REVIEW ARTICLE

Efficacy of Aquatic Plants for Removal of Heavy Metals from Wastewater

Vineet Soni*, Preetpal Kaur
Plant Bioenergetics and Biotechnology Laboratory, Department of Botany, Mohanlal Sukhadia University, Udaipur, India,

***Address for Correspondence:** Dr. Vineet Soni, Asst. Professor, Department of Botany, Mohanlal Sukhadia University, Udaipur, India

Received: 25 Oct 2017/Revised: 28 Nov 2017/Accepted: 24 Dec 2017

ABSTRACT- Wastewater treatment is a problem of grave concern in most developing countries. In the last two decades, there has been a lot of research to develop appropriate technologies to alleviate pollution in water resources. Efficient wastewater treatments through conventional methods are expensive and difficult to get optimum results. Currently, phytoremediation is an effective and affordable solution used to remediate toxic pollutants from aquatic ecosystems. The review describes various aquatic plants, which have high potential to remove heavy metals from wastewater.

Key-words- Aquatic plants, Heavy metals, Phytoremediation, Wastewater treatment, Water pollution

INTRODUCTION

Water pollution by heavy metal ions is one of the worldwide environmental problems [1]. Heavy metal pollution due to increased industrialization and urbanization is a global problem. Toxic heavy metals such as cadmium, copper, lead, chromium, zinc, and nickel are important environmental pollutants, particularly in areas with high anthropogenic pressure. They can't be biodegraded so released into the environment and contribute to lots of toxic effects even in relatively lower concentrations on living organisms in food chain [2-6] by bioaccumulation and bio-magnification [7].

Several methods already used to clean up the environment from these heavy metals including chemical precipitation, oxidation or reduction, filtration, ion exchange, reverse osmosis, membrane technology, evaporation and electrochemical treatment (but most of them are expensive, time consuming and environmentally destructive [8]. Therefore, it is essential for a remediation technology to be effective, economic/affordable and consistent; moreover, it should effectively reduce HM concentrations to environmentally acceptable levels, and be applicable to field conditions such as effluents and aquatic bodies. Currently, phytoremediation of metals is an effective and affordable "green" technology based on the use of specially selected metal accumulating plants to remove toxic metals from soils and water.

This environment friendly technology has aesthetic advantages and long-term applicability. It is a rapidly developing method that uses plants to reduce, degrade, assimilate and metabolize environmental pollutants such as heavy metals, hydrocarbons, pesticides, etc. Phytoremediation techniques do not require specialized equipment and are accepted by local communities. Plants with exceptional metal-accumulating capacity are known as hyperaccumulator plants [9]. Phytoremediation utilizes the unique and selective uptake capabilities of plant root systems, together with the translocation, bioaccumulation, and contaminant degradation abilities of the entire plant body. Many species of plants have been successful in absorbing contaminants such as lead, cadmium, chromium, arsenic, and various radionuclides from soils. As reported by Valipour and Ahn [10], plant species used for phytoremediation should be possibly native and have a quick growth rate, extensive root system, high biomass yield, various habitats adaptation, high tolerance and the ability to accumulate the pollutants in the aboveground parts. Aquatic macrophytes represent a diverse group of plants with a great potential for removal heavy metals and are categorized as merged, submerged and free-floating

Access this article online	
Quick Response Code	**Website:** www.ijlssr.com
	crossref **DOI:** 10.21276/ijlssr.2018.4.1.1

plants. Presently, over 400 species of plant are identified to have potential for remediation of water sources [11]. A wide range of wetland plant species, such as *Eichhornia*, *Salvinia*, water lettuce (*Pistia stratiotes*), duckweed, *Azolla*, *Potamogeton*, *Myriophyllum*, *Typha*, *Scirpus*, *Limnocharis flava*, *Spartina*, *Cyperus* and *Phragmites* are frequently used for the heavy metal remediation in aquatic system [12,13]. Different kinds of processes are used in phytoremediation techniques such as phytoextraction, phytodegradation, rhizofiltration, phytostabilization, phytovolatilization, phytodesalination and phytofiltration [14]. According to Thakur *et al.* [15], among these methods, phytoextraction, rhizofilteration and phytostabilization are commercially important. Kumar *et al.* [16] investigated seven aquatic plant species: *Ipomoea aquatica, Eichhornia crassipes, Typha angustata, Echinochloa colonum*, *Hydrilla verticillata*, *Nelumbo nucifera* and *Vallisneria spiralis* for phytoremediation of heavy metal in water. The result showed greatest and lowest accumulation of heavy metals in *N. nucifera* and *E. colonum*, respectively.

Aquatic plants for Heavy metal removal

Duckweed

Kingdom	: Plantae
Subkingdom	: Tracheobionta
Division	: Magnoliophyta
Class	: Liliopsida
Order	: Arales
Family	: Lemnaceae

Duckweed, the common name for four main genera of Lemnaceae: *Lemna, Spirodela, Wolffia and Wolffiella*, is the smallest and fastest-growing flowering plant on the planet. Recently, the Lemna spp. has been proved the most used plant for phytoremediation in comparison with the other aquatic macrophytes [17]. This plant is used widely for nutrient recovery of nitro-gen, phosphorus and toxic metals from domestic and agricultural wastewater [18-19]. *Lemna minor* (Fig. 1) and *Lemna gibba* have been used extensively for phytoremediation of heavy metals [20]. *L. gibba* behaves as bio-indicator for heavy metals that transfer heavy metals from contaminated site to the plant and could be used to monitor the transfer of metal from lower to higher trophic levels [21]. As stated by Bocuk *et al.* [22], *L. minor* accumulate high concentrations of several metals and metalloids, like nickel, copper, cadmium, zinc, manganese, boron, uranium and arsenic. Interestingly, Miretzky *et al.* [23] demonstrated that dried dead *L. minor* was able to remove heavy metals (Zn, Cu, Cd) from contaminated water.

Fig. 1: Collection of *L. minor* from wastewater accumulated at Udaipur, India

Giant duckweed (*Spirodela polyrhiza)* is frequently found growing in rivers, ponds, lakes, and sloughs (Fig. 2). *S. polyrhiza* was identified as a good arsenic phytofiltrator by physicochemical adsorption mechanism [24]. Tang *et al.* [25] evaluated the influences of a polyculture system of three duckweed species (*Lemna aequinoctialis*, *Landoltia punctata*, and *S. polyrhiza*) on the removal efficiency, as compared to a monoculture of duckweed, and majority of polycultures found to have median removal efficiency as compared to respective monocultures. Recently *L. minor* and *S. polyrhiza* are considered as an effective bioaccumulator and sensitive bioindicator for Pb [26]. *S. polyrhhiza* has been found to uptake and transform DDT and phosphorus pesticides [27]. According to Chaudhuri *et al.* [28], *L. minor* and *S. polyrhiza* are potential cadmium accumulator, as they were capable of removing 42–78% and 52–75% cadmium respectively from media depending upon initial cadmium concentrations.

Fig. 2: *Spirodela polyrhiza*

Eichhornia crassipes

Kingdom : Plantae
Division : Magnoliophyta
Class : Liliopsida
Order : Liliales
Family : Pontederiaceae
Genus : *Eichhornia*
Species : *crassipes*

E. crassipes, a native of South America, is a major freshwater weed in most of the frost-free regions of the world and is generally regarded as the most troublesome aquatic plant. It has been widely planted as water ornamental around the world because of its striking flowers. Liao and Chang [29] investigated the ability of water hyacinth to remove cadmium lead, copper, zinc, and nickel in water. In their investigation, they found water hyacinth plants high bio-accumulator of these trace elements when grown in water environments with low concentrations of the five elements. The detected values of cadmium and lead fall within normal range, while that of cobalt and nickel were within the critical range. However, zinc and copper showed the highest accumulation with alarming toxicity levels [16].

Azolla pinnata

Kingdom : Plantae
Phylum : Pteridophyta
Class : Filicopsida
Family : Azollaceae
Genus : *Azolla*
Species : *pinnata*

Azolla pinnata (Fig. 3) is locally distributed in its native range of Africa and Madagascar, India, Southeast Asia, China and Japan, Malaysia and the Philippines, the New Guinea mainland and Australia. *A. pinnata* spreads rapidly by vegetative growth and can form dense mats, interfering with boating, fishing and swimming. It can block sunlight from reaching submerged plants and can also reduce oxygen levels in the water by blocking the interface between the water surface and the atmosphere. *A. pinnata* was observed to purify waters polluted by two heavy metals, i.e., mercury and cadmium under a microcosm condition [30]. The phoyoremediation potential of *A. pinnata* has also been recently observed [31,32].

Fig. 3: *Azolla pinnata* forming dense mat over the Roopsagar, Udaipur, India

Potamogeton pectinatus

Kingdom : Plantae
Class : Liliopsida
Order : Najadales
Family : Potamogetonaceae
Genus : *Potamogeton*
Species : *pectinatus*

P. pectinatus is commonly known as sago pondweed, is a submersed plant that grows from a creeping rhizome. Except for the Polar Regions and Pacific islands, this species occurs worldwide. Sago pondweed grows in fresh, brackish, and saline waters throughout the state. It is found in stagnant ponds, spring-fed rivers, and slow flowing marshes. Underwater stands may look like grassy meadows. The stems are slender and flexible. The plant has high capabilities to remove heavy metals (Cd, Pb, Cu, Zn, and Mn) directly from the contaminated water [33].

Pistia stratiotes

Kingdom : Plantae
Division : Magnoliophyta
Class : Liliopsida
Order : Arales

Family : Araceae
Genus : *Pistia*
Species : *stratiotes*

Pistia stratiotes is a free-floating aquatic with feathery roots that can reach up to 50 cm in length. The fleshy leaves of this plant are arranged in a rosette and measure 2-15 cm in length. The leaves are green to grayish-green and have dense white hairs and parallel veins on their surface. *P. stratiotes* flowers in the late summer, but the flowers plant are small and inconspicuous. Phytoremediation efficacy of *P. stratiotes* has been evaluated by Farnese *et al.* [34] and Ugya *et al.* [35].

CONCLUSIONS

Water pollution is one of the biggest environmental concerns and it is evident that phytoremediation is a providing a better solution to handle this problem. Hence, the harvesting of *aquatic plants* from water bodies should be avoided in order to control pollution in the aquatic environment and reduce the health risks to humans and animals caused by heavy metal contamination. Meanwhile, after harvesting plants, accumulated metals could be removed from plant mass through leaching methods.

REFERENCES

[1] Hong KS, Lee HM, Bae JS, Ha MG, Jin JS, et al. Removal of heavy metal ions by using calcium carbonate extracted from starfish treated by protease and amylase. J. Anal. Sci. Technol., 2011; 2(2): 75–82.

[2] Kushwaha S. Heavy metal concentrations in feathers of critically endangered long-billed vultures (*Gyps Indicus*) in Bundelkhand region, India. Int. J. Life. Sci. Scienti. Res., 2016; 2(4): 365-75.

[3] Menon P, Joshi N. Effect of heavy A. metals on seed germination of *Trigonella foenum-graceum* L. Int. J. Life. Sci. Scienti. Res., 2016: 2(4): 488-93.

[4] Njagi JM, Akunga DN, Njagi MM, Ngugi MP, Njagi EMN. Heavy metal pollution of the environment by dumpsites: a case of Kadhodeki Dumpsite. Int. J. Life. Sci. Scienti. Res., 2016; 2(2): 191-97.

[5] Rao MV, Acharya Y, Bala AS, Paramben S, Sowmya K, et al. Study of heavy metals in abnormal growth and development using an alternate animal model: *Heterometrus fulvipes*. Int. J. Life. Sci. Scienti. Res., 2017; 3(1): 800-07.

[6] Singh CB, Ansari BA. Biochemical markers of oxidative stress in brain of zebra fish *Danio rerio* exposed to different heavy metals lead and Cobalt. Int. J. Life. Sci. Scienti. Res., 2017; 3(6): 1484-94.

[7] Akpor OB, Muchie. Remediation of heavy metals in drinking water and wastewater treatment systems: Processes and applications. Int. J. Phys. Sci., 2010; 5(12): 1807-17.

[8] Rakhshaee R, Giahi M, Pourahmad A. Studying effect of cell wall's carboxyl-carboxylate ratio change of *Lemna minor* to remove heavy metals from aqueous solution. J. Hazardous Mat., 2009; 163(1): 165–73.

[9] Cho-Ruk K, Kurukote J, Supprung P, Vetayasuporn S. Perennial plants in the phytoremediation of leadcontaminated soils. Biotechnol., 2006; 5(1): 01–04.

[10] Valipour A, Raman VK, Ahn YH. Effectiveness of domestic waste water treatment using a bio-hedge water hyacinth wetland system. Water, 2015; 7: 329–47.

[11] Lone MI, He Z, Stoffella PJ, Yang X. Phytoremediation of heavy metals polluted soils and water: progress and perspectives. J. Zhejiang Univ. Sci. B, 2008; 9(3): 210-20.

[12] Hua J, Zhang C, Yin Y, Chen R, Wang X. Phytoremediation potential of three aquatic macrophytes in manganese-contaminated water. Water Environ. J., 2012; 26: 335–42.

[13] Singh D, Tiwari A, Gupta R. Phytoremediation of lead from wastewater using aquatic plants. J. Agric. Sci. Technol., 2012; 8: 01–11.

[14] Rahman MA, Hasegawa H. Aquatic arsenic: phytoremediation using floating macrophytes. Chemosphere, 2011; 83: 633–46.

[15] Thakur S, Singh L, Wahid ZA, Siddiqui MF, Atnaw SM, et al. Plant-driven removal of heavy metals from soil: uptake, translocation, tolerance mechanism, challenges, and future perspectives. Environ. Monit. Assess., 2016; 188: 01–11.

[16] Kumar JIN, Soni H, Kumar RN, Bhatt I. Macrophytes in phytoremediation of heavy metal contaminated water and sediments in Pariyej Community Reserve, Gujarat, India. Turk. J. Fish. Aquat. Sci., 2008; 8: 193-200.

[17] Newete SW, Byrne MJ. The capacity of aquatic macrophytes for phytoremediation and their disposal with specific reference to water hyacinth, Environ. Sci. Pollut. Res., 2016; 23: 10630–43.

[18] Mohedano RA, Costa RH, Tavares FA, Belli Filho P. High nutrient removal rate from swine wastes and protein biomass production by full-scale duckweed ponds. Bioresourc. Technol., 2012; 112: 98–104.

[19] Zhang D, Gersberg RM, Ng WJ, Tan SK. Removal of pharmaceuticals and personal care products in aquatic plant-based systems: A review. Environ. Pollut., 2014; 184: 620–39.

[20] Guimaraes FP, Aguiar R, Oliveira JA, Silva JAA, Karam D. Potential of macrophyte for removing arsenic from aqueous solution. Planta Daninha, 2012; 30: 683–96.

[21] Mkandawire M, Dudel EG. Accumulation of arsenic in Lemna gibba L. (duckweed) in tailing waters of two abandoned uranium mining sites in Saxony, Germany. Sci. Total. Environ., 2005; 336: 81–09.

[22] Bocuk H, Yakar A, Türker OC. Assessment of *Lemna gibba* L. (duckweed) as a potential ecological indicator for contaminated aquatic ecosystem by boron mine effluent. Biol. Indic., 2013; 29: 538–48.

[23] Miretzky P, Saralegui A, Fernandez Cirelli A. Simultaneous heavy metal removal mechanism by dead macrophytes. Chemosphere, 2006; 62(2): 247-54.

[24] Ray S, Islam S, Tumpa DR, Kayum MA, Shuvro SD. A study on arsenic and copper extraction capacity of *Spirodela polyrhiza* from water. J. Civil Eng. Constru. Technol., 2015; 6(1): 01-09.

[25] Tang J, Chen C, Chen L, Daroch M, Cui Y. Effects of pH, initial Pb^{2+} concentration, and polyculture on lead remediation by three duckweed species. Environ. Sci. Pollut. Res., 2017; 24: 23864–71.

[26] Hegazy AK, Emam MH, Lovett-Doust L, Azab E, El-Khatib AA. Response of duckweed to lead exposure: phytomining, bioindicators and bioremediation. Desalination and Water Treatment. 2017; 70: 227–34.

[27] Gao J, Garrison AW, Hoehamer C, Mazur CS, Wolfe NL. Uptake and phytotransformation of organophosphorus pesticides by axenically cultivated aquatic plants. J. Agric. Food Chem., 2000; 48: 6114─20.

[28] Chaudhuri D, Majumder A, Misra AK, Bandyopadhyay K. Cadmium removal by Lemna minor and Spirodela polyrhiza. Int. J. Phytoremediation, 2014; 16(11): 1119-32.

[29] Liao SW. Chang WL. Heavy metal phytoremediation by water hyacinth at constructed wetlands in Taiwan. J. Aquat., Plant Manag., 2004; 42: 60-08.

[30] Rai PK. Phytoremediation of Hg and Cd from industrial effluents using an aquatic free floating macrophyte *Azolla pinnata*. Int. J. Phytoremed., 2008; 10: 430-39.

[31] Kooh MRR, Lim LBL, Lim LH, Bandara JMRS. Batch adsorption studies on the removal of malachite green from water by chemically modified *Azolla pinnata*. Desalination and Water Treatment, 2016; 57: 14632-46.

[32] Mandakini LLU, Bandara NJGJ, Gunawardana D. A Study on the phytoremediation potential of *Azolla pinnata* under laboratory conditions. Journal of Tropical Forestry and Environment, 2016; 6(1): 36-49.

[33] Peng K, Luo C, Lou L, Li X, Shen Z. Bioaccumulation of heavy metals by the aquatic plants *Potamogeton pectinatus* L. and *Potamogeton malaianus* Miq. and their potential use for contamination indicators and in wastewater treatment. Sci. Total Environ., 2008; 392(1): 22-09.

[34] Farnese FS, Oliveira JA, Lima FS, Leão GA, Gusman GS, et al. Evaluation of the potential of *Pistia stratiotes* L. (water lettuce) for bioindication and phytoremediation of aquatic environments contaminated with arsenic. Braz. J. Biol., 2014; 74: 108-12.

[35] Ugya AY, Imam TS, Tahir SM. The use of *Pistia stratiotes* to remove some heavy metals from Romi stream: A case study of Kaduna Refinery and Petrochemical company polluted stream. IOSR J. Environ. Sci. Toxicol. Food Technol., 2015; 9: 48-51.

How to cite this article:
Soni V, Kaur P. Efficacy of Aquatic Plants for Removal of Heavy Metals from Wastewater. *Int. J. Life Sci. Scienti. Res.*, 2018; 4(1): 1527-1530. DOI:10.21276/ijlssr.2018.4.1.1
Source of Financial Support: Nil. **Conflict of interest:** Nil