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Phytoremediation potential of *Lagenandra ovata* L. and *Nelumbo nucifera* Gaertn. associated with Aruvikkara Reservoir, Kerala- South India

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ABSTRACT

Heavy metals such as copper, zinc, cadmium, chromium and lead in two selected macrophytes- *Lagenandra ovata* L. and *Nelumbo nucifera* Gaertn., sediment and water samples collected from Aruvikkara Reservoir were studied. It was observed that in both *L. ovata* and *N. nucifera* all the five metals studied remained higher when compared to their normal range in plants. Metal accumulation pattern observed in *L. ovata* was zinc > chromium > lead > copper > cadmium and in *N. nucifera* it was in the order of zinc > chromium> copper > lead > cadmium. Sediment analysis also revealed the presence of all the five elements except cadmium which was in below detection level, and it was in the order of chromium > zinc > lead > copper > cadmium. Presence of copper and lead in water samples lower than permissible limit of drinking water standard values is a sign of the non-polluted nature of Reservoir water with respect to copper and lead indicating its suitability for drinking purpose. A general pattern of metal accumulation was observed in both *L. ovata* and *N. nucifera* > sediment > water. Concentration factor for heavy metals observed in both the species were >1 for all metals. This reveals the metal accumulation potential of both the species for different heavy metals and can be used as bioindicator for heavy metal pollution. Even though the plants under study showed heavy metal absorption potential periodic cleaning of the Reservoir is essential as the dead and decayed remnants will deposit all contaminants in the water body itself.

***Key words**: Heavy metal, Sediment, Bioindicator, Macrophytes, Phytoremediation*

Introduction

Heavy metal contamination in aquatic systems is a matter of global concern today. Heavy metals are the elements having metallic properties with atomic number greater than 20. These enter inside the water bodies through various sources such as agricultural run-off, phosphate fertilisers, tobacco smoking, forest fires, volcanoes, weathering of rocks, industrial activities, mining, refining etc. Heavy metals are either essential for the proper growth and functioning or non-essential with unknown function. Some metals such as copper, zinc, manganese, nickel and cobalt are micronutrients essential for the plant growth, while cadmium, lead and mercury have unknown function. The persistence of heavy metals in the ecosystem and their bioaccumulation as they move through food chains causes them to present a substantial health danger to humans (Wagner, 1993). Pollution with copper, zinc and cadmium is particularly serious because these are frequent heavy metal contaminants present in wa-

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ter, and reach toxic concentrations in aquatic foodstuffs through food chain biomagnification. Once they enter the human body they cannot be degraded or destroyed but tend to be accumulate (Shakya *et al.,* 2008). Even though copper is a micronutrient essential for the proper growth and development of plants its excessive concentration in aquatic systems is considered as highly toxic (Wu *et al.,* 2015). Non-essential element cadmium and its compounds are highly toxic and cause itai-itai diseases, kidney failure, lung diseases, neurological disorders, cancer, cardio- vascular disorders etc.

Phytoremediation, the use of plants for the removal of heavy metal contaminants from the aquatic systems is of great significance. Generally aquatic plants are the potent tool for the purification of contaminated water bodies by absorbing heavy metals from the system (Yabanli *et al.,* 2014; Raj *et al.,* 2013; Shibukrishnan and Ajithkumar, 2014; Islam *et al.,* 2015) and play an important role in the maintenance of aquatic ecosystem (Kabeer *et al.* (2014). Various species show different capacities for metal accumulation. Worldwide more than 400 plant species are known as hyper-accumulators for various trace metals such as copper, zinc, cadmium, cobalt, manganese etc in their shoots (Yadav, 2010). Phytoremediation takes the advantage of the unique and selective uptake capabilities of plant root systems, together with translocation, bioaccumulation, and contaminant degradation ability of the entire plant body (Cho-Ruk et al., 2006). Heavy metals exceeding the carrying capacity of water can cause aquatic ecosystem imbalance (Ndimele and Jimoh, 2011) as well as ecological degradation (Baldantoni *et al.,* 2004). Plants act both as 'accumulators' and 'excluders' (Sinha *et al.,* 2004) and accumulators survive in spite of concentrating contaminants in their aerial tissues and biodegrade or bio-transform the contaminants into inert forms in their tissues, whereas the excluders restrict contaminant uptake into their biomass. Present study aims in the analysis of heavy metal accumulation in two selected macrophytes-*Lagenandra ovata* L. and *Nelumbo nucifera* Gaertn. collected from Aruvikkara Reservoir. Heavy metal content in sediment samples was also analyzed in order to calculate the metal accumulation potential of the species. Since Aruvikkara Reservoir is the primary source of drinking water supply, the analysis of heavy metal content in water is also focussed.

Materials and Methods

Study site

Karamana River with a length of 68 Km originates from the Western Ghats at Agasthyar Koodam flows westwards and joins with the Arabian Sea at Panathura near Kovalam. A dam was constructed across the River at Aruvikkara especially for water supply. It is the primary source of drinking water supply to the capital city of Kerala, Thiruvananthapuram. Aruvikkara Reservoir is located nearly 16 Km from Thiruvananthapuram city. It holds an area of nearly 50 hectares and lies between 8° 57′ 55′′ North latitude and 77° 02′ 54′′ East longitude (Fig. 1) and was selected as the study site (Plate 1).

Methodology

Collection of samples

Aquatic macrophytes associated with the Aruvikkara Reservoir were collected and identified. Out of the 27 species identified *Lagenandra ovata* L., an endemic species restricted to the south western states of India and Sri Lanka and *Nelumbo nucifera* Gaertn. native to India was selected for heavy metal analysis. Sediment and water samples were also collected for analysis. Herbarium of both the species were prepared as voucher specimen and deposited to TBGT Herbarium (Coll No. 91911 & 91912).

Extraction and analysis

The method used for analysis was APHA (1992). All glass and plastic wares used for analysis were pre-cleaned with detergent and soaked in dilute nitric

Plate 1. Aruvikkara Reservoir

acid for one day. All the reagents used were of analytical grade. The whole plant for analysis was washed thoroughly, dried in shade for two days and oven dried at 60 ^{o}C. Dried samples were powdered using mortar and pestle and kept in polythene bags for analysis. A known quantity of powdered sample was digested with a mixture of nitric acid and perchloric acid (4:1) using hot plate. After complete digestion the whole content was made up to a known volume in standard flask and transferred the content in a pre cleaned polythene bottle and kept in refrigerator until analysis. The same method adopted for plant sample extraction was used for sediment extraction. For water analysis sample was filtered through Whatman No. 1 filter paper and pre-concentrated using heating mantle and made up to a known volume. Analyses were done through Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES, iCAP7000) against multi-element standard stock solution. Results obtained in ppb were converted in to microgram per gram (µg g^{-1}) for plants and sediments and microgram per litre (µg L^{-1}) for water samples. All the analyses were done in triplicates.

Results and Discussion

Heavy metal content detected in *L. ovata, N. nucifera*, sediment and water samples collected from Aruvikkara Reservoir are shown in Table 1 and its graphical representation in Figure 2. Metal accumulation in different aquatic/riparian macrophytes studied by various workers is shown in table 2 for the comparison of the present findings. Copper content recorded in both *L. ovata* and *N. nucifera* were higher than their normal range in plants (4-15 µg g^{-}

Fig. 1. Map showing study site Aruvikkara Reservoir

Table 1. Heavy metal content in plants, sediment and water sample collected from Aruvikkara Reservoir (Plants and sediment µg g^{-1}, water µg L^{-1}), n=3

Metals	Lagenandra ovata	Nelumbo nucifera	sediment	water
Copper	50.00±0.58	50.00±0.58	18.55±0.84	4.48±0.005
Zinc	347.82±0.11	142.64±0.03	52.31±1.55	bdl
Cadmium	20.00±0.50	10.00±0.29	bdl	bdl
Chromium	252.50±0.55	104.85±0.09	88.11±0.52	bdl
Lead	67.41±0.11	45.64±0.20	29.51±0.86	0.40±0.001

bdl- below detection level

[1]) and exceeding the toxic limit of 30 µg g^{-1} (Leeper, 1978). More or less similar results were reported by Thomas and Fernandez (1997); Vardanyan *et al.* (2008) and Prasannakumari *et al.* (2012, 2014 & 2016) in various aquatic macrophytes. In the case of zinc, the results obtained in both the species remained higher than their normal range (8 and 15 µg g^{-1}) but within the toxic limit of 500 µg g^{-1}. Concentration of zinc observed in both *L. ovata* and *N. nucifera* were within the reported values of Munshi *et al (*1998) in *Potamogeton pectinatus*, *Potamogeton pusilus* and *Hydrilla verticillata*, Arathy *et al* (2014) in *Limnocharis flava* and *Jussiaea repens* and Prasannakumari *et al* (2016) in *Colocasia esculenta*. Results in both the species remained higher when compared to the zinc accumulation in different aquatic species reported by Vardanyan *et al* (2008) and Yabanli *et al.* (2014). Normal range of cadmium in plants is between 0.2 and 1.8 µg g^{-1} with a toxic limit of 100 µg g^{-1} (Leeper, 1978). Both the plants under study exceed their normal range but within the toxic limit. Cadmium accumulation observed in both the species in the present study remained higher when compared to the reports of Jain *et al.* (1990); Chakraborty *et al.* (1993), Vardanyan *et al.* (2008); Yucel *et al.* (2010) and Yabanli *et al.* (2014) in various aquatic species. However, in both the species the cadmium concentration were more or less within the reported values of Arathy *et al.* (2014) and Prasannakumari *et al.* (2012, 2014 and 2016). Normal range of chromium in plants is 1.5 µg g^{-1} (Markert, 1994) but in the present study it was higher. Chromium content observed in the present study in both *L. ovata* and *N. nucifera* remained higher when compared to the findings of Prasannakumari *et al.* (2012, 2014 & 2016), Arathy et al (2014) and Yabanli *et al.* (2014) in various aquatic macrophytes. Lead content observed in the present study also exceeds their normal range (0.1 to 10) in plants (Leeper, 1978). Comparatively lower lead content reported by Munshi *et al* (1998) in two different species of *Potamogeton*, Vardanyan *et al* (2008) in *Batrachium rionii*, *Butomus umbellatus* and *Lepidium latifolium*, Arathy *et al.* (2014) in *Limnocharis flava* and *Jussiaea repens* and Yabanli *et al* (2014) in *Myriophyllum spicatum*. Present findings in both the species were well within the reports of Thomas and Fernandez (1997); Yucel *et al* (2010) and Prasannakumari *et al.* (2014 & 2016). Comparatively higher lead content were reported by Jain et al (1990) in *Azolla pinnata*.

Table 2. Concentration factor for heavy metals in *Lagenandra ovata* and *Nelumbo nucifera*

Metals	*Lagenandra ovata*	*Nelumbo nucifera*
Copper	2.70	2.70
Zinc	6.65	2.73
Cadmium	-	-
Chromium	2.87	1.19
Lead	2.28	1.55

Zinc, cadmium, chromium and lead recorded in *Lagenandra ovata* was comparatively higher than that in *Nelumbo nucifera* and copper concentration observed in both the species were almost same. Metal accumulation pattern observed in *Lagenandra ovata* was Zinc > chromium > lead > copper > cad-

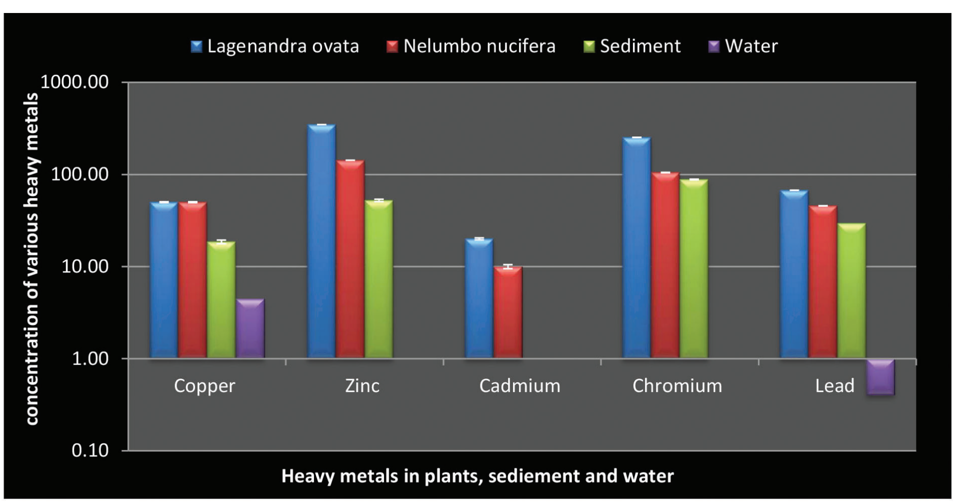

Fig. 2. Graphical representation of heavy metal concentration in *L. ovata, N. nucifera*, sediment and water

mium and in *Nelumbo nucifera* it was in the order of zinc > chromium > copper > lead > cadmium. However, in both the species maximum accumulation observed was zinc and minimum of cadmium. Even though copper, zinc and chromium are essential elements, both the species under study showed its higher accumulation than their normal need. Cadmium and lead are toxic and non essential elements with unknown function and its presence in both the species revealed the capability of their metal accumulation potential. Results revealed that sediment was also rich source of heavy metals except for cadmium and it was in the order of chromium > zinc > lead > copper > cadmium. Analysis of heavy metals in water samples revealed the occurrence of negligible amounts of copper and lead. Cadmium in sediment and zinc, cadmium and chromium in water samples were in below detection levels.

Even though both the species revealed heavy metal accumulation *L. ovata* showed comparatively higher metal accumulation than *N. nucifera*. Below detection level of cadmium in sediment and its presence in both *L. ovata* and *N. nucifera* indicates the cadmium absorption potential of both the species.

Table 3. Heavy metal accumulation in different aquatic/riparian macrophytes analyzed by various workers along with present findings for comparison

	Name of the plant species	Copper	Zinc	Cadmium	Chromium	Lead
Jain *et al.* (1990) µg g^{-1}	*Azolla pinnata*	-	-	-	-	158-7654
Chakraborty *et al.*	*Avicinnia marina*	-	-	1-2	-	-
(1993) µg g^{-1}	*Acanthus ilicifolius*	-	-	2	-	-
Thomas and	*Avicinnia officinalis*	6.2-38	-	-	-	7.5-225
Fernandez (1997) µg g^{-1}	*Sonneratia caseolaris*	16.1		-	-	25-125
Munshi *et al.* (1998)	*Vallisneria spiralis*	194-2055	804.2-1751.2	-	-	60-82.1
µg g^{-1}	*Potamogeton pusillus*	221.10-661	41.20-1065	-	-	18-29
	Potamogeton pectinatus	452.30-1194	63-176.1	-	-	18.2-40.4
	Hydrilla verticillata	100-560	108-380			18.2-82
Vardanyan *et al.* (2008)	*Batrachium rionii*	18.90	113.00	0.46	-	6.90
mg Kg^{-1}	*Butomus umbellatus*	-	-	0.03	-	0.22
	Lepidium latifolium	3.1	14	-	-	-
Yucel *et al* (2010)	*Myriophyllum spicatum*	-	-	0.81		61.50
mg Kg^{-1}	Leaf					
	Stem	-	-	1.81		59.63
Prasannakumari *et al.* (2012) µg g^{-1}	*Lagenandra ovata*	27.00-87.11	67.00-1224.00	29.00-96.00	17.00-59.00	3.00-122.00
Arathy *et al.* (2014)	*Limnocharis flava*	270.34	158.81	39.96	15.92	10.90
µg g^{-1}	*Jussiaea repens*	339.07	170.46	23.29	13.26	11.10
Prasannakumari *et al*	*Bacopa monnieri*	17.00-48.00	32.50-106.00	13.00-119	22.00-77.00	20.00-154
(2014a) µg g^{-1}	*Cyperus tenuispica*	7.00-19.00	15.00-42.00	9.00-116.00	22.00-65.00	6.00-122.00
	Mariscus javanicus	7.00-22.00	13.00-65.00	4.30-115.00	24.50-58.00	3.00-154.00
	Acanthus ilicifolius	5.00-20.00	13.00-58.00	4.00-123.50	22.63-150.50	4.86-42.00
Prasannakumari *et al.*	*Blechnum orientale*	11.60-20.67	21.29-26.50	29.95-103.00	11.38-66.00	51.41-116.00
(2014b) µg g^{-1}	*Pityrogramma calomelanos*	13.67-20.75	17.00-40.00	39.13-79.98	36.80-43.90	54.60-84.95
	Adiantum latifolium	17.67-19.25	30.50-47.63	43.25-123.50	30.50-61.00	41.17-113.00
	Acrostichum aureum	11.33-27.25	17.98-34.25	19.70-87.57	33.13-40.19	13.38-24.65
Yabanli *et al* (2014)	*Myriophyllum spicatum*	-	-	0.06±0.02	4.59±0.97	6.25±0.94
mg Kg^{-1}	Leaf					
	Stem	-	-	0.04±0.02	5.34±1.07	3.05±0.43
	Root	-	-	0.36±0.07	9.07±2.24	17.04±2.21
Prasannakumari *et al.*	*Colocasia esculenta*	8.00-30.00	35.00-183.00	1.00-114.00	16.00-61.00	11.00-130.00
(2016) µg g^{-1}	*Limnocharis flava*	14.00-28.00	39.00-89.00	9.00-101.00	10.00-68.00	11.00-121.00
	Sachharum spontaneum	4.00-26.00	6.00-50.00	1.50-142.00	6.00-67.00	3.00-399.00
Present study µg g^{-1}	*Lagenandra ovata*	50.00±0.58	347.82±0.11	20.00±0.50	252.50±0.55	67.41±0.11
	Nelumbo nucifera	50.00±0.58	142.64±0.03	10.00±0.29	104.85±0.09	45.64±.19

As there were no point sources of heavy metal contamination in the nearby area of the Reservoir the presence of metals in the system may be due to the leaching of elements from the nearby agricultural fields. This may also be due to the influence of forest fires in the catchment area from where the river is flowing. Concentration factor for heavy metals (Table 2) observed in both *L. ovata* and *N. nucifera* were >1 for all metals. This indicates the metal accumulation potential of both the species for all the five metals analyzed and can be used as bioindicator for heavy metal pollution. Heavy metal content detected in water sample was very little when compared to the plant and sediment samples. The results obtained were below the permissible limit (2 mg L^{-1} and 0.05 to 1.5 mg L^{-1} for copper and 0.01 mg L^{-1} for lead) of WHO (1993) and IS: 15000 (2012) standards respectively. This indicates the non-polluted nature of Aruvikkara Reservoir with respect to copper and cadmium and the suitability of water for drinking purpose.

Conclusion

On the basis of above findings, it can be concluded that both *L. ovata* and *N. nucifera* analyzed during the present study revealed higher absorption potential for all the five metals than their normal concentration in plants suggesting to exploit these species as bioindicator for heavy metals. Both *L. ovata* and *N. nucifera* will be useful for the purification of contaminated water bodies as well as in effluent treatment areas by allowing its growth in particular areas. The absorption and accumulation of metals in plants depends upon the quantity of metals present in the surroundings. Even though the plants under study showed heavy metal absorption potential, periodic cleaning of aquatic macrophytes from the Reservoir is essential as the dead and decayed remnants of the plants will deposit all the contaminants in the water body itself. Seasonal growth of aquatic macrophytes and removal of dead remnants from the aquatic systems is the major problem in phytoremediation studies. Since Aruvikkara Reservoir is a source of drinking water supply, the continuous monitoring, detection and remediation of heavy metals in the water are important. Protection of Reservoir from anthropogenic influences such as bathing and washing clothes and animals is recommended. Presence of copper, zinc, cadmium, chromium and lead in *L. ovata* and *N. nucifera* revealed the need for the detection of more elements from more plants as every plant have its own potential for one or another metal.

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