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Removing heavy metals like Arsenic (As), Mercury (Hg) and other pollutants from water by aquatic weeds through phytoremediation: A review

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Abstract
Environmental pollution affects the quality of biosphere. Great attempts have been made in the last two decades to reduce pollution sources and mitigate the polluted water resources. Phytoremediation, being more cost-beneficial and fewer side effects than the traditional processes, has gained increasing popularity in both academic and practical life. Continues agricultural practices and other anthropogenic activities lead to heavy metals contamination. Over the past several years, scientists have discovered many examples of living plants that can remove heavy metals and other pollutants from water. Among the various techniques used. Phytoremediation is one of the least harmful, eco-friendly and natural method. Phytoremediation is based upon several process such as phytoextraction, phytostabilization, phytovolatilization and rhizofilteration. Researchers using a variety of plants have reported Phytoremediation of toxic metals. There have been a number of reports that aquatic weeds such as Eichhornia *crassipes*, *Polygonum amphibium*, *Lemna minor*, *Oenathe javanica*, *Lepironia articulate* and *Potamogeton crispus* can accumulate Pb, As, N, P, Cu, Ni, Cd, Fe and Hg from contaminated water (Mo *et al*., 1989; Jackson, *et al*., 1990; Dierberg, *et al*; 1987). This paper review the mechanisms involved in phytoremediation of heavy metals and other pollutants for water resources. This paper also review the focused on the capabilities of aquatic weeds and as an important tool in phytotechnologies in the controlling of contaminants in aquatic environment.

Keywords: aquatic weeds, cost effective, eco-friendly, heavy metals, phytoremediation

Introduction

Water is one of the valuable natural resource, which is depend on for agricultural sustainability and humankind civilization. Due to rapid urbanisation and industrialization, agricultural lands have become gradually contaminated by organic, inorganic and -metallic pollutants (Litchfouse and Ellington 1995, Sivarajasekar *et al*. 2008, 2018 b: Sivarajasekar and Baskar 2014 a, b, c). This affects the ecosystems, surface, subsurface, ground water, food quality and health (Heinaru *et al*. 2005; Ayoub *et al*. 2010; Sivarajasekar and Baskar 2015 a, b).

Many technologies that are easy to use have been developed as part of the continuous efforts to make water free from contamination, be of good quality of waters, sustainable and economically feasible. Physicochemical approaches (involving isolation and containment, chemical extraction, chemical redox process, thermal method, electrokinetics) have been widely used for treating polluted water, especially at a small scale while difficult to use at large scale due to high costs and side effects. Therefore, the search for an alternative clean and cheap technique for water cleaning became important.

The use of aquatic plant species for cleaning polluted waters named as phytoremediation has gained great interest and adopted by scientist, governmental and non-governmental organizations. However, the concept of using plants to clean up contaminated environments is not new. About 300 years ago, plants were proposed for use in the treatment of wastewater and have gained increasing attention since last two decade, as an emerging cheaper technology. United Nations Environment Program defined phytoremediation as ‘‘the efficient use of plants to remove, detoxify or immobilize environmental contaminants” (UNEP, 2019).

Various aquatic plant species have been identified and tested for their traits in the uptake and accumulation of different heavy metals and organic pollutants in water. Aquatic weeds can uptake large amounts of metals from water through active and passive absorption, with this absorption capacity of metals through different organs such as roots, stems and leaves, making these plants suitable for heavy metal alterations in the aquatic environment.

Mechanisms of Phytoremediation

Phytoremediation is most applicable for sites that have been contaminated with organic pollutants and as such protection Agency, 2000). Aquatic plants such as the *Echhornia crassipes* (Water hyacinth), *Lemna minor* (Duckweed), and *Pistia* have been investigated for use in rhizofilteration (Karkhanis *et al*. 2005). Recently, a fern *Pteris vitatta* has been shown to accumulate as much as 14,500 mg kg -1 arsenic in ponds without showing of indications of toxicity (Ma et, al; 2001).

Phytoremediation follows different mechanisms such as phytoextraction, phytostabilization, phytovolatilization and rhizofilteration during the uptake or accumulation of heavy metals in the plants. These are the various mechanisms involved in the phytoremediation process are given below:-

Phytoextraction

Phytoextraction is also known as phytoaccumulation and it involves the uptake of heavy metal in the plant roots and then their translocation into an above ground level portion of the plant like shoots etc. Once the phytoextraction is done the plant can be harvested and burned for gaining energy and recycling metal if required from the ash.

Sometimes phytoremediation and phytoextraction are used synonymously which is not true, phytoextraction is a clean-up technology while phytoremediation is the name of a concept. Phytoextraction is an appropriate phytoremediation technique for the remediation of heavy metals from wastewater, sediments and soil.

Phytostabilization

Phytostabilization involves the use of the plant to restrict the movement of contaminants in the soil and water. In phytostabilization, plants prevent or act as a barrier for the filtration of water within soil. This method is generally used to treat the metals like As, Cd, Cr, and Cu and Zn contaminants.

Rhizofilteration

Rhizofilteration involves the use of the plant to absorb the contaminants, resulting in controlled movement of these contaminants in underground water. Roots play a major role in rhizofilteration. Both aquatic plants with long fibrous roots systems can be used in rhizofilteration. Rhizofilteration is effectively used for handling and management of the agricultural runoff, industrial discharge, radioactive contaminant and metals. Heavy metals that are mostly retained in the soil such as Cd, Pb, Cr, Ni, Zn and Cu can be efficiently remediated through rhizofilteration. Rhizofilteration is mainly use to remediate surface water, removed ground water and wastewater with low concentrations of contaminants.

Phytovolatilization

Phytovolatilization is the process in which a plant converts pollutants into a different volatile nature and then their continual release into the surrounding environment with the help of the plant stomata. Hg and Se are the most favourable contaminants that can be remediated in phytovolatilization.

Role of Aquatic weeds in Phytoremediation Technique

The aquatic ecosystem is a cost beneficial and resourceful clean-up technique for phytoremediation of a large contaminated area. Aquatic weeds act as a natural absorber for contaminants and heavy metals. Removal of different heavy metals along with other contaminants through the application of aquatic plants is the most proficient and cost-effective method. Constructed wetlands along with aquatic plants were broadly applied throughout the world for the treatment of wastewater. The selection of aquatic plant species for the accumulation of heavy metal is a most important matter to increase the phytoremediation. Some aquatic weeds like duckweeds have unexpected efficiency to improve very fast toward high heavy metals exposure (Ekperusi *et al*., 2019). The use of Duckweed in phytoremediation of various biochemical processes such as biochemical oxygen demand, TSS, NH4NO3, P, NH3 and total nitrogen (Ekperusi *et al*., 2019). In addition, Common duckweed has potential to enhance the quality of water contaminated with blue and textile dyes (Ekperusi *et al*., 2019; Neag *et al*., 2018; Yaseen & Scholz, 2017). Rezania *et al*. discovered that among four species of free-floating macrophytes (*Pistia stratiotes, Eicchornia spp., Lemna spp. and Salvinia spp.). Pistia stratiotes* was found to have the highest phytoaccumulation potentials. Badr El-Din *et al*. established that aquatic plants (*Lemna minor, Eichhornia crassipes* and green algae) are capable of decreasing all tested indicators of water quality in wastewater to a level that permit its use for irrigation purpose. Aquatic weeds and their role in heavy metal accumulation potential has been shown in (Table-I). Species *Polygonum amphibium* efficiently accumulates Iron, Copper, Manganese, Mercury and Arsenic, which is in accordance with some literature data (Samecka-Cymerman, Kempers 2001; Kumar *et al*., 2006; Yabanli *et al*., 2014). You *et al*. (2000) investigated the contents of heavy metals (Cu, Cd, Pb, Zn) in Water dropwort for decontamination of eutrophic water and discovered that heavy metals mostly accumulated in the roots, while the substances in the stem and leaf were in the range of being eatable.

Over the years, aquatic plants have gained a reputation because of their capability to clean up contaminated sites throughout the world. Aquatic plants always develop an extensive system of roots that helps them, makes them the best selection for the accumulating in their roots, and shoots. The growth and cultivation of aquatic plants are time – consuming, which may restrict the growing demand of phytoremediation. However, this shortcoming is substituted by the number of advantages that this technology possesses for the treatment of wastewater.

Table 1: Removal Performance of heavy metals by various aquatic weeds

S.no	Aquatic weeds	Common name	Metals accumulation	References
1.	*Eichhornia Crassipes*	Water hyacinth	Pb, Hg, Cu, Cr, Zn, Ni	Molisani *et al*.
2.	*Lemna minor L.*	Duckweed	As, Cr, Cu, Pb, Ni	Kara, Ater *et al*., Basile *et al*.
3.	*Pistia stratiotes*	Water lettuce	Cr, Cu, Fe, Mn, Zn	Maine *et al*., Miretzky *et al*.
4.	*Polygonum amphibium L.*	Sharp dock	Fe, Cu, Mn, Hg, As	Samecka-Cymerman, Kempers, Kumaret, Yabanli *et al*.
5.	*Lepironia Articulate*	Calamus	Fe, Al	Nur Izzati Ismail, Siti Rozaimah Sheikh Abdullah *et al*.
6.	*Oenathe javanica*	Water dropwort	Cd, Cu, Pb, Zn	You *et al*.
7.	*Potamogeton crispus*	Pondweed	Cu, Fe, Mn, Ni, Zn	Borisova *et al*.
8.	*Lemna gibba*	Duckweed	Cd, Ni, NH3, P	Ekperusi *et al*.

Conclusion

The water is continuously contaminated due to various kinds of anthropogenic activities; consequently, it would be a direct threat to the survival of all living organisms. Heavy metal pollution and other water contaminants has emerged as a very serious problem globally. Phytoremediation technique is preferred because of its cost effectiveness, efficiency and eco-friendly nature. Plants used in this technique adopted a variety of mechanisms to deal with heavy metals and other contaminants. Plants used in this technique adopted a variety of mechanisms to deal with heavy metals and other pollutants. Heavy metals form one of largest category of contaminants that are efficiently removed by aquatic weeds. Various plant species studied for phytoremediation accumulated considerable amounts of metals and thus proved to be potential for being used as phytoremediation species in aquatic bodies contaminated with heavy metal pollution and other pollutants. The review also reveals the importance of free-floating aquatic plants because of their extraordinary capabilities to bio-accumulate the heavy metals and other contaminants.

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