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Review

Review on heavy metal pollution in major lakes of India: Remediation through plants

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The historical lakes of India are getting over burdened with the loads of pollution due to the rapid growth of small scale industries, nutrient enrichment and other anthropogenic activities. The high concentrations of metals in the water bodies, their entry into ecological food chain and the resulting health effects are of great concern to the researchers in the areas of ecology. Due to the problems associated with the conventional methods of pollutant removal, phytoremediation method is gaining more attention. The plants to be used in this technique, it must have high capacity of metal absorption, its accumulation and reduction in the time of decontamination in an ecosystem. It is an environment friendly and cost beneficial technique for the removal of toxicants from the environment. This article present over view on status of heavy metal pollution in lake and remediation through plants in Indian context may helpful to researcher not only in India but around the world also. This base line data can help governmental and non-governmental organization for the management of water pollution.

Key words: Lakes, heavy metals, toxicants, phytoremediation, India.

INTRODUCTION

A lake can be viewed as the most attractive and expressive characteristic of a landscape. In India there are some natural lakes that lies in the Himalayan region and in the flood plains of the Indus, Ganga and Brahmaputra. These lakes with various dimensions possess different names that are summarized in Table 1. However during the last 1000 years a large number of man-made water bodies were constructed in the western and peninsular India (Gopal et al., 2010).

Water qualities in such lakes have been studied by many researchers in different areas (states) of the country and are tabulated in Table 2 and the location of these lakes are shown in Figure 1. Accumulation of heavy metals in the freshwater ecosystem is a problem of global concern. On the recent time scale due to the continuous rise in the population, rapid industrialization, toxic chemicals used by agricultural industries and the technologies involved in waste disposals, there is increase in the rate of release of pollutants into the environment than the rates of their purification. Entry of these toxic metals to the ecosystem results in geo-accumulation, bio accumulation and bio magnifications

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Table 1. Various water bodies' dimensions have different names in India.

S/N	Name of lake In India	Features of lake
1	Bawri	Small, usually shallow pond
2	Beel	Oxbow lakes in Assam
3	Bheel	Oxbow lakes in Bengal
4	Bheri	Brackish water impoundments
5	Chaur	Oxbow lakes in Bihar
6	Jheel	Usually large and deep lakes
7	Johad	Shallow water bodies of Rajasthan
8	Kayal	Backwater lakes in Kerala
9	Kere	Tanks in Karnataka
10	Maun	Oxbow lakes in Uttar Pradesh and Bihar
11	Pat	Shallow floodplains in Manipur
12	Sagar	Very large and deep manmade lakes
13	Sar	Sanskrit word for lakes
14	Sarovar	Sanskrit Words for shallow lakes
15	Tal	Large spread of water (oxbow)
16	Talao	Usually a small pond natural/manmade
17	Talaiya	Shallow small pond
18	Tso	Tibetan word for lakes

Source: Conservation and management of lakes-an Indian perspective (2010).

(Lokeshwari and Chandrappa, 2006). The major sources of heavy metals are summarized in Table 3 and the most contaminated states of heavy metal in India are also depicted (Table 4 and Figure 2).

Heavy metals can be described as any metallic elements which have a relatively high density and are poisonous even at very low concentration in every organism (Lenntech, 2004). These groups of metals and metalloid have atomic density greater than 4 gm/cm^3 which is 5 times higher than water (Nriagu, 1989; Garbarino et al., 1995).

In counties like ours, with developing economies, the sustainable development, efficient utilization and effective management of their water bodies should be the acceptable strategy for economic growth. But in the recent past improper management and the ineffective utilization of the natural resources for various purposes has resulted in various problems such as water logging and salinity in the field of agriculture and heavy metals contamination due to mining industries and municipal uses (Rai and Pal, 2001; Kumar et al., 2008). According to the Indian standards, the maximum permissible level of these heavy metals is shown in Table 5. Status of heavy metal pollution in lakes of different states of the country is summarized in Table 6.

Phytoremediation as an emerging clean up technology used for pollutes groundwater and wastewater treatment is described as the engineered use of green plants (including grasses, forbs, and woody species) to remove or eliminate environmental contaminants such as heavy metals, trace elements, organic compounds and radioactive compounds in many aquatic ecosystems. Macrophytes is one of the important component of the aquatic ecosystems, these can be used as an effective accumulator of heavy metals and is also a food source for many aquatic invertebrates (Preetha and Kaladevi, 2014).

ROLE OF PLANTS IN REMEDIATION

Plants can be used to cleanup or remediate contaminated sites by several ways in order to remove contaminants from the soil, sediment, or water. Such plants can breakdown or decompose organic pollutants or may stabilize metal pollutants by acting as filters or traps. Plants usually take contaminants through their root system in which the main mechanism for controlling the contaminant's toxicity lies. The root system of plants provides wide surface area to absorb and accumulate the nutrients and water that is required for growth and other non-essential pollutants. Research is still going on finding the use of trees rather than smaller plants for affective treatment in deeper contamination because tree roots can penetrate more deeply into the soil. Further polluted ground water can undergo treatment by pumping out the water from the ground and using plants to treat the contamination.

Table 2. Status of water quality of different lakes of India.

States	Lakes	Parameter									References
		pH	EC	Turb.	DO	TDS	BOD	TN	TP	Temp.	
Andhra Pradesh	Hussain Saga	7.78	-	7.2	2.26	680	2.69	5.4	7.2	30	Sailaja and Reddy (2015)
Chandigarh	Sukhna Lake	8.1	-	42	6.8	-	3.0	0.16	0.6	25	Chaudhry et al. (2013)
Chattisgarh	Bhilai	6.5	807.6	-	5.14	452.3	-	0.26	-	25	Jena et al. (2013)
Haryana	Sanhit Sarovar	8.8	-	18.5	-	-	14.5	1.5	0.6	31	Kazmi et al. (2013)
Gujarat	Sarkhej Lake	8.7	489	18	3.36	184.2	1.21	8.22	0.77	20	Umerfaruq et al. (2015)
Himachal Pradesh	Renuka Lake	7.3	-	-	6.66	363.8	1.81	4.29	0.16	-	Singh and Sharma(2012)
Jammu and Kashmir	Wular Lake	7.8	232.3	-	9.3	143.5	-	0.80	-	14.1	Yaseen et al. (2015)
Karnataka	Bhattrahalli Lake	8.51	1707	3.25	4.7	584.00	12.00	-	-	-	Veena et al. (2016)
Madhya P.	RoopSagar	7.4	_	6.5	4.2	-	4.2	0.19	0.24	26	Vaheedunnisha and Shukla (2013)
Maharashtra	Futala Lake	7.8	-	1.1	7.8	263	2.4	3.5	1.4	26	Kazmi et al. (2013)
Manipur	Loktak Lake	7.31	-	-	8.58	71.33	5.07	-	-	-	Laishram and Dey (2014)
Mizoram	PalakDil	8.0	70	-	5.8	51.03	3.4	47	0.42	32	Lalmuansangi and Lalramnghinglova (2014)
Odisha	Chillka Lake	8.03	-	-	7.56	26.66	3.5	16.74	0.17	33.5	Patra et al. (2010)
Punjab	Harike Lake	8.37	-	-	9.35	445.6	4.5	4.74	-	-	Parmar and Bhardwaj (2013)
Rajasthan	Mansagar Lake	8.0	-	35.8	15.4	1840	2.1	11.3	0.2	21.8	Kazmi et al. (2013)
Tamilnadu	Kolavai Lake	7.38	811	1.1	7.8	576	11.2	-	0.08	30.8	Babu and Selvanayagam (2013)
Telangana	Kargil Lake	7.8	258	4.6	15.8	213	3.9	9.2	4.8	24.5	Bondugula and Rao(2015)
Tripura	Rudrasagar Lake	9	115	25	8.6	-	4.1	7.0	-	-	Pal et al. (2016)
Uttarakhand	Naini Lake	8	-	0.34	9.9	440	2	4.6	0.2	18.8	Kazmi et al. (2013)
Uttar Pradesh	KeeratSagar	8.3	778.2	8.2	6.34	502	3.48	10	_	25.4	Pal et al. (2013)

EC, Electrical conductivity; Turb., Turbidity; DO, Dissolved oxygen; TDS, Total dissolved solid; BOD, Biochemical oxygen demand; TN, Total nitrogen; TP, Total phosphorus.

Plants roots releases organic and inorganic compounds (root exudates) in the rhizosphere that causes changes at the soil root interface. This is an effective alternative technology which can replace mechanical conventional clean-up technologies that often needs high capital inputs, labour and energy. Phytoremediation is an in-situ remediation technique that uses the inherent capacities of living plants. It is also an eco-friendly, solar energy driven clean-up technology based on the principle of using nature itself to clean nature. Some hyperaccumulator species and their accumulation level are summarized in Table 7.

Most of the phytoremediation processes are targeted on inorganic pollutants through different attempts which is termed as phytoextraction (the utilization of metal accumulating species to transport and accumulate metals from the soil to roots and above ground biomass), rhizofiltration (the utilization of plant roots to absorb, precipitate and concentrate toxic contaminants from polluted effluents, phytovolatilization (some metal pollutants such as As, Hg and Se occur in gaseous forms in the environment; scientists have recently discovered genetically-modified plants that are capable of absorbing metals in their elemental forms from the soil, thus converting them biologically to gaseous species within the plants and release them into the atmosphere) and phytostabilization (the utilization of plants in lowering down the mobility of metals) (Mandal, 2014).

APPLICATIONS OF PHYTOREMEDIATION IN INDIA

One of the most promising applications of

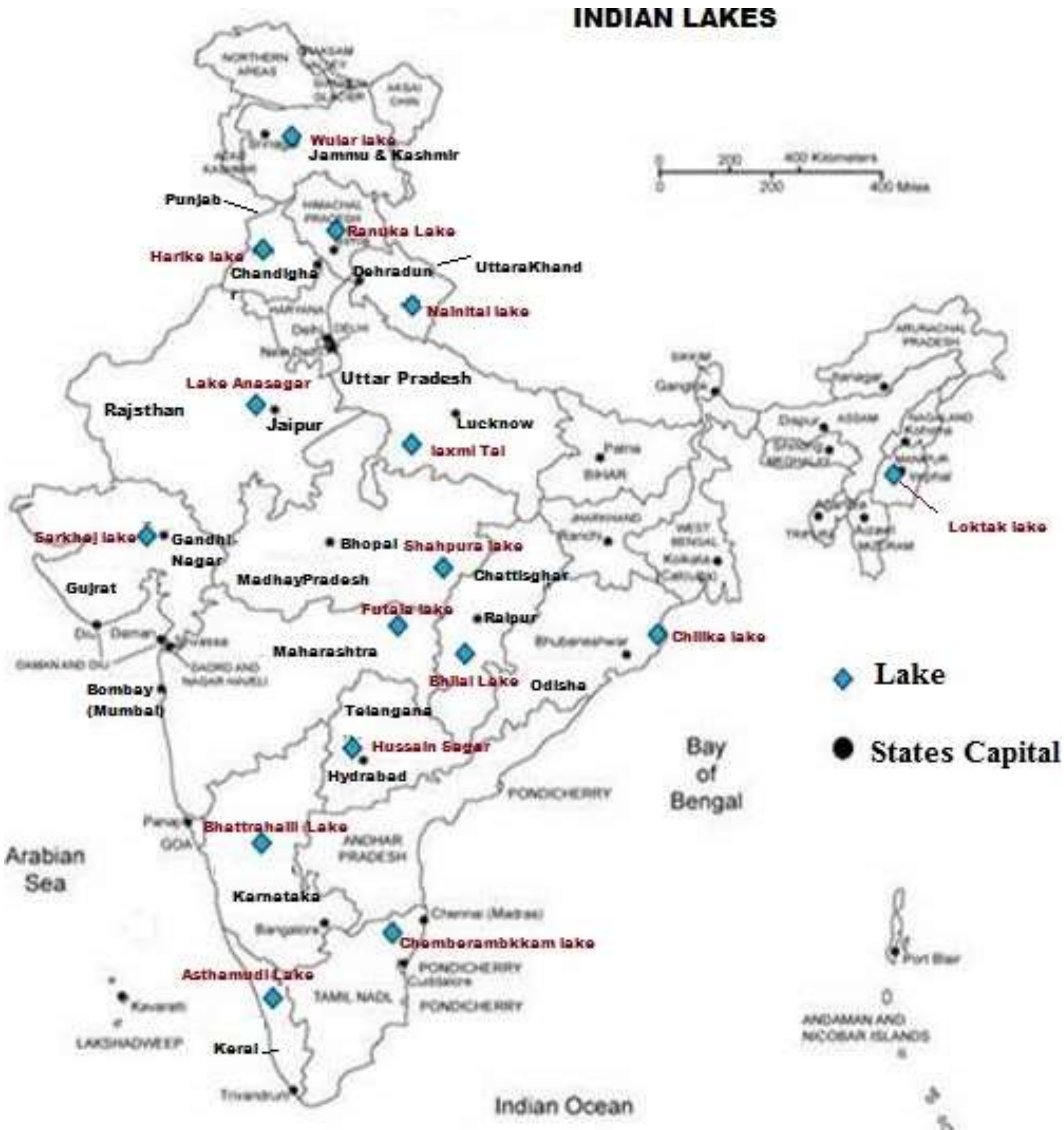

Figure 1. Location of studies lakes.

phytoremediation techniques is the possibility of deriving additional benefit from the plant system during or after the prevention or clean-up technology. Ali et al. (1999) studied the physico- chemical parameters of Nainital lake and the functions of macrophytes in phytoremediation and biomonitoring of metallic ions that are toxic in nature. Reports showed that the concentrations of metals such as Cr, Cu, Fe, Mn, Ni, and Pb are much higher than their recommended maximum permissible limits. Metal extracting capacity of existing plants is highly significant for biomonitoring studies. Sharma et al. (2014) prove to be an effective phytoremediation technique to restore the quality of water by harvesting both the submerged and the floating species from the littoral zone of the lake. Recently large numbers of submerged, free floating and emergent plant species have been recognized that can

Table 3. Different sources of heavy metals (Lone et al., 2008).

S/N	Heavy metals	Sources
1	As	Semiconductors, wood preservatives, mining and smelting coal power plants, herbicides, volcanoes, petroleum refining, animal feed additives
2	Cu	Electroplating industry, mining, biosolids , smelting and refining
3	Cd	Geogenic sources anthropogenic activities metal smelting and refining,fossil fuel burning, application of phosphate fertilizers, sewage sludge.
4	Cr	Electroplating industry, sludge, solid waste, tanneries
5	Pb	Mining and smelting of metalliferous ores, burning of leaded gasoline,municipal sewage, industrial wastes enriched in Pb, paints
6	Hg	Volcano eruptions, forest fire, emissions from industries producing causticsoda, coal, peat and wood burning
7	Se	Coal mining, oil refining, combustion of fossil fuels, glass manufacturing industry, chemical synthesis (e.g., varnish, pigment formulation)
8	Ni	Volcanic eruptions, land fill, forest fire, bubble bursting and gas exchange in ocean, weathering of soils and geological materials
9	Zn	Electroplating industry, smelting and refining, mining, biosolids

As, Arsenic; Cu, Copper; Cd, Cadmium; Cr, Chromium; Pb, Lead; Hg, Mercury; Se, Selenium; Ni, Nickel; Zn, Zinc.

Table 4. Major heavy metals contaminated states in India (Mandal, 2014).

Chromium	Lead	Mercury	Arsenic	Copper
Ranipet, Tamil Nadu	Ratlam, Madhya Pradesh	Kodaikanal, Tamil Nadu	Tuticorin, Tamil Nadu	Tuticorin, Tamil Nadu
Kanpur, Uttar radesh	Bandalamottu Mines, Andhra Pradesh	Ganjam, Orissa	West Bengal	Singbhum Mines, Jharkhand
Vadodara, Gujarat	Vadodara, Gujarat	Singrauli, Madhya Pradesh	B a l l i a Uttar Pradesh	Malanjkhand, Madhya Pradesh
Talcher, Orissa	Korba, Chattisgarh			

be effectively used in phytoremediation of metal pollutants from water bodies (Rai et al., 1995; Nirmal Kumar et al., 2006; Prasad, 2007; Shah and Nongkynrih, 2007; Shrivastava, 2008; Dixit and Dhote, 2009; Mishra and Tripathi, 2009; Narendra et al., 2012; Swain et al., 2014; Phukan, 2015; Shafi et al., 2015; Kumar and Chopra, 2016; Shekhar and Prashik, 2016). Researches on phytoremediation in different states of India are shown in Table 8.

CONCLUSION

Phytoremediation for pollution control has many drawbacks as well and it requires further intensive research on plants and site-specific conditions. It is comparatively a slow process than other treatment processes viz chemical, physical process. Plants with low production yields and reduced root systems do not carry out effective phytoremediation and do not prevent the leaching of contaminants into the aquatic system. Environmental conditions play an important role in phytoremediation as the growth and the survival of plants are negatively affected to extreme environmental conditions. In this technology multiple metal polluted bodies are desire more metal accumulator species and thus it requires a broad range research studies before its applications. There are also several limitations like metals must be in their bio-available form to plants. The metals will pass down the root systems without accumulation if it is water soluble. Despite these drawbacks, phytoremediation technology has many applications

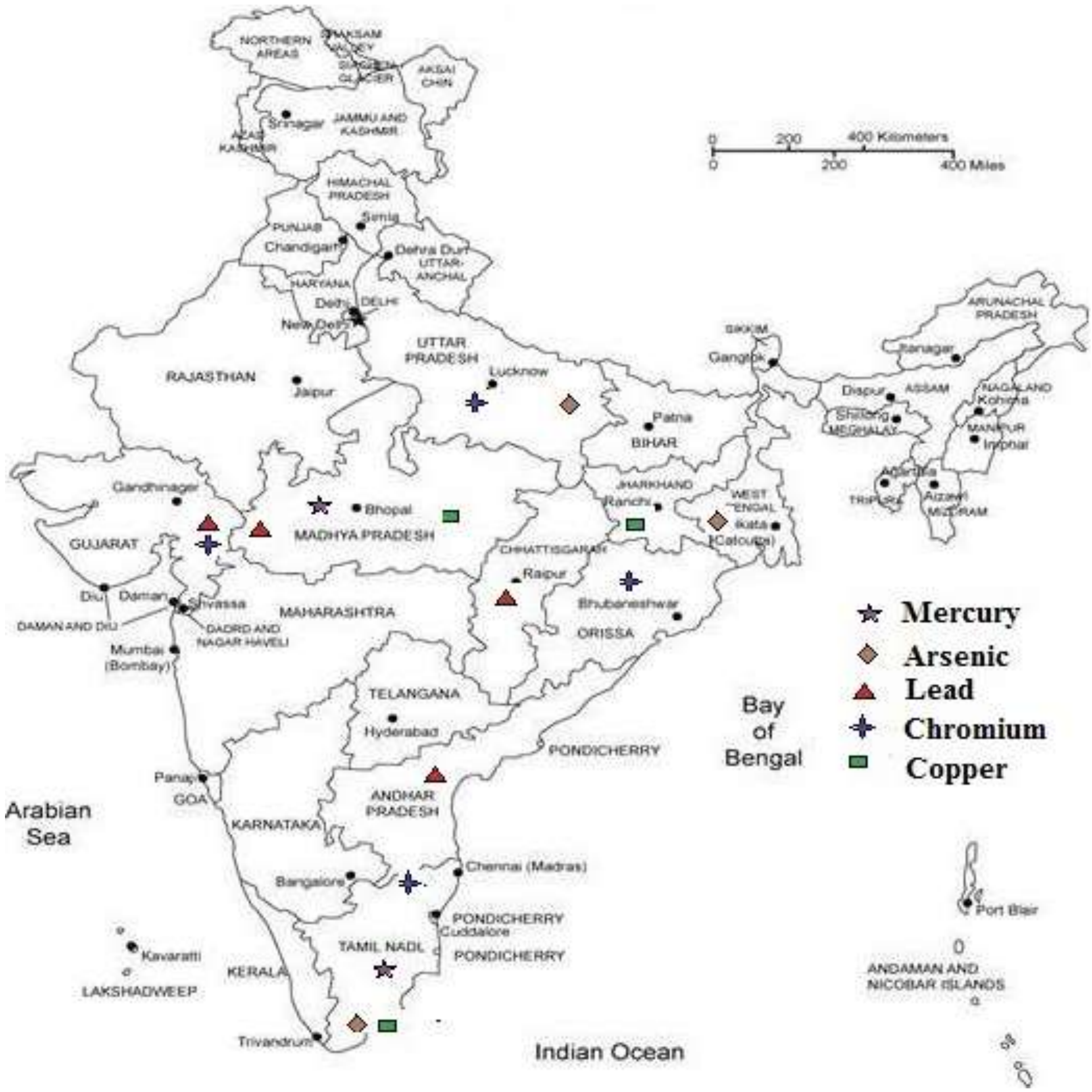

Figure 2. Heavy metals contaminated states of India.

Table 5. Permissible level of heavy metal.

S/N	Heavy metals	BIS, IS:10500- Desirable (mg/l)	Indian Council of Medical Research (mg/l)
1	Iron	0.3	1.0
2	Copper	0.05	3.0
3	Fluoride	0.06-1.2	1.5
4	Arsenic	0.05	0.05
5	Cadmium	0.01	0.01
6	Chromium	0.05	0.05
7	Lead	0.1	0.1
8	Mercury	0.001	0.001
9	Nickel	0.02	0.02

Table 6. Status of heavy metals pollution in different lakes of India.

States	Lakes	Heavy metals						References
		Pb	Fe	Mn	Cu	Cr	Zn	
Andhra P.	HussainSagar	0.84	-	-	-	-	-	Suneela et al. (2008)
Chattisgarh	Bhilai	0.26	0.822	-	0.002	0.326	0.0533	Tiwari et al. (2015)
Gujarat	Sarkhej lake	0.06	-	0.63	-	-	-	Patel and Vediya (2012)
Himachal P.	Renuka lake	0.35	1.49	0.87	0.00	-	0.15	Singh and Sharma (2012)
Jammu and Kashmir	Wular lake	0.9	-	0.9	0.6	-	2	Sheikh et al. (2014)
Karnataka	Bhattrahalli lake	0.002	0.283	0.059	0.003	0.003	0.009	Veena et al. (2016)
Kerala	Ashtamudi lake	0.001	8.41	-	0.02	0.01	0.03	Karim and Williams (2015)
Maharashtra	Futala lake	0.026	0.035	-	-	0.042	0.048	Puri et al. (2011)
Manipur	Loktak lake	0.7	-	-	-	1.3	3.6	Singh et al. (2015)
Odisha	Chilika lake	0.385	1.1	-	0.29	0.07	0.247	Nayak et al. (2010)
Punjab	Harike lake	0.53	1.30	0.02	0.26	0.12	0.69	Brraich and Jangu (2015)
Tamilnadu	Kolavai lake	0.138	7.820	-	0.126	0.008	0.232	Babu et al (2013)
Uttar P.	Laxmi Tal	1.52	1.49	1.64	0.07	0.33	0.02	Sharma et al (2014)
Uttarakhand	Nainital Lake	…	0.011	0.007	0.024	-	0.216	Gupta et al. (2010)
Madhya P	Shahpura lake	0.06	-	-	0.39	-	-	Anu et al. 2011
Andhra P	Cherlapally Lake	-	0.50	8.2	0.50	-	0.22	Amruthakalyani and and Gangadhar (2014)
Rajsthan	Lake Anasagar	0.122	0.660	-	0.072	-	0.963	Dutta et al. (2009)
Tamil Nadu	Chemberambakkam Lake	0.29	0.284	0.052	0.019	0.035	0.026	Batvari and Surendran (2015)

Pb, Lead; Fe, Iron; Mn, Manganese; Cu, Copper; Cr, Chromium; Zn, Zinc.

Table 7. Some hyperaccumulator species and their accumulation level.

Plant species	Metal	Results	Reference
C. papyrus	Pb	3.14 mghg^{-1}	Mugisa et al. (2015)
Phragmites australis	Pb	1.68 mghg^{-1}	
Hydrilla verticillata	Cd	3.58 mg g-^{1} DW at 1 mg l^{-1}con.	He et al.(2016)
Hydrocotyle ranoncloides	Cd	6.28 mg kg^{-1}	VahdatiRaad and Khara (2012)
	Pb	77.80 mg kg^{-1}	
Ceratophyllum demersum	Cd	4.46 mg kg^{-1}	VahdatiRaad and Khara (2012)
	Pb	53.11 mg kg^{-1}	
Alyssum heldreichii	Ni	11800 (mg kg^{-1})	Bani et al. (2010)

Table 7. Cont.

Alyssum markgrafii	Ni	19100 (mg kg^{-1})	
Alyssum bertolonii	Ni	10900 (mg kg^{-1})	Li et al. (2003)
Alyssum caricum	Ni	12500 (mg kg^{-1})	
Alyssum corsicum	Ni	18100 (mg kg^{-1})	Bani et al. (2010)
Alyssum murale	Ni	4730–2010 (mg kg^{-1})	
Myriophyllum spicatum	Cu	74.97 (mg kg^{-1})	Kamel (2013)
Ceratophyllum demersum,	Cu	96.3 mgl^{-1}	
Eicchornia crassipes,	Cu	53.8 mgl^{-1}	
Lemna gibba,	Cu	36.4 mgl^{-1}	
Phragmites australis	Cu	129.21mgl^{-1}	
Typha domingensis.	Cu	153.2 mgl^{-1}	
Salvinia *sp*	Cr	0.94 (mg kg^{-1} dry matter)	Espinoza-Quinones et al. (2005
	Cu	1.42 (mg kg^{-1} dry matter)	
	Zn	6.80 (mg kg^{-1} dry matter)	
Thlaspi caerulescens	Cd	263 (mg kg^{-1})	Lombi et al. (2001)

Pb, Lead; Cd, Cadmium; Ni, Nickel; Cu, Copper; Zn, Zinc; Cr, Chromium.

Table 8. Worked carried out heavy metal remediation through plants in different states of India.

State	Plant species	Metal	Results	Reference
Delhi	*Lemna minor*	Ni	3500 mg/kg	Kaur et al. (2008)
Uttarakhand	*T. natans*	Cd	4 mg/l	Kumar and Chopra (2016)
		Cu	9 mg/l	
		Fe	12 mg/l	
		Ni	3 mg/l	
		Pb	4 mg/l	
		Zn	11 mg/l	
Madhay Paradesh	*E. crassipes; J. Americana; A. philoxeroides; T. latifolia*	Cu	1; 3;1; 7 (kg/ha/year)	Archana Dixit et al. (2011)
		Zn	4; 30; 6; 6 (kg/ha/year)	
		Mn	300; 13; 27; 79 (kg/ha/year)	
		Fe	19; 120; 45; 23 (kg/ha/year)	
Maharashtra	*E. crassipes; Azolla*	Cu	0.013; 0.006 gm/l	Shekhar and Prashik (2016)
		Cr	0.071; 0.0625 gm/l	

Table 8. Cont.

Odisha	*E. crassipes*	Cd Cu	0.56 mg/l 0.48 mg/l	Swain et al. (2014)
Mizoram	*Spirodelapolyrhiza*	Cd Ni Pb	4.5 mg/g 3.4 mg/g 3 mg/g	Prabhat kumarai and Tripathi (2011)
Assam	*Hydrilla verticillata*	Cr Cd	2 mg/g 3 mg/g	Phukan et al. (2015)
Jammu&Kashmir	*Azolla pinnata*	Cu;Pb;Cr;Cd; Zn	88;335;0.2;0.03;2.04 ppm	Shafi et al. (2015)
Gujarat	*E. colonum* *E. crassipes* *H. verticillata* *I. aquatic* *N. nucifera* *T. angustata* *V. spiralis*	Cd;Co;Cu;Ni; Pb;Zn	0.56;8.16;113;11;4;2; 53 0.79;25;44;28;9;709 0.15;5;16;5;7;457 24;24;54;14;5;328 .35;7;1600;5;8;423 2;14;104;20;6;276 0.83;3.09;27;4;82;377	Kumar et al. (2008)
Uttar Pradesh	*B.monnieri* *E.crassipes* *H.verticillata* *I.aquatica* *M.minuta*	Cr;Ni;Cu;Pb	94;4;7;5, ug/g 46;26;8;4.5 µg/g 25;3;4;7; µg/g 25;3.5;3;6.5 µg/g 10;6;3;3.5 µg/g	Narendra et al. (2012)
Kerala	*Eichhornia* sp. *Pistia* sp. *Salvinia* sp.	Cu;Fe;Pb	172; 137.5; 107.5 mg/l 27.5; 17.5; 12.5 mg/l 12.5; 17.5; 6.5 mg/l	Preetha and Kaladevi (2014)
West Bangal	*Typha sp* *Pistia* sp. *Salvinia* sp. *Eichhornia* sp.	Pb; As; Cu;Cd	1.1;0.045;0.187;0.074 mg/g 0.47;0.032;0.135;0.052 mg/g 0.47;.018;0.155;0.038 mg/g 4;0.029;0.115;0.039 mg/g	Sukumaran (2013)
Karnataka	*E. crassipes*	Pb Cu	1.069 mg/l 1.488 mg/l	Seema et al. (2013)
Meghalaya	*S. mucronatus* *R. rotundifolia*	Cd	7000 µg/g 5000 µg/g	Marbaniang and Chaturvedi (2014)

Cd; Cadmium; Ni, Nickel; Cd, Cadmium; Zn, Zinc; Cr, Chromium; Cu, Copper; As, Arsenic; Fe, Iron; Mn, Manganese; Co, Cobalt.

worldwide and research laboratories are at presently engaged to deal with these limitations.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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