International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.9, No.02 pp 189-195, 2016

Bioaccumulation of Heavy Metals from Wastewaters (Pb, Zn, Cd, Cu and Cr) in Water Hyacinth (*Eichhornia crassipes*) and Water Lettuce (*Pistia stratiotes*).

Kouame Kouame Victor[1]*, Meite Ladji[1], Adjiri Oi Adjiri[2], Yapi Dope Armel Cyrille[2], Tidou Abiba Sanogo[2]

[1]Department of Management and Environmental Sciences, University of Nangui-Abrogoua, Côte d'Ivoire, 02 BP 801, Abidjan.
[2]University of Jean Lorougnon Guédé, Côte d'Ivoire, B.P 150 Daloa.

Abstract: Aquatic macrophytes are well known accumulators for heavy metals from wetlands. The objective of this study is to evaluate the capacity of lead (Pb), zinc (Zn), cadmium (Cd), copper (Cu) and chromium (Cr) uptake and bioaccumulation factor of *Eichhornia crassipes* and *Pistia stratiotes* from wastewaters. Young plants of *Eichhornia crassipes* and *Pistia stratiotes* of equal size were grown in industrial wastewater effluents for 20 days. The plants in the experiment removed more than 50 % of Zn, Cu, Cr and Pb. Removal of metals from water was fast especially in the first ten days. Metals accumulation in water hyacinth and water lettuce was in the order of Zn> Pb> Cr > Cu> Cd. Roots of *Eichhornia crassipes* proved better accumulator of the metals than leaves. Bioconcentration factor (BCF) of Pb, Zn and Cu was more than 1000 in two species. The translocation factor (TF) of Cr, Pb, Cu and Zn in water hyacinth was low (0.07 – 0.46) except for Cd (3.35). *Eichhornia crassipes* and *Pistia stratiotes* are found to be suitable candidates for effective removal of heavy metals from wastewaters.
Keywords: Aquatic macrophytes, Phytoremediation, Bioconcentration factor, Trace metals.

Introduction

Water pollution by heavy metals is a major environmental problem in the modern world[1, 2]. Pollutants enter aquatic systems via effluent discharge, industrial, urban and agricultural run-off. Unlike organic pollutants, natural processes of decomposition do not remove heavy metals. On the contrary, they may be accumulated in aquatic biota and can be converted to organic complexes, which may be even more toxic[3]. Moreover, heavy metals can have ecological impact on water bodies leading to increased nutrient load especially if they are essential metals. These metals in effluent may increase fertility of water leading to eutrophication which in open water can progressively lead to oxygen deficiency, algae blooms and death of aquatic life[4]. Contaminants present in aquatic systems commonly include a wide range of metallic such as cadmium, lead, chromium, zinc and copper particularly in areas with high anthropogenic pressure.

The removal of toxic heavy metals from industrial wastewater is essential for the environmental pollution control[5]. Many technologies have been used to reduce aquatic pollution, but they are generally costly. An interesting alternative approach is phytoremediation where plants are used to stabilize or even to remove metals from water through phytoaccumulation, phytodegradation and phytostabilization mechanisms[6]. It is an emerging technology that utilizes the capacity of vascular aquatic macrophytes such as water hyacinth and water lettuce and their associated microbes for soil or water cleanup[7, 8].

They can remove suspended materials, nutrients and heavy metals from wastewater with great efficiency[9, 10]. Plants species used in phytoremediation are biologically active plants and most are suitable for removal of heavy metal ions and are capable of phytoaccumulating heavy metals from soil and water[11, 12]. The objective of this study is to evaluate the capacity of heavy metals (Pb, Zn, Cd, Cu and Cr) uptake and the bioaccumulation factor of *Eichhornia crassipes* and *Pistia stratiotes* from wastewaters.

Materials and methods

Sampling and batch studies

Triplicate batch tests were conducted in cylindrical tanks of 1000 L capacity with 0.8 m radius and 0.5 m depth. In each tank, 400 L of wastewater (0.2 m deep) coming from industrial park of Yopougon township were poured and it was planted with 4 kg (fresh weight) of young plants (figure 1). Experiments were performed with an additional single unplanted control to assess the role of *Eichhornia crassipes* and *Pistia stratiotes* in the removal of heavy metals. Young plants of *Eichhornia crassipes* and *Pistia stratiotes* were collected from a local unpolluted River (Côte d'Ivoire). The plants were thoroughly washed with tap water before being placed in tanks containing industrial wastewater effluents. Three replicates in each group were conducted for a residence times of 20 days each one. Heavy metals (Pb, Zn, Cd, Cu and Cr) from effluents were analyzed at initial level, 5th, 10th, and 15th day. Metals concentration of each plant species were analyzed at initial and final stage of the experiment.

Figure 1: Picture of three tanks used for the study at the end of the 3rd week

Chemical analysis

Water samples were collected in duplicate at the time of harvesting the plants and the samples were acidified to a pH less than 2 with concentrated HNO_3. 50 mL of water samples were digested with 2 M HNO_3 at 95 °C for 2 hours 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).

The plant samples were separated into root and leaves to determine the accumulation trend from water to the roots 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 (500 mg) 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 hours. The resulting cleared colored solutions were made up to the mark in a 25 mL volumetric flask with the 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 five metals (Pb, Zn, Cd, Cu and Cr) by a Perkin Elmer 3000DV Inductively Coupled Plasma-Atomic Emission Spectrometer (ICP-AES).

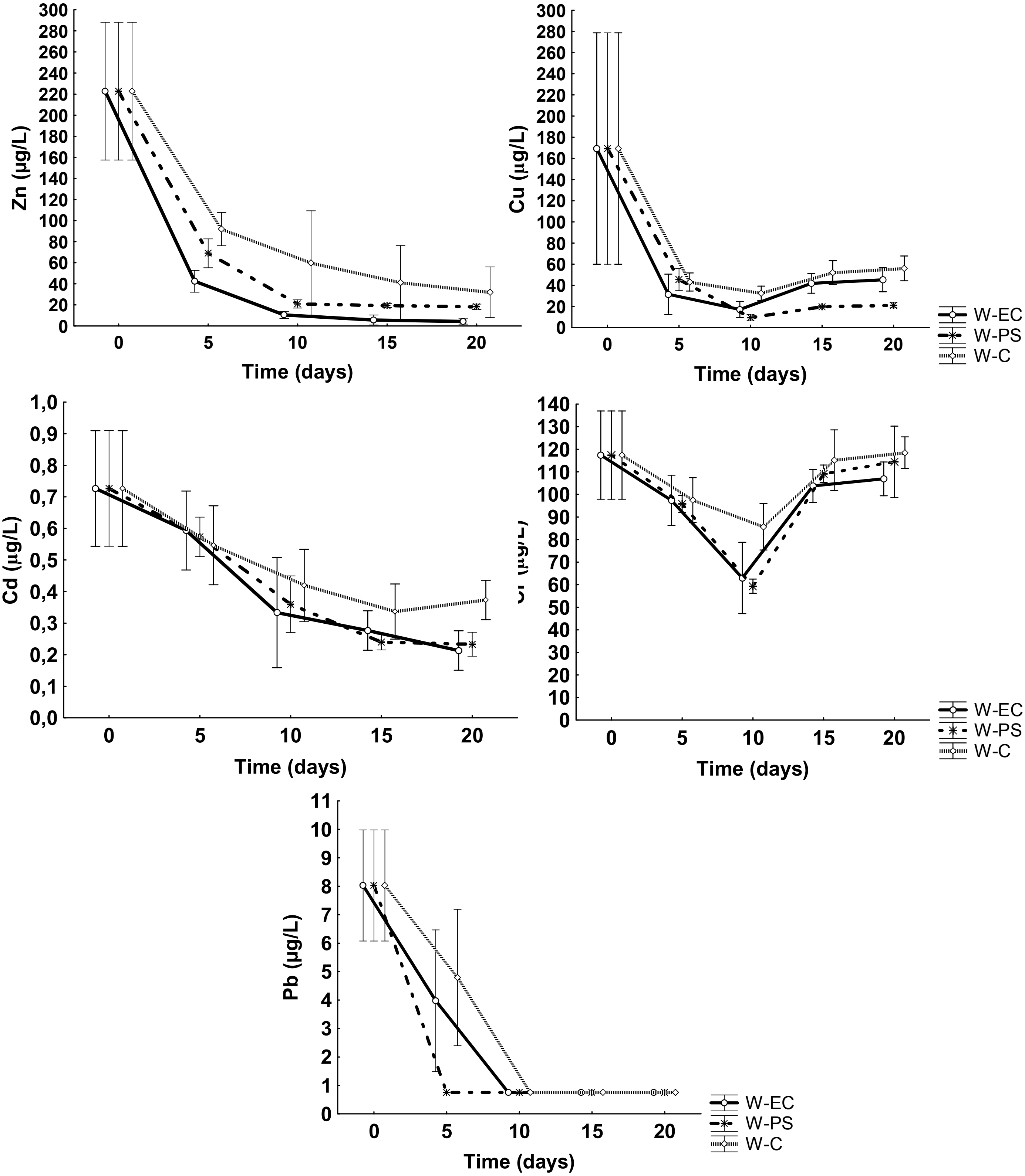
In the present investigation, the bioconcentration factor (BCF) and the translocation factor (TF) of heavy metals within hydrophytes were calculated as shown below[13, 14] :

$$\text{BCF} = \frac{\text{Trace element concentration in plant tissue (mg/kg) at harvest}}{\text{Initial concentration of the element in water (mg/L)}}$$

$$\text{TF} = \frac{\text{Root concentration (mg/kg)}}{\text{Leave concentration (mg/kg)}}$$

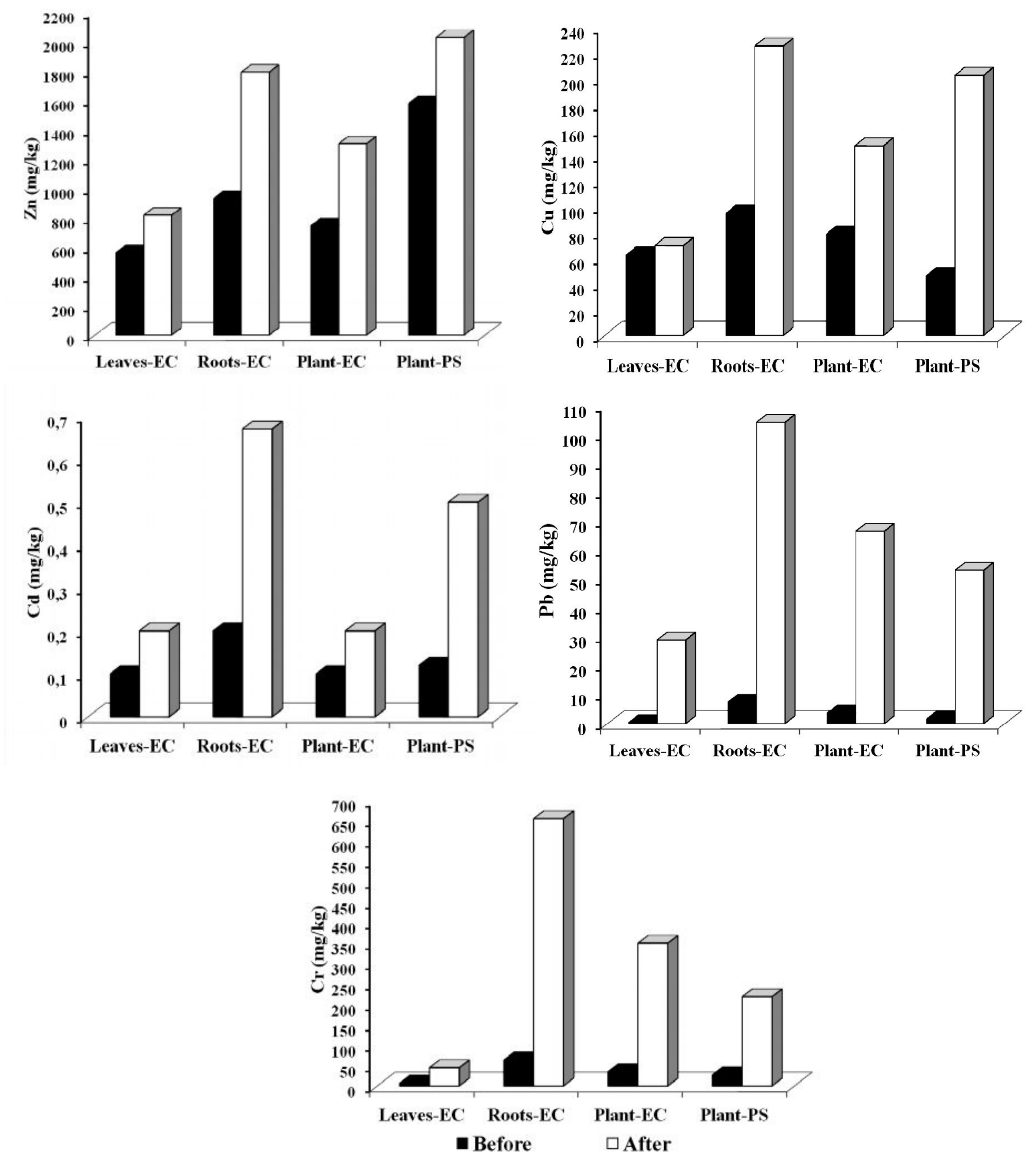
Results and discussion

The concentrations of metals (Zn, Cu, Cd, Cr, Pb) in experimental tanks during the treatment are showed in figure 2. In all cases, the final concentration of each metal in wastewater with *Eichhornia crassipes* or *Pistia stratiotes* was lower than in control wastewater. The concentration of zinc decreased rapidly in all containers until the 10th day. Then it noticeably decreased to stabilize. The initial value was reduced from 212.74 to 5.2 µg.L^{-1} in wastewater treated by water hyacinth and to 13.81 µg.L^{-1} in water lettuce tanks. Thus, the percentage reduction was 97.56 and 93.51 %, respectively. Cadmium concentration decreased until 15th day from 0.7 µg.L^{-1} to 0.25 µg.L^{-1} for water hyacinth and 0.23 µg.L^{-1} for water lettuce. The reduction on copper concentrations was similar. However, this reduction was greatly the first five days. At the 15th day, copper value was lowest in wastewater treated by water lettuce. Contrary to the three previous heavy metals, the concentrations of chrome decreased during the first 10 days then increased highly in all containers. According to Liao and Cheng[15], water hyacinth is able to absorb and translocate Cd, Cu and Zn in the plant's tissue as a root or shoot. This shows that water hyacinth can be a promising candidate to remove the heavy metals. Some researchers found similar metal uptake in water lettuce and water hyacinth for heavy metals[16, 17, 18]. Highest removal of these heavy metals may be due to its fast growth and to the plant bioaccumulation[19].



W-EC: water treated by *Eichhornia crassipes* W-PS: water treated by *Pistia stratiotes* W-C: Water control
Figure 2: Variation of heavy metals (Zn, Cu, Cd, Cr, Pb) in different tanks of wastewater treatment with time

In the present study, contrary to water hyacinth, metals accumulation by water lettuce was determined for all plant because it was difficult to make the difference of plant organs after experiments. The accumulation of metals in the roots and the leaves of water hyacinth and in water lettuce collected in natural environment (before experiments) and after wastewaters phytoremediation was showed in figure 3. Zn and Cu concentrations in both plants collected in natural environment were higher than Cd, Pb and Cr contents. After the experiments, the concentrations of all metals increased. Zn increased from 745.16 to 1304.29 mg/kg for *Eichhornia crassipes* and from 1577.71 to 2036.01 mg/kg for *Pistia Stratiotes.* Cu increased from 78.12 to 147.51 mg/kg and from 46.29 to 202.30 mg/kg for *Eichhornia crassipes* and *Pistia Stratiotes* respectively. From the experiment, water hyacinth accumulated the highest concentration of metals in roots (1792.66 mg/kg for Zn, 655.25 mg/kg for Cr, 225.19 mg/kg for Cu and 104.54 mg/kg for Pb). The high metal concentration in the plant roots is found to be similar with the results of previous studies[1, 20]. In general, most studies reported that higher levels of metals were accumulated more in roots compared to leaves. One of the reasons for higher accumulation factor in the plant roots may be due to of their absorption to the surface of root tissue[21]. The highest metals accumulations in water hyacinth leaves were found to be 817.91 mg/kg for Zn and 69.83 mg/kg for Cu. Zn and Cu were more accumulated because they are micro-nutrients for plants[17].



EC: *Eichhornia crassipes* ; PS: *Pistia stratiotes*

Figure 3: Metals concentrations in the organs of *Eichhornia crassipes* and *Pistia stratiotes* before and after wastewater treatment.

Bioconcentration factor of heavy metals in water hyacinth and water lettuce and their translocation factor in the present study are given in table 1. BCF of the roots is higher than that of the leaves for the five metals which indicates that the roots accumulated more than leaves. That showed that metals accumulated by water hyacinth were largely retained in roots[22, 23]. BCF values in water hyacinth were 6136.77 for Zn, 4874.45 for Pb and 2931.74 for Cr and those in water lettuce were 7417.54 for Zn, 3883.94 for Pb and 1831.74 for Cr respectively. Low values were obtained for cadmium for the two species plants. For the two species, metals accumulation was in the order of Zn> Pb> Cr > Cu> Cd. The BCF values were also comparable to those reported for wetland plants recommended for use in phytoremediation[13, 24]. According to Zu et al.[25], a BCF value ≥ 1000 has been suggested to indicate that a plant species is a hyperaccumulator. The results of the present study showed that *Eichhornia crassipes* and *Pistia stratiotes* are good accumulators of Zn, Pb, and Cr. Translocation factor revealed that metals were largely retained in the roots of water hyacinth. Water hyacinth had low TF values of Cr, Pb, Cu and Zn (0.07 – 0.46) except for Cd (3.35) (Table 1). Lower accumulation of metal in leaves than roots can be associated with protection of photosynthesis from toxic levels of heavy metals[26]. Moreover, metals are accumulated in roots, probably due to some physiological barriers against metal transport to the aerial parts of plants, while others are easily transported in plants[27].

Table 1: Bioconcentration factor (BCF) of heavy metals in *Eichhornia crassipes* and *Pistia stratiotes* and their translocation factor (TF)

Metals	*Eichhornia crassipes*				*Pistia stratiotes*
	BCF in roots	BCF in leaves	BCF in plant	TF	BCF in plant
Pb	7630.66 ± 778.78	2117.52 ± 104,93	4874.45 ± 528.17	0.28 ± 0.13	3883.94 ± 654.71
Zn	8428.12 ± 561.52	3845.37 ± 234,67	6136.77 ± 981.37	0.46 ± 0.42	7417.54 ± 346.65
Cd	957.14 ± 78,43	285.71 ± 45.27	485.71 ± 35.34	3.35 ± 1.73	171.43 ± 35.42
Cu	1260.86 ± 761.68	390.99 ± 91,89	825.92 ± 78.90	0.31 ± 0.12	1132.70 ± 317.08
Cr	5487.86 ± 617.24	375.54 ± 87,31	2931.74 ± 445.77	0.07 ± 0.09	1831.74 ± 97.91

Conclusion

Results from the present study show that water hyacinth and water lettuce can be use effectively in the removal of selected heavy metals present in wastewaters. These species are good accumulators of Zn, Pb, Cr and Cu from wastewater. Metals accumulation was in the order of Zn> Pb> Cr > Cu> Cd. 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 the removal of heavy metals. Water hyacinth had low TF values of Cr, Pb, Cu and Zn. TF value of Cd was highest.

References

1. Hassan SH, Talat M, Rai S. Sorption of cadmium and zinc from aqueous solutions by water hyacinth (*Eichchornia crassipes*). *Bioresource Technology*, 2007; 98: 918-28.
2. Chatterjee S, Chetia M, Singh L, Chattopadhyay B, Datta S,. Mukhopadhyay SK. 2011. A study on the phytoaccumulation of waste elements in wetland plants of a Ramsar site in India. *Environ. Monit. Assess*, 2011, 178: 361-371.
3. Chiodi LB, Escalante A, Haeften GV, Moreno V, Gerpe M. Assessment of Heavy Metal Accumulation in Two Aquatic Macrophytes: a Field Study. *J. Braz. Soc. Ecotoxicol.*, 2011, 6 (1): 57-64.
4. Pickering KT, Owen LA. Water Resources and Pollution. In: An Introduction to Global Environmental Issues 2nd (eds). London, New York, 1997 : 187-207.
5. Yuan Y, Hall K, Oldham C. A preliminary model for predicting heavy metal contaminants loading from an urban catchment. *The Science of the Total Environmental*, 2001, 226: 299-307.
6. EPA. US Environmental Agency Report EPA/600/R-99/107, Introduction to phytoremediation, 2000, 72p.
7. Fang YY, Yang XE, Chang HQ, Pu PM, Feng XD, Rengel Z. Phytoremediation of Nitrogen-Polluted Water Using Water Hyacinth. *J. Plant Nutr.*, 2007, 30 : 1753-1765.

8. Polomski RF, Taylor MD, Bielenberg DG, Bridges WC, Klaine SJ, Whitwell T. Nitrogen and Phosphorus Remediation by Three Floating Aquatic Macrophytes in Greenhouse-Based Laboratory-Scale Subsurface Constructed Wetlands. *Water Air Soil Pollut.*, 2009, 197 : 223-232.
9. Nahlik AM, Mitsch WJ. Tropical treatment wetlands dominated by free-floating macrophytes for water quality improvement in Costa Rica. *Ecol Eng.*, 2006, 28 : 246-257.
10. Shuvaeva OV, Ludmila A, Belchenko, Romanova TE. Studies on Cadmium Accumulation by Some Selected Floating Macrophytes. *International Journal of Phytoremediation*, 2013, 15 : 979-990.
11. Mohanty M, Dhal NK, Patra P, Das B, Reddy PSR. Phytoremediation: A Novel Approach for Utilization of Iron-oreWastes. *Reviews of Environmental Contamination and Toxicology*, D.M. Whitacre (ed.), 2010, 206 (8): 29-47.
12. Herniwanti, Priatmadi JB, Yanuwiadi B, Soemarno. Water Plants Characteristic for Phytoremediation of Acid Mine Drainage Passive Treatment. *Inter. J. Basic & Appl. Sci.*, 2013, 13 (06): 14-20.
13. Zayed A, Gowthaman S, Terry N. Phytoaccumulation of trace elements by wetland plants. Duckweed. *J. Environ. Qual.*, 1998, 27: 715-721.
14. Wu FY, Sun EJ. Effects of Copper, Zinc, Nickel, Chromium and Lead on the growth of water convolvulus in water culture. *Environ. Prot.*, 1998, 21 (1): 63-72.
15. Liao WS, Chang LW. Heavy Metal Phytoremediation by Water Hyacinth at Constructed Wetlands in Taiwan. *J. Aquat. Plant Manage*, 2004, 42 : 60-68.
16. Mishra VK, Tripathi BD. Accumulation of chromium and zinc from aqueous solutions using water hyacinth (*Eichhornia crassipes*). *J. Hazard. Mater.*, 2009, 164: 1059-1063.
17. Yapoga S, Yapo BO, Victor Kouamé KV. Phytoremediation of zinc, cadmium, copper and chrome from industrial wastewater by *Eichhornia crassipes*, *Inter. J.Conserv. Sci.*, 2013, 4 (1) : 81-86.
18. Adamu YU, Tasiu SI, Salisu MT. The Use Of *Pistia stratiotes* To Remove Some Heavy Metals From Romi Stream: A Case Study Of Kaduna Refinery And Petrochemical Company Polluted Stream. *J. Env. Sci., Toxi. Food Tech.*, 2015, 9 (1) : 48-51.
19. Maine MA, Sune NL, Lagger SC. Chromium bioaccumulation: comparison of the capacity of two floating aquatic macrophytes. *Water Res.,* 2004, 38 : 1494-1501.
20. Lu X, Kruatrachue M, Pokethitiyook P, Homyok K. Removal of Cadmium and Zinc by Water Hyacinth *Eichhornia crassipes*. *Research Article*, 2004, 30: 93-103.
21. Mohamad HH, Puziah AL. 2010. Uptake of Cadmium and Zinc from Synthetic Effluent by Water Hyacinth (*Eichhornia crassipes*). *Envir. Asia*, 2010, 3 (1) : 36-42.
22. Kevin BC, Aradhana M, Margaret EF, Dipak KB. Uptake of Cd, Cu, Ni and Zn by the water hyacinth, *Eichhornia crassipes* (mart.) solms from pulverized fuel ash (PFA) leachates and slurries. *Envir. Geoch. Health*, 2000, 22: 297-316.
23. Virendra KM, Alka RU, Vinita P, Tripathi BD. Phytoremediation of Mercury and Arsenic from Tropical Opencast Coalmine Effluent Through Naturally Occurring Aquatic Macrophytes. *Water Air Soil Pollut*, 2008, 192: 303-314.
24. Wang Q, Cui Y, Dong Y. 2002. Phytoremediation of Polluted Waters Potentials and Prospects of Wetland Plants. *Acta Biotec.,* 2002, 22 (1-2) : 199-208.
25. Zhu YL, Zayed AM, Qian JH, De Souza M, Terry N. Phytoaccumulation of trace elements by wetland plants: II. Water hyacinth. *J. Environ. Qual.*, 1999, 28: 339-344.
26. Landberg T, Greger M. Difference in uptake and tolerance to heavy metal in Salix from unpolluted and polluted areas, *Appl. Geoch.*, 1996, 11: 175-180.
27. Gomati S, Adhikari S, Mohanty P. Phytoremediation of Copper and Cadmium from Water Using Water Hyacinth, *Eichhornia Crassipes*. *Inter. J. Agr. Sci. Tech.*, 2014, 2 (1): 1-7.

*****