of the fresh weight, the dominant species are Don buot (20,86 %), Tam bop (10,30 %), Thai lai (9,94 %), Rau muong (7,61 %), Co la tre (7,75 %). In which, Tam bop had the most dominant and followed by Don buot, these species had high biomass values and only appeared at the disposal areas (KV1). If based on the dry weight, there were five dominant species including *Bidens pilosa* L. (19.94 %), *Physanlis angulala* (9.81 %), *Acroceras munroanum* (7.55 %), *Commelina coelestis* (7.41 %), *Carex capillacea* (7.23 %) (Figure 6).

Table 6. The number and fresh, dry weight of plant species appearing in the study area

Vietnamese name	Latin name	Individual, %	Fresh weight, %	Dry weight, %
Don buot	<i>Bidens pilosa</i> L.	33.03	23.86	19.94
Co la tre	<i>Acroceras munroanum</i>	10.26	7.75	7.55
Thai lai	<i>Commelina coelestis</i>	7.41	9.94	7.41
Kiet toc	<i>Carex capillacea</i>	5.12	4.24	7.23
Rau muong	<i>Ipomoea aquatic</i>	5.16	7.61	6.37
Co long vuc nuoc	<i>Echinochloa crus - galli</i> (L.)	4.91	1.18	2.58

Vietnamese name	Latin name	Individual, %	Fresh weight, %	Dry weight, %
Ngai cuu	<i>Artemisia vulgaris L.</i>	4.29	0.74	0.83
Co man trau	<i>Eleusine indica (L.)</i>	3.43	1.18	1.18
Co ba canh	<i>Cyperus serotinus Rottb</i>	2.65	2.29	3.36
Tuong anh	<i>Parietaria debilis</i>	2.39	1.10	0.96
Cai	<i>Sp1</i>	2.13	0.01	2.25
Tam bop	<i>Physanlis angulala</i>	2.04	10.30	9.81
Co	<i>Sp3</i>	1.97	1.61	2.06
Dua nuoc	<i>Ludwigia adscendens (L.)</i>	1.91	2.76	2.66
Rau deu	<i>Alternanthera sessilis</i>	1.90	1.78	2.24
Co bo	<i>Marsilea quadrifolia L.</i>	1.60	0.29	0.33
Nghe nuoc	<i>Polygonum hydropiper L.</i>	1.06	4.42	6.49
Ngu sac	<i>Lantana camara L.</i>	1.03	0.23	0.32
Co	<i>Sp2</i>	0.91	1.01	1.32
khoai nuoc	<i>Coloscasia esculenta L.</i>	0.94	2.25	0.99
Nho noi	<i>Eclipta prostrata (L.)</i>	0.80	0.31	0.23
Beo tay	<i>Eichhornia crassipes</i>	0.70	2.50	1.77
Nghe ram	<i>Polygonum hydropiper L.</i>	0.61	0.23	0.21
Ngo dai	<i>Torenia asiatica L.</i>	0.52	1.10	0.95
Rau muong	<i>Ludwigia octovalvis</i>	0.44	0.06	0.06
Lulu duc	<i>Solanum americanum</i>	0.37	3.12	3.39
Co	<i>SP 1</i>	0.65	0.19	0.11
Co ga	<i>Cynodon dactylon</i>	0.84	0.54	1.43
Co gau	<i>Cyperus rotundus L.</i>	0.28	0.03	0.03
Rau ma	<i>Centello asiatica</i>	0.22	0.04	0.03
Guot	<i>Dicranopteris dichotoma</i>	0.17	2.85	4.87
Duong xi	<i>Pteris vittata L.</i>	0.10	0.21	0.35
Khoai nuoc than tim	<i>Colocasia Black</i>	0.06	0.50	0.26
Ke nuoc	<i>Panicum paludosum</i>	0.04	0.54	0.36
Cai dong	<i>Grangea maderaspanata L.</i>	0.03	0.01	0.03
Chut chit	<i>Rumex chinensis Campd.</i>	0.03	0.04	0.03
Bau dat	<i>Gynura divaricata L.</i>	0.01	0.04	0.02

Figure 6: The dominant values of five plant species

Table 7. Pb and Zn absorption of the selected plants

Vietnamese name	Latin name	Location	Pb (mg/kg) in soil	Zn (mg/kg) in soil	Pb (mg/kg) in plant	Zn (mg/kg) in plant
Don buot	<i>Bidens pilosa L</i>				380	58
Tam bop	<i>Physalis angulala</i>				71	33
Co la tre	<i>Acroceras munroanum</i>	KV1	23426	237	288	69
Thai lai	<i>Commelina coelestis</i>	KV3	102762	366	270	73

3.4. Verification of Pb and Zn absorption ability of the selected plant species

Table 7 showed that *Bidens pilosa L* and *Acroceras munroanum* had ability to absorb Pb respectively 380 mg/kg and 288 mg/kg at the dry area, higher than other species within the same area. For Zn, *Acroceras munroanum* can absorb 69 mg/kg Zn and higher than the remaining *Bidens pilosa L* and *Physalis angulala*. At the wetland areas, *Commelina coelestis* and *Ipomoea aquatic* can absorb Pb at 270 mg/kg and 223 mg/kg, respectively. *Ipomoea aquatic* can absorb Zn at 59 mg/kg and better than *Cyperus serotinus Rottb* and *Carex capillacea*.

Vietnamese name	Latin name	Location	Pb (mg/kg) in soil	Zn (mg/kg) in soil	Pb (mg/kg) in plant	Zn (mg/kg) in plant
Rau muong	<i>Ipomoea aquatic</i>	KV2	131778	1559	223	59
Co ba canh	<i>Cyperus serotinus Rottb</i>				42	46
Kiet toc	<i>Carex capillacea</i>				37	54

4. Conclusions

The results showed that the study area was contaminated lightly by Zn and seriously by Pb, especially at the KV1, KV2, KV3 with the corresponding concentrations of 23 426 mg/kg; 131,778 mg/kg; 102,762 mg/kg of Pb. There were 37 species belonging to 17 families identified. In which, there were 5 dominant species accounted due to individual number as *Bidens pilosa* L. (33,03 %), *Acroceras munroanum* (8,14 %), *Commelina coelestis* (7,83 %), *Carex capillacea* (5,41 %), *Ipomoea aquatic* (5,26 %).

At the dry land locations (KV1, KV7, KV6), when Pb and Zn concentrations in soil increased, diversity decreased. Pb and Zn concentrations in soil of KV6 were 164 mg/kg; 117 mg/kg and were 23,426 mg/kg; 237 mg/kg at KV1 respectively, the diversity decreased from KV6 (2.13) to KV1 (0.38). The same trend was found at the dry area. At the canal areas, the concentrations of Pb and Zn in soil were 7,321 mg/kg; 142 mg/kg respectively at KV5 and increased at KV3 (102, 762 mg/kg Pb, 366 mg/kg Zn), the diversity also increased from 2.05 to 2.42. In contrast to the diversity, the dominant value changes in the same direction with the increase of the heavy metal concentrations. In seven researched plant species, *Bidens pilosa* L., *Acroceras munroanum*, *Commelina coelestis* and *Ipomoea aquatic* had the highest Pb absorption ability. While Zn is absorbed the highest by *Commelina coelestis*. *Commelina coelestis* and *Bidens pilosa* L. can be used to treat both Pb and Zn in polluted soil.

5. References

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