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Review

Phytoremediation Potential of Free Floating Macrophytes – A Review

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Abstract

Water bodies are the main targets for disposing the pollutants directly or indirectly and are again at the receiving end as the storm water, residential and commercial waste is disposed into it. The prevailing conventional purification technologies such as waste water treatment plants, drinking water purification plants used to remove these contaminants are too costly and sometimes non-eco friendly also. Therefore, the research is oriented towards low cost and eco friendly technologies for water purification, which will be beneficial for community. The present review highlights the phytoaccumulation potential of free floating macrophytes with emphasis on utilization of *Azolla* spp., *Lemna* spp. and *Salvinia* spp. for phytoremediation. We find that these species have many unique properties ideal for phytoremediation: they have fast growth and *primary production, high bioaccumulation capacity, ability to transform or degrade* contaminants, ability to regulate chemical speciation, resilient to extreme contaminant concentration and can be applied on multiple pollutants simultaneously.

Keywords: Freshwater, Free-floating macrophytes, phytoremediation, heavy metals

INTRODUCTION

The legacy of rapid urbanisation, industrialization, population explosion, fertilizer and pesticide use in the last few decades have added huge loads of pollutants in the water resources (CPBC, 2008). Among various pollutants, heavy metals are of major concern because of their persistant and bio accumulation nature (Chang *et al*., 2009 and Yadav *et al*., 2009). The increased pollutants in the receiving water are toxic to the living communities in the aquatic ecosystem, and also cause health problems in human. A definite need exists to develop a low cost and eco friendly technology to remove pollutants particularly heavy metals from aquatic ecosystems. Phytoremediation offers an attractive alternative in which macrophytes are used for removal, disposal and recovery of heavy metals from eutrophic water of urban areas, agricultural fields before they are discharged to surface water systems (Arora *et al*., 2006).

Phytoremediation

The term "phytoremediation" comes from the greek word (phyto=plant, and Latin "remedium" = restoring balance; consists of mitigating pollutant concentrations in soil, water or air with naturally occurring or genetically engineered plants that have ability to accumulate, degrade or eliminate metals, crude oil and its derivatives etc. (Flathman and Lanza 1998 and Prasad and Freitas, 2003). Phytoremediation has been increasingly used to clean up contaminated water systems because of its lower costs and fewer negative effects than physical or chemical engineering approaches (Reddy and DeBusk, 1987). The principles of phytoremediation system to clean up water include: (1) identification and implementation of efficient aquatic plant systems; (2) uptake of dissolved nutrients and metals by the growing plants (Billore *et al.,* 1998 and Gumbricht, 1993).

Aquatic plants are utilized for nutrient and metal removal from water due to their fast growth rates, simple growth requirements and ability to accumulate biogenic elements and toxic substances. Since the first recognition of their value in water quality improvement in the 1960s and the 1970s (Steward, 1970 and Wooten and Dodd, 1976), aquatic plants have been widely used to treat wastewaters or increasingly used to remediate eutrophic waters in forms of constructed wetlands or retention ponds. This is a low-cost treatment with low land requirements, which is attractive to urban areas with high land prices. Seidal (1976), Wolverton and McDonald (1976) and Wolverton and Mckown (1976) experimentally proved the importance of aquatic plants in removing organic contaminants from aquatic environments. Thereafter this approach is emerging as an innovative tool, because plants are solar driven and thus makes this technology a cost effective mode, with great potential to achieve sustainable environment. This review is an attempt to gather information available regarding phytoaccumulation potential of free floating macrophytes, emphasizing its strength and need for in-depth research related to its exploitation at commercial level.

Free floating macrophytes

Aquatic macrophytes are more suitable for wastewater treatment than terrestrial plants because of their faster growth, larger biomass production, capability of pollutant uptake and better purification effects due to direct contact with contaminated water. They also play an important role in the structural and functional aspect of aquatic ecosystems by altering water movement, providing shelter to aquatic invertebrates, regulating oxygen balance, nutrient cycle and accumulating heavy metals (Srivastava *et al*., 2008; Dhote and Dixit, 2009).Their ability to hyperaccumulate heavy metals make them interesting especially for the treatment of industrial effluents and sewage waste water (Mkandawire *et al*., 2004; Arora *et al*., 2006; Upadhyay *et al*., 2007; Mishra *et al*., 2009). The potential of aquatic macrophytes for heavy metal removal has been investigated and reviewed extensively. Many researchers have reported that high heavy metal concentrations (Cu, Cd, Mn, Pb, Hg, etc.) were measured in the tissues of aquatic plant growing in waters with elevated metal concentrations and no toxic effects or reduction in plant growth were observed(Brooks and Robinson, 1998; Prasad and Freitas, 2003; Dhote and Dixit, 2009; Rai, 2009). Phytoremediation potential of aquatic plants are regulated by tolerance capacity, accumulation potential and environmental factors like pH, temperature and concentration of heavy metal. Aquatic macrophytes have ability to concentrate heavy metals in their roots, shoots as well as leaves (Mishra *et al*., 2009).

Aquatic plants are grouped into submerged, emergent, rooted floating and free floating according to their leaf's relation with water. Among the free floating aquatic plants, duckweed (*Lemna spp.* and *Spirodela polyrrhiza*) and common salvinia (*Salvinia minima*) are the best candidates (Jain *et al*., 1990; Maine *et al*., 2004 and Sanchez-Galvan *et al*., 2008). With regard to the uptake capacity of aquatic plants, and subsequently the amount of nutrients or contaminants that can be removed when the biomass is harvested, floating plants are in the lead, followed by emergent species and then submerged species. Free floating macrophytes representing plants that are non-rooted to substratum, highly diversified group in habitats and forms e.g. *Salvinia* spp., *Azolla* spp., *Lemna* spp., etc.

Azolla spp.

Azolla spp. is a small aquatic fern belonging to phylum pteridophyta, class polypodiopsida, order Salviniales, Family Azollaceae (Wagnar, 1997 and Pabby *et al*., 2003). The fern has symbiotic association with nitrogen fixing cyanobacteria. This fern can hyperaccumulate variety of pollutants such as heavy metals, dyes and pesticides etc. from ecosystems along with other macrophytes (Padmesh *et al*., 2006; Rai and Tripathi, 2009; Mashkani and Ghazvini, 2009 and Sood *et al*., 2011). Jain *et al*. (1989) found that *A. pinnata* removed the heavy metals iron and copper from polluted water. If present at low concentrations the treatment could be done by passing it through ponds containing these water plants. *Azolla pinnata* removed 92.7, 83.0, 59.1, 65.1, 95.0, 90.0 and 73.1% of the initial Fe, Zn, Cu, Mn, Co, Cd and Ni, respectively from mixture of waste waters (Elsharawy *et al*., 2004). Arora *et al*., 2006) compared *A. filiculoides* with *A. microphylla* and *A. pinnata* for its phytoaccumulation potential of Cd, Cr, and Ni. They recorded that Cd, Ni and Cr content (ppm) in tissues was in the following order: *A. microphylla>A. filiculoides>A. pinnata; A. pinnata> A. microphylla> A. filiculoides and A. pinnata>A. filiculoides>A. microphylla,* respectively. The content of heavy metal Pb was upto 416 mg kg-1dry weight and that of Cd was up to 259 mg kg-1dry weight in fronds of A. *caroliniana* (Rakhshaee *et al*., 2006). *Azolla* biomass, in dead or pretreated form, has also been used for biosorption of heavy metals like Cs, Sr, Pb, Zn, Ni, Cu, Au, Cd, and Cr by various workers (Cohen Shoel *et al*., 2002 and Umali *et al*., 2006).

Lemna spp.

Lemna spp. of the family Lemnaceae have been widely studied for their potential application in phyto-remediation. Research with *Lemna minor* and heavy metals (sp. Cu, Cd, Hg, Pb) dates back to the early 1970's at the advent of phytoremediation (Antonovics *et al.,* 1971). There are several studies that have shown that most *Lemna* spp. show an exceptional capability and potential for the uptake and accumulation of heavy metals, radionuclides as well as metalloids, surpassing that of algae and other aquatic macrophytes (Korner and Vermaat 1998 and Zimmo *et al*., 2004). *Lemna minor* can be found on almost every continent and in nearly all non-polar regions (Germplasm Resources Information Network (GRIN)). *Lemna minor* can be found under some of the most extreme toxic conditions such as sludge ponds and mining waste ponds, thus showing its potential for use in remediating these environments. Previous research suggests that the absorption of heavy metals in free floating aquatic plants, such as *Lemna minor*, occur via the roots (Marschner, 1995). *Lemna minor* was chosen as the aquatic plant species for removal of copper for several reasons. The most essential reason for its use is well documented by other researchers in its ability to act as a bioaccumulator of heavy metals (Prasad and Frietes, 2003). Another reason for using *Lemna minor* is its tolerance to a large range of habitats. Boule *et al*. (2009) found lower Cu uptake and tolerance level in *Lemna minor* from the non-contaminated area compared to another ecotype from uranium polluted mine. Mkandawire *et al*. (2004) estimated that L. *gibba* biomass can extracted arsenic and uranium in the magnitude of 751.9 ± 250 and 662.7 ± 203 kg ha-1 per year representing extraction potential of 48.3 ± 15.1 and 41.4 ± 11.9% under ideal laboratory condition optimal steady state condition with unlimited growth.

*Salvinia*spp.

Salvinia, a free-floating aquatic fern holds a distinct position because of several advantages including high productivity and tolerance to a wide range of temperatures (Olguin *et al*., 2002). The potential of *Salvinia* for heavy metal removal has been studied extensively (Srivastav *et al*., 1993; Banerjee and Sarkar, 1997; Hoffman *et al*., 2004; Mukherjee and Kumar, 2005 and Molisani *et al*., 2006). The metal uptake in *Salvinia* occurs through a biological or physical mode. The metals Cr, Pb uptake by physical processes is fast and involves adsorption, ionic exchange and chelation, while biological processes such as intracellular uptake (transported through plasma lemma into cells) is comparatively slow but help in subsequent translocation of metals Cd from roots to leaves (Sune *et al*., 2007). High metal removal capacity of *Salvinia* biomass has been attributed to great specific surface (264 m2 g−1) that is rich in carbohydrates (48.50%) and carboxyl groups (0.95 m mol g−1) (Sanchez-Galvan *et al*., 2008). Among various *Salvinia* species, *S. minima,* is considered as a hyperaccumulator of lead and cadmium because it shows high bioconcentration factor (BCF)which can reach in the range of 2000–2600 in batch systems and 4134 to 17170 in continuous systems (Olguin *et al*., 2005). Non-living biomass of *Salvinia* exhibit equivalently high potential to remove heavy metals. The higher concentration of lipids and carbohydrates present on the plant surface act as the cationic weak exchanger groups that contribute to metal sorption by ion exchange reactions. Sorption of heavy metals by dry biomass also follows the Langmuir isotherm (Schneider and Rubio, 1999).

CONCLUSION

An integrated approach could be developed from present review by using free floating as phytoremediation toolbased on the use of specially selected metal accumulating plants in abatement of heavy metal pollution. These macrophytes possess all the properties for use in phytoremediation process, such as fast growth rate, high biomass production, easy to harvest and tolerance to a wide range of heavy metals.They are confirmed to be good accumulators and potential hyperaccumulators for many metals including the widely reported Cu, Cr, Cd, Ni, Pb, U, As, Zn as well as Cs and Sr. The harvested residues could be a good source of protein rich feed for animals, green manure and a source of bio-ore for recovery of precious heavy metals from contaminated waste waters. Much research is still needed around elemental defense mechanism and their regulation at gene level to get effective strategies for multi element contaminated aquatic ecosystems.

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