Review article

The efficiency of macrophytes for heavy metals removal from water

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Abstract: *Nowadays heavy metals pollution has become one of the most serious environmental problems. Advances in science and technology are leading to the degradation and contamination of aquatic environments. Pollution in aquatic ecosystems poses a serious threat to aquatic biodiversity and serves health hazards in humans. The traditional methods of the environment cleaning in practice are expensive and non-eco friendly can lead to the secondary pollution. It is a reason why the aquatic plants (macrophytes) as the biological remediation methods have been used. Macrophytes play an important role in the biological methods of the water remediation because they have capability to improve the quality of water by absorbing heavy metals with their leaves and effective root systems. This review discusses the potential of different aquatic plants (macrophytes) in purifying water and wastewater.*

Keywords: *water ecosystem, macrophytes, contaminants, remediation.*

Introduction

The contamination of aquatic environments is one of the most serious problems in the world. Advances in science and technology as well as human activity contribute in increasing a level of metals concentrations, pesticides and fertilizers in water thus affecting water quality [1, 2, 3]. Contaminants can induce oxidative stress by generating reactive oxygen species (ROS) which are highly reactive and toxic. ROS are capable of inducing cellular damage by degradation of proteins, lipids, nucleic acids, inactivation of enzymes, alterations in the gene and interfere in various pathways of metabolic importance [4].

Traditional methods of the environment clearing in practice are expensive and non-eco friendly and can lead to the secondary pollution. Many researches conducting study to improve the water quality using biological method to overcome this problem. One of such methods is phytoremediation. The phytoremediation as the biological remediation method with a use of water-loving plants (macrophytes) does not affect the surrounding environment and influences the better quality of the water ecosystems because the mentioned plants have ability to uptake organic and inorganic pollutants and grow well in polluted water [5].

The aim of our work was to analyze the aquatic plants' properties for the remediation of contaminated water.

Macrophytes division and profile

Macrophytes are defined as photosynthetic organisms that are permanently or periodically rooted in shallow water, floating on, or growing up with vegetative parts emerging above the water surface [6]. They have several intrinsic properties that allow them to the functioning in permanent contact with ground and surface water [7].

Macrophytes are important elements in aquatic ecosystems because they are often used in phytoremediation. These plants are commonly found throughout the world and constitute an essential component of wetlands [8]. Also, the assessment of water purity is often based on the environmental characteristics of macrophyte populations. In natural and man-made filtering systems, macrophytes play far more important role in the biochemical processes of water treatment than terrestrial plants because of their faster growth and larger biomass production. Also they have higher capability of pollutant uptake resulting from the well-developed root systems and better purification effects due to direct contact with contaminated water [9].

There are few types of macrophytes. One of the species is free-floating macrophytes. They are vascular plants with floating stems and unanchored roots that live at water surface. The free-floating macrophytes are diverse in form ranging from large plants with rosettes and floating leaves and well-developed submerged roots, to minute surface-floating plants with few roots. The examples of amphiphytes are: water hyacinth (*Eichornia crassipes*), duckweed (*Lemna minor* L.), azolla (*Azolla filiculoides* Lam.) [10].

The other type of the macrophytes are submerged macrophytes. They are plants that occur at all depths within the photic zone. Also they are rooted in bottom soils and they have whole body submerged in water. Examples of submerged macrophytes are: hornwort (*Ceratophyllum demersum* L.), canadian waterweed (*Elodea canadensis* Michx.), starwort (*Callitriche stagnalis* Scop.) [11].

The last types of the macrophytes are emergent macrophytes. They are defined as the plants that are rooted in shallow water with stems and leaves emerging above the water surface. This species are dominant form in wetlands and marshes growing within a water-table range from 50 cm below the soil surface to a water depth of 150 cm or more. The emergent macrophytes are represented by the following species: common reed (*Phragmites australis* (Cav.) Trin. Ex Steud), sweet flag (*Acorus calamus* L.), red mannagrass (*Glyceria maxima* Hartman.), common bulrush (*Typha latifolia* L.) [12].

Effectiveness of macrophytes in water remediation process

The free-floating macrophytes examples are water hyacinth (*Eichornia crassipes*) and duckweed (*Lemna minor* L.). *Lemna minor* has been studied for its tendency to accumulate the heavy metals from stream polluted by wastewater. Ugya [13] investigated the ability of *Lemna minor* in the phytoremediation of stream polluted by wastewater from Refinery and Petrochemical Company. The experiment lasted for three weeks and the rate of reduction was recorded. After 21 days, the water was analyzed. The results of his study shows that the highest rate of mean reduction were for heavy metals accounting 99.6%, 93.3%, 99.3%, 94.3%, 100% and 95.4% of Cd, Hg, Zn, Mn, Pb and Ag, respectively. These investigation suggest that duckweed as a suitable candidate for effectively treatment of water.

Goswami et al. [14] investigated the phytoremediation potential of *Lemna minor* grown hydroponically in artificially contaminated water over 3 weeks over a varied nickel (Ni) concentration (3,05 mg/L; 3,98 mg/L; 4,9 mg/L) for removal of this heavy metal. Ni concentrations in water samples were analyzed on the 2^{nd}, 5^{th}, 10^{th}, 15^{th} and 22^{nd} days. After experimental period 3 weeks, metal content in plant biomass was also analyzed to study the metal accumulation. They observed that duckweed removed in 87,33%; 72,5% and 65,2% respectively for the concentrations: 3,05 mg/L; 3,98 mg/L and 4,9 mg/L. The author concluded that *L. minor* is a plant with good tolerance and high uptake of heavy metals.

The other plants which are the examples of the submerged macrophytes are canadian waterweed (*Elodea canadensis* Michx.) and starwort (*Callitriche stagnalis* Scop.). The whole plant is submerged in water. In a process of contaminants removal the whole surface of the plants plays a significant role. Nyquist and Greger [15] studied the ability to accumulation of Zn, Cu and Cd by *E. canadensis* in their tissues from contaminated water. Plants were first loaded with metals for 48 h period. Twenty shoots of *Elodea canadensis* where placed in containers with water containing four different concentrations of Zn (as $ZnCl_2$), Cu (as $CuCl_2 \cdot 2H_2O$) or Cd (as $Cd(NO_3)_2$. After 72 h of exposure, plants were harvested and the ability to accumulation were measured. The results shown that *E. canadensis* accumulates high amounts of all three investigated metals in its tissue. The effective uptake of Zn, Cu and Cd decreases with increasing exposure concentration of Zinc, Copper and Cadmium, independently of the tissue concentration of thus metals. The authors found that the shoots of the Canadian waterweed are effective in a phytoremediation of the contaminated water.

Pratas et al. [16] investigated the capacity of three plant species (*Callitriche stagnalis*, *Potamogeton natans* and *P. pectinatus*) grown in the laboratory phytofiltration system to reduce the uranium (U) concentration in contaminated water. They observed rapid uptake of U resulting in a reduction of its concentration in water of up to 85.5%. The amounts of U absorbed by *C. stagnalis* ranged from 0.98 to 1567 $mg \cdot kg^{-1}$, by *P. natans* from 3.46 to 271 $mg \cdot kg^{-1}$, and by *P. pectinatus* from 2.63 to 1588 $mg \cdot kg^{-1}$. The authors conclude that selected plant species might be successfully used for remediation of waters contaminated with U.

The examples of emergent macrophytes are a common reed (*Phragmites australis* (Cav.) and a common bulrush (*Typha latifolia* L.). The emergent macrophytes have a great potential for storing the nutrients over a longer period and they have more supportive tissues than other macrophytes.

Kumari and Tripathi [17] studied the ability of two emergent macrophytes-*Typha latifolia* and *Phragmites australis* to removal of Cr, Fe and Zn from urban sewage mixed with industrial effluents within 14 days. The authors reported higher removal of Cr, Fe and Zn (66.2±3,5%; 70.6±1.2%; 71.6±3.9%) from treated effluent using the combination of the *Typha latifolia* and *Phragmites australis*. The authors concluded that the selected plant species might be used successfully for remediation of wastewater contaminated with heavy metals.

In 2014 Plechońska and Klink [18] conducted a study on the phytoremediation abilities of red canary grass (*Phalaris arundinace*) towards trace metals (Zn, Fe, Mn, Pb, Cu, Ni, Cd, Co and Cr) accumulated in water and sediments. The results showed different concentrations of trace metals in various organs of the plant. That the greatest proportions of all the metals studied were accumulated in *P. arundinacea* roots. Only a small fraction of the metals taken up by roots is allocated to stems and leaves. The authors concluded that limited translocation of trace metals absorbed by the red canary grass makes this plant a potential species for phytostabilization of sediments contaminated by metal (especially of Co and Cd).

Table 1. Summary of results of water remediation

Type of macrophytes	Macrophytes	Heavy metals	End point/Results	Ref.
Free-floating macrophytes	*Lemna minor* L.	Cd, Hg, Zn, Mn, Pb and Ag	The results of study shows that the highest rate of mean reduction were for heavy metals accounting 99.6%, 93.3%, 99.3%, 94.3%, 100% and 95.4% of Cd, Hg, Zn, Mn, Pb and Ag respectively.	[13]
		Ni	After experimental period 3 weeks duckweed removed in 87.33%; 72.5% and 65.2% respectively for the concentrations: 3.05 mg/L; 3.98 mg/ L and 4.9 mg/L.	[14]
Submerged macrophytes	*Elodea canadensis* Michx.	Zn, Cu and Cd	*E. canadensis* accumulates high amounts of Zn, Cu and Cd in its shoots.	[15]
	Callitriche stagnalis, *Potamogeton natans* and *P. Pectinatus*	U	*Callitriche stagnalis*, *Potamogeton natans* and *P. Pectinatus* strongly absorbed U from contaminated water. The amounts of U absorbed by *C. stagnalis* ranged from 0.98 to 1567 $mg \cdot kg^{-1}$, by *P. natans* from 3.46 to 271 $mg \cdot kg^{-1}$, and by *P. pectinatus* from 2.63 to 1588 $mg \cdot kg^{-1}$.	[16]

Emergent macrophytes	*Typha latifolia* and *Phragmites australis*	Cr, Fe and Zn	After experimental period 2 weeks authors reported higher removal of Cr, Fe and Zn (66.2±3.5%; 70.6±1.2%; 71.6±3,9%) from contaminated sewage using *Typha latifolia* and *Phragmites australis*.	[17]
	Phalaris arundinace	Fe, Mn, Pb, Cu, Ni, Cd, Co and Cr	Results showed that metal contents in various organs of the *Phalaris arundinace* differed significantly. That the greatest proportions of all the metals studied were accumulated in *P. arundinacea* roots.	[18]

Conclusions

The process of phytoremediation has become popular for two decades as one of the biological methods of waste utilization. Many macrophytes respond to various abiotic stresses by producing the mechanisms which effected in decreasing of the water pollution by absorbing and degrading chemical compounds. The aquatic plants are a good alternative in water remediation as the natural tool used in this process.

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