INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE

ISSN: 2067-533X Volume 4, Issue 1, January-March 2013: 81-86 www.ijcs.uaic.ro

PHYTOREMEDIATION OF ZINC, CADMIUM, COPPER AND CHROME FROM INDUSTRIAL WASTEWATER BY EICHHORNIA CRASSIPES

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Abstract

Eichhornia crassipes was tested for its high capacity to bioconcentrate four heavy metals (Zn, Cd, Cu, and Cr) commonly found in wastewater from industries. Young plants of equal size were cultured in plastic tub containing industrial wastewater. Therefore, control experimental sets contained only mining effluent without any plants. The digested samples were analyzed for four metals (Zn, Cu, Cd and Cr) by a Perkin Elmer 3000DV Inductively Coupled Plasma-Atomic Emission Spectrometer (ICP-AES). *Eichhornia crassipes* removed appreciable amount of heavy metals during a 15 days experiment. Maximum removal of metals was recorded on the 10^{th} day of exposure. Roots of *Eichhornia crassipes* proved better accumulator of the metals than leaves. *Eichhornia crassipes* can be used to serve as a phytoremediation plant in the cleaning up of Zn, Cd, Cu and Cr from industrial wastewater.

Keywords: *Eichhornia crassipes; phytoremediation; accumulation capacity; industrial wastewater.*

Introduction

Heavy metals pollution of water is a major environmental problem the modern world faces [1, 2]. Common pollutants related to the kinds and amounts of urban and industrial discharges as well as to the contribution of anthropogenic sources enter into the aquatic environment (many of which are considered potent toxicants capable of producing a wide spectrum of adverse health effects such as chloracne, carcinogenicity, disruption of the endocrine System, and antiestrogen effects) in both dissolved and particulate forms.

The removal of toxic heavy metals from industrial wastewater is essential from the environmental pollution control [3]. Many industries release heavy metals such as Zn, Cd, Cu and Cr in wastewater. Heavy metals can cause brain damage and many diseases in human beings [4]**.** They cannot be degraded easily and their cleanup usually requires their removal [5]. Therefore, the direct release of reused wastewater for the irrigation of agriculture and horticultural is viewed as posing potential risk to human health [6, 7].

For the treatment of such industrial wastewater containing toxic metals, various chemical and engineering method are available, however, they are expensive and energy consuming [8]. Treatment systems are low cost and suits to our environment. The uptake of metals by watery macrophytes may give an indication of the major source of pollutants to the aquatic System. Plant uptake of pollutants from water is one of the pathways considered in models aimed at assessing the hazard of chemical contaminants in water.

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Plants such as *Eichhornia crassipes* can facilitate biodegradation of organic pollutants, it can absorb heavy metals and it is a good accumulator of Zn, Cr, Cu, Pb, Ag, and Cd [9]**.**

In Côte d'Ivoire, the aquatic ecosystem is becoming progressively polluted with various heavy metal produce by several anthropogenic activities, and this represents an environment problem. Therefore, the present study gives a report on the results obtained following tests carried out for the absorption of heavy metals (Pb, Zn, Cd, Cu and Cr) by *Eichhornia crassipes*.

Materials and methods

Sampling

Yang plants of *Eichhornia crassipes* (Fig.1) were obtained from a local unpolluted pond located (GPS) in Côte d'Ivoire.

Fig. 1. Water hyacinth (*Eichhornia crassipes*), plant and graphic

Eichhornia crassipes (water hyacinth) is a member of pickerelweed family (Pontederiaceae). It is a free floating (except when stranded in mud) aquatic plant [10]**.** It is one of the most widespread water plants in Ivorian waters. It has been used successfully in wastewater treatment systems to improve water quality by reducing the levels of heavy metals and organic nutrients [11].

The water hyacinth or *Eichhornia crassipes* is widespread in many areas of the world South America (Brazil), Central America (certain islands of the Caribbean, states of the South and the South-West of the United States), Asia of South-East (Java, Ceylon etc…), Africa (basins of the Nile and Congo, Senegal, Ghana, Togo, Benin, Nigeria), and Europe (basin of Tage in Portugal). In Côte d'Ivoire, many water levels are also invaded by the water hyacinth, the Ono, Aghien and Potou lagoons; East of Ebrié lagoon; the Mé river, the Comoé river, and hydroelectric storage reservoirs Taabo and Buyo [12, 13].

These watery macrophytes constitute a major risk for the ecosystems because of their often spectacular growth and their ecological impacts (clogging and draining of the lake) and socio-economic (gene with navigation, impossibility of fishing etc.).

It presents strong concentrations out of nitrogen and with a less degree out of phosphorus, that mainly on the level of its system foliar [14]**.** Few studies were carried out for its use in the phytoepuration of worn water.

The plants were thoroughly washed with distilled water before they were placed in plastic tub diameter 60cm and depth 40cm containing 30L of industrial wastewater effluents. Each tub was containing the same weight (300 g) of plants.

Plants were cultured with 100% coverage of the total surface area of the plastic used for aquaculture. Control experimental sets contained only same effluents without any plants. The experiment was conducted in triplets and repeated tree times for a period of 15 days each one.

Effluents used of aquaculture experiment and plants were analyzed at initial level, 5th, 10th, and 15th day (figure 2).

Fig. 2. Experimental device located at the University of Abobo-Adjamé:
(1) and (4) *Eichhornia crassipes* in industrial wastewater effluents,
(2) and (3) Same industrial wastewater effluents without any plants.

Chemical analysis

Samples of wastewaters were collected in duplicate at the time of harvesting the plants and the samples were acidified to a pH less than 2 with concentrate HNO_3.Water samples (50 mL) were digested with 2 M HNO_3 at 95 °C for 2 h and were made up to 100 mL in a volumetric flask with distilled water. The digestion was done in glassware previously soaked in nitric acid and washed with distilled water. The digested samples were analyzed for metals in duplicate using a Perkin Elmer 3000DV Inductively Coupled Plasma-Atomic Emission Spectrometer (ICP-AES). Sample blanks were also analyzed and results that were between 1% and 5% of each metal determined in samples were used to correct for any contamination in the course of the analysis.

The plant samples were separated into root and leaves to determine the accumulation trend from water to root and to the leaves. They were each dried in an oven at 60 °C till well dried. The dried samples were ground before digestion. Five hundred milligrams of dried weight of each fraction were digested with 10 mL of $HClO_4$ and HNO_3 mixture (1:3) at about 80 °C for 4 h. The resulting cleared colored solutions were made up to a mark in a volumetric flask (25 mL) with distilled water. All the reagents that were used were of analytical grade and all the reaction vessels were treated well to avoid external contributions of the metals. Sample blanks were analyzed to correct the possible external contributions while replicate samples were also evaluated and all the analyses were done in triplicate to ensure reproducibility of the results. The digested samples were analyzed for four metals (Zn, Cu, Cd and Cr) by a Perkin Elmer 3000DV Inductively Coupled Plasma-Atomic Emission Spectrometer (ICP-AES).

Results and discussion

When plants are used as bioindicators, the measured uptake of contaminants may give an indication of the contamination level in the urban environment, as well as of the kinds of Systems of discharge from agriculture and industry. In general, polluter-plant association in the aquatic System can occur influenced by several factors such as pH, reactivity of the elements, nature of the organic matter, organic and inorganic ligands, etc. In our field data, the water body pH (about 7) was an important parameter in controlling ions availability and hence the uptake by an individual plant. However, the final concentration in the plant was also associated with the weather conditions, growth, humidity, temperature regimens, etc.

Figure 3 shows a non significant decrease in Zn, Cd, Cu, Cr concentration as observed in control wastewater without plants. In all cases, the final concentration of each metal in wastewater with *Eichhornia crassipes* was lower than in control wastewater. We were found in decreasing order up to 10th day of analysis.

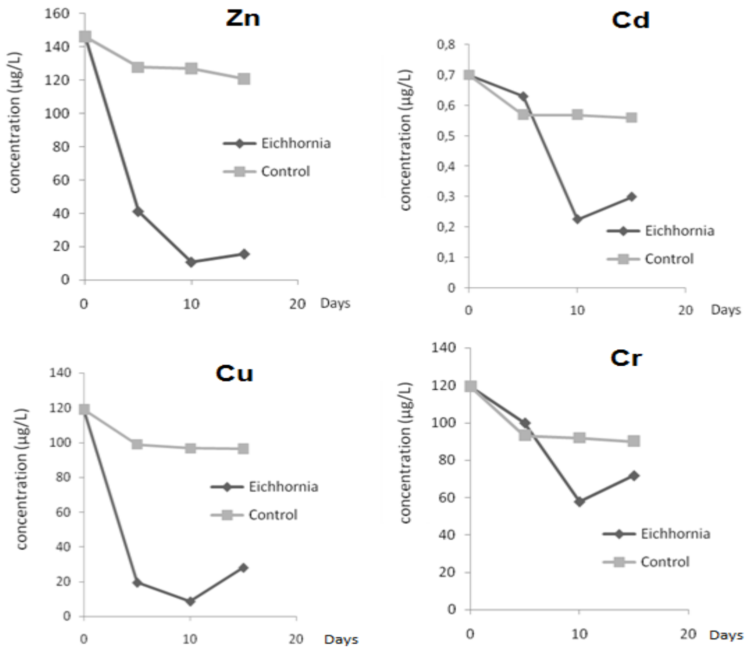

Fig. 3. Concentration of heavy metals in wastewater effluent during experimentation

The variations in tolerance indices to the different metals used in this study indicate that genetically based tolerance may exist in plants that could survive heavy metal contaminated habitat. Highest removal of these heavy metals may be due to its fast growth [15] and mainly to the plant bioaccumulation [1].

Zinc (Zn) and copper (Cu) are more accumulated because they are micro-nutrients for plants. Copper (Cu) is a component of an electron carrier called plastocyanin that is active during photosynthesis. The results of the present study showed that *Eichhornia crassipes* is a good accumulator of Zn, Cr, Cu, and Cd. Other studies have also shown that the plant was a good accumulator of Cd and Cr [16].

The presence of Cu and Zn in the control plants was normal, as these elements are present in healthy plants as micro-nutrients. Copper (Cu) is a component of an electron carrier called plastocyanin that is active during photosynthesis. The element is also a constituent of ascorbic acid oxidase, tyrosinase, and phenoloxidase. Zinc (Zn) is a component of enzymes like carbonic anhydrogenase, alkaline phosphatase, carboxypeptidase, and glutamic dehydrogenase. The element is essential for carbohydrate and phosphorus metabolism and synthesis of RNA [17].

Analysis on 15th day revealed a little increase in the heavy metals concentration in wastewater with *Eichhornia crassipes*. That may be associated with decaying of plants and release of metals into effluent [18].

Aquatic plants generally have the ability to accumulate larger metal concentrations in their organs than those present in the surrounding water [19].

The accumulation factor (BCF) is defined as the metal concentration in plant tissue (micrograms per gram) divided by the metal concentration in water (micrograms per milliliter) [20].

$$BCF = \frac{\text{Metal concentration in plant tissue } (\mu g.g^{-1})}{\text{Metal concentration in water } (\mu g.mL^{-1})}$$

Accumulation factors of Zn, Cd, Cu, and Cr in *Eichhornia* plants in the present study are given in figure 4.

The uptake of all metals is stronger in the roots than in the tops of the plant, which agrees with several other studies [21, 19]. The Bioaccumulation factor of the roots is higher than that of the leaves for the four metals which indicates that the roots accumulated more than leaves. That showed that metals accumulated by *Eichhornia crassipes* were largely retained in roots [18].

Lower accumulation of metal in leaves than roots can be associated with protection of photosynthesis from toxic levels of heavy metals [22].

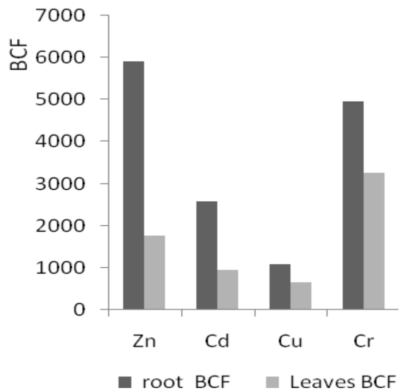

Fig. 4. Bioaccumulation factors (BCF) of Zn, Cd, Cu, and Cr in *Eichhornia crassipes* grown in wastewater.

Conclusions

Results from the present study show that *Eichhornia crassipes* has a very high accumulation capacity for Zn, Cd, Cu and Cr from wastewater during 15 days experiment. Maximum removal of metals was recorded on 10th day of exposure.

Roots of *Eichhornia crassipes* proved better accumulator of the metals than leaves. Based on these results *Eichhornia crassipes* can be used on large scale for removal of heavy metals.

It can be proposed that *Eichhornia crassipes* can act as powerful agents of Zn, Cr, Cu, and Cd removal from water. Since this specie grow abundantly in wetlands covering almost the entire water surface, the ability to absorb Zn, Cr, Cu and Cd and to withstand high levels of these metals as demonstrated here shows that specie will effectively remove Zn, Cr, Cu, and Cd in the field. A suitable harvesting system will be required for obtaining meaningful results. The harvested plant tissue, rich in accumulated metal, can be processed by drying, ashing or composting. Dried material may be combusted to produce energy. Zn, Cr, Cu, and Cd can be reclaimed from the ash after an acid treatment.

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Received: September, 12, 2012
Accepted: December, 10, 2012