Sys Rev Pharm 2020;11(9):264-271
A multifaceted review journal in the field of pharmacy

Atomic Spectroscopy Technique Employed to Detect the Heavy Metals from Iraqi Waterbodies Using Natural Bio-Filter (*Eichhornia crassipes*): Thera Dejla as a Case Study

Ghalib Adrees Atiya Ali[1], Mohammed Nsaif Abbas[2*]

[1]University of Diyala, College of Education for Pure Science, Department of Chemistry /Iraq
[2]Mustansiriyah University, College of Engineering, Environmental Engineering Department/Iraq
***Corresponding Author**: mohammed.nsaif.abbas@uomustansiriyah.edu.iq

ABSTRACT
Water pollution has become one of the most serious intractable issues of this era. The use of aquatic plants is considered as one of the suitable routes to remove pollutants from industrial wastewater, to protect the environment and restore resources for reuse, especially water hyacinth plant. Multi studies have shown that the water hyacinth plant has an ability to recover heavy metals from different water bodies. This paper aims to study the efficiency of the different parts of water hyacinth plant to remove many ions of heavy metals, namely chromium (Cr), cobalt (Co), iron (Fe), manganese (Mn), lead (Pb) and zinc (Zn) from polluted water bodies in Iraq, Thera Dejla channel in the northwest of Baghdad as a case study. The results obtained showed the ability of water hyacinth plant roots to adsorb lead, manganese and zinc metals with concentrations of 3.668, 3.1297 ppm and 1.1057 ppm, respectively and the rafts to adsorb 10.1545 ppm of iron while cobalt and chromium were adsorbed by stem with 0.2652 and 0.0852 ppm respectively. However, the leafs of water hyacinth were the lowest ability to adsorb the heavy metals than other parts. On the other hand, the concentrations of these heavy metals were close to zero in the water near this plant. Therefore, this plant can be used as a cheap and low-cost bio-filter to purify polluted water in rivers, lakes and ponds despite the harmful effects caused by its excessive spread.

Keywords: heavy metals; toxicity; role of chemistry; biofilter

Correspondence:
Mohammed Nsaif Abbas
Mustansiriyah University, College of Engineering, Environmental Engineering Department/Iraq
Email: mohammed.nsaif.abbas@uomustansiriyah.edu.iq

INTRODUCTION
The water hyacinth is a plant or herb that belongs to the *Pontoderiaceac* family and has the scientific name *Eichhornia crassipes* [1], which is one of the jungles or aquatic plants affecting the water resources in many countries as it spreads in all continents of the world [2]. This plant is a perennial plant and is characterized by being broad-leaved and a floating aquatic plant, as it rafts on the surface of the water by rafts that are spread on the surface of the water and its stems are usually short and floating [3], but it may be rooted in the mud when the depth of the water is shallow, and it may be rhizome or purlin [4]. The water hyacinth plant reproduces by seeds and budding. The main reproduction and growth period of this plant is the period between April and November, and its peak growth and reproduction is in the hot months which are June, July, August and September [5]. It spreads and reproduces very quickly, as it is one of the most productive plants on our planet, as it doubles its numbers present during a period of (5-18) days and forms dense surfaces on the surface of the water and begins to compete with other submerged plants floating in the water [6]. A single plant of water hyacinth occupies an area of up to 2,500 square meters per season, and this poses a serious threat to the environmental situation in the water [7]. It usually prevails with the direction of the water flow, and the spreading process is helped by the presence of bays and meanderings in the stream. It also protects and helps its reproduction by the existence of reeds and grasses on the banks of the river [8]. Thus, it forms what looks like a floating cancer, which leads to increase the water evaporation from the surface of its leaves by 3.2-3.7 times the amount of water lost from the water surface without the plant as a result, huge amounts of water evaporate from water bodies, reaching billions of cubic meters of water, which is sufficient to cultivate large areas of land [5]. On the other hand, the accumulation of this plant impedes the water flow in the irrigation channels, for example the spread of a dense cover of the water hyacinth in a channel of a cross section of 72.36 square meters may reduce the flow of water by 50% and stop it completely in the channels and streams that branch from them as well as shuts off the irrigation pumps [9]. The leaves and roots of the water hyacinth plant accumulate in thicknesses that may reach more than 1-3 meters annually, and its mechanical removal needs huge costs [10]. This plant has harmful effects as it affects the quality of the water by reducing its oxygen content resulting in an environment inadequate for other beneficial biological species and encourages the growth of other harmful organisms [11]. It also consumes large quantities of water, as it is estimated that one plant consumes between 1-4 liters of water per day. In addition, it causes great pressure on floating bridges standing on rivers, which leads to displacement and breakdown [12]. In most cases, the water hyacinth leads to block the sunlight from reaching to other organisms that live in the water, especially phytoplankton, which form the basic base of the ecosystem and the basic food for zooplankton or fish, causing an imbalance in the delicate balance of the food chain [10]. In spite of the damage caused by the accumulation of the water hyacinth plant over water bodies, there are some positives that occur as a result of its growth over these surfaces [13]. The growing plants from the water hyacinth contain urease enzyme, by which this plant analyzes urea resulting from disposing farm wastes (such as chemical fertilizers) into irrigation channels and water drains then the urea is removing [14]. Therefore, it is preferable to leave the roots and rhizomes in the agricultural drainage areas for several times, as they are used in the analysis of urea, after which

the plant is removed as a whole and extracted the urease enzyme from its roots [15]. The leaves and stems are used after excluding the roots and rhizomes in animal nutrition as a renewable source of animal fodder [14]. Some studies have indicated the possibility of using this plant as a source of fuel and alternative energy, as the water hyacinth is used to produce biogas in digesters and fermenters [16]. However, one of the very important benefits of this herb is the purification of water bodies, especially drains and irrigation channels, which are heavily polluted by heavy metals such as iron, zinc, lead, chromium and others, meaning that its presence reduces the water pollution with these heavy, deadly metals that destroy living cells [17-19]. In this way, it plays a significant role in saving all living organisms, whether living in water bodies or benefiting from those water resources and on their shores, from poisoning [20]. Moreover, wastewater and sludge can be treated using the water hyacinth plant by reducing the concentration of pollutants, heavy metals and other chemical compounds [21]. This plant can be used to purify industrial wastewater, sewage, get rid of pesticides and dyes, and control pests [22,23]. The aim of this study is to determine the ability of water hyacinth plant by various parts of it (i.e. roots, stems, leaves and rafts) to recover different heavy metals spontaneously from polluted water in Thera Dejla channel in the northwest of Baghdad as a case study and study the possibility using of this plant as a natural bio-filter for heavy contaminated waterbodies in Iraq.

Absorption spectroscopy: This study is based on determining the concentrations of heavy metals present in polluted water as well as in parts of the water hyacinth plant using atomic absorption spectroscopy (AAS) device. Therefore, it is necessary to get acquainted with the principle of spectroscopy and its main sections, and to clarify the scientific basic of this device adequately in order to know how to measure the metals and prediction of their concentrations in water or in parts of plants. It is well known that the basic principle of ultraviolet-visible spectroscopy and infrared spectroscopy is absorption at the molecular level [24]. As a result of this energetic absorption, electron transitions occur in atoms within the molecules, causing vibrations within the molecules [25]. The transition of the molecule from the zero vibration level to the high-energy vibrational levels occurs, which leads to expansion or contraction of the chemical bonds between the atoms, or a change in the angles between the bonds forming the molecules [26]. In the case of the atomic absorption spectrometer of the elements, the absorption takes place only at the atomic level and not at the level of the molecule, so the element to be measured in the molecule must be converted to the atomic state [27]. The atomic absorption spectrometer checks the wavelengths of the absorbed photons during the excitation of the element's atoms, while the atomic emission spectrometer checks the wavelengths of the photons emitted by the atoms as they move from the excited state to the ground state or of lower energy [28]. It is known that each element emits a distinct set of separate wavelengths according to its electronic structure, and by studying these wavelengths it is possible to know the elements that make up the sample, and then absorption and atomic emission spectroscopies estimate the elements in their solutions as a method of spectroscopy [29,30]. The idea of estimation depends on converting the solution of sample into a spray by atomization process, then mixing the spray with a mixture of gases such as acetylene or acetylene and air, thus the element is burned by the flame resulting from mixing these gases and the element turns into an atomic state, which is exposed to a hollow cathode lamp specific to the element wanted to be measured [31,32]. The hollow cathode lamp of each light element gives a specific frequency similar to the atomic spectrum of the element to be measured [33,34]. Therefore, the element's atoms will absorb a measure of this light proportional to their concentration in the flame, meaning that whenever the number of atoms of the element or the concentration of the element's atoms in the flame is high, a large amount of energy will be absorbed [34]. By comparing the amount of energy absorbed or emitted with known concentrations of the same element with the amount of energy absorbed by the unknown concentrations of the same element, the amount of the element is estimated [30,34].

Experimental Work: Saplings of the water hyacinth plants were collected from Thera Dejla channel, northwest of Baghdad (33.471344 N and 44.293715 E) as shown in Figure 1-3. Saplings were similar in age and size and average weights were 47.6631 g. Initially, the seedlings were washed with an increase of tap water until the impurities, mud and dusts attached to them from their harvest place were removed, and then with ionic water to complete the washing process perfectly. The plant parts were carefully cut separately (raft, leaf, stem, and root) as shown in Figure 4 and then dried at 80 °C until the weight was fixed and only the water was removed. Five grams of the various dried plant parts were weighed and burned in a muffle furnace (Nabertherm, Germany) at a temperature of 500 °C. After ending the time of incineration, and let the furnace cooled to room temperature, the charred samples were extracted and the weight of the rafts, leaves, stems and roots were (1.7407, 3.9255, 0.4823 and 1.8534) g, respectively. The charred samples then treated with 50 ml of concentrated nitric acid for 3 hours under laboratory conditions, the treatment process was repeated twice to complete the digestion of the samples. After that the samples were placed in an Erlenmeyer flask, distilled water was added to it and heated to a boil to ensure any excess nitric acid was removed. Finally, the concentrations of the heavy metals of this study (Co, Cr, Fe, Mn, Pb and Zn) were measured in water hyacinth samples and in the water samples of the Thera Dejla channel at a surface of 1.5 meters distance from the plants collected using the atomic absorption spectrometer.

RESULTS AND DISCUSSION

The concentrations of heavy metals in the waters of Thera Dejla channel and the concentrations adsorbed by the different parts of the water hyacinth plant (rafts, leaves, stems, and roots) were tested using an atomic absorption spectrometer (AAS) device. The results obtained illustrated that this plant has a high ability to adsorb various heavy metals, which are cobalt, chromium, iron, manganese, lead and zinc, at levels that vary in different parts of the plant. This indicates a high possibility of using this plant as a bio-filter for water contaminated with various heavy metals at the same time. It was found through the results shown in Figures 5 and 6 that the zinc, lead and manganese elements were higher adsorbed by the roots, with concentrations reaching to 1.1057, 3.668 and 3.1297 ppm, respectively. The part of herb known as the raft, was adsorbed the iron element at a higher concentration than the rest of other parts and the rest of the elements, which is 10.1545 ppm, this is what is shown in Figure 5. While Figure 7 indicates that the stems of the water hyacinth had adsorbed 0.0852 and 0.2652 ppm of chromium and cobalt elements respectively, thus this part was the best in the adsorption of these elements alone.

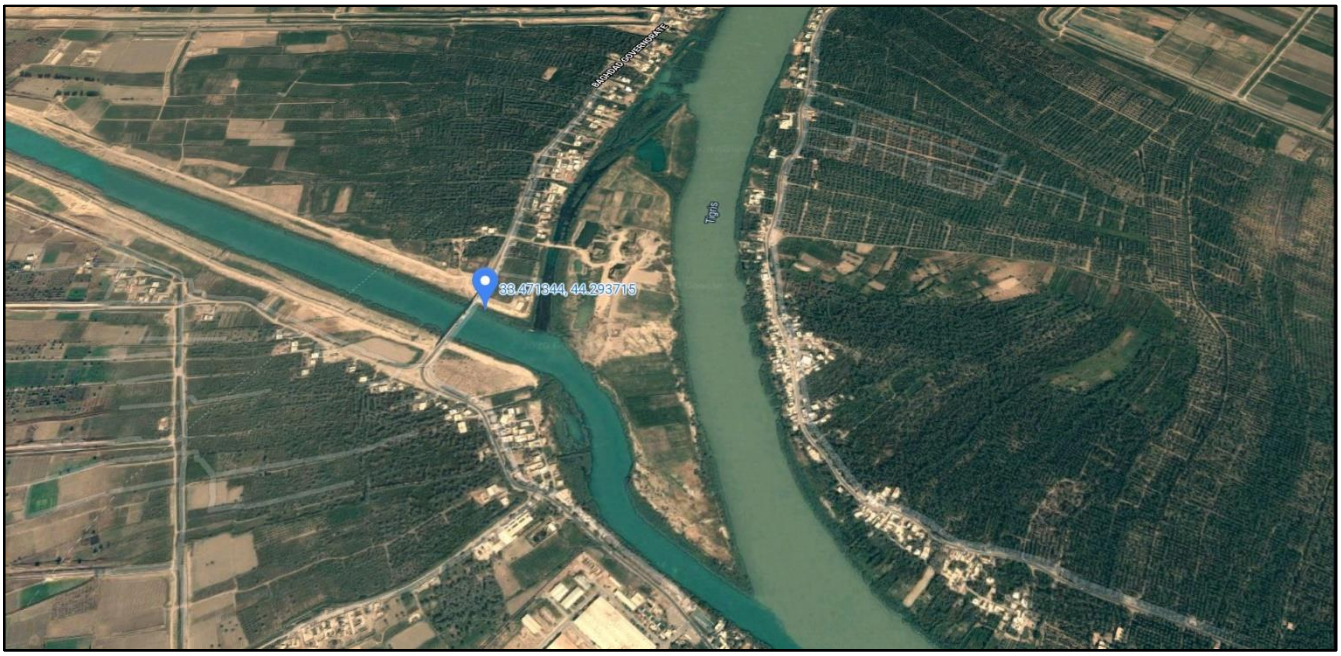

Figure 1. water hyacinth collected location in Thera Dejla channel

Figure 2 Invasive Water Hyacinth

Figure 3 Flower of Water Hyacinth

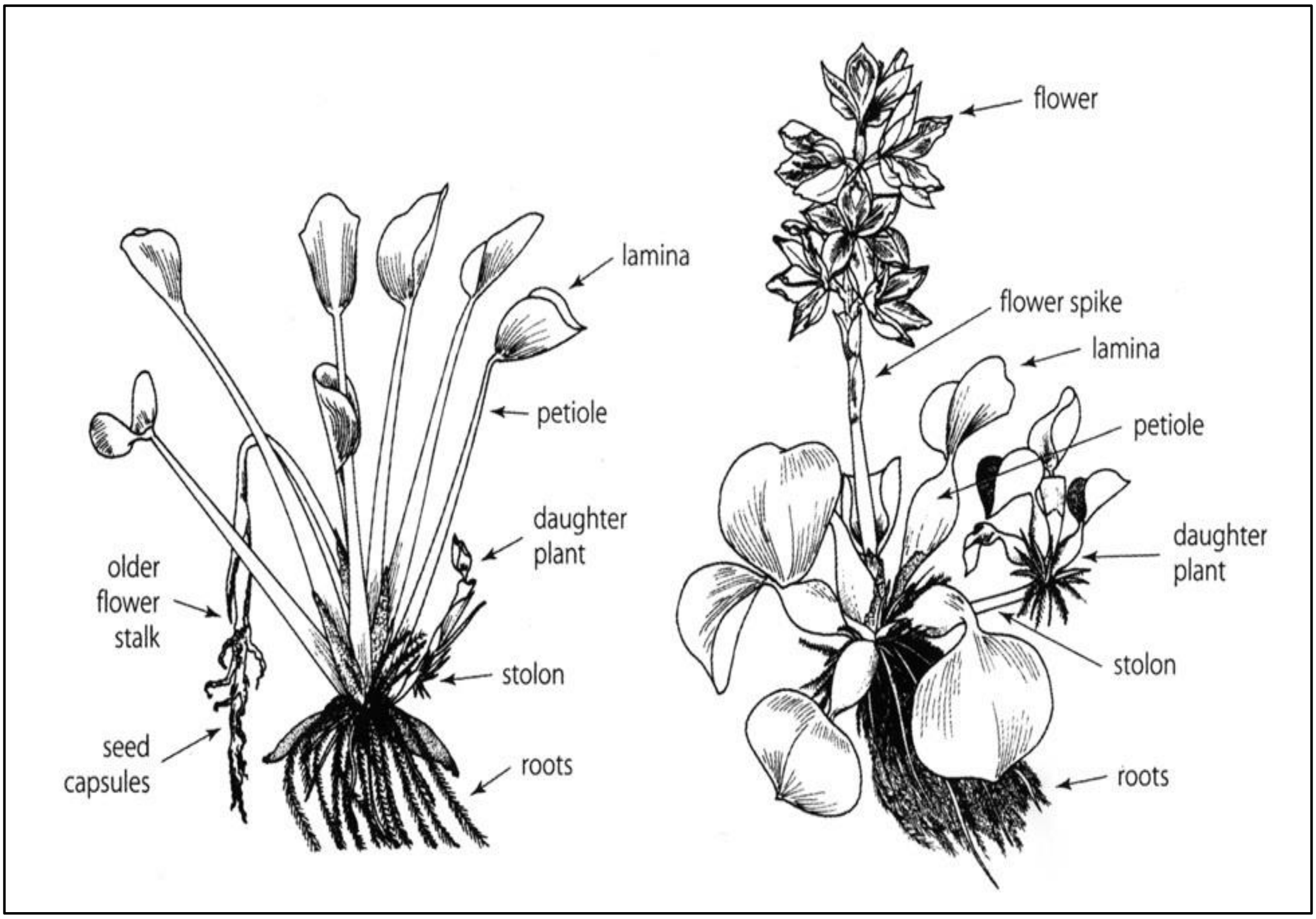

Figure 4. Anatomy of Water Hyacinth Plant **[35]**

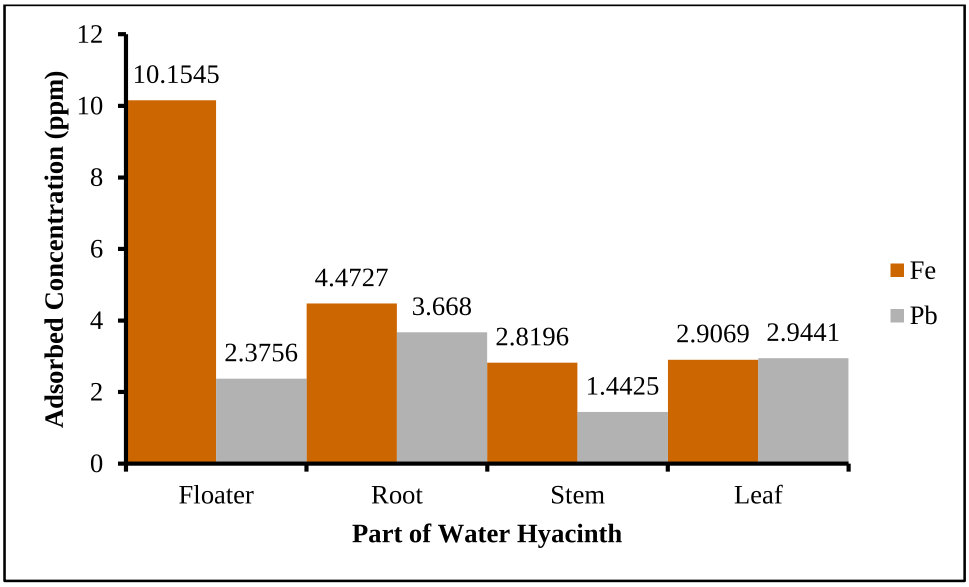

Figure 5. Adsorbed Concentrations of Iron and Lead metals by Different Parts of Water Hyacinth Plant

The irregularity in the results is due to several reasons, one of them is because of the plants' size, as the larger the plant size, the greater its surface area (and this includes all parts), thus its ability to adsorb a greater amount of different metals or one metal in the same time These results are agreement with **[36]**. On the other hand, the roots and the rafts had a capacity for adsorbing heavy metals amounting to 12.4369 and 14.3214 ppm, respectively. These concentrations are twice as high as stems and leaves (5.9155 and 7.0838 ppm respectively).

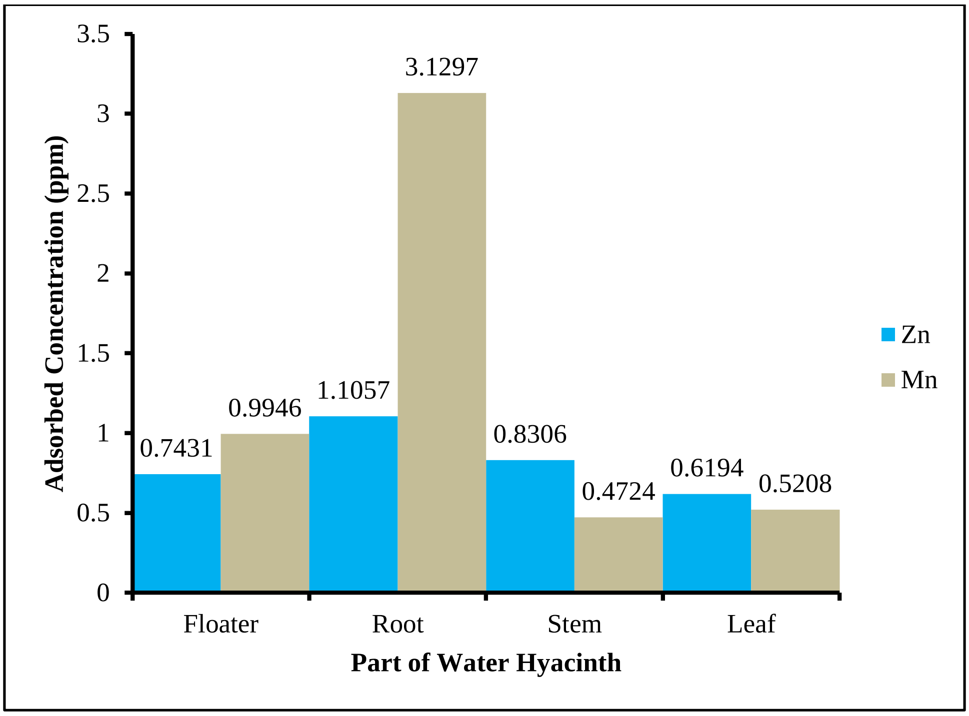

Figure 6 Adsorbed Concentrations of Zinc and Manganese Metals by Different Parts of Water Hyacinth Plant

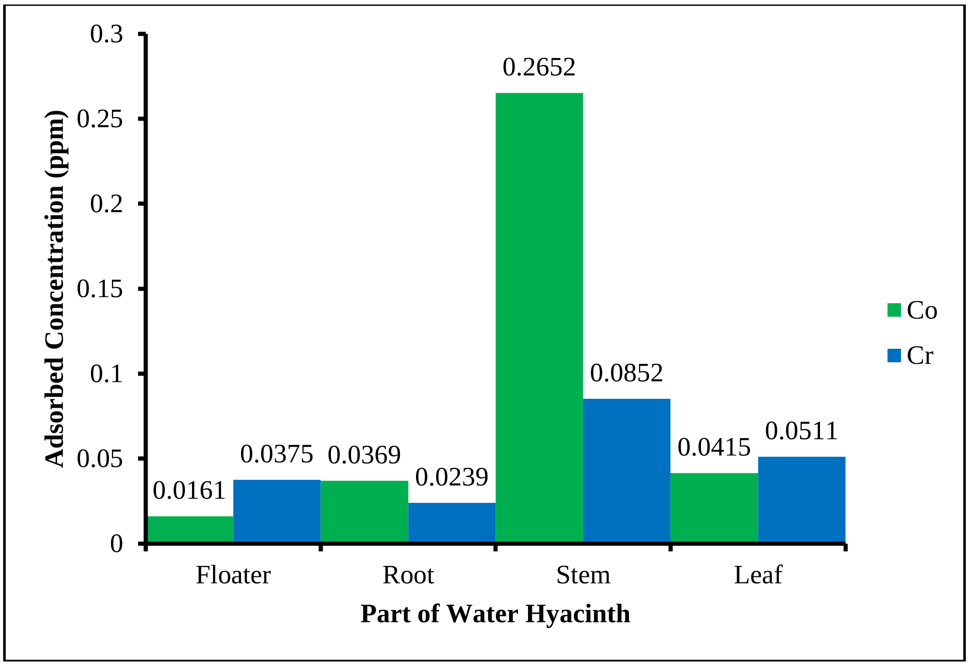

Figure 7 Adsorbed Concentrations of Cobalt and Chromium Metals by Different Parts of Water Hyacinth Plant

These results may be attributed to the location of these parts which are always in direct contact with high concentrations of heavy metals that are either spread on the surface of the water or spread near the bottom of the river depending on their density **[18]**. **Figure 8** indicates that the highest removal percentage of heavy metal ions was by the rafts 36.0218%, followed by roots 31.2818%, then leaves 17.81747%, and finally stems 14.8789%. This supports the previous hypothesis about the distribution of heavy metal ions in water of the channel **[19]**. **Figure 9** shows the percentage of pollutants removal and water purification with very high efficiency by the water hyacinth plant, as the concentrations of heavy metals in the water are very close to the plants were almost neglected, while the concentrations of the same elements in the waters 1.5 meters away from the water hyacinth plant were close to the concentration of metals adsorbed by the different parts of the plant after testing **[37]**.

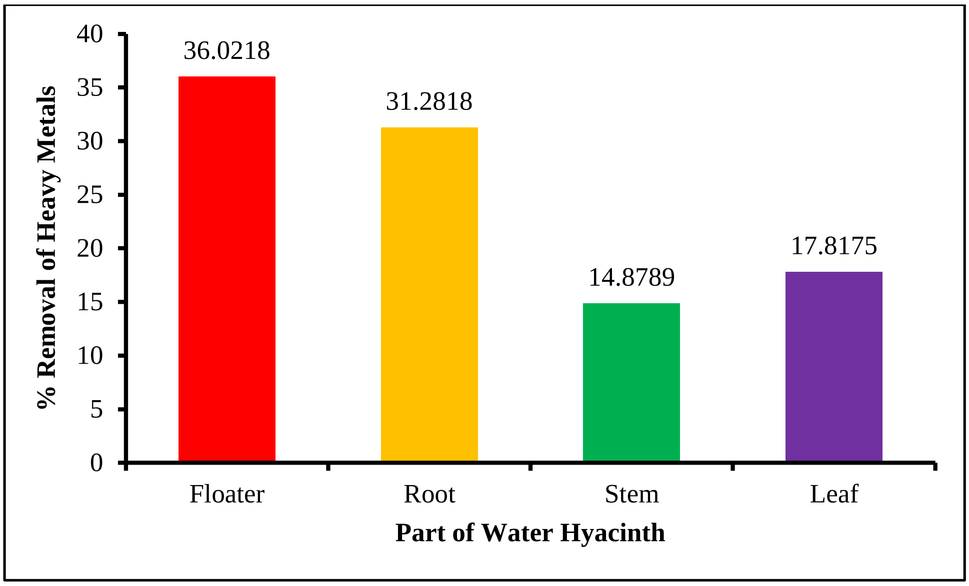

Figure 8. Percent Removal of All Heavy Metals by Different Parts of Water Hyacinth Plant

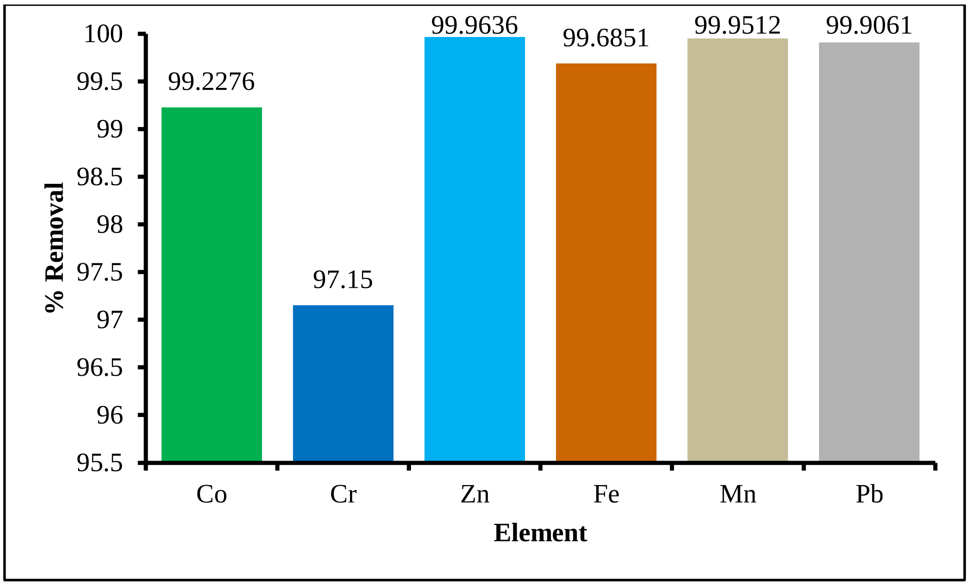

Figure 9. Percent removal of different heavy metals by water hyacinth plant

CONCLUSION

It is evident from the results obtained by this study that it is possible to use the water hyacinth plant (*Eichhornia crassipes*) in its various parts as an effective adsorbent available inexpensively and at low cost to remove a number of different heavy elements at the same time with high efficiency reaching the ideal value. Thus, it can be used in treating industrial waste streams that put their pollutants into streams, ponds, lakes and other water bodies.

REFERENCES

1. Pellegrini M., Horn C. N., and Almeida R. F. (2018), "Total evidence phylogeny of *Pontederiaceae* (*Commelinales*) sheds light on the necessity of its recircumscription and synopsis of *Pontederia* L. PhytoKeys, Volume 108, pp: 25–83. https://doi.org/10.3897/phytokeys.108.27652
2. Tobias V. D., Conrad J. L., Mahardja B. and Khanna S. (2019), "Impacts of water hyacinth treatment on water quality in a tidal estuarine environment", Biological Invasions volume 21, pp: 3479–3490. https://doi.org/10.1007/s10530-019-02061-2
3. Gopal B., (1987), "Water Hyacinth (Aquatic Plant Studies)", Elsevier Science, ISBN 978-0444427069.
4. Pierret A., Maeght J. L., Clément C., Montoroi J. P., Hartmann C., and Gonkhamdee, S. (2016). Understanding deep roots and their functions in ecosystems: an advocacy for more unconventional research, Annals of botany, Volume 118, Issue 4, pp: 621–635. https://doi.org/10.1093/aob/mcw130
5. Phiri G. and Navarro L. A., (2001), "Water Hyacinth in Africa and the Middle East: A Survey of Problems and Solutions", IDRC (International Development Research Centre), ISBN: 088936933X, 9780889369337

6. Abdel Shafy H. I., Farid M. R., and Shams El-Din A. M., (2016), "Water-Hyacinth from Nile River: Chemical Contents, Nutrient Elements and Heavy Metals". Egyptian Journal of Chemistry, Volume 59, Issue 2, pp: 131-143, Article 1, April. http://doi.org/10.21608/EJCHEM.2016.934
7. Yan S. and Guo J. Y., (2017), "Water Hyacinth: Environmental Challenges, Management and Utilization", CRC Press/Taylor & Francis Group. ISBN: 1498743897, 978-1-4987-4389-1.
8. Cho M. E. and Tifuh J., (2012), "Quantification of the impacts of water hyacinth on riparian communities in Cameroon and assessment of an appropriate method of control: the case of the Wouri River Basin", World Maritime University Dissertations. 29. https://commons.wmu.se/all_dissertations/29
9. Ezama D. O., (2019), "Impact of water hyacinth infestation in Nigerian inland waters: utilization and Management", World Maritime University Dissertations. 1132. https://commons.wmu.se/all_dissertations/1132
10. Chu J. J., Ding Y., and Zhuang Q. J., (2006), "Invasion and control of water hyacinth (*Eichhornia crassipes*) in China", Journal of Zhejiang University, Science B, Volume 7, Issue 8, pp: 623–626. https://doi.org/10.1631/jzus.2006.B0623
11. Worku M. and Sahile S., (2018), "Impact of Water Hyacinth, *Eichhornia crassipes* (Martius) (*Pontederiaceae*) in Lake Tana Ethiopia: A Review", Journal of Aquaculture Research & Development, Volume 9, Issue 1, 1000520.
12. Arguelles E. D. (2019). Systematic Study of Some Epiphytic Algae (Non-diatoms) on the Submerged Parts of Water Hyacinth [*Eichhornia crassipes* (Mart.) Solms-Loubach] Found in Laguna de Bay, Philippines. Tropical life sciences research, Volume 30, Issue 1, pp: 1–21. https://doi.org/10.21315/tlsr2019.30.1.1
13. Mishra S. and Maiti A., (2017), "The efficiency of *Eichhornia crassipes* in the removal of organic and inorganic pollutants from wastewater: a review", Environmental Science and Pollution Research, Volume 24, Issue 9, pp 7921–7937. https://doi.org/10.1007/s11356-016-8357-7
14. Fu Y., Bhadha J. H., Rott P., Beuzelin J. M. and Kanissery R., (2020), "Investigating the use of aquatic weeds as biopesticides towards promoting sustainable agriculture", PloS one, Volume 15, Issue 8, e0237258. https://doi.org/10.1371/journal.pone.0237258
15. Andika D. O., Ogada J. A. and Hayombe P. O., (2016), "Producing Liquid Organic Fertilizer from Water Hyacinth; A Case of Lake Victoria, Kenya", International Journal of Science and Research (IJSR), Volume 5 Issue 2, pp: 1229-1238, February.
16. Bušić A., Kundas S., Morzak G., Belskaya H., Marđetko N., Ivančić Šantek M., Komes D., Novak S., and Šantek B., (2018). Recent Trends in Biodiesel and Biogas Production, Food technology and biotechnology, Volume 56, Issue 2, pp: 152–173. https://doi.org/10.17113/ftb.56.02.18.5547
17. Rezania S., Ponraj M., Talaiekhozani A., Mohamad S. E., Din M. F. N., Taib S. M. and Sairan F. M., (2015), "Perspectives of phytoremediation using water hyacinth for removal of heavy metals, organic and inorganic pollutants in wastewater", Journal of Environmental Management. Volume 163, pp: 125-133, November. https://doi.org/10.1016/j.jenvman.2015.08.018
18. Al-Saoor T. N. and Albaiaty A. H., (2018), "The Efficiency of (*Eichhornia Crassipas*) in Removing Iron and Copper Ions from Polluted Wastewater", Journal of the College of Basic Education-Al-Mustansyriah University, Volume 4, Number 102, pp: 63-70. (*in Arabic*)
19. Zhou J. M., Jiang Z. C., Qin X. Q., Zhang L. K., Huang Q. B., Xu G. L. and Dionysiou D. D., (2020), "Efficiency of Pb, Zn, Cd, and Mn Removal from Karst Water by *Eichhornia crassipes*", International Journal of Environmental Research and Public Health, Volume 17, Issue 15, 5329. https://doi.org/10.3390/ijerph17155329
20. Bai L., Liu X. L., Hu J., Li J., Wang Z. L., Han G., Li S. L. and Liu C. Q., (2018), "Heavy Metal Accumulation in Common Aquatic Plants in Rivers and Lakes in the Taihu Basin," International journal of environmental research and public health, Volume 15, Issue 12, 2857. https://doi.org/10.3390/ijerph15122857
21. Sayago U., Castro Y. P., Rivera L. and Mariaca A. G., (2020), "Estimation of equilibrium times and maximum capacity of adsorption of heavy metals by *E. crassipes* (review)", Environmental monitoring and assessment, Volume 192, Issue 2, 141. https://doi.org/10.1007/s10661-019-8032-9
22. Luo B., Gu W., Zhong J., Wang Y. and Zhang G., (2015), "Revealing crosstalk of plant and fungi in the symbiotic roots of sewage-cleaning *Eichhornia crassipes* using direct de novo metatranscriptomic analysis", Scientific reports, Volume 5, 15407. https://doi.org/10.1038/srep15407
23. Kong L., Hu X., Xie Z., Ren X., Long J., Su M., Diao Z., Chen D., Shih K. and Hou L., (2018), "Accelerated phosphorus recovery from aqueous solution onto decorated sewage sludge carbon", Scientific reports, Volume 8, Issue 1, 13421. https://doi.org/10.1038/s41598-018-31750-6
24. Ellis A. M., Feher M. and Wright T. G., (2005), "Electronic and photoelectron spectroscopy: fundamentals and case studies", Cambridge University Press, ISBN: 0521817374,9780521817370,9780511080531,0521520630
25. Scoog D. A., Holler F. J. and Crouch S. R., (2007), "Principles of Instrumental Analysis", BrooksCole, ISBN: 0495012017
26. Banwell C. N. and McCash E. M., (1994), "Fundamentals of molecular spectroscopy", 4th Edition, McGraw-Hill Publisher, ISBN: 0077079760, 9780077079765
27. "Atomic Absorption Spectrometry: Theory, Design and Applications", Volume 5, 1st Edition. Elsevier Science, November. Hardcover ISBN: 978-0-444-88217-2 eBook ISBN: 9780080933979. Analytical Spectroscopy Library
28. Farrukh M. A., (2012), "Atomic Absorption Spectroscopy", IntechOpen, ISBN: 978-953-307-817-5; eBook (PDF) ISBN: 978-953-51-4933-0
29. Noguerra F., (2016), "Atomic Absorption Spectroscopy", Illustrated Edition, Scitus Academics LLC Publisher, ISBN: 168117460X, 9781681174600
30. Welz B. and Sperling M., (1999), "Atomic Absorption Spectrometry", 3rd Edition, Completely Revised Edition, Wiley-VCH, ISBN: 978-3-527-28571-6
31. Varma A., (1990), "Crc handbook of furnace atomic absorption spectroscopy", CRC Press, Reissued in 2019. ISBN: 9781351366502, 1351366505, 978-1-138-10507-2,978-1-315-15078-9

32. Lajunen L. H. J. M., (1992), "Spectrochemical Analysis by Atomic Absorption and Emission". The Royal Society of Chemistry, ISBN: 0-85186-873-8
33. Robinson J. W., (1996), "Atomic Spectroscopy", 2nd Edition Revised and Expanded. Marcel Dekker, Inc., New York. ISBN: 0-8247-9724-6
34. Ebdon L., Evans E. H., Fisher A. S. and Hill S. J., (1998), "An Introduction to Analytical Atomic Spectrometry", John Wiley and Sons Ltd. ISBN: 0-471-97418-8
35. Julien M. H., Griffiths M. W. and Wright A. D., (1999), "Biological Control of Water Hyacinth: The Weevils Neochetina Bruchi and N. *Eichhorniae* : Biologies, Host Ranges, and Rearing, Releasing and Monitoring Techniques for Biological Control of *Eichhornia Crassipes*", Edition illustrated, Australian Centre for International Agricultural Research, ISBN: 1863202676, 9781863202671
36. Yapoga S., Ossey Y. B. and Kouamé V., (2013), "Phytoremediation of Zinc, Cadmium, Copper and Chrome from Industrial Wastewater by *Eichhornia Crassipes*", International Journal of Conservation Science, Volume 4, Issue 1, pp: 81-86, January-March.
37. Ijaola T. O., Babajide S. O., Taiwo A. A, Osunkiyesi A. A., Akindele O. I. and Sojobi O. A., (2015), "Phytoremediation of Heavy Metals (Cu, Zn, and PB) Contaminated Water Using Water Hyacinth (*Eichornia Crassipes*)", Journal of Applied Chemistry, Volume 8, Issue 5 Ver. II (May), pp: 65-72.