

## Full Length Research Paper

### Biosorption Potentials of Water Hyacinth (*Eichhornia crassipes*)

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The study investigated the biosorption potentials of *Eichhornia crassipes*, commonly known as water hyacinth. The biosorption efficacy of *Eichhornia crassipes* showed that the dosage factor recorded its highest adsorption by the root at 3 g (99.80±0.00%) by the root at 1 g. At pH 8, cadmium had maximum adsorption (96.85±0.01%) at pH of 4. Chromium had the highest adsorption value in temperature (98.90±0.01% at 50°C by the stem) and time (99.81±0.00% at 30 min by the stem). Lead was the least adsorbed (88.13±0.00%) at temperature 70°C by the root) and

chromium for time (89.94±0.00% at 70°C by the root). In concentration chromium was the highest adsorbed metal (99.31±0.00% by the stem at 20 mg/L) and lead the least (90.04±0.01%) by the root at 60 mg/L. These results indicate the potentials of the biosorption efficacies of the leaf stem and root of the *Eichhornia crassipes* plant.

**Keywords:** Biosorption potentials, *Eichhornia crassipes*, heavy metals, water hyacinth

## INTRODUCTION

Aquatic plants, e.g water hyacinth (*Eichhorniacrassipes*) impact both positive and negative effects on man, either directly or indirectly (Mitchell, 1974) Aquatic plants are considered nuisance when excessive growth interferes with desired water uses in a number of ways (Adeniji, 1979). In line with increased industrialization, travel and communication, agricultural productivity and changes in consumption, problems associated with aquatic plants have increased in the last century (Davis and Hirji, 2003). Enrichment of water bodies by poor land use practices, effluents from human and industrial wastes have aggravated the negative impacts of aquatic plants. The discharge of heavy metals into aquatic and terrestrial ecosystems has become a matter of concern in various countries all over the world over the last few decades. These pollutants are introduced into the aquatic systems significantly as a result of various industrial operations (Ahalya *et al.*, 2003). These toxic materials may be derived from mining operations, refining ores, and sludge

disposal, fly ash from incinerators, processing of radioactive materials, metal plating, and the manufacture of electrical equipment, paints, alloys, batteries, pesticides or preservatives. The pollutants of concern include lead, chromium, cadmium, mercury, uranium, selenium, zinc, arsenic, gold, silver, copper and nickel. The toxicity and health hazards associated with these pollutants which are also heavy metals have been established beyond any doubts. Considerable attention has been paid to methods for metal removal and those commonly used include; electrochemical methods, reverse osmosis, chemical precipitation, ion exchange, biological processes, flotation and membrane process (Park *et al.*, 2010). Limitations synonymous with these methods have been understood to include incomplete metal removal, high energy or reagent requirement, generation of toxic sludge and other waste products which require disposal. In addition, these methods are also limited when used for the decontamination of aquatic

systems with adsorbents in a low concentration range (Vieira and Volesky, 2000; Volesky, 2007). As a result of these challenges, the search for new technologies involving the use of other sorbent materials has directed attention to biosorption, which is based on metal binding capacities of various biological materials. Biosorption' has been defined by Volesky (2007), a pioneer in the field, as the property of certain bio-molecules (or types of biomass) to bind and concentrate selected ions or other molecules from aqueous solutions. Biosorption by dead biomass (or by some molecules and/or their active groups) is passive and based mainly on the affinity between the (bio) sorbent and sorbate (Volesky, 2007). The biosorption process involves a solid phase (sorbent or bio-sorbent) and a liquid phase (solvent, normally water) containing a dissolved specie(s) to be sorbed (sorbate, metal ion). Due to the higher affinity of the sorbent for the sorbate species, the latter is attracted and bound with different mechanisms. The process continues till equilibrium is established between the amount of solid bound sorbate species and its portion remaining the solution (Hussaini *et al.*, 2010). The bio-sorbent materials possess metal-sequestering property and can be used to decrease the concentration of heavy metal ions in solutions. In their recent review paper, Park *et al.* (2010) observed that biosorbents that have been sought for the removal of metal ions primarily fall into the following categories: bacteria, fungi, algae, industrial wastes, agricultural waste, natural residues and other biomaterials. Some mycelia from large scale fermentation processes have been used as a source of biosorbents conveniently (Kapoor and Virraghavan, 1995). Seaweeds which can be gotten in larger quantities from the ocean have also attracted attention as possible biosorbents (Suzuki *et al.*, 2005). Agricultural waste materials such as polymerized corn cob (Odozi *et al.*, 1985), modified groundnut husk (Okieimen *et al.*, 1988), modified peanut shells (Marshall *et al.*, 2003) and cassava waste biomass (Horsfall *et al.*, 2003) have shown positive results in biosorption studies. Aquatic macrophytes such as *Lemnaminor* and *Pistia stratiotes*, which are present at high growth rate, have been investigated for their heavy metal removal potential (Wang, 1990; Klumpp *et al.* 2002). Low cost, high efficiency, minimization of chemical and/or biological sludge, no additional nutrient requirement, regeneration of biosorbent and possibility of metal recovery are the advantages associated with biosorption (Gadd, 1993). Recent research indicates that aquatic plants are threats to biological diversity affecting fish fauna, plant diversity, fresh water life and food chains (Garry *et al.*, 1997). Aquatic plants offer a variety of products and services which are of considerable benefits. Agriculturally, they are used as food fodder, feed ingredients, fertilizers etc. They are also used in the production of biofuel, paper, fibre board, yarn, rope, basket, charcoal briquetting, matting and bedding. Their strands act as filters for excessive nutrients, also making

it possible for them to remove heavy metals, biocides and other toxins from water. Recreation and horticulture have also been enhanced by great potentials of aquatic plants. The paucity of knowledge concerning the productivity of aquatic plants emphasizes the urgent need to study these plants for their adequate management and utilization. It is on this premise that this study was embarked upon to evaluate the biosorption ability in the removal of certain heavy metals from industrial effluents

## MATERIALS AND METHODS

### Sources of materials

The *E. crassipes* in Figure 1 (a, b and c) used for the work were obtained from the New Calabar River also known as Choba River, located in Obi//Akpor Local Government Area of Rivers State, South-South Nigeria (Figures 1 to 3).



Figure 1 (a) (b) (c)

### Processing of samples

The plant was harvested from the river, cleaned and separated into the different parts (leaf, stem and root). Each part was separately oven-dried, ground and stored in air tight containers.

### Biosorption studies

Biosorption of the heavy metals, Lead, Chromium and Cadmium were carried out by the Batch sorption method as reported by Dubey and Shiwani, (2011).

### Method of data analysis

All samples were analyzed in triplicates. The data were analyzed using tables, range, means, percentages, standard deviation and hence standard error (SE). Sample mean was calculated for all the three replicate samples, while standard deviation (S.D) was calculated from the sample mean by the standard statistical method for all the variables. The standard deviations were used to calculate the standard errors ( $\pm$ S.E) as reported by Osuji *et al.* (2005). Standard error ( $\pm$ S.E) was estimated at the 95% confidence level by multiplying the standard error with 1.96. The proximate composition data obtained

**Table 1.** Biosorption of lead metal with various dosages of the leaf, stem and root of *Eichhorniacrassipes*.

Dosage (g)	Leaf (%)	Stem (%)	Root (%)
1	98.50 ± 0.00 <sup>ab</sup>	98.51 ± 0.01 <sup>ab</sup>	96.92 ± 0.00 <sup>c</sup>
3	98.91 ± 0.00 <sup>a</sup>	96.49 ± 0.01 <sup>b</sup>	97.86 ± 0.00 <sup>c</sup>

Values are mean ± standard deviation of triplicate determinations. Values in the same row bearing different superscripts are significantly different at the 0.05 level.

**Table 2.** Biosorption of Cadmium metal with various dosages of the leaf, stem and root of *Eichhorniacrassipes*.

Dosage (g)	Leaf (%)	Stem (%)	Root (%)
1	93.50 ± 0.01 <sup>abc</sup>	96.91 ± 0.00 <sup>b</sup>	92.35 ± 0.00 <sup>c</sup>
3	95.44 ± 0.02 <sup>abc</sup>	96.94 ± 0.00 <sup>b</sup>	93.94 ± 0.00 <sup>c</sup>

Values are mean ± standard deviation of triplicate determinations. Values in the same row bearing different superscripts are significantly different at the 0.05 level.

**Table 3.** Biosorption of chromium metal with various dosages of the leaf, stem and root of *Eichhorniacrassipes*.

Dosage (g)	Leaf (%)	Stem (%)	Root (%)
1	99.04 ± 0.00 <sup>abc</sup>	99.58 ± 0.00 <sup>abc</sup>	99.33 ± 0.01 <sup>abc</sup>
3	99.33 ± 0.00 <sup>abc</sup>	99.37 ± 0.00 <sup>abc</sup>	99.80 ± 0.00 <sup>abc</sup>

Values are mean ± standard deviation of triplicate determinations. Values in the same row bearing different superscripts are significantly different at the 0.05 level.

from this study were subjected to one-way analysis of variance (ANOVA) at 5% level of confidence using Genstat 9th edition software as reported by Ndlovu and Afolayan, (2008).

## RESULTS AND DISCUSSION

### Biosorption of lead, cadmium and chromium ions at various dosages of the leaf, stem and root of *Eichhornia crassipes*

At 1 g of sample, adsorption of lead was highest in the stem, while cadmium and chromium also recorded their highest adsorption in the stem. Their values were significantly ( $p < 0.05$ ) different from each other. At 3 g sample, more adsorption of metal ions was observed in all samples for the metals with the exception of adsorption of chromium ions by the stem. This also agrees with the report of Aboul-Fetouch *et al.* (2010) which stated that the adsorbent dosage varies significantly with adsorption percentage (Tables 1- 3).

### Biosorption of lead, cadmium and chromium ions at various pHs using the leaf, stem and root of *Eichhornia crassipes*

Adsorption was highest in the stem for lead, chromium and cadmium at pH of 4 and 8. There was significant

( $p < 0.05$ ) difference in the values of pH-4 for cadmium and pH 8 for lead and chromium (Tables 4 - 6). The higher pH 8 which fell into the alkaline pH brought about more adsorption of lead and cadmium by the leaf, stem and root of *Eichhornia crassipes*. Shekinah *et al.* (2002) showed that the removal of lead ion ( $Pb^{2+}$ ) from aqueous solution using activated carbon from *Eichhornia crassipes* increased with increase in pH. Cationic dyes have also been noted to be highly adsorbed at basic pH (Aboul-Fetouch *et al.*, 2010).

**Table 4.** Biosorption of lead metal at various pH values using the leaf, stem and root of *Eichhorniacrassipes*.

pH	Leaf (%)	Stem (%)	Root (%)
4	98.27 ± 0.01 <sup>ab</sup>	98.45 ± 0.01 <sup>ab</sup>	96.85 ± 0.01 <sup>c</sup>
8	98.59 ± 0.00 <sup>a</sup>	99.20 ± 0.00 <sup>b</sup>	99.32 ± 0.00 <sup>c</sup>

Values are mean ± standard deviation of triplicate determinations. Values in the same row bearing different superscripts are significantly different at the 0.05 level.

**Table 5.** Biosorption of Cadmium Metal at various pH values using the leaf, stem and root of *Eichhorniacrassipes*.

Dosage (g)	Leaf (%)	Stem (%)	Root (%)
4	91.85 ± 0.00 <sup>ab</sup>	97.05 ± 0.00 <sup>b</sup>	89.90 ± 0.03 <sup>c</sup>
8	95.25 ± 0.01 <sup>a</sup>	97.40 ± 0.01 <sup>b</sup>	99.81 ± 0.01 <sup>c</sup>

Values are mean ± standard deviation of triplicate determinations. Values in the same row bearing different superscripts are significantly different at the 0.05 level.

**Table 6.** Biosorption of Chromium Metal at various pH values using the leaf, stem and root of *Eichhorniacrassipes*.

pH	Leaf (%)	Stem (%)	Root (%)
4	99.18 ± 0.01 <sup>abc</sup>	99.63 ± 0.01 <sup>abc</sup>	98.57 ± 0.00 <sup>abc</sup>
8	98.46 ± 0.00 <sup>ac</sup>	96.33 ± 0.00 <sup>b</sup>	98.12 ± 0.01 <sup>ac</sup>

Values are mean ± standard deviation of triplicate determinations. Values in the same row bearing different superscripts are significantly different at the 0.05 level.

### Biosorption of lead, cadmium and chromium ions at various temperatures using the leaf, stem and root of *Eichhornia crassipes*

At 50°C, adsorption was highest in the leaf for lead, stem for cadmium and chromium. Highest adsorption at 70°C was recorded in the stem for lead and cadmium, and leaf for chromium. Significant ( $p < 0.05$ ) differences were observed at 50°C for cadmium and 70°C for lead and cadmium. More adsorptions were observed at the lower temperature (50°C) for cadmium and chromium all the samples. Increase in adsorption rate has been observed by El-khaiary, (2007) in the adsorption of methylene blue by nitric acid treated *Eichhornia crassipes* at room temperature. Adsorption increase was also observed by Jie, (1998) at a temperature increase from 6-36°C by *Eichhorniacrassipes* in colour removal from dyeing waste water (Tables 7-9).

**Table 7.** Biosorption of lead metal at various temperatures using the leaf, stem and root of *Eichhorniacrassipes*.

Temp. (°C)	Leaf (%)	Stem (%)	Root (%)
50	97.54 ± 0.00 <sup>ab</sup>	97.50 ± 0.00 <sup>ab</sup>	94.53 ± 0.00 <sup>c</sup>
70	97.68 ± 0.00 <sup>a</sup>	98.18 ± 0.00 <sup>b</sup>	88.13 ± 0.00 <sup>c</sup>

Values are means ± standard deviation of triplicate determinations. Values in the same row bearing different superscripts are significantly different at the 0.05 level.

**Table 8.** Biosorption of cadmium metal at various temperatures using the leaf, stem and root of *Eichhorniacrassipes*.

Temp. (°C)	Leaf (%)	Stem (%)	Root (%)
50	91.32 ± 0.01 <sup>a</sup>	94.81 ± 0.00 <sup>b</sup>	89.80 ± 0.01 <sup>c</sup>
70	90.99 ± 0.01 <sup>a</sup>	94.07 ± 0.00 <sup>b</sup>	89.05 ± 0.01 <sup>c</sup>

Values are means ± standard deviation of triplicate determinations. Values in the same row bearing different superscripts are significantly different at the 0.05 level.

**Table 9.** Biosorption of chromium metal at various temperatures using the leaf, stem and root of *Eichhorniacrassipes*.

Temp. (°C)	Leaf (%)	Stem (%)	Root (%)
50	98.53 ± 0.00 <sup>abc</sup>	98.90 ± 0.00 <sup>abc</sup>	98.21 ± 0.01 <sup>abc</sup>
70	97.87 ± 0.00 <sup>abc</sup>	97.83 ± 0.00 <sup>abc</sup>	98.25 ± 0.01 <sup>abc</sup>

Values are means ± standard deviation of triplicate determinations. Values in the same row bearing different superscripts are significantly different at the 0.05 level.

### Biosorption of lead, cadmium and chromium ions at various times using the leaf, stem and root of *Eichhornia crassipes*

Highest adsorption was recorded in the stem for lead, cadmium and chromium at 10mins while at 30mins cadmium highest adsorption was in the leaf, and lead and chromium were in the stem. There were significant ( $p < 0.05$ ) differences at 10 and 30mins for lead and cadmium. Increase in time resulted to increase in adsorption of metals by the leaf, stem and root of *Eichhornia crassipes*. This has also been observed by Kardivelu *et al.* (2004), who stated that sorption is dependent on contact time in their work with *Eichhornia crassipes*-derived activated carbon (Tables 10-12).

**Table 10.** Biosorption of lead metal at various times using the leaf, stem and root of *EichhorniaCrassipes*.

Time (minutes)	Leaf (%)	Stem (%)	Root (%)
10	97.06 ± 0.01 <sup>a</sup>	97.97 ± 0.01 <sup>b</sup>	95.17 ± 0.01 <sup>c</sup>
30	97.29 ± 0.00 <sup>a</sup>	98.54 ± 0.01 <sup>b</sup>	5.56 ± 0.00 <sup>c</sup>

Values are means ± standard deviation of triplicate determinations. Values in the same row bearing different superscripts are significantly different at the 0.05 level.

**Table 11.** Biosorption of cadmium metal at various times using the leaf, stem and root of *Eichhorniacrassipes*.

Time (minutes)	Leaf (%)	Stem (%)	Root (%)
10	91.55 ± 0.00 <sup>ab</sup>	91.94 ± 0.00 <sup>ab</sup>	89.94 ± 0.00 <sup>c</sup>
30	91.78 ± 0.00 <sup>ab</sup>	91.76 ± 0.01 <sup>abc</sup>	90.33 ± 0.00 <sup>abc</sup>

Values are means ± standard deviation of triplicate determinations. Values in the same row bearing different superscripts are significantly different at the 0.05 level.

**Table 12.** Biosorption of chromium metal at various times using the leaf, stem and root of *Eichhorniacrassipes*.

Time (minutes)	Leaf (%)	Stem (%)	Root (%)
10	98.34 ± 0.00 <sup>a</sup>	99.52 ± 0.00 <sup>abc</sup>	97.60 ± 0.01 <sup>c</sup>
30	98.33 ± 0.00 <sup>a</sup>	99.81 ± 0.01 <sup>b</sup>	97.97 ± 0.00 <sup>c</sup>

Values are means ± standard deviation of triplicate determinations. Values in the same row bearing different superscripts are significantly different at the 0.05 level.

### Biosorption of lead, cadmium and chromium ions at various concentrations using the leaf, stem and root of *Eichhornia crassipes*

At 20, 40 and 60 mg/L of metals, the stem recorded the highest adsorption. Significant ( $p < 0.05$ ) differences were observed at 20mg/L for cadmium, 40 mg/L for cadmium and chromium, and 60mg/L for lead, cadmium and chromium. Adsorption in lead reached equilibrium at 40 mg/L in the leaf and stem, and dropped at 60mg/L.

In cadmium adsorption, there is an increased with increase in concentration while adsorption dropped with increase in metal concentration for the leaf, stem and root (Tables 13-15). Malik (2007), Schneider *et al.* (1995), Mahmood *et al.* (2010) and, Mahamadi and Nharingo, (2010) have worked with the *Eichhornia crassipes* biomass and found it to be effective in the removal pollutants. This ability of *Eichhornia crassipes* in removal of pollutants is attributed to its poly-functional metal - binding sites for both cationic and anionic metal complexes (Mahamadi, 2011).

**Table 13.** Biosorption of lead metal at various concentrations using the leaf, stem and root of *Eichhorniacrassipes*.

Concentration (mg/L)	Leaf (%)	Stem (%)	Root (%)
20	97.61 ± 0.01 <sup>ab</sup>	97.72 ± 0.00 <sup>ab</sup>	96.10 ± 0.01 <sup>c</sup>
40	98.34 ± 0.00 <sup>ab</sup>	98.57 ± 0.00 <sup>ab</sup>	94.27 ± 0.01 <sup>c</sup>
60	96.50 ± 0.00 <sup>a</sup>	97.14 ± 0.00 <sup>b</sup>	90.04 ± 0.01 <sup>c</sup>

Values are means ± standard deviation of triplicate determinations. Values in the same row bearing different superscripts are significantly different at the 0.05 level.

**Table 14.** Biosorption of cadmium metal at various concentrations using the leaf, stem and root of *Eichhorniacrassipes*.

Concentration (mg/L)	Leaf (%)	Stem (%)	Root (%)
20	91.63 ± 0.01 <sup>a</sup>	96.38 ± 0.00 <sup>b</sup>	90.06 ± 0.00 <sup>c</sup>
40	93.50 ± 0.01 <sup>a</sup>	95.73 ± 0.00 <sup>b</sup>	92.87 ± 0.01 <sup>c</sup>
60	95.18 ± 0.05 <sup>a</sup>	96.06 ± 0.00 <sup>b</sup>	94.61 ± 0.01 <sup>c</sup>

Values are means ± standard deviation of triplicate determinations. Values in the same row bearing different superscripts are significantly different at the 0.05 level.

**Table 15.** Biosorption of chromium metal at various concentrations using the leaf, stem and root of *Eichhorniacrassipes*.

Concentration (mg/L)	Leaf (%)	Stem (%)	Root (%)
20	98.32 ± 0.00 <sup>ac</sup>	99.31 ± 0.00 <sup>b</sup>	98.02 ± 0.01 <sup>ac</sup>
40	96.58 ± 0.00 <sup>a</sup>	98.53 ± 0.00 <sup>b</sup>	95.90 ± 0.01 <sup>c</sup>
60	94.83 ± 0.00 <sup>ac</sup>	97.35 ± 0.01 <sup>b</sup>	94.76 ± 0.00 <sup>ac</sup>

Values are means ± standard deviation of triplicate determinations. Values in the same row bearing different superscripts are significantly different at the 0.05 level.

## Conclusion

The findings of this study have shown the biosorptive capacity of the plant, *Eichhorniacrassipes*. The excellent removal capabilities of some metals of environmental concern by *Eichhorniacrassipes* were apparent in this study.

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