Review of heavy metal pollution load and aquatic plants used for the remediation of heavy metals in different lakes of the country

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Abstract: The impact of agricultural and industrial development has lead a serious environmental contaminants nowadays by adding heavy metals in water bodies. The heavy metals exhibits toxic effects on human health and environment and cause serious diseases in human beings. Heavy metal pollution comes from different sources into lake/aquatic ecosystems all over the world, especially in our country; India needs rapid consideration so that our degrading aquatic ecosystems will be remediated. There are several remediation techniques used for removing of heavy metal from the polluted environments but these techniques are not ecofriendly and have high limitations such as high cost, logistic problems, long time, and mechanical burden and have negative effects on the environment. Phytoremediation using different green plants is an eco-friendly technology, efficient and cost effective technology that reflects promising results for contaminants like heavy metals and other compounds. The plants, terrestrial or aquatic, play an important role in remediation of heavy metals from contaminated environments. Different countries have recommended some plants that have the capability to reduce the pollutant load from the polluted environs are commonly used in phytoremediation. To improve the feasibility of phytoremediation in environmental restoration, more research is needed to investigate the effects of different types of catalysts on phytoremediation efficiency. Therefore, the present review provides a recent update of different countries for the growth and applications of phytoremediation in diverse environments, including water, air and soil.

Key Words: Heavy metals, plants, water, phytoremediation, Countries, Lakes.

Introduction:

Nature's most important gift to humanity and all living things is water. Without this important gift of nature, man hardly exists as stated by (Maguvu and Mutengu, 2008; Ugya et al., 2015). Water is the most important natural resource that is required for the living in nature. But due to increased industrialization, urbanization, agricultural development and the discharge of domestic sewerage into these water resources, these water resources are now facing severe pollution. Heavy metals are the main pollutants in the environment, having high metallic chemical elements. Heavy metal pollution in water bodies is a global concern (Gade 2000).

Various anthropogenic activities like the discharge of municipal wastes, burning of fossil fuels and the use of fertilizers and pesticides, etc. have increased the concentration of heavy metals in the environment. The increase in the concentration of heavy metals that are non-biodegradable is a major apprehension to both humans and ecosystems (Kabata-Pendias 2011).

The heavy metal load from domestic wastewater and sewage alone signifies that this will be a continuing problem for science and humankind (Rai, P.K., 2009. Water in rivers and lakes can become heavily polluted, depending on the volume flow and its proximity to point sources (Ritter et al., 2002). Toxic metal contamination of aqueous water streams and groundwater poses a major environmental and health problem that is still in need of an effective and affordable technological solution (Salt et al., 1995).

The main sources of trace metal pollution in aquatic ecosystems, including the ocean, are domestic wastewater effluents (Cu, Mn and Ni), coal-fired power plants (As, Hg and Se), metals non-ferrous foundries (Cd, Ni, Pb and Se), steel (Cr, Mo, Sb and Zn) and sewage sludge discharges (As, Mn and Pb) (Nriagu et al., 1998). The atmosphere is an important gateway to natural waters for Pb (Lone et al. 2008). Activities such as mining and smelting operations and agriculture have contaminated large areas of the world, including Japan, Indonesia and China, mainly with heavy metals such as Cd, Cu and Zn (Herawati, 2000), Cu, Cd and Pb in Greece (Zanthopolus 1999) and Cd, Fe, Pb, Cr and Zn in India (Dutta et al. 2009; Nayak 2010; Batvari and Surendran 2015; Veena et al. 2016).

Pesticides and metals in the soil can reach aquatic ecosystems through soil erosion, leaching and surface runoff. (Naveedullah HMZ, Yu C, et al., (2013).The combination of heavy metals with pesticides is very hazardous because they can cause very critical health consequences for humans and animals. They contribute to musculoskeletal diseases, neurodegenerative disorders and hormonal imbalances, are carcinogenic, cause genetic damage. (Alengebawy et al., (2021).

Now the immediate and indispensable methods are required to remove or illuminate these pollutants by using eco-friendly remediation technologies. Among all the available remediation technologies, phytoremediation has been preferred because of its simple maintenance Kamran et al., (2014), cost-effectiveness and eco-friendly in nature (Uqab et al., 2016).

Phytoremediation also referred to as green technology is used for the treatment of environmental problems using green plants to remove both organic and inorganic pollutants present in soil, water and air (Gratao et al., 2005). It is use of green plants in contaminated sites to remove or neutralize contaminants from both soil and water environments (Van Der Lelie et al., 2001) Phytoremediation reduces the risk of exposure by providing ground cover using plants and is applicable to a diverse range of contaminants present in the environment (Blaylock, 2000) and is also the facilitator in recovering the soil fertility after the contaminants are removed from the soil (Schwitzguebel, 2001). When compared to other alternative remediation methods, Phytoremediation is more economical (Wantanabe 1997). After the innovation of hyper-accumulating plants, Phytoremediation has acknowledged increasing attention because of green plant based technology that is able to translate, accumulate and concentrate a high amount of different fatal elements on their ground, above or harvestable plant parts. Remove heavy metals and other metallic compounds by using metal accumulating plants were first introduced in 1983. However, the concept has actually been applied for the last 300 years (Henry, 2000). The term "Phytoremediation" consists of the two words, a Greek prefix "Phyto" (means plant), and the Latin word remedian (to correct or remove and evil) (Prasad, 2004). Phytormediation is an alternative attractive technology that can be used in place of mechanical/ conventional treatment method that requires more labor, energy and capital inputs (Cunningham et al., 1996). Phytoremediation has been called green remediation, agro remediation, butane-remediation and vegetative remediation (Erakhrumen, 2007). Phytoremediation is preferred over traditional methods because It is the most suitable approach for developing countries because of its being cost-effective, less destructive to the environment and aesthetic removing environmental pollutants (Pivertz, 2001) and the plants used in phytoremediation technique must have the high metal accumulation capacity, metal absorption, and strength to decrease the treatment time (Mudgal et al., 2010).

Mechanism of Phytoremediation:

Phytoremediation technology includes:

(1) Phytoextraction: The process in which metal accumulating plants are used to transport and concentrate metals into the harvestable parts of roots and above-ground shoot (Kumar et al., 1995);

(2) Rhizofiltration: The process in which plant roots absorb, precipitate, and concentrate toxic metals from polluted effluents (Dushenkov et al., 1995).

(3) Phytostablization: The process in which mobility of heavy metals is reduced through the use of tolerant plants (Salt et al., 1995).

(4) Phytotransformation/Phytodegradation: The process in which a contaminant can be eliminated via phytodegradation or phytotransformation by plant enzymes or enzyme co-factors (Susarla et al., 2002).

The main focus of this paper is to discuss the potential of phytoremediation of macrophytes to remove heavy metal from contaminated sites, to provide information about the different heavy metals present in aquatic/lake ecosystems in different countries and the plants used for remediation of such heavy metals.

Azolla in Phytoremediation of Heavy Metals:

Phytoremediation is one of the emerging technologies that uses selected plants to clean up polluted environmental degradation, extraction or immobilization of pollutants (Lasat, M.M., (1999). The hyperaccumulation capacity of aquatic *Azolla* macrophytes is well known and can be used successfully for phytoremediation of heavy metals from soil and water Sharma, S.et al,.(2015). *Azolla* accumulates toxic elements, namely arsenic, mercury, cadmium, chromium, copper, nickel and zinc in its biomass by taking them from soil and water bodies in which it is grown (Rahman et al., 2011). If it is hyper-accumulating biomass is removed properly, and then the concentration of toxic heavy metals will deplete soil and water bodies. This hyper-accumulating *Azolla* biomass can also be used for the recovery of these heavy metals through industrial processes to use them for other useful purposes (Ghosh et al., 2005). Dead and alive *Azolla* biomass has been exploited for the removal of heavy metals from industrial effluents and wastewater (Sood et al., 2012) there is great variation in the bioaccumulation potential of *Azolla* strains.

Table 1 : Showing the bioaccumulation potential of *Azolla* strains.

***Azolla* Spp.**	**Heavy Metal**	**Duration of Experiment (Days)**	**Initial Concentration of Heavy Metal**	**Heavy Metal Accumulated (Dry Weight Basis)**	**Reference-***
	Cd	7	10.0 mg/l	2759 µg Cd g/l	Arora et al., 2004
	Cr (6)	14	20.0 µg/l	9125 µg Cr g/l	Arora et al., 2006
A. pinnata	Ni	7	500.0 mg/l	16252 µg Ni g/l	Arora et al., 2004
	Cd	12	1.0 mg/l	259 µg Pb g/l	Stepniewska et al., 2005
	Cr (6)	12	1.0 mg/l	356 µg Cr g/l	Bennicelli et al., 2004
A. caroliniana	Cr (3)	12	1.0 mg/l	964 µg Cr g/l	Bennicelli et al., 2004
	Hg	12	1.0 mg/l	578 µg Hg g/l	Bennicelli et al., 2004
	Cr	14	20.0 µg/l	12383 µg Cr/g	Arora et al., 2006
	Cd	4	9.0 mg/l	10441 ppm	Sela et al., 1989
	Ni	7	500.0 mg/l	28443 µg Ni/g	Arora et al., 2004
	Cu	4	9.0 mg/l	9224 ppm	Sela et al., 1989
A. filiculoides	Zn	4	9.0 mg/l	6408 ppm	Sela et al., 1989
	Cr (6		20.0 µg/l	14931 µg Cr g/l	Arora et al., 2006
	Ni		500.0 mg/l	21785 µg Ni g/l	Arora et al., 2004
A. microphylla	Cd		10.0 mg/l	1805 µg Cd g/l	Arora et al., 2004

It is evident from the **Table 1,** that the different *Azolla* strains shows different accumulation potential capacity, the highest accumulation of Cd was found more in *Azolla filiculoides* and the lowest accumulation was found in *Azolla microphylla,* the highest chromium accumulation was found in *Azolla microphylla* and the lowest accumulation was found in *Azolla caroliniana.* While as the highest Ni accumulation was found in *Azolla filiculoides* and the lowest accumulation was found in *Azolla pinnata.* The Zn and Cu accumulation was found 6408 ppm and 9224 ppm with initial concentration of 9.0mg/l in *A. filiculoides* respectively.

Table 2: Showing the heavy metal removal potential of different types of macrophytes:

S.No	Type of macrophytes	Macrophytes	Heavy metals	End point/Results	Ref.
01.	Freefloating macrophytes	*Lemna minorL.*	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.	(Ugya A. 2015)
		Lemna minorL.	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.	(Goswami C,. et al 2015)
02.	Submerged macrophytes	*Elodea canadensis Michx.*	Zn, Cu and Cd	*E. Canadensis* accumulates high amounts of Zn, Cu and Cd in its shoots.	(Nyquist J,. et al 2007)
		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·kg-1, by *P. natans* from 3.46 to 271 mg·kg-1, and by *P. pectinatus* from 2.63 to 1588 mg·kg-1.	(Pratas J,. et al 2014)
03.	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.*	(Kumari M,. et al 2015)
		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.	(Plechońska L,. et al 2014)

It is observed from the **Table 2**, that the free-floating aquatic macrophytes has the highest removal efficiency of heavy metals than the submerged and emergent macrophytes. The highest removal percentage of heavy metals such as Cd, Hg, Zn, Mn, Pb and Ag was found in *Lemna minor*. The previous studies show that the free-floating aquatic plants show the highest removal efficiency of different heavy metals in different water bodies.

Table 3: Showing the heavy metal pollution in different lakes of country:

State	Lake	Heavy Metal Pollution in Lakes (ppm)						References
		Pb	**Fe**	**Mn**	**Cu**	**Cr**	**Zn**	
WHO's permissible limit (mg L^{-1})		**0.01**	**0.30**	**0.02**	**0.02**	**0.003**	**3.0**	Singh Sankhla et al,. (2021)
Andhra P	Hussain Sagar	0.84	-	-	-	-	-	Suneela et al. (2008)
Rajasthan	Ana Sagar	0.122	0.660	-	0.072	-	0.963	Dutta et al. (2009)
Odisha	Chilika lake	0.385	1.1	-	0.29	0.07	0.247	Nayak et al. (2010)
Uttarakhand	Nainital Lake	Nil	0.011	0.007	0.024	Nil	0.216	Gupta et al. (2010)
Madhya P.	Shahpura Lake	0.06	Nil	Nil	0.39	Nil	Nil	Anu et al. (2011)
Maharashtra	Futala Lake	0.026	0.035	Nil	Nil	0.042	0.048	Puri et al. (2011)
Meghalaya	Umiam Lake	0.06	0.12	0.186	0.023	0.016	0.031	Nongbri and Syiem (2012)
Gujarat	Sarkhej lake	0.06	-	0.63	-	-	-	Patel & Vediya (2012)
Himachal P.	Renuka lake	0.35	1.49	0.87	0.00	-	0.15	Singh & Sharma (2012)
Uttar P.	Laxmi Tal	1.52	1.49	1.64	0.07	0.33	0.02	Sharma et al (2014)
Jammu & Kashmir	Wular lake	0.9	0.9	0.6	Nil	Nil	2	Sheikh et al. (2014)
Assam	Patkai Lake	---	0.18	0.019	---	----	0.34	Bhagabati and Borkotoki 2014
Tamil Nadu	Chembarambakkam	0.29	0.284	0.052	0.019	0.035	0.026	Batvari and Surendran (2015)
Kerala	Ashtamudi Lake	0.001	8.41	-	0.02	0.01	0.03	Karim& Williams (2015)
Punjab	Harike lake	0.53	1.30	0.02	0.26	0.12	0.69	Brraich & Jangu (2015)
Chhattisgarh	Bhilai	0.26	0.822	-	0.002	0.326	0.0533	Tiwari et al. (2015)
Manipur	Loktak lake	0.7	----	-----	----	1.3	3.6	Singh et al. (2015)
Karnataka	Bhattarahalli Lake	0.002	0.283	0.059	0.003	0.003	0.009	Veena et al. (2016)
Jammu & Kashmir	Anchar Lake	0.13 ± 0.01	---	---	0.47 ± 0.11	0.25 ± 0.01	0.06 ± 0.02	Irfana Showqi et al 2017

From **Table 3**, the comparisons of different lakes in different states with heavy metal pollution load, the highest heavy metal pollution was found in Laxmi Tal in Uttrarpardesh as reported by sharma et al,. 2014 and the lowest heavy metal pollution load was found in Nainital Lake Uttarakhand where the level of heavy metal pollution load is found less as per the WHO's permissible limits in water bodies (Gupta et al. 2010). While as the rest of the lakes in different states referred in table 3 shows higher pollution load as per the WHO's permissible limits in water bodies.

Table 4: Showing the aquatic plants used for remediation of metals in different lakes of the country:

State	Lake	Plants	Metals	References
Gujarat	Sarkhej lake	*E. colonum E. crassipes H. verticillata I. aquatic N. nucifera T. angustata V. spiralis*	Cd; Co; Cu; Ni; Pb; Zn	Kumar et al. (2008)
Delhi	----	*Lemna minor*	Ni	Kaur et al. (2008)
Madhya P.	Shahpura Lake	*E. crassipes; J. Americana; A. philoxeroides; T. latifolia*	Cu, Zn Mn, Fe	Archana Dixit et al. (2011)
Mizoram	------	*Spirodela polyrhiza Prabhat and Tripathi 2011*	Cd, Ni, Pb	Prabhat and Tripathi 2011
Uttar P.	Laxmi Tal	*B. monnieri; E. crassipes H. verticillata, I. aquatica M. minuta .*	Cr; Ni; Cu; Pb	Narendra et al. (2012)
Chhattisgarh	Bhilai	*Pistia stratiotes*	Cr, Co	Prajapati et al. 2012
Karnataka	Bhattarahalli Lake	*E. crassipes*	Pb, Cu	Seema et al (2013)
West Bengal	---------	*Typha sp, Pistia sp. Salvinia sp. Eichhornia sp.*	Pb; As; Cu; Cd	Sukumaran (2013)
Meghalaya	Umiam Lake	*S. mucronatus R. rotundifolia*	Cd	Marbaniang and Chaturvedi (2014)
Kerala	Ashtamudi Lake	*Eichhornia Sp; Pistia Sp;*	Cu, Fe Pb	Preetha and Kaladevi (2014)
Odisha	Chilika lake	*E. crassipes*	Cd, Cu	Swain et al. (2014)
Jammu & Kashmir	Wular lake	*Azolla pinnata*	Cu; Pb: Cr; Cd; Zn	Shafi et al. (2015)
Jammu & Kashmir	Dal lake	*Azolla pinnata*	Zn,Cu,Pb, Cr, Cd.	Nuzhat Shafi et al (2015)
Assam	Patkai Lake	*Hydrilla verticillata*	Cr Cd	Phukan et al. 2015
Uttarakhand	Nainital Lake	*T. natans*	Cd	Kumar and Chopra (2016)
Maharashtra	Futala Lake	*E. crassipes ; Azolla*	Cu, Cr	Shekhar and Prashik (2016)
Tamil Nadu	Chembarambakkam	*Lemna polyrrhiza*	Pb, Zn, Cr, Cu	Abubacker And Sathya 2017
Andhra P	Hussain Sagar	*Ipomea carnea,*	As, Pb	Subha and Srinivas 2017
Jammu &Kashmir	Anchar Lake	*Lemna minor*	Cu, Cr, Zn, Ni, Cd, Pb	Irfana Showqi et al 2017

From **Table 4**, it is observed that the most aquatic plant species such as *E. colonum, E. crassipes H. verticillata, N. nucifera, T. angustata, V. spiralis, J. Americana, A. philoxeroides; T. latifolia philoxeroides; Spirodela polyrhiza , B. monnieri, I. aquatica , M. minuta, Pistia stratiotes, Typha sp, Pistia sp. Salvinia sp. Eichhornia sp., S. mucronatus R. rotundifolia* are mostly commonly used for the remediation of heavy metals in diferent lakes of the country and *Azolla sp, Lemna minor, Lemna major, Typha sp, Salvinia sp, N. nucifera* etc are the most commonly known species used in Jammu and Kashmir for the remediation of different heavy metals in water bodies.

CONCLUSIONS:

Heavy metal pollution of lakes and rivers has occurred a serious problem worldwide and is an important class of pollutants in the environment. Now the important methods are required to illuminate such pollutants, and for the methods phytoremediation is the most important, cost-effective technique, eco-friendly and has high efficiency in removing the heavy metals from the contaminated environs. Phytoremediation is plant-based techniques that have different mechanisms to deal with heavy metals. The different plant species accumulated different heavy metals that have been studied for phytoremediation and are considered as the best phytoremediation species in contaminated aquatic ecosystems. Aquatic macrophytes have drawn more attention worldwide because of having effective tool in removing heavy metals from aquatic water bodies. Macrophytes act as tool for biofiltration of heavy metals in both constructed and natural wetlands. The disposed biomass of macrophytes can be reused and the municipal wastewater and industrial effluents can be improved by the application of macrophytes.

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