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Aquatic Plants in phytoremediation of contaminated water: Recent knowledge and future prospects

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Abstract

The increase of heavy metals in natural resources, including land and water has been rapidly raised due to a variety of natural methods, higher agricultural activities, contaminated irrigation water, speedy industrial development, amplified industrial wastes and mining. Heavy metals (HM) are able to remain in the environment longer time and go in the food chain, and ultimately accumulate in humans for biomagnification since they are not biodegradable. HMs contamination is extremely dangerous for humans and the ecology due to its poisonous nature. Traditional methods of cleanup are expensive and could harm the environment. Therefore, phytoremediation is an alternate method via plants to eliminate toxic HMs from the atmosphere as well as to avoid additional contamination, due to its environment-friendly, economic, efficient, exclusive and cost-effective approach. Aquatic plants can be utilized to decontaminate the contaminated sites as they are not food crops, thus reducing the danger of food chain contamination. Here, sources of HMs and their impact on human health have been briefly discussed. Several phytoremediation techniques and factors affecting the phytoremediation methods are also described. In addition, different strategies to decontaminate the metal-polluted water using aquatic plants are also reviewed. Finally, future perspectives for usages of aquatic plants in phytoremediation techniques were briefly summarised.

Keywords: Phytoremediation, Heavy metals, Aquatic plants, Contaminated water

1. Introduction:

There is an increase in heavy metal production into the surroundings due to growing urbanization, industrialization, agricultural practices and overconsumption of natural water sources. As heavy metals are very persistent and non-biodegradable, they pose a prolonged environmental threat. HMs accumulate in the environment and the polluted aquatic environment disturbs the entire aquatic ecosystem and cause major health problems for humans, plants, animals and microbes. HMs include a set of metal components with comparatively high atomic numbers, atomic weights and densities (>5 g/cm3) (Bhat et al., 2022). As per their action in biological systems, HMs are classified into essential and nonessential. While nonessential HMs e.g. cadmium (Cd), arsenic (As), mercury (Hg), lead (Pb), etc., are extremely lethal and also have no known role in biological systems; essential HMs like manganese (Mn), cobalt (Co), copper (Cu), iron (Fe), zinc (Zn), nickel (Ni), etc. are necessary for biochemical and physiological activities during plant life cycle, however, consuming larger amount can have adverse impact (Yan et al., 2020).

HMs can be the primary reasons of conditions such as skin disorders, dehydration, cancer, respiratory issues, asthma, problems with the cardiovascular and excretory systems, nervous and immune system disorder and stunted growth in humans (Rizwan et al., 2019). Therefore, remediation methods are required to reduce the impact of the polluted area and also prevent the entry of HMs into habitats with water. Many remediation strategies are created for restoring water contaminated with heavy metals. These physiochemical methods, however, have been found to have some drawbacks, including high costs, permanent changes to the biological, chemical and physical features of water.

Therefore, an economical, efficient and environmentally-safe approach named phytoremediation uses plants to absorb and eliminate contaminants or to reduce their bioavailability in water. Aquatic plants play a vital role in phytoremediation as hyper-accumulator in complex aquatic ecosystem (Ali et al., 2020). Even at small amounts, plants can absorb ionic elements in water via roots, accumulate in tissues, break down and alter contaminants to a less detrimental structures. Certain heavy metals like Zn, Cr, Cd, Fe, Cu etc. are extracted by Eelgrass and water mint (Shi et al., 2021). Amidst the many aquatic plants, *Eichhornia, Wolfia, Lemna, Azolla, Potamogeton* etc. are mainly utilized for the phytoremediation of aquatic ecosystem (A. A. Ansari et al., 2020).

2. Sources of Heavy Metals Causing Pollution:

Both anthropogenic & natural sources are one of the main reasons of heavy metal pollution. There are several sources, including (a) home effluent, (b) industrial sources, (c) agricultural sources, and (d) natural sources (Hasan et al., 2019). Naturally occurring sources consist of breakdown of rocks, soil erosion, and eruptions of volcano, whereas man-made sources involve mineral extraction, incomplete fossil burning, metal refining, landfilling, dyes, wastewater, agricultural chemicals, military operations, smelting, and vehicle emissions (Bhat et al., 2022).

The usage of pesticides and manures on agricultural land has increased Cd, Zn, and Cu concentrations in the land and water. The utilization of phosphate and inorganic fertilizers results in an unequal distribution of Zn, Pb, Ni, Cd, Cr etc. (Ali et al., 2020). Potentially hazardous substances like Cd, Cu, Pb, Ni, Zn, Cr etc. are found in sewage water. Wastewater from sewage, dyes, alloys, mines, and other substances are common sources of HMs like Cd, As, Pb, Cu, Hg, Cr etc. Heavy metals like Zn, Pb, Ni, Cd and other substances can gather because of irrigation of wastewater (Bhat et al., 2022; Ali et al., 2020).

3. Impact of Heavy Metals on Human Health:

Now-a-days, a significant debate is going on throughout the world about the rate of metal pollution in the environment (Shikha & Singh, 2020). Destructive HMs can cause several health problems according to its concentration, kind and oxidation process (Bhat et al., 2022). It is harmful to our health to drink contaminated groundwater. Increased levels of Cr, Cd, Pb, As in groundwater have occasionally been linked to health risks for cancer (Ravindra and Mor, 2019). The detection of the impact of heavy metals in fish is a crucial part of human health concern since fish are beneficial to human diet. Deadly heavy metals initially accumulate in fish and get entry into the food chain by other organisms through biomagnification, causing negative conditions like kidney, cardiac and neural diseases (Shikha & Singh, 2020).

Reactive oxygen species (ROS) resulting from HMs, which interfere with the antioxidant defines system and damage cells in humans and other animals, lead to oxidative damage. In severe situations, ROS may be lethal. For example, reduction of hexavalent chromium (Cr^{6+}) to trivalent chromium (Cr^{3+}), damages biological components and creates free radicals that damage DNA. Hexavalent chromium also causes cancer in humans (Saxena et al., 2019).

4. Phytoremediation of metal-contaminated water:

Phytoremediation is an environment-friendly, cost-effective, useful process to clean up a large polluted medium. There are many plant species that are able to absorb contaminants through roots, accumulate in body parts, such as a leaf, stems and root and degrade and alter contaminants to a less harmful forms (Ansari et al., 2020). Plants used for phytoremediation show the following characters like rapid growth, yielding high biomass, easily managed, hyperaccumulation capacity, capacity to carry metals in aerial parts of the plant and hyper-tolerance to toxic metals. Aquatic plants can absorb pollutants and toxic heavy metals naturally (Ali et al., 2020). Ability of diverse aquatic species for reducing several heavy metals is given in Table 1.

Table 1: Different aquatic plants and also their accumulation capability (Ali et al., 2020; Mohebi and Nazari et al., 2021)

Aquatic Species	Common Name	Heavy Metals	Contaminated Water
Lemna minor	Duckweed	Cu, As, Pb, Cr, Ni	Industrial and domestic wastewater
Eichhornia crassipes	Water hyacinth	Hg, Zn, Ni, Pb, Cu, Fe, As, Cr	Industrial and domestic wastewater, sewage effluents
Pistia stratiotes	Water lettuce	Pb, Cd, Ni, Cu, Cr, Zn	Industrial wastewater, sewage water
Ipomoea aquatica	Water spinach	Ni, Pb, Cd	Palm oil mill effluent
Typha latifolia	Common cattail	Ni, Fe, Cu, Pb, Zn, Mn	Textile Wastewater

5. Phytoremediation Techniques:

The different phytoremediation techniques are briefly described below (Figure 1) –Phytoextraction: Phytoextraction is one of the most significant phytoremediation methods to recover HMs from contaminated land, wastewater, and sediments. It is also known as phytoaccumulation, in which the HMs are taken by the roots and then moved to its different above-ground parts like shoots etc. (Ali et al., 2020).

Phytostabilization: By reducing the movement and bioavailability of harmful contaminants, this method stops them to migrate into the groundwater or their entrance into the food chain. Plant roots are essential to immobilize various HMs in the land and water bodies (Ansari et al., 2020).

Phytovolatilization: In the process, pollutants are absorbed by plants, converted into volatile forms, and then liberated into atmosphere through leaves. Both organic contaminants and some HMs, like Cd, Se, Hg can be removed by this technique (Yan et al., 2020; Bhat et al., 2022).

Rhizofiltration: In this method, plant roots play important role to remove contaminants from wastewater. HMs are absorbed by root exudates, which can change the pH level of the rhizosphere (Yan et al., 2020; Bhat et al., 2022).

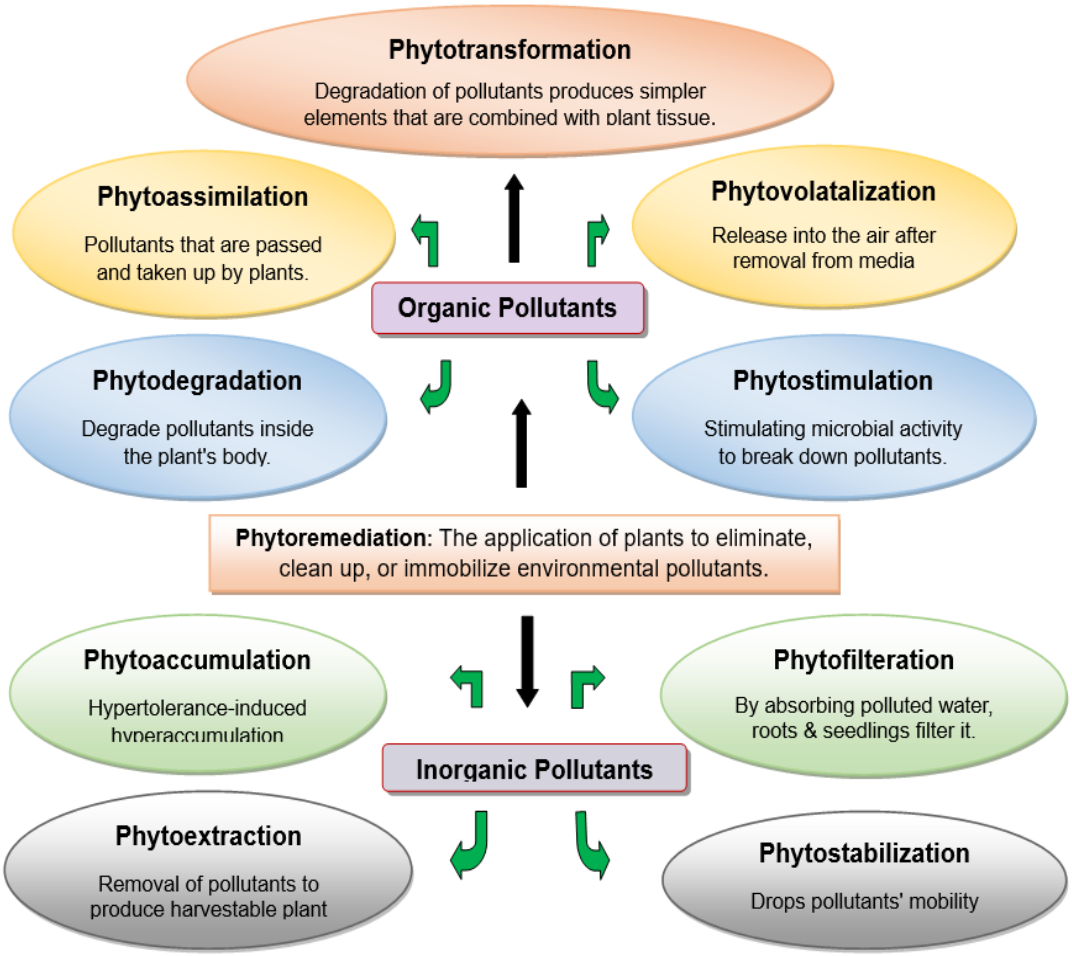

Figure 1: Phytoremediation Techniques used in aquatic habitats

6. Several aspects influencing the phytoremediation of HMs:

Various factors may have an impact on how plants absorb heavy metals. Some of the factors include:

1. Plant Species: The ability of a plant to absorb a chemical substance depends on the species to which it belongs. The successful phytoextraction procedure depends on selecting a suitable plant that can absorb the required metal.
2. Medium Properties: Several properties of the growth media can influence the amount of metals absorbed by the plant. Some features include pH, metal concentration, organic matter content, soil texture, the addition of chelators, and fertilizers.
3. Root Structure: Metal absorption rates will be influenced by the roots. Metals may be absorbed, stored, transported, or metabolized in the roots of the plant.
4. Bioavailability: A plant's capability of to absorb metals depends on their bioavailability in the aqueous stage. To enable plant absorption, metal should react with water and other substances.
5. Effect of Age: The biophysiological function of a plant is most significantly influenced by the age effect. Young roots have a greater ability than its mature ones to absorb ions. (Ghosh et al., 2023)

7. Conclusion and Future Prospects:

Heavy metal pollution is one of the major hazards to water bodies. The utilization of low-cost, eco-friendly methods appears to be a feasible strategy for cleaning up these pollutants. Therefore, phytoremediation is one of the most well-known and successful plant-based methods for cleaning up contaminated media. Some aquatic species are more resistant to pollutants and can prevent their entry into food chains. However, this method will be accepted worldwide, if it is provided with understandable and correct details. Further study, invention and initiatives are required to improve this technique and inspire developing countries to use it. Besides, there are still a number of barriers preventing the complete prospective of aquatic plants for the resourceful managing of pollutants in aquatic habitat. In future, genetically modified plants will be used by

boosting their potentiality of heavy metal absorption and decontamination. Later, the removal of plant biomass can be utilized as animal fodder and also for biogas manufacturing.

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