

Bioaccumulation of Heavy Metals in *Eichhornia crassipes* Used as a Potential Substrate for Edible Mushroom Cultivation

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Abstract

Eichhornia crassipes is a depolluting plant having properties of absorbing heavy metals, minerals and other chemicals present in its environment. *E. crassipes* can be an excellent substrate for mushroom cultivation but because of galloping industrialization, and some anthropogenic activities that tend to pollute water and this leads to the accumulation of heavy metals in water hyacinth. The main goal of the current research was to give a contribution to a better knowledge of *E. crassipes*, a species used as a substrate for the cultivation of edible mushrooms, but also liable to accumulate toxic elements and the identification of these elements contained in its various organs by determining their concentrations. The X-rays emitted by the material will be converted using an appropriate detector into an electrical voltage of which the amplitude is proportional to the energy of the incident X-ray photon and makes it possible to carry out the qualitative analysis. The findings of the current research show that areas having anthropogenic activities contain a lot of pollutants precisely heavy metals. The concentration of these metals is higher in the roots than in the aerial part (stem and leaves) and it was observed that these toxic elements accumulate precisely in the roots. While major bio-elements are in a high concentration in the aerial parts than in the roots.

Keywords

Water Hyacinth, Heavy Metals, Bioaccumulation, Water Pollution

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1. Introduction

Water hyacinth (*Eichhornia crassipes*) is a free floating perennial plant with thick dark green leaves, circular to oval in their shape and attached to the plant by a spongy inflated petiole [1]. The leaves are usually 10–20 cm across and float above the water surface on long bulbous stalks. Plants consist of a rosette of six to ten leaves attached to a rhizome with a well-developed, fibrous, root system. The roots are unbranched and have a conspicuous root cap. Water hyacinth

also exhibits foliar plasticity, which allows variation in the morphology and physiological function of foliage produced in response to climatic and environmental conditions. It can grow in both saline and freshwater. It reproduces both sexually and by budding and stolen production [2]. Underneath the water it has a numerous of dark fibrous roots. The size of the plant varies between a few centimeters up to a meter and it has light blue to violet flowers on a loose terminal spike [2].

Its rapid growth produces dense mats that can clog water

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bodies, thus creating blockages that can cause flooding, interfere with navigation, power generation, crop irrigation and ecological status [2]. In many countries with a tropical or sub-tropical climate, water hyacinths have been introduced and become an invasive weed taking over lakes and rivers. They are considered to be one of the world's worst freshwater plants due to their very rapid growth rate, especially in waters with high nutrient levels [1]. The existent records of its invasion of the River Nile in the late 18th century was reported and it was subsequently introduced in other countries as a specimen for ornamental ponds and botanical gardens [2]. The species was discovered in 1823 by the German naturalist C. von Martius who was studying the flora of Brazil. He named it *Pontederia crassipes*. Sixty years later, Solms included it in the *Eichhornia* genus as described by Kuntz in 1829. Currently, *E. crassipes* is distributed across the tropics and subtropics between 39°N and 39°S [3]. Due to their fast growth and relatively high nutrient (vitamins A, B1, B2, B3, B5, B6, B12 and E) and crude protein contents (20-25%) [4] they could be used as natural fertilizers and soil improvers, as well as a potential raw material for producing biogas or paper in the paper industry. It has the ability to absorb and concentrate nutrients in its different parts [1].

E. crassipes is a depolluting plant having properties of absorbing heavy metals, minerals and other chemicals present in its environment as well it plays an essential role in bioremediation [5]. This plant has been introduced in the Democratic Republic of the Congo (DRC) and elsewhere in order to clean up waters. In DRC, it was introduced to the Congo River and Albert Lake. The Congo River being favorable for its growth, it reproduced itself exponentially until it became invasive leading to the obstruction of the fluvial traffic. Facing this untimely invasion, some countries such as Vietnam made this invasion an opportunity by using water hyacinth as a substrate for mushrooms cultivation in order to regulate this invasion [6]. Fungi being heterotrophic towards carbon, so they need to take preformed organic and inorganic materials in their environment. Several strategies were developed to respond to this need for "food" [7, 8]. The plant's attributes create a paradox, in that it is suitable for use as a hyperaccumulator, though its prolific growth rate causes a negative impact upon the environment, human health and economic development in many countries [2]. Conversely, the fact that it is an excellent hyperaccumulator of pollutants, it is abundantly available in many countries, where it is mechanically harvested in attempts to limit its spread and so presents an attractive source as a low-cost, green, remediation strategy [2].

E. crassipes can be an excellent substrate for mushroom

cultivation but because of galloping industrialization, and some anthropogenic activities that tend to pollute water, this leads to the accumulation of these heavy metals in water hyacinth [6]. Since, it would serve as a substrate for mushroom cultivation, and these being true bio-accumulators will automatically store these heavy metals [6]. It has been reported that the mobilization of heavy metals in the environment due to industrial activities is of serious concern due to the toxicity of these metals in human and other forms of life [9]. Therefore, the risk of consuming these heavy metals is real and their accumulation in the organism can be related to some pathologies. It is really risky to consume these heavy metals because their accumulation in the organism is related to certain pathologies. For instance, Aluminum known to be neurotoxic and it is suspected to be the cause of Alzheimer's disease, Arsenic known to be carcinogenic and it leads to skin lesions, digestive and reproductive disorders, Cadmium known to be carcinogenic, it is a nephrotoxic component and can damage the Central Nervous System, Mercury is a powerful neurotoxic, nephrotoxic and carcinogen. Lead known to be neurotoxic, its intoxication can lead to several disorders namely the decreasing of intelligence, lower intelligence quotient-IQ, delayed or impaired neurobehavioral development, speech and language handicaps, growth retardation and anti-social and diligent behaviors in children. On the other side, its adverse effects are observed in the reproductive system (decreased sperm count in men and spontaneous abortions in women), brain damage, kidney damage, gastrointestinal diseases, vitamin D metabolism [10]. Vanadium exposure induces the irritation of the lungs, throat, eyes and nasal cavities, digestive as well as neurological disorders [11-14]. The main goal of the current research was to determine the concentration of different chemical contained in different organs of *E. crassipes*. This will contribute to a better knowledge a species used as a substrate for the cultivation of edible mushrooms, but also liable to accumulate toxic elements. The hypothesis of this study was that the water hyacinth of Congo River is contaminated by heavy metals.

2. Material and Methods

2.1. Study Area

Different sites were chosen along the edge of the Congo River due to the high anthropogenic activities (industrial activities) that take place around these areas as well as the eventual abundance of water hyacinth. Based on these facts, four sites were chosen as sampling sites notably: Chanimental, Port de Ndolo, Kinkole and Maluku (figure 1).

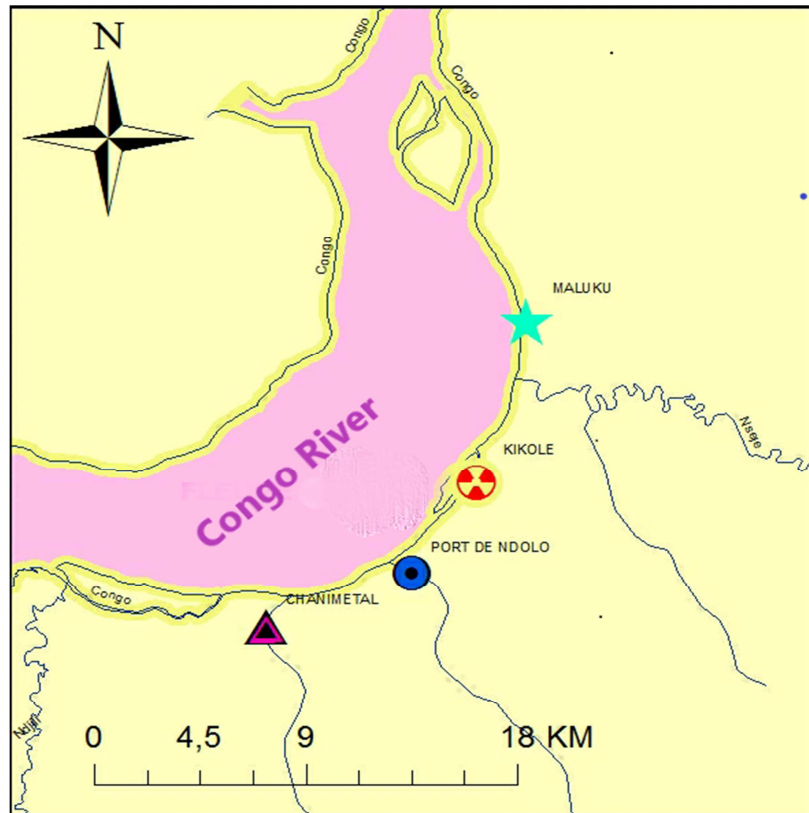


Figure 1. Map of different sampling stations along the Congo River.

The geographical coordinates of different stations used in this study are given below.

- Chanimetal station: is located at Kintambo municipality and its geographical coordinates are $4^{\circ} 19' 37''$ South and longitude $15^{\circ} 16' 2''$, East, and the main activities occurring at this station are shipbuilding, artisanal fishing and more than 20 firms are found around.

- Port de Ndolo Station: is located at Limete municipality and its geographical coordinates are $4^{\circ} 20' 59''$ South and $15^{\circ} 20' 17''$ East / -4.349749, 15.3381, The main activity occurring at this station is fishing and there is a fluvial traffic as well as the presence of more than 50 firms around.

- Kinkolé station: is located at N'sele municipality and its geographical coordinates are $4^{\circ} 22' 28''$ South $15^{\circ} 29' 41''$ East/ -4.374482, 15.4948. The main activity is fishing and there is also a fluvial traffic and the presence of some firms.

- Maluku station: it is located at Maluku commune and its geographical coordinates are $4^{\circ} 27' 41''$ South $16^{\circ} 04' 43''$, East / -4.461427, 16.0784. Fishing is the main activity and there is a fluvial traffic as well the presence of industrial firms (Sosider and Siforco).

2.2. Material

The biological material used for the experiment in this

research was *E. crassipes*, found at the surface of water. The leaves of *E. crassipes* is given in the figure below.

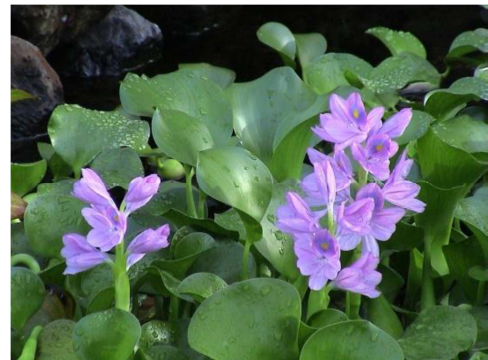


Figure 2 *Eichhornia crassipes* leaves (Water hyacinth).

2.3. Methods

2.3.1. Principle of Chemical Element Identification

The protocol described by Germaneau *et al.* [15] was used in this research for the determination of chemical elements in our samples.

The empty spaces left when an atom is excited are filled by electrons of higher layer that emits X rays of which the difference in energy equals to the energy of the excited layer and the initial one. Sources of X rays are the following:

certain radioisotopes, X rays generators and particle accelerators. The X-rays emitted by the material were converted using an appropriate detector (semiconductor Si, Ge, etc.) into an electrical voltage of which the amplitude is proportional to the energy of the incident X-ray photon and makes it possible to carry out the qualitative analysis. The intensity of these pulses makes it possible to carry out the quantitative analysis. This quantitative analysis is performed in several ways and the simplest is to compare the intensities of the standards with those of the neighboring matrix samples (external calibration).

2.3.2. Sample Preparation

Dry samples of *E. crassipes* were crushed and pulverized using the FRITSCH electromechanical grinder operating twice 10 minutes at 400 rpm (revolutions per minute) with a rest of 2 minutes. The powder obtained was homogenized by vigorous stirring in the plastic bags No. 8. The powder used as a laboratory sample was kept in the desiccator while the test portion consisted of 5 g of sample powder mixed with 1 g of binder before being compressed into the "Carver" brand pelletizer.

2.3.3. Operating Mode

The pellets were positioned on one of the positions of the sample changer plate and the X-ray fluorescence spectrum was taken successively with the aid of the secondary targets operating under the following conditions:

- Target 1, MB: Working voltage 39.76 kV, Current 0.88 mA, Gain 2048 channels, Energy range 0 - 25 keV; Exciting energy $K\alpha_1$ 17.441 keV $K\beta_1$ 19.60 keV;
- Target 2, Al_2O_3 : Working voltage 49.15 kV, Current 0.7 mA, Gain 4096 channels, Energy range 0 - 50 keV; Exciting energy $K\alpha_1$ 21,121 keV $K\beta_1$ 23,808 keV and $L\alpha$ 2,838 keV of Pd;
- Target 3, Co: Working voltage 35.79 kV, Current 1.0 mA, Gain 1024 channels, Energy Range 0 - 12.5 keV; Exciting energy $K\alpha_1$ 6.924 keV, $K\beta_1$ 7.6483 keV, and
- Target 4, Bragg HOPG crystal: Working voltage 17.4 kV, Current 1.99 mA, Gain 1024 channels, Energy Range 0 - 12.5 keV.

Detector: "Si Drift Detector sdd" of 7.0 mm² section cooled by the effect of the furs. Resolution 134.5 eV at the peak 5.895 keV Mn. The calculation algorithm was "FP-pellet",

i.e. Fundamental Parameter Pellet, supplied by the machine. The excitation time was one minute per target and each was measured thrice (triplicate). The algorithm calculates the attenuation correction factor in the matrix using the ratio of the cumulative net area under the characteristic peak of interest and the net area under the coherent peak. The characteristic peaks of the elements of interest were: Cu - $K\alpha_1$ 8.04 and $K\beta_1$ 8.904 keV; Zn - $K\alpha_1$ 8.63 keV and $K\beta_1$ 9.57 keV and Pb $L\alpha_1$ 10.55 keV, $L\beta_1$ 12.612 keV using the intensity of the signal at target 4 for Cu and Zn and target 1 for Pb).

The correction of the spectral interferences and the contribution of the secondary X-ray fluorescence was ensured by a factor intrinsic to the algorithm when calculating the intensity of the net surface. Finally, a normalized intensity proportional to the concentration of the element in the sample was delivered. The standardized intensities of the samples were compared with the standards.

2.3.4. Calculation

The standards were delivered to the laboratory in a stabilized bag or bottle. The sample sizes were obtained and processed in a similar way. The concentrations of our samples were calculated using the equation below:

$$C_{ech} = \frac{I_{ech} \cdot C_{etal}}{I_{etal}} \quad (1)$$

With I_{ech} : Standardized intensity of the element in the sample, the standard; C_{ech} , C_{etal} : Concentration of the element in the sample and the standard.

The calculated levels for each element of interest in each sample were subjected to the Fischer test to obtain the confidence interval at $\alpha = 0.05$ after elimination of the outliers following this equation.

$$\sigma_F = \frac{t_n \cdot \sigma_{mes}}{\sqrt{n}} \quad (2)$$

Where t_n : Fischer factor according to the number n of values.

2.3.5. Quality Control

If we apply on the IAEA-V10 the quality control of the results obtained from the other reference materials, we observe the graph below of the best biases according to the equation:

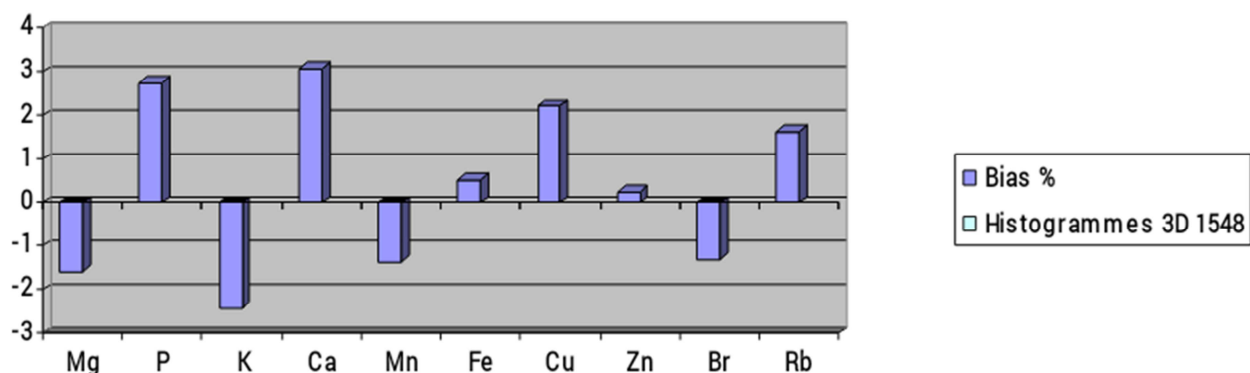


Figure 3. Better bias in quality control on IAEA V10.

2.4. Data Analysis

The mean and standard deviation of different samples were determined using Excel 2013.

3. Results and Discussion

3.1. Results

Chemical analyses of Water hyacinth collected at different stations of Kinshasa are presented in tables (1-4).

Table 1. Concentration of different chemicals in samples collected at Port de Ndolo.

Elements	Leaves	Stems	Root
	Mean±SD	Mean±SD	Mean±SD
Al	431.22±70.61	462.93±75.80	54436.37±891 3.19
AS	2.41±0.02	2.12±0.14	10.97±1.24
Ba	17.10±4.64	22.56±6.11	25.19±9.65
Br	34.51±4.21	90.92±11.09	8.27±1.36
Ca	15761.14±2694.63	13661.48±2335.66	3920.14±727.19
Cd	<0,5	<0,5	<0,5
Cl	12513.58±844.16	25715.74±1734.77	1214.04±104.23
Co	ND	< 1.0	<1.0
Cr	1.73±0.47	1.49±0.41	16.83±3.48
Cu	8.80±1.34	5.54±0.84	25.72±5.37
Fe	328.65±142.32	215.69±93.40	16135.25±17170.1
I	1.87±0.17	3.26±0.30	1.04±0.21
K	36983.79±6616.72	37080.84±6634.09	3655.63±666.70
Mg	2313.24±363.45	2552.43±401.03	3265.79±495.62
Mn	132.25±17.79	149.49±20.11	185.30±43.61
Mo	<0.5	<0.5	<.0.5
Na	ND	11817.73±1234.12	8612.03±456.36
Ni	2.66±0.30	2.18±0.25	7.54±1.12
P	4121.52±370.61	3370.09±303.04	1710.20±164.19
Pb	-	2.36±0.94	71.83±14.41
Rb	37.03±3.67	36.76±3.65	13.25±1.73
S	2535.92±152.77	1488.32±89.66	1693.92±137.81
Sb	<1.0	<1.0	< 1.0
Se	-	-	<0.5 (0.33)
Si	2942.98±732.49	2292.68±570.63	177469.36±44171.01
Sn	16.90±2.35	14.15±1.97	11.59±4.07
Sr	82.26±11.55	106.58±14.96	29.15±4.32
Ti	13.61±5.37	8.98±3.55	1324.52±210.79
V	2.04±0.58	1.06±0.30	29.12±6.02
Y	-	-	18.52±2.14
Zn	68.93±21.24	144.87±44.65	309.47±59.63

Legend: In red: toxic elements (heavy metals); In blue: oligoelements (comprising some heavy metals); In green: macroelements and minerals; In black: elements having an unknown use; ND: Not determined, -: absence of the element.

From the above table, it emerges that there is an accumulation of heavy metals in the roots, stems and leaves of *E. crassipes*,

The metal content is higher in the roots while that of the minerals and macro-elements is higher in the aerial parts of the plant (stem and leaves). The aluminum, arsenic, vanadium are present in all parts of the plant while lead is present only in the stem and in the roots. It should be noted that Cadmium is in insufficient quantity <0.5 ppm.

Table 2. Concentration of different chemicals in samples collected from Chanimetal (Naval Construction).

Elements	Leaves	Stems	Roots
	Mean±SD	Mean±SD	Mean±SD
Al	521.06±85.32	1350.65±221.15	35194.54±5762.61
AS	6.13±1.24	-	8.82±1.69
Ba	25.40±6.89	31.37±8.50	19.29±7.39
Br	43.15±5.26	87.56±10.68	17.41±3.08
Ca	10420.21±1781.51	8753.88±1496.62	3002.52±578.27
Cd	<0,5	<0.5	<0.5
Cl	27387.22±1847.52	57058.45±3849.13	8228.89±706.51
Co	<1.0	1.77±0.37	1.08±0.57
Cr	1.74±0.48	1.33±0.36	10.63±2.13
Cu	7.77±1.18	4.17±0.63	9.32±2.22
Fe	353.99±153.29	389.68±168.74	10867.32±4459.54
I	1.28±0.12	1.58±0.15	1.17±0.46
K	32829.12±5873.41	46889.97±8389.03	18194.27±3254.13
Mg	3017.54±474.10	6047.67±950.18	4672.56±709.12
Mn	193,36±26,01	244.93±32.95	991.33±256.16
Mo	<0,5	<0.5	<0.5
Na	ND	ND	1504.82±123.56
Ni	2.58±0,29	1.92±0.22	5.61±0.67
P	2359,10±212,13	1244.32±111.89	1284.22±123.29
Pb	7,96±3,17	4.89±1.95	57.63±12.97
Rb	39,61±3,93	52.23±5.18	31.35±4.28
S	2359,28±142,13	1134.27±68.33	1449.69±138.89
Sb	< 1,0	< 1.0	ND
Se	ND	ND	ND
Si	2535,96±631,18	4913.98±1223.06	115479.61±28742.19
Sn	11,03±1,53	10.27±1.43	9.01±5.57
Sr	63,40±8,90	57.23±8.03	23.98±3.54
Ti	13.77±5.44	18.02±7.12	793.89±126.84
V	1.37±0.39	7.67±2.18	17.77±3.84
Y	-	-	13.38±1.04
Zn	35.93±11.07	46.91±14.46	62.23±12.55

Legend: ND: Not determined, -: absence of the element.

From the table above, it can be observed that the concentrations of the chemical elements in a sample of water hyacinth collected next to Chanimetal (the shipbuilding station). These findings show a high concentration of metals in the roots and a high concentration of major bio-elements (minerals and macro-elements) in the aerial parts of the plant. Aluminum, lead, vanadium are present in all parts of the plant. Arsenic is only present in the leaves and roots. Cadmium is in insufficient quantity <0.5 ppm.

Table 3. Concentration of different chemicals in samples collected from Kinkole station.

Elements	Leaves	Stems	Roots
	Mean±SD	Mean±SD	Mean±SD
Al	722.47±118.29	1347.10±220.57	15077.66±2468.75
AS	-	ND	7.79±2.34
Ba	30.54±8.28	40.52±10.98	31.83±8.63
Br	62.47±7.62	127.02±15.49	35.24±4.30
Ca	12913.99±2207.87	8467.19±1447.61	3032.62±518.48
Cd	<0.5	<0.5	<0.5
Cl	27014.95±1822.41	49576.58±3344.40	7043.05±475.12
Co	< 1.0	ND	1.87±0.40
Cr	1.83±0.50	1.32±0.36	4.81±1.32
Cu	6.27±0.95	3.39±0.52	8.47±1.29
Fe	443.87±192.21	665.98±288.39	9101.35±3941.20
I	1.47±0.14	1.36±0.13	1.57±0.15
K	30291.16±5419.35	37839.29±6769.78	23736.29±4246.63
Mg	5577.15±876.26	7349.62±1154.74	6071.92±953.99

Elements	Leaves	Stems	Roots
	Mean±SD	Mean±SD	Mean±SD
Mn	506.84±68.17	629.85±84.72	2157.21±290.16
Mo	<0.5	<0.5	<0.5
Na	ND	ND	1366.47±145.36
Ni	240±0.27	2.33±0.27	6.19±0.71
P	1843.87±165.80	629.35±56.59	785.28±70.61
Pb	1.45±0.58	1.10±0.44	3.22±1.28
Rb	23.76±2.36	35.83±3.56	33.78±3.35
S	2430.99±146.45	906.42±54.60	3225.46±194.31
Sb	-	-	-
Se	-	-	-
Si	4133.47±1028.80	6275.51±1561.94	59263.72±1475039
Sn	942±1.31	13.24±1.84	9.08±1.26
Sr	71.90±10.09	60.78±8.53	24.48±3.44
Ti	12.37±4.89	21.23±8.38	366.33±144.66
V	1.31±0.37	0.38±0.11	11.18±3.17
Y	-	ND	ND
Zn	45.76±14.10	75.65±23.31	424.74±130.90

Legend: ND: Not determined, -: absence of the element.

It can be observed that these findings show a high concentration of metals in the roots and a high concentration of major bio-elements (minerals and macro-elements) in the aerial parts of the plant. Lead and vanadium are present in all parts of the plant in very small quantities in the aerial parts. Aluminum was present in all parts of the plant while Arsenic was present only in the roots, absent in the leaves and not determined in the roots.

Table 4. Concentration of different chemicals in samples collected from Maluku.

Eléments	Leaves	Stems	Roots
	Mean±SD	Mean±SD	Mean±SD
Al	836.63±136.99	722.35±118.27	32069.59±5250.94
AS	-	-	3.95±0.96
Ba	25.89±7.02	27.33±7.41	25.82±9.90
Br	22.15±2.70	37.69±4.60	10.05±1.58
Ca	17984.25±3074.71	16768.33±2188.25	3066.44±550.76
Cd	<0.5	<0.5	ND
Cl	14483.48±977.05	24877.32±1678.21	3178.20±272.87
Co	0	< 1.0	1.13±0.26
Cr	1.83±0.50	1.44±0.39	12.67±2.61
Cu	6.77±1.03	3.74±0.57	6.77±1.29
Fe	383.38±166.01	282.30±122.25	11376.91±1069.69
I	1.78±0.17	<0.5	-
K	33532.92±5999.33	35450.67±6342.43	8853.51±1632.76
Mg	3482.37±547.13	2875.71±377.95	3219.89±488.66
Mn	304.42±40.95	312.05±41.97	928.65±214.34
Mo	<0.5	<0.5	ND
Na	ND	4760.40±235.69	3715.11±247.34
Ni	2.68±0.30	2.38±1.08	5.44±0.79
P	2895.32±260.35	2462.54±211.46	1043.06±100.14
Pb	0.63±0.25	0.53±0.07	1289±1.56
Rb	32.75±3.25	35.25±3.50	2033±2.51
S	1782.97±107.41	971.77±52.43	1018.17±64.56
Se	ND	<0.5	-
Si	6687.51±1664.48	1299.77±401.05	163657.23±40733.31
Sn	12.08±1.68	11.65±1.62	-
Sr	75.95±10.66	83.72±9.67	22.23±3.31
Ti	34.23±13.52	29.57±5.62	1383.58±222.49
V	1.62±0.46	1.01±0.29	26.17±6.30
Y	ND	0.61±0.09	21.52±2.48
Zn	72.98±22.49	58.49±10.13	149.16±28.17

Legend: ND: Not determined, -: absence of the element.

The above findings show a high concentration of metals in the roots and a high concentration of major bio-elements (minerals and macro-elements) in the aerial parts of the plant.

Aluminum is present in all parts of the plant. Lead and vanadium are present in all parts of the plant but in very small quantities in the aerial parts and Arsenic is present only

in the roots while Cadmium was in insufficient quantity.

3.2. Discussion

The environmental pollution is the result of rapid industrialization, technological advancement and unprecedented increase in population. Meanwhile the human evolution has led to immense scientific and technological progress [16, 22]. Meanwhile Heavy metals are significant environmental pollutants, and their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons [17]. It should be noted that the metal uptake by plants depends on the bioavailability of the metal in the water phase, which in turn depends on the retention time of the metal, as well as the interaction with other elements and substances in the water [18]. Heavy metal toxicity in plants varies with plant species, specific metal, concentration, chemical form and soil composition and pH, as many heavy metals are considered to be essential for plant growth [17, 21].

The distribution of these stations was performed according to the increasing order of pollution notably Kinkole, Maluku, Chanimetal and Port de Ndolo. The findings of the current research show that sites with strong activities have a lot of pollutants precisely heavy metals. The concentration of these metals is higher in the roots than in the aerial part (stem and leaves) and it was observed that these toxic elements accumulate precisely in the roots. While major bio-elements are in a high concentration in the aerial parts than in the roots. Our findings are consistent with previous findings where it was shown as well that the majority of toxic elements accumulate in the roots while concentrations in the aerial parts remain acceptable. Shaon *et al.* [9] reported that individual metals differ in their distribution in a plant such as Fe in water hyacinth is localized at the root surface with the concentration decreasing towards the root centre while Cu, Zn and Pb are more at the root centre as compared to the surface. There is relatively less accumulation in leaves in most of the cases. This metal toxicity causes conformational changes by altering overall configuration of proteins, ribonucleic acids and osmotic balance of the whole body. It is linked to direct release of industrial wastes into water channels and streams and is not limited to aquatic organisms only, but it also influence soil properties [19]. Heavy metals produce undesirable effects, even if they are present in extremely minute quantities, on human, animals and plant life. The release of various heavy metals into aquatic environment is a worldwide problem of increasing magnitude [16].

It was observed that aluminum was the most abundant element and it was present in all parts of the plant and in greater concentration in the roots. The presence of this

element can be explained by the fact that aluminum is the most abundant metal in the earth's crust and is the third most common element [20]. Our findings showed that water hyacinth is a true bio-accumulator as it depollutes waters. Consistent with previous analyzes that have shown that water hyacinth is a phytoremediant plant for its ability to hyperaccumulate to extract certain nutrients and heavy metals from sludge, in sewage treatment ponds [12-13]. To cultivate mushrooms with water hyacinth, roots must be removed. But where are we going to put these roots? Even if we remove the roots, the risk of intoxication remains linked to aluminum, which is omnipresent.

4. Conclusion and Suggestions

The main aim of this study was to give a contribution to a better knowledge of *E. Crassipes*, a species used as a substrate for the cultivation of edible mushrooms, but also liable to accumulate toxic elements. From our findings, it was shown that water hyacinth of the Congo River contains a lot of nutrients as well as heavy metals following our hypothesis. The sites with major activities in particular Chanimetal and Ndolo contain a lot of heavy metals; according to our forecasts. We found the antagonism between the accumulation of metals and that of major bio-elements. Indeed, the greatest amount of major bio-elements accumulated in the aerial parts of the plant. While that of metals accumulates in the roots. By its amount in major bio-elements, water hyacinth can allow a good mushroom cultivation. It is potentially dangerous because it contains a lot of heavy metals especially aluminum.

In the future, it will be necessary to extract these heavy metals, to allow a fair healthy production (uncontaminated mushrooms). It would be necessary to make an experiment of the cultivation of the mushrooms with the aerial parts of the water hyacinth; and then perform analyzes of these fungi to assess the level of accumulation of toxic elements.

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