Phycoremediation of heavy metals from a point source in asa drainage systems using Water Hyacinth (*Eichornia crassipes*)

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Abstract. The indiscriminate release of untreated or poorly treated effluent from industries into the environment is one of major challenge of industrialization. Heavy metals remain of the components of these effluent that has a deleterious effect on both aquatic lives and man who directly or indirectly depends on the aquatic system for survival. The persistent and non-biodegradable nature of heavy metals has required extended attention to materials that have the ability to remove the non-biodegradable metals by adsorption. The potential of *Eichornia crassipes* as an adsorbent in removing heavy metals present in pharmaceutical effluent was investigated. The adsorbent was introduced to the effluent under different concentrations (1, 5 and 10 mg) and contact time (24, 48 and 72 h). The concentration of Manganese, Copper, Lead and Zinc before and after the experiment was measured using Induced Coupled Plasma Mass Spectrophotometer. The percentage reduction in concentration of each metal was calculated, for manganese, the highest percentage reduction of 61.86 % (1 mg at 24 h), 63.09 % (1 mg at 24 h), 38.99 % (1 mg, 72 h) and 93.37% (10 mg, 48 h) was reported for Manganese, Zinc, Copper and Lead respectively. This work has presented *Eichornia crassipes* as a potential adsorbent with high heavy metal removal efficiency.

Keywords: Phycoremediation, Heavy metals, Drainage Systems, Water Hyacinth (*Eichornia crassipes*), Waste water

1. INTRODUCTION

The release of effluents from industries into the environment is one of problems facing the wellbeing of man and the environment. Heavy metals as a major component of industrial effluent is a problem in the economy of any nation especially where poorly treated or untreated effluent is indiscriminately released into the environment. Heavy metals are characterized with atomic weights between 63.5 and 200.6, and a specific gravity higher than 5.0 (Ahalya et al. 2003). Advances in industrial activities and technologies are the reason why the environment is heavily contaminated with heavy metals (Wong et al., 2006). Their composition accounts for their ability to persist in the environment and non-degradability by microorganisms. Their presence in the environment especially in the aquatic system has a toxic influence on all life bearing organisms especially human being (Florea and Büsselberg 2006; Olafisoye et al. 2012; Adagunodo 2017; Adagunodo et al. 2018).

The carcinogenic potential of heavy metals available in the aquatic environment has both direct and indirect effects of both the flora and fauna in the water bodies (Srivastava and Majumder, 2007). In order to prevent the harmful impact of heavy metals, it is expedient to look for ways to get rid of their presence in the environment and the proposed way must be friendly to the...
environment as well as inexpensive to apply. Removing them from the environment will require the use of adsorbent which are able to adhere to the surface of these metals in order to remove them from solution (Kini et al., 2004). Adsorption has been reported to be an emerging heavy metal removal technology which is effective, inexpensive and the ease at which it is applied in removing heavy metals is commendable (Geethamaniet al., 2014). Phytoremediation involving the use of plants has shown that metals are found attached to organs and tissues as nanoparticles (Makarov et al., 2014). Several plant-based biosorbents are in use for removing heavy metal pollutants found in wastewaters (Jain et al., 2016). These include eucalyptus bark (Cumberland et al., 2018), bush mango (Reynel-Avila et al., 2016) lignocellulose (Thamilarasi et al., 2018) marula (Moyo et al., 2015) rice husk (Cao et al., 2013), and switch grass (Regm et al., 2012). The rate at which aquatic plants adsorb pollutants has been extensively investigated (El-Khaiary, 2007; Hasan et al., 2007). Some agricultural-based waste materials, sea weeds and some other microbial biomass yeasts, moulds and dead materials, have been reported as bioadsorbent in removing heavy metals (Sudha and Abraham, 2003). *Eichornia crassipes* (Water hyacinth) is an aquatic weed known for its rapid growth. The name Eichornia has its source since the 19th century from a man known as J.A.F. Eichhorn (Shree et al., 2007). It is a problematic plant because of its rapid growth which is responsible for its abundance on water ways. Research has shown that *E. crassipes* when used as a biosorbent can effectively remove pollutants from oxidative ponds and thereby improve the quality of effluent and also aid in treating agricultural, municipal, and industrial wastewater and municipal (Sangeeta and Savita 2009).

Some of the characteristics of water hyacinth that has presented it as an alga with economic importance are its high affinity for polyphenolic compounds and global availability as seaweed (Rashidipour et al., 2014). Attention has been given to water-hyacinth as a biosorbent with appreciable potential for contaminants (Ibrahim et al., 2010). Malik (2007) discussed that water hyacinth can survive in areas that are heavily polluted by toxic substances and this is why they can be used as adsorbent to remove pollutants from contaminated sites. Kaur et al. (2013) employed water hyacinth as biosorbent at different operational parameters in removing dye crystal violet from aqueous solution. It was observed that adsorption of the dye was dose, pH, temperature and contact time dependent. Also, water hyacinth has been successful applied as biosorbent in the drastic reduction of heavy metal concentration (Mary et al., 2011) and removal of methylene blue from aqueous solution (Nasir et al., 2014). *Eichornia crassipes* was investigated in this work for its ability to absorb heavy metals from a point source in a known drainage system.

2. Materials and Methods

2.1 Collection and Processing of *Eichornia crassipes*

*Eichornia crassipes* was collected from Ogudu lagoon in Lagos State, Nigeria (Figure 1). Water from the seaweed surroundings was poured into transparent covered plastic then into a polythene bag containing the seaweed and it surrounding water before transportation to the laboratory. The method of Esteves et al. (2000) was adopted in cleaning and pretreatment of the sea weed prior to the biosorption experiment. Removal of impurities and epiphytes attached to the seaweed was done by washing with distilled water after which it was dried for 7 days and crushed into powder using an electric blender.
2.2 Collection of Pharmaceutical Effluent

The pharmaceutical effluent was collected from the water discharge point of a Pharmaceutical industry situated at Ilorin, Kwara State using a 4-liter container which has been previously washed with 3% nitric acid. The pH of the pharmaceutical effluent was measured with a pocket size pH meter (HANNA product) before transportation to the laboratory for further work.

2.3 Bioadsorption Experiment

Three different concentrations of the dried sea weed were prepared by weighing 1 mg, 5 mg and 10 mg into 40 ml of the effluent in different bottles. The contact time was at an interval of 24 h (24 h, 48 h and 72 h). At the end of each time duration, the mixture was separated and the solution was collected for further analysis. Induced Coupled Plasma–Mass Spectrophotometer was used to determine the concentration of each metal. The percentage reduction in the concentration of four heavy metals (Manganese, Zinc, Copper and Lead) was calculated as follow:

\[
\text{Reduction in metal concentration} = \frac{\text{Initial concentration} - \text{Final concentration}}{\text{Initial concentration}} \times 100
\]  

(1)

Figure 1: *Eichhornia crassipes* collected from Ogudu lagoon sand fill port Ojota, Lagos

3. Results and Discussion

3.1 Processed Eichornia crassipes

*A dried biomass of Eichornia crassipes* was obtained after processing the leaves and the shoots of the plant collected (Figure 2)
Figure 2: Powdered biomass of *Eichornia crassipes*

### 3.2 Adsorption of Manganese by *Eichornia crassipes*

There was a reduction in the concentration of manganese at the different concentration of the adsorbent. At 1 mg, the percentage reduction in the concentration of manganese was 61.86% (24 h), 43.42% (48 h) and 6.67 % (72 h) (Figure 3). While at 5mg concentration of the adsorbent, manganese had the highest percentage reduction in concentration of 59.96% (72 h) followed by 49.96 % (24 h) and the lowest percentage reduction concentration of 24.12% (48 h) (Figure 4). The adsorbent at 10 mg concentration had highest percentage reduction of manganese at 24 h (51.39 %) and the lowest at 72 h(7.21%) (Figure 3).
Figure 4: Percentage reduction of manganese by adsorbent at 5mg concentration at different contact time.

Figure 5: Percentage reduction of manganese by adsorbent at 10mg during different contact time.

3.3 Adsorption of Copper by *Eichornia crassipes*

The result for copper shows highest percentage reduction of 38.99% (72 h) at 1mg concentration of the adsorbent while the lowest percentage reduction of 13.03% was obtained after 48 h (Figure 6). At 5mg concentration of the adsorbent, the copper has the highest percentage reduction concentration of 89.06% after 72hrs while the lowest percentage reduction in concentration of 42.03% was obtained after 24h (Figure 7). The adsorbent at 10mg concentration had the highest percentage reduction in concentration of copper at 72 h(30.51%) while the lowest was 1.49% (24 h) (Figure 6).
Figure 6: Percentage reduction of copper by adsorbent at 1mg during different contact time

Figure 7: Percentage reduction of copper by adsorbent at 5mg during different contact time
3.4 Adsorption of Lead by *Eichornia crassipies*

The result for lead shows an increase in the reduction percentage concentration of 67.14%, at 1mg concentration of the adsorbent after 72 h while the lowest percentage reduction in concentration was 13.83 % after 48hrs (Figure 9). At 5mg concentration of the adsorbent, lead had the highest percentage reduction in concentration at of 72 h (54.69%) and the lowest percentage reduction in concentration of 24.12 % after 48 h (Figure 10). The adsorbent at 10mg concentration has a higher percentage reduction in concentration of lead of 93.37% after 48 h and 58.79 % percentage reduction in concentration of lead after 24 h (Figure 11).

![Figure 8: Percentage reduction of copper by adsorbent at 10mg during different contact time.](image)

![Figure 9: Percentage reduction of lead by adsorbent at 1mg during different contact time](image)
3.5 Adsorption of Zinc by *Eichornia crassipies*

There was a high percentage reduction in concentration zinc of 63.09 % (24 h) at 1mg of the adsorbent while the lowest was 26.34% at 72 h (Figure 12). The highest percentage reduction of zinc at 5mg of the adsorbent was51.42% (24 h) and the lowest 36.59 % (48 h) (Figure 13). The adsorbent at 10mg had the higher percentage reduction in concentration of 48.57 % (72 h) and the lowest of 36.59 % (72 h) (Figure 14)
Figure 12: Percentage reduction of zinc by adsorbent at 1mg concentration during different contact time.

Figure 13: Percentage reduction of zinc by adsorbent at 5mg during different contact time.
4. Conclusion

The ICP analysis is powerful for analyzing trace metals in the wastewater (Crouch et al., 2007). Metals investigated in this work are copper, lead, zinc and manganese at different concentration (1mg, 5mg and 10mg) and time (24h, 48h and 72h), comparing the different concentration of each metals, the following deductions were observed. The least uptake of the absorbent for zinc was at 5mg with 2.89% percentage reduction in concentration at 72 hours and highest uptake was at 1mg of the adsorbent with percentage reduction in concentration of 63.08% at 24hrs thus, time factor has an effect in the absorption of heavy metals. Also for copper, the highest uptake was 89.09% (EC-EX) at 72 hours at 5mg of the adsorbent while the least percentage reduction of copper was 1.29 (EC-EX) at 24 hours of the 10mg of the adsorbent, thus similar to experiments reported by Mithra et al. (2012). Moyo et al. (2013) suggested that large surface area occupied by the EC-EX on polluted water increased the removal efficiency of pollutants. This suggests that heavy metal biosorption efficiency was influenced by the biomass of seaweeds. The highest uptake for lead and manganese was at 5mg and 1mg respectively, while the least uptake was at 1mg and 10mg at 48 respectively, and contact time is also evaluated as one of the most important factors affecting the bio sorption efficiency. Bio sorption efficiency increases with increasing contact time. Therefore, we could say the accumulation of heavy metals by seaweeds nanoparticles provides an advantage for phytoremediation over other conventional methods which are costlier and not environmentally friendly.

One of the major problems in industrialization is the discharge of untreated effluent or inadequately treated effluent into the environment thereby resulting in deleterious effect on human, aquatic and terrestrial lives. In this work, Eichhornia crassipes was used as bio agents in the adsorption of heavy metals (Zinc, Manganese, copper and Lead) present in pharmaceutical effluent for 72 hours. The plant has the higher adsorption potential for lead (Pb) at 1mg of the extract, for manganese, the higher adsorption was at 1mg concentration of the 24 hours of the extract, for copper, the higher adsorption was at 5mg concentration of 72 hours the extract, for zinc the highest adsorption was at 1mg at 24hrs. The lowest reduction of each metals by the plant,
for zinc, the lowest reduction was at 5mg of the 72 hours of the extract, for manganese the lowest reduction was at 10mg of the 48hrs of the extract, for copper, the lowest reduction was at 10mg concentration of the 24hours of the extract and for the lead the lowest reduction was at 1mg of the 48hours of extract. The performance of this plant which is natural seaweed in absorbing zinc, copper, manganese and lead has confirmed it as potential bio agent for bioremediation and adsorption of heavy.

REFERENCES

[1] Adagunodo T.A., Sunmonu L.A., Emetere M.E. (2018). Heavy Metals’ Data in Soils for Agricultural Activities. Data in Brief, 18C: 1847 – 1855. https://doi.org/10.1016/j.dib.2018.04.115.

[2] Adagunodo Theophilus Aanuoluwa (2017). Groundwater Contamination: Performance, Effects, Limitations and Control. Chapter 3 in Book: Groundwater Contamination: Performance, Limitations and Impacts, 1 – 135. ISBN: 978-1-153611-017-3; 978-1-153611-003-6.

[3] Adhoum, N, Monser, L, Bellakhal, N and Belgaied, J.E M. I., (2004) “Treatment of electroplating wastewater containing Cu2+, Zn2+ and Cr(VI) by electrocoagulation,” Journal of Hazardous Materials, vol. 112, no. 3, pp. 207–213.

[4] Chapman, P. M., Wang, F., Janssen, C. R., Goulet, R. R., and Kamunde, C. N. (2014). Conducting Ecological risk assessments of inorganic metals and metalloids: Current Chemical Engineering, vol. 2014, Article ID 306519, 13 pages.

[5] Davydova, S. (2005). Heavy metals as toxicants in big cities. Microchem. J., 79 1–2, 133–136 pp.

[6] El-Khaiary, M. I., (2007) “Kinetics and mechanism of adsorption of methylene blue from aqueous solution by nitric-acid treated water-hyacinth,” Journal of Hazardous Materials, vol. 147, no. 1-2, pp. 28–36.

[7] Florea, A. M., and Büsselberg, D. (2006). Occurrence, use, and potential toxic effects of metals and metal compounds. Bio Metals, 19 4, 19–427 pp.

[8] Geethamani, K, Ramesh S.T, Gandhimathi, R and Nidheesh, P. V (2014) “Alkali-treated fly ash for the removal of fluoride from aqueous solutions,” Desalination and Water Treatment, vol. 52, no. 19-21, pp. 3466–3476.

[9] Hasan, S.H Talat, M and Rai, S (2007) “Sorption of cadmium and zinc from aqueous solutions by water hyacinth (Eichhornia crassipes),” Bio resource Technology, vol. 98, no. 4, pp. 918–928.

[10] Jain, K., Malik, D. S., and Yadav, A. K. (2016) Applicability of plant based bio sorbents in the removal of heavy metals: a review, “Environmental Processes, vol. 3, no. 2, pp. 495–523.

[11] Kabata-Pendias, A. (2001). Trace elements in soils and plants, 3rd Ed., A., Kabata-Pendias and H., Pendiaseds., C. R. C., BocaRaton, Fla. McLaughlin, M. J., Zarcinas, B. A.,
Stevens, D. P., and Cook, N. (2000). Soil testing for heavy metals. Commun. Soil Sci. Plant Anal., 31 11–14, 1661–1700pp.

[12] Kini, M.S, Saidutta, M and Murty, V.R (2014) “Studies on biosorption of methylene blue from aqueous solutions by powdered palm tree flower (Borassus flabellifer),” International Journal of Chemical Engineering. Vol. 2014, 13pp.

[13] Makarov, V. V., Love, A. J., Sinitsyna, O. V., Makarova, S. S., Yaminsky, I. V., Taliansky, M. E. & Kalinina, N. O. (2014). “Green” Nanotechnologies: Synthesis of Metal Nanoparticles Using Plants. Acta Naturae, 6(1), 35-44pp.

[14] Malik, D.S (2007) “Environmental challenge vis a vis opportunity: the case of water hyacinth,” Environment International, vol. 33, no.1, pp. 122–138, 2007.

[15] Mary, Lissy, P. N., B. Dr. G., Madhu (2011), ACEEE Int. J. on Transportation and Urban Development; Vol. 01, No. 01.

[16] Moyo, M. U. , Guyo, M. U, Mawenyiyo, G., Zinyama, N. P. and Nyamunda, B. C (2015) “Marula seed husk (Sclerocarya birrea) biomass as a low cost bio sorbent for removal of Pb(II) and Cu(II) from aqueous solution,” Journal of Industrial and Engineering Chemistry, vol. 27, pp. 126–132.

[17] Nasiruddin, M. D., Tariqul Islam, M. D. and Sreejon, D. A. S (2014) A novel biosorbent, water-hyacinth, uptaking methylene blue from aqueous solution: kinetics and equilibrium studies Volume 2014, Article ID 819536, page 1-13, http://dx.doi.org/10.1155/2014/819536.

[18] Olafisoye E.R., Sunmonu L.A., Ojoawo A., Adagunodo T.A. and Oladejo O.P. (2012). Application of Very Low Frequency Electromagnetic and Hydro-physicochemical Methods in the Investigation of Groundwater Contamination at Aarada Waste Disposal Site, Ogbomoso, Southwestern Nigeria. Australian Journal of Basic and Applied Sciences, 6(8), 401–409.

[19] Rashidipour, M. and Heydari, R. (2014). Biosynthesis of silver nanoparticles using extract of olive leaf: synthesis and in vitro cytotoxic effect on MCF-7cells. Journal of Nanostructure in Chemistry, 4(112),1-6.

[20] Regmi, P J, Garcia, J.L, Moscoso, S., Kumar, S X., Cao, XJ., Mao, J and G., Schafran, G (2012) “Removal of copper and cadmium from aqueous solution using switchgrass biochar produced via hydrothermal carbonization process,” Journal of Environmental Management, vol. 109, pp. 61–69, 2012.

[21] Reynel-Avila, H. E, Mendoza-Castillo, D., I Olumide, A. A and Bonilla-Petriciolet, A (2016) “A survey of multi-component sorption models for the competitive removal of heavy metal ions using bush mango and flamboyant biomasses,” Journal of Molecular Liquids, vol. 224, pp. 1041–1054.

[22] Sangeeta Dhote and Savita Dixit (2009), Water quality improvement through macrophytes—a review, Environmental Monitoring and Assessment, 152:149–153pp

[23] Sharma, R. K., and Agrawal, M. (2005). “Biological effects of heavy metals: An overview.” J. Environ. Biol., 26 2, 301–313pp.
[24] Shree N., Singh, Rudra D. Tripathi (2007), Environmental bioremediation technologies, Springer. status. Hum. Ecol. Risk Asses, 9, 641–697 pp.

[25] Song, W., Liang, J., Wen T (2016) Accumulation of Co(II) and Eu(III) by the mycelia of Aspergillus niger isolated from radionuclide-contaminated soils, Chemical Engineering Journal, vol. 304, pp. 186–193.

[26] Sudha, B.R. and Abraham, E. (2003), “Studies on Cr (VI) adsorption-desorption using immobilized fungal biomass”, Bioresource Technology 87, 17-26.

[27] Thamilarasi, M.J.V., Anilkumar, P., Theivarasu, C. and Sureshkumar, M.V (2018) Removal of vanadium from wastewater using surface-modified lignocellulosic material, Environmental Science and Pollution Research, vol. 25, no. 26, pp. 26182–26191.

[28] Wan Ngah W.S and Hanafiah, M. A. K. M (2008) “Removal of heavy metal ions from wastewater by chemically modified plant wastes as adsorbents: a review,” Bioresource Technology, vol. 99, no. 10, pp. 3935–3948.

[29] Wolverton, R., McDonald, and Gordon (1976) “Water hyacinths and alligator weeds for final filtration of sewage,” NASA Technical Memorandum TM-X72724, NASA, Washington, DC, USA.

[30] Wong, C. S. C., Li, X. D., and Thornton, I. (2006), “Urban environmental geochemistry of trace metals.” Environ. Pollut. 142 1, 1–16 pp.

[31] Xu., X Cao, X and Zhao, L (2013) “Comparison of rice husk- and dairy manure-derived biochars for simultaneously removing heavy metals from aqueous solutions: role of mineral components in biochars,” Chemosphere, vol. 92, no. 8, pp. 955–961.