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Heavy Metals Uptake, Translocation and Bioaccumulation Properties by Ipomoea Aquatica

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Abstract
Heavy metal pollution of lake water is of great environmental and health concern and needs attention. This study was carried out to assess the content of heavy metals in *I. aquatica* plant and associated sediment and water in different seasons. The concentrations of the metals followed the trend: sediment > *I. aquatica* root > *I. aquatica* shoot > water. There were differences in the sequences of the metal content in the plant compared to the sequences of their bioaccumulation ability. These differences suggest a different capacity of the plant for different metals. The present study revealed that *I. aquatica* can tolerate heavy metals and may be used as a biological agent in phytoremediation.
Keywords: Heavy metals, bioaccumulation, translocation

Introduction

Heavy metals are defined as metallic elements with atomic number higher than 20. Heavy metals are always present in trace amounts in most natural water bodies, concentration being less than one µg/l but when present beyond permissible limits act as pollutants because, firstly they cannot be destroyed through biological degradation as in case with most organic pollutants and secondly metals tend to accumulate in the environment [1-3].

Therefore, the way in which metals act in response to sediment and their acquisition by the plant is certainly of considerable importance for research in the environment. There is not a single type of theoretical model to be used to predict the metal content of plants from its content in a nearby sediment or water. In the same way, no device existed by which plants obtained metals and transported them through their tissues.

The application of plant organisms for research of heavy metal pollution in a lake environment has a number of advantages over standard methods for the detection of metals in water by chemical analysis. Thus, metal concentrations in water are often below the detection limit of the employed instrument whereas the concentrations of metals in plants are much higher and allow for the determination of the available biological and cellular metals in aqueous medium [4-6].

There are a small number of studies on the trace metal concentrations in Gorewada Lake, Nagpur. However, the data presented provides insufficient information on their concentration in different parts of *Ipomoea aquatica* and their seasonal variations.

In the present study, the content of heavy metals (Cd, Cr, Ni, Pb, and As) in sediment, water and different organs of *I. aquatica* collected from Gorewada lake, Nagpur was investigated during different seasons.

The aim of this study was to determine the ways and means of metal adoption within *I. aquatica* tissue, as well as the differences and degree of bioaccumulation in dependence on the metal, plant part, location and season.

Material and methods

Sample collection

Samples of *I. aquatica* were collected at three seasons from Gorewada Lake. *Ipomoea aquatica* is a twining wine growing on riverbanks, lakeshores and roadsides. The plant material was packed in polyethylene bags and transferred to laboratory. Water and sediment samples were also taken from the same place as the plant material. Stones and coarse plant material were mechanically removed. The sediment samples were placed in plastic boxes, carefully labelled and transferred to the laboratory for further analysis. Water samples were collected from the depth of 0.5–1 m using 1.5 L PET bottles.

Sample analyses

The sampled plant material was first washed with tap water, and then twice with deionised water to clear dust particles and gently dried with a paper towel. The samples of the *I. aquatica* plants were separated into shoot and root to determine bioaccumulation diversity of the plant organs. The plant material was then sundried. The samples were ground into a fine powder using mortar and pestle.

1 g of prepared plant samples was taken in a beaker and 50ml aquaregia was added along with 5% HNO_3 and then digested for 3-4 hours on hot plate. After digestion, the samples were left to cool and then filtered with Whatman Ashless filter paper (no. 40). The samples were then transferred to 100ml volumetric flasks and the rinsing water was added to the volumetric flask to make the volume up to 100ml, followed by ICPAES analysis [Thermofischer model no. IRIS Intrepid II].

The sediment samples were dried in air and then in an oven at 110 ° C for 24 h. The dried sediment samples were ground in mortar and pestle and sieved through a 1.5 mm sieve to obtain homogenized fine particles. Approximately, 1g of sediment sample was taken in a beaker and 50ml aquaregia was added and then digested for 3-4 hours on hot plate. After digestion, the samples were left to cool and then filtered with Whatman Ashless filter paper (no. 40). The samples were then transferred to 100ml volumetric flasks and the volume was made up to the mark with 5% HNO3. The plant samples were ready for analysis by ICPAES.

Water samples were collected from Gorewada lake in the clean plastic bottle during all seasons and directly subjected to chemical analysis by ICPAES for heavy metal contents.

The ability of plants to absorb and accumulate metals from sediment was evaluated using Enrichment coefficients. Enrichment coefficient is calculated as the concentrations of metals in the plant part and the associated sediment. Higher enrichment factor values imply greater phyto-accumulation ability of the plant.

$$\text{Enrichment coefficient} = [\text{Metal}]_{\text{part of plant}} / [\text{Metal}]_{\text{sediment}}$$

The possibility of plants to transport metals from the root to the shoot was estimated using translocation factor. Translocation ability was calculated as the ratio of concentration of metals in shoot and root.

$$\text{Translocation factor} = [\text{metal}]_{\text{shoot}} / [\text{Metal}]_{\text{root}}$$

The TF of more than 1 indicates a very efficient ability to translocate metals from root to shoot, most likely due to efficient metal transport systems [7].

Results and Discussion

Variation of heavy metals in all matrixes

Table 1: Concentration of heavy metals in water (mg/l) in different seasons

Season	Chromium	Arsenic	Nickel	Cadmium	Lead
Winter	0.003	0.0061	0.004	0.003	0.003
Summer	0.027	0.0398	0.041	0.007	0.314
Rainy	0.029	0.0346	0.03	0.003	0.03

Table 2: Concentration of heavy metals in sediment (ppm) in different seasons

Season	Chromium	Arsenic	Nickel	Cadmium	Lead
Winter	17.15	7.764	19.836	3.56	3.9
Summer	40.74	2.338	24.472	4.33	4.2
Rainy	38.97	2.694	22.856	4.978	3.41

The concentrations of heavy metals from Gorewada lake water were determined seasonally. Chromium and arsenic concentrations were detected in traces. The highest concentrations of heavy metals were observed during summer and rainy season while lower in winter season. This trend could be attributed to the evaporation of water from lake during summer and subsequent dilution due to precipitation and run off from catchment area during rainy season [8]. The chromium and arsenic content indicated that it remained below toxic limits in all seasons. The concentrations of nickel, cadmium and lead during summer were found above permissible level.

Table 3: Concentration of heavy metals in different plant parts in different seasons

Seasons	Chromium		Arsenic		Nickel		Cadmium		Lead	
	Shoot	**Root**	**Shoot**	**Root**	**Shoot**	**Root**	**Shoot**	**Root**	**Shoot**	**Root**
Winter	7.214	3.448	0.255	0.836	2.702	3.4	0.26	0.206	0.84	1.032
Summer	6.632	7.108	0.662	1.216	9.87	10.6	0.308	1.294	3.032	4.13
Rainy	1.416	217.6	1.262	2.58	9.168	133.3	0.428	0.494	2.74	5.072

The concentrations of metals in the individual parts of *I. aquatica* were significantly different from their concentrations in water and sediment and followed the trend: sediment > root > shoot > water. Concentrations of the metals in the shoot and root of I. aquatica followed the trend: Cr > Ni > Pb > As > Cd. Significantly higher values of the concentration of Cr and Ni were recorded during rainy season compared to other seasons.

The enrichment coefficient value of *I. aquatica* was shown through the enrichment factors. Differences in the sequences of the metal contents in the plant, the sequences of their bioaccumulation capacity and their numerical relationships could be seen to a certain extent. These differences suggest a different bioaccumulation capacity of *I. aquatica* for different metals. The plant accumulates certain metals irrespective of their concentrations in water and sediment, which is obviously a characteristic provided by its capacity for each individual element.

The orders of the intensity of bioaccumulation of the examined metals in the shoot and root were different. These differences cannot be interpreted solely by differences in metal translocation through the plant because, most probably, the bioaccumulation capacities of the shoot for individual metals directly from the water are different.

Table 4: Enrichment factors and Translocation factor for heavy metals at different seasons

Heavy Metals	EFS			EFR			TF		
	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy
Cr	0.42	0.16	0.036	0.2	0.17	5.58	2.09	0.93	0.0065
As	0.0328	0.2831	0.4684	0.1077	0.52	0.95	0.305	0.54	0.4891
Ni	0.13	0.403	0.401	0.79	0.85	5.83	0.7947	0.47	0.068
Cd	0.073	0.071	0.086	0.0579	0.0679	0.0992	1.26	1.04	0.86
Pb	0.216	0.712	0.8047	0.2637	0.97	1.4874	0.82	0.73	0.541

Table 5: Enrichment factor (shoot) for heavy metals at different seasons

Enrichment factor (shoot)	Winter	Summer	Rainy
Chromium	0.42	0.16	0.036
Arsenic	0.0328	0.2831	0.4684
Nickel	0.13	0.403	0.401
Cadmium	0.073	0.071	0.086
Lead	0.216	0.712	0.8047

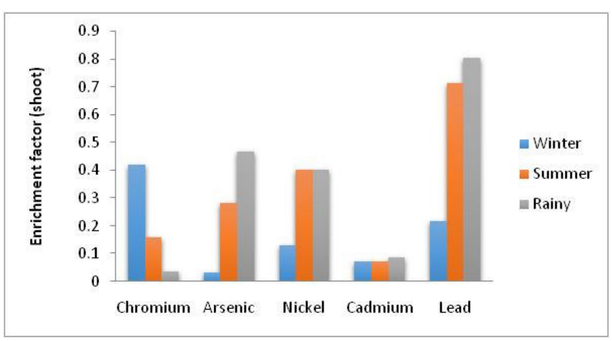

Figure 1: Enrichment factor (shoot) for heavy metals at different seasons

The enrichment coefficient value of *I. aquatica* shoot was below 1 for all studied metals indicating that shoot does not have the special ability to absorb and transport metals from sediment and then store them in their above-ground part.

Table 6: Enrichment factor (root) for heavy metals at different seasons

Enrichment factor root Chromium	Winter 0.2	Summer 0.17	Rainy 5.58
Arsenic	0.1077	0.52	0.95
Nickel	0.79	0.85	5.83
Cadmium	0.0579	0.0679	0.0992
Lead	0.2637	0.97	1.4874

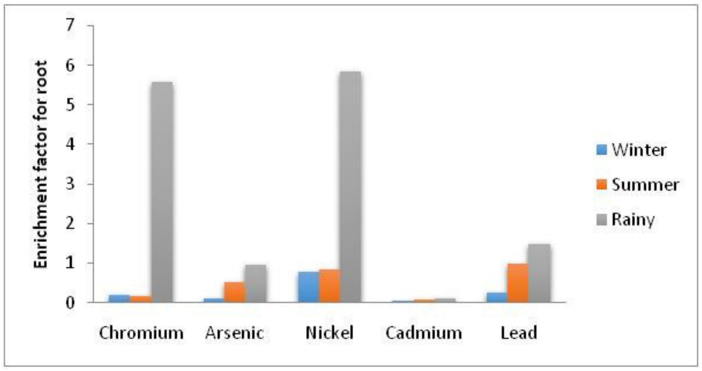

Figure 2: Enrichment factor (root) for heavy metals at different seasons

The enrichment coefficient value of *I. aquatica* (root) for Pb was higher than 1 during summer and rainy. The enrichment coefficient value of chromium, arsenic and nickel were higher than one during rainy season indicating that the roots have the property to accumulate heavy metals.

Table 7: Translocation factor for heavy metals at different seasons

Translocation factor	Winter	Summer	Rainy
Chromium	2.09	0.93	0.0065
Arsenic	0.305	0.54	0.4891
Nickel	0.7947	0.47	0.068
Cadmium	1.26	1.04	0.86
Lead	0.82	0.73	0.541

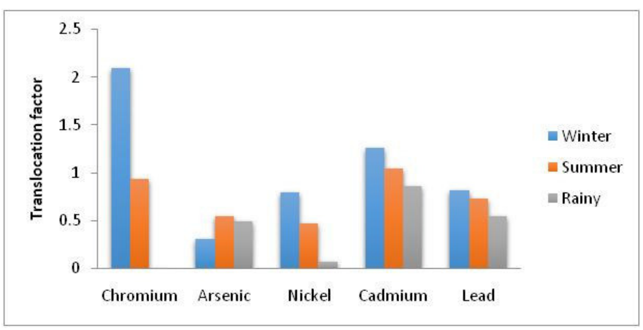

Figure 3: Translocation factor for heavy metals at different seasons

The seasonal values of the translocation ability are given in table 7. The translocation factor for Cr and Cd were found to be greater than 1 indicating that the plant can effectively translocate these metals from roots to shoots.

Chromium

Significant seasonal variations in concentrations of Cr have been observed. Cr content ranges from 1.416 ppm to 7.214 ppm in the shoot while in the root it ranges from 3.448 ppm to 217.6 ppm. The chromium content in the shoot declined from winter to rainy while that of root increased from winter reaching a maximum at the rainy season. Enrichment factor (root) of Cr in relation to sediment in *I. aquatica* is greater than 1 during rainy season. However, there is a noticeable translocation of the average ratio shoot/root during winter and summer.

Arsenic

The concentration of arsenic in the shoot ranged from 0.255 ppm to 1.262 ppm whereas in the root it was 0.836 ppm to 2.58 ppm. The arsenic content in the shoot and root were significantly increased from winter to rainy. Enrichment factor (shoot) was found to be less than one whereas enrichment factor (root) during rainy season was considerable. Translocation factor revealed that *I aquatica* do not have ability to accumulate As in its tissues.

Nickel

The Ni concentrations ranged from 2.702 ppm to 9.87 ppm in the shoot and in the root the Ni content ranged from 3.4 to 133.3 ppm. The content of nickel in the root was higher than shoot in all seasons. Nickel does not exhibit the bioaccumulation as well as translocation ability showing that *I. aquatica* do not have ability to accumulate Ni in its tissues.

Cadmium

Of the studied metals, cadmium was present in the lowest amount in the tissues of *I. aquatica* in the shoot from 0.26 ppm to 0.428 ppm and from 0.206 ppm to 1.29 ppm in the root. The concentration of Cd in the shoot increased from winter to rainy. Enrichment factor (root) for Cd was the lowest. However, there is a noticeable translocation of the average ratio shoot/root during winter and summer. Enrichment coefficients for shoot and root were found to be less than one.

Lead

The Pb concentrations ranged from 0.84 ppm to 3.03 ppm in the shoot and in the root the Pb content ranged from 1.032 ppm to 5.07 ppm. The enrichment factor for shoot and root shows that these values increased from winter to rainy. Compared to enrichment factor (shoot), the value of enrichment factor (root) was found to be 1 during summer and rainy seasons. Therefore, *I. aquatica* shows ability to tolerate lead in its root.

Conclusion

Concentrations of metals in different parts of *I. aquatica* were significantly different from their concentration in water and sediment following the trend: sediment > root > shoot > water. The enrichment factor for root shows that *I. aquatica* can tolerate Cr, Ni and Pb in root. Similarly, TF values for Cd and Cr indicated that *I. aquatica* can effectively translocate Cr and Cd to the aboveground portion. The results of the present study indicated that *I. aquatica* is a promising plant for metal accumulation. So, it may be used to ameliorate polluted water.

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