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Biomonitoring of selected freshwater macrophytes to assess lake trace element contamination: a case study of Nal Sarovar Bird Sanctuary, Gujarat, India

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ABSTRACT

A biomonitoring study was carried out at Nal Sarovar Bird Sanctuary, a proposed Ramsar site, Gujarat State, India, to ascertain the degree of trace element contamination. The study focused on assessment of trace element contamination in certain aquatic macrophytes to be used as biomonitors, in comparison with the sediments (abiotic monitor) for heavy metal pollution. Good information was provided by analyzing roots, stems and leaves of native aquatic plants (biomonitors) represented by eight species: Bergia odorata, Hydrilla verticillata, Ipomoea aquatica, Najas graminea, Nelumbo nucifera, Phragmites karka, Typha angustata *and* Vellisnaria spiralis*, alongwith surface sediments and water, were analyzed for Cd, Co, Cu, Cu, Ni, Pb and Zn contamination. The highest concentrations of the trace elements were measured in* Ipomoea aquatica *and the lowest in* Bergia odorata*. Based on the concentration and toxicity status observed in the lake's vegetation, the six metals are arranged in the following decreasing order: Zn > Cu > Ni > Co > Pb > Cd. Compared with the standard, normal and critical toxicity range in plants, the detected values of Cd and Pb falls within normal range, while that of Co, Ni and Cu were within the critical range. However, Zn showed the highest concentration and alarming toxicity levels, which is considered as one of the most hazardous pollutants in Nal Sarovar Bird Sanctuary. Certain aquatic macrophytes species are also proposed as biomonitors for the investigated heavy metal pollutants. Such result was significant in the plant species such as* Ipomoea aquatica *and* Phragmites karka*, which are the two most useful species in biomonitoring studies due to their ability to accumulate elements in high concentration in the roots and their availability throughout the year. The results showed the significant difference in accumulation rate of some metals like Zn, Cu and Ni in different plant organs, which showed more accumulation in root than that of stem and leaves. Also, there is a high positive correlation between combinations of different metal-pairs in either plant's root, stem or leaf system.*

Key words: freshwater macrophytes, trace element, contamination, Nal Sarovar Bird Sanctuary

1. INTRODUCTION

Direct discharge or wet and dry depositions of contaminants increase the concentrations of trace elements of aquatic systems, thus resulting in their accumulation in sediments (Dunbabin & Bowmer 1992; Sinicrope *et al*. 1992). Aquatic plants absorb elements through roots and/or shoots (Pip & Stepaniuk 1992; Jackson 1998). Various species show different behaviour regarding their ability to accumulate elements in roots, stems and/or leaves. Therefore, it is useful to identify the plant organ that absorbs the greatest amount of trace elements (Baldantoni *et al*. 2004). In aquatic systems, where pollutant inputs are discontinuous and pollutants are quickly diluted, analyses of plant tissues provide time-integrated information about the quality of the system (Baldantoni *et al*. 2005).

Biomonitoring has several advantages and is the most significant-one in study of sublethal levels of bioaccumulated contaminants within the tissues of organisms, which indicate the net amount of pollutants integrated over a period of time (Lovett-Doust *et al*. 1994). Biomonitoring of pollutants using some plants as accumulator species, which accumulate relatively large amounts of certain pollutants, even from very diluted solutions without obnoxious effects (Ravera *et al*. 2003). It may be performed in two ways, based on the kind of sampled organisms: i) "endemic" or native organisms (passive biomonitoring) and ii) introduced organisms (active biomonitoring) (Chaphekar 1991).

Rana & Nirmal Kumar (1988) observed heavy metal content through EDAX in certain sediments of Central Gujarat and noticed that Fe content was highest in sediments of Undeva, followed by Si and Al. Nirmal Kumar *et al*. (1989) have investigated elemental composition of certain aquatic plants of Central Gujarat by Energy Dispersive X-Ray Microanalysis (EDAX). High level of heavy metals such as Al, Si, Mn and Fe were found accumulated in *Vellisnaria spiralis*, *Hydrilla verticillata* and *Azolla pinnata*.

As the macrophytes concentrate great amount of various substances (e.g. metals) and are consequently useful indicators of local pollution, the aim of the present study was to assess the toxicity status induced by six heavy metals (Cd, Co, Cu, Ni, Pb and Zn) in selected plant parts (roots, stems, leaves) of eight native

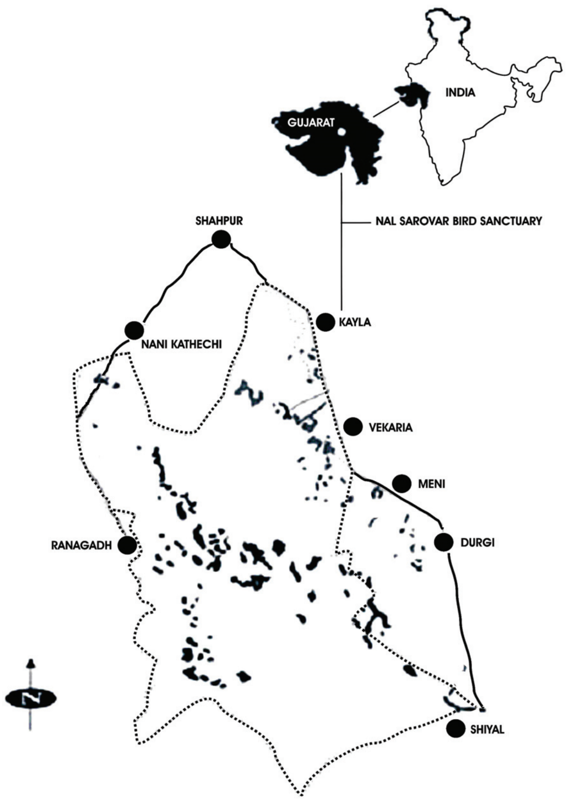

Fig. 1. Location map of Nal Sarovar Bird Sanctuary (NSBS).

aquatic macrophyte species (passive biomonitors) in comparison with sediment and water samples.

2. MATERIALS AND METHODS

Nal Sarovar Bird Sanctuary (NSBS) is located between 22°78' N to 22° 96' N latitude and 71° 92' E to 72° 64' E longitude, falls in 4B Gujarat-Rajwara biotic province of the semi arid lands of Central Gujarat, India. The details of NSBS have been depicted in table 1. The lake has more than 300 islets, occupies 120 km^2, and is the principal source of food and fishing for local dependent communities of peripheral twelve villages. It receives water from two rivers: Brahmini and Bhogavo, carries household sewage and agricultural run-off from village pockets at north-western boundary. The water-flow pattern of the area is exhibited by gentle slope from north-west to south. No industrial effluent enters into the lake. The water temperature rises up to 35 °C during the month of May and falls below 15 °C in January. The average rainfall is about 580 mm (Fig. 1). The marginal planes of NSBS support more than 260 species of aquatic birds besides two endangered mammalian species: Wild ass (*Equus hemionus khur*) and the threatened Blackbuck (*Antilope cervicapra*). The population estimation of waterfowl clearly signifies the lake as an internationally important wetland as per the criteria of Ramsar Convention. Accordingly, it is one of the proposed Ramsar Sites in India.

Tab. 1. Important characteristics of Nal Sarovar Bird Sanctuary.

Genesis	Late quaternary period
Latitude	220 78’ N to 220 96’ N
Longitude	710 92’ E to 720 64’ E
Biotic province	4B Gujarat-Rajwara (semi arid lands of Central Gujarat)
Area (km^2)	120.89
Slope	North-west to south
Shape	Ovo-ellispoidal
Maximum depth (m)	1.5 to 2.0
Average depth (m)	1.0
Number of islets	More than 300
Temperature (°C)	15 to 35
Average rainfall (mm)	580
Wind velocity (km h^{-1})	60 (during summer)
Planktons	48 phytoplanktones 76 zooplanktons
Flora	41 terrestrial plants 30 aquatic macrophytes
Fauna	20 fishes, 11 herpetofauna 46 terrestrial birds, 260 waterfowl 13 mammals
Significance	Wetland of International Importance Proposed Ramsar site

The National Wetland Committee also identifies NSBS as one of the important wetlands for evolving management action plan. Due to human interference, considerable changes occurred in its geomorphology, structure, water characteristics, hydrology and biotic composition in recent past.

2.1. Field work

2.1.1. Water and sediment sampling

Surface water and composite sediment samples were collected at random from different areas of the lake covering all directions during November 2004. Soon after collection, the water samples were filtered through 0.45 µm (pore size) Millipore filter and preserved in plastic bottles by the addition of a few drops of nitric acid. Sediment samples were preserved in air-dry plastic bags. The samples were labeled carefully and brought to the laboratory for further analysis.

2.1.2. Plant sampling

Eight native aquatic macrophytes from the lake were selected as passive biomonitors for estimating the toxicity status induced by six heavy metals (Cd, Co, Cu, Ni, Pb and Zn) and were collected in November 2004. The plant species selected were: *Bergia odorata*, *Hydrilla verticillata*, *Ipomoea aquatica*, *Najas graminea*, *Nelumbo nucifera*, *Phragmites karka*, *Typha angustata* and *Vellisnaria spiralis*. Healthy aquatic plants were collected by hand, washed with lake water to remove periphyton and sediment particles. Therefore, the element concentrations in the plant parts refer not only to tissue concentrations but also to adsorbed elements on part surfaces. The collected plant species were preserved in plastic bags, labeled carefully and brought to the laboratory. To avoid the introduction of metal contamination, polythene tools were used in sampling and storing the collected matrices (Allen 1989). Plant species were identified according to Shah (1962).

2.2. Laboratory work

2.2.1. Chemical analysis of water, sediment and plant samples

Sediment samples were air-dried, sieved through 2 mm governorates sieve and kept for analyses. Each aquatic plant species sorted into different parts: roots, stems and leaves. The 50 g of each fresh sample dried at 80 °C in hot air oven for 48 hrs. The samples of water, sediment and plant-parts were chemically analyzed for detection of heavy metals (Cd, Co, Cu, Ni, Pb and Zn). Accurately one g of dry powder of each sample was weighed, and digested with con. HNO_3, H_2SO_4 and H_2O_2 (2:6:6) as prescribed by Saison *et al.* (2004). Towards the end of the digestion, the flasks were brought to near dryness. The solutions were made to 20 ml each in a measuring cylinder with doubled distilled water. The blanks were run with set, and the samples were analysed in Inductive Coupled Plasma Analyzer (ICPA) (Perkin-Elmer ICP Optima 3300 RL, U.S.A.) at Sophisticated Instrumentation Center for Applied Research and Testing (SICART), Vallabh Vidyanagar, Gujarat. The concentration of heavy metals such as Cd, Co, Cu, Ni, Pb and Zn was analyzed and calculated in mg l^{-1}. Mean values of duplicate sub-samples of the water, sediment and plant samples were considered.

2.3. Data analysis

The mean values of heavy metals were calculated for water, sediment and plant samples. The unilateral *F*-test was carried out between heavy metal contents in roots, stems and leaves to check if significant differences exist between the accumulation rate of each metal and different plant parts. Pearson correlation coefficient analysis was done between metal-pairs in plants to check if differences exist between different metal combinations in either root, stem or leaf system. The products of the correlation coefficient (*r*) were evaluated as follows:
(-1)–0.3: No correlation; 0.3–0.5: Low correlation; 0.5–0.7: Medium correlation; 0.7–0.9: High correlation; 0.9–1.0: Very high correlation.

The comparison of the concentration of an element in an aquatic organism with that of the same element in the water in which the organism lives. This is the ratio between the concentration of the element in the organism and that of in the water, which is known as Concentration Factor (De Bortoli *et al.* 1968). The Concentration Factor (C.F.) was calculated.

3. RESULTS

3.1. Water and sediments

The concentrations of the elements considered were far higher in the sediments than those calculated for the same elements in the lake water filtered through Millipore filter (0.45 µm opening size). Of the elements analyzed Zn was the most abundant both in sediments (553.47 mg l^{-1}) and water (94.03 mg l^{-1}), followed by Co with a concentration of 64.83 mg l^{-1} in the sediments and 17.58 mg l^{-1} in the water. Other metals (Ni, Cu, Cd and Pb) exhibit the receding trend in both sediments and water. The values of the ratio between element concentrations in the sediments and those in the water were lower (1.15-5.89) for Pb, Cu, Co, Ni and Zn, whereas that of Cd was observed high (25.78 mg l^{-1}) (Tab. 2, Fig. 2).

Tab. 2. Element concentration ratios between sediments and water.

	Sediment (mg l^{-1})	Water (mg l^{-1})	Sediment/Water
Cd	8.83	0.34	25.78
Co	64.83	17.58	3.69
Cu	32.88	9.42	3.49
Ni	50.33	12.90	3.90
Pb	5.59	4.87	1.15
Zn	553.47	94.03	5.89

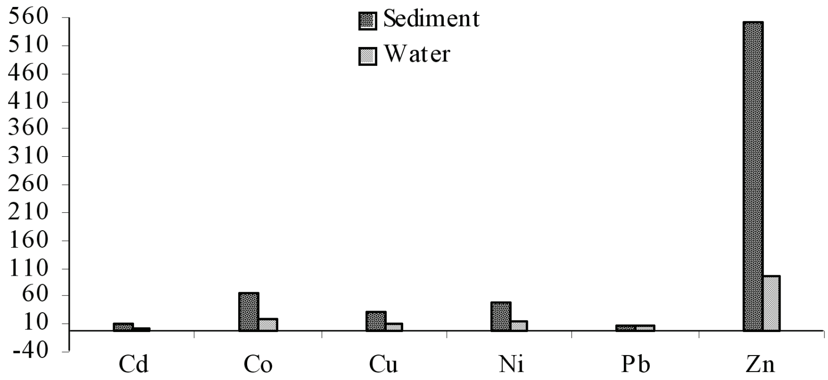

Fig. 2. Mean concentration (mg l^{-1}) of six heavy metals in water and sediment samples of NSBS.

Tab. 3. Element concentration (mg l^{-1}) in certain macrophyte species.

	Cd	Co	Cu	Ni	Pb	Zn
Bergia odorata	0.40	2.62	27.75	23.01	4.11	128.63
Hydrilla verticillata	0.44	3.04	21.80	20.09	6.20	155.18
Ipomoea aquatica	0.21	10.48	7.41	7.95	2.67	639.04
Najas graminea	0.58	6.00	39.70	28.16	13.90	509.93
Nelumbo nucifera	0.59	1.68	23.20	20.50	5.28	221.03
Phragmites karka	0.74	7.59	18.99	15.10	2.87	168.59
Typha angustata	0.46	2.99	31.35	28.86	8.28	169.48
Vellisnaria spiralis	1.28	6.66	66.26	28.75	9.20	239.17
Mean	0.59	5.13	29.56	21.55	6.56	278.88
SD	0.32	3.04	17.56	7.38	3.78	188.99

Tab. 4. Concentration factors calculated for the various species and elements.

	Cd	Co	Cu	Ni	Pb	Zn	Mean
Bergia odorata	1.17	0.15	2.95	1.78	0.84	1.37	1.38
Hydrilla verticillata	1.28	0.17	2.31	1.56	1.27	1.65	1.38
Ipomoea aquatica	0.62	0.60	0.79	0.62	0.55	6.80	1.66
Najas graminea	1.72	0.34	4.21	2.18	2.85	5.42	2.79
Nelumbo nucifera	1.73	0.10	2.46	1.59	1.08	2.35	1.55
Phragmites karka	2.16	0.43	2.02	1.17	0.59	1.79	1.36
Typha angustata	1.34	0.17	3.33	2.24	1.70	1.80	1.76
Vellisnaria spiralis	3.78	0.38	7.03	2.23	1.89	2.54	2.98
Mean	1.73	0.29	3.14	1.67	1.35	2.97	
SD	0.95	0.17	1.86	0.57	0.78	2.01	

3.2. Macrophytes

Table 3 shows the values of concentration of six elements in eight species of macrophytes. The mean concentration values of the elements in the plants decrease according to this sequence: Zn > Cu > Ni > Pb > Co > Cd. *Ipomoea* sp. has the greatest capacity for concentrating trace element with highest concentration (639.04 mg l^{-1}) of Zn and lowest concentration of Cd (0.21 mg l^{-1}), followed by *Najas*, *Vellisnaria*, *Nelumbo*, *Typha*, *Phragmites* and *Hydrilla* spp. Conversely, *Bergia* sp. has the lowest number of trace element concentration with high concentration of Zn (128.63 mg l^{-1}) and low concentration of Cd (0.40 mg l^{-1}).

Table 4 gives values of Concentration Factor (C.F.) for each species and element. The mean C.F. value of the elements in the plants decrease according to this sequence: Cu > Zn > Cd > Ni > Pb > Co. This sequence, which is rather different from that of the mean concentrations of elements in the plants, reflects the capacity of the macrophytes to accumulate elements independently from their concentration in the water that is the regulation capacity of the plants. Mean concentration factor for the various elements calculated for *Vallisneria* sp. are generally rather high, followed by *Najas* and *Typha* spp., while those for *Phragmites* and *Hydrilla* spp. are lower than those of the other species.

At least, two sources of contamination are responsible for pollution in NSBS, namely agricultural run-off and household (sewage) effluents, coming through several drains alongwith washing, bathing, cattle wading and agricultural run-off from peripheral villages at

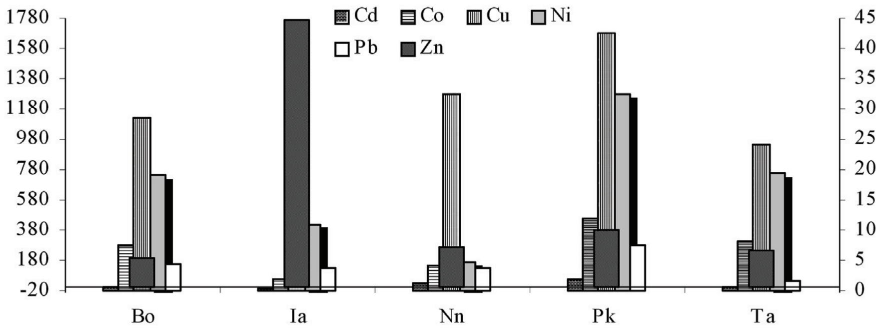

Fig. 3. Mean concentration (mg l^{-1}) of six heavy metals in roots of five plant species from NSBS. (**Bo** = *Bergia odorata*, **Ia** = *Ipomoea aquatica*, **Nn** = *Nelumbo nucifera*, **Pk** = *Phragmites karka*, **Ta** = *Typha angustata*).

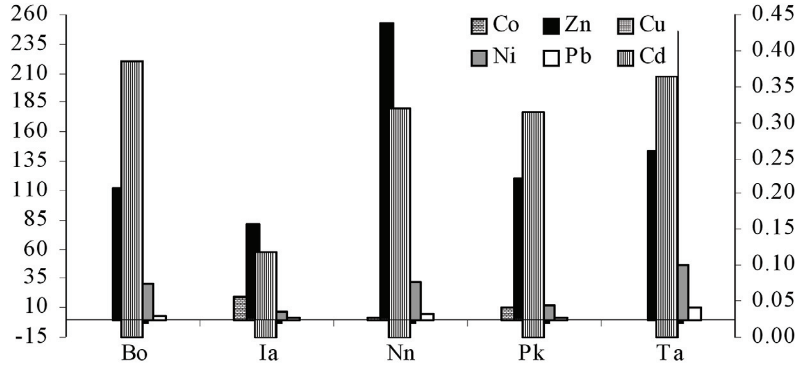

Fig. 4. Mean concentration (mg l^{-1}) of six heavy metals in stems of five plant species from NSBS. (**Bo** = *Bergia odorata*, **Ia** = *Ipomoea aquatica*, **Nn** = *Nelumbo nucifera*, **Pk** = *Phragmites karka*, **Ta** = *Typha angustata*).

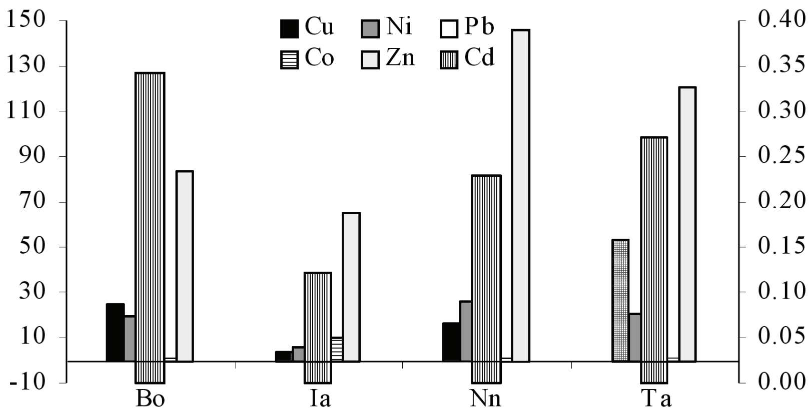

Fig. 5. Mean concentration (mg l^{-1}) of six heavy metals in leaves of four plant species from NSBS. (**Bo** = *Bergia odorata*, **Ia** = *Ipomoea aquatica*, **Nn** = *Nelumbo nucifera*, **Ta** = *Typha angustata*).

north-west boundary. Heavy metals are the most dangerous contaminants since they are persistent and accumulate in water, sediments and in tissues of the living organisms, through two mechanisms, namely "bioconcentration" (uptake from the ambient environment) and "biomagnification" (uptake through the food chain) (Lambou & Williams 1980; Chaphekar 1991). The present results include assessment of six heavy metals (Cd, Co, Cu, Ni, Pb and Zn) and evaluation of their toxicity status in different plant parts of eight native aquatic plant species (Figs 3, 4, 5).

3.2.1. Heavy metal pollution in plants

The chemical analysis (for roots, stems and leaves) of five native plant species from NSBS was carried out. These species are: *Bergia odorata*, *Ipomoea aquatica*, *Nelumbo nucifera*, *Phragmites karka* and *Typha angustata*. Besides *Hydrilla verticillata*, *Najas graminea* and *Vellisnaria spiralis* were analysed intact without sorted into different parts due to their incoherent phenophases. All the selected aquatic macrophytes were collected mostly from all directions of NSBS from at least 0.5 m depth. Compared to the standard, normal and critical toxicity range of metals in all selected plants, the concentrations of Cd and Pb was observed within normal ranges, while that of Co, Cu and Ni were registered within the critical ranges. However, Zn showed the highest concentration and alarming toxicity levels, which is considered as one of the most hazardous pollutants in Nal Sarovar Bird Sanctuary (Tab. 5).

Tab. 5. Ranges of heavy metals contents and toxicity status in the tested plant species, compared with normal and critical ranges in plants. * Data after Kabata-Pendias & Pendias (1992).

	Mean range (mg l^{-1})	Normal range (mg l^{-1})*	Critical range (mg l^{-1})*	Toxicity status
Cd	0.12-1.89	0.1-2.4	10-30	Normal
Co	0.09-19.10	0.75-1.07	1-8	Critical
Cu	3.85-53.35	7.53-8.44	25-90	Critical
Ni	4.68-46.80	0.89-2.04	10-50	Critical
Pb	1.11-12.57	0.2-20	30-300	Normal
Zn	64.25-1771.39	1-400	100-400	Critical

The concentrations of Cd and Pb fall within the normal range. All observed values of Cd (0.12-1.89 mg l^{-1}) and Pb (1.11-12.57 mg l^{-1}) falls within the standard normal range 0.1-2.4 mg l^{-1} and 30-300 mg l^{-1}, respectively, in studied plants, whereas concentration of Co (0.09-19.10 mg l^{-1}), Cu (3.85-53.35 mg l^{-1}), Ni (4.68-46.80 mg l^{-1}) and Zn (64.25-1771.39 mg l^{-1}) was recorded within critical ranges, 1-8 mg l^{-1}, 25-90 mg l^{-1}, 10-50 mg l^{-1} and 100-400 mg l^{-1}, respectively.

3.2.2. Zinc (Zn) in plants

Compared with the standard critical range of Zn (100-400 mg l^{-1}), a critical amount (1771.39 mg l^{-1}) existed in roots of *Ipomoea* sp. The same applies to stems and leaves of *Nelumbo* sp., 253.43 mg l^{-1} and 145.53 mg l^{-1}, respectively. Thus Zn seems to be the most hazardous pollutant in NSBS, since it reached extremely high concentrations and may cause serious toxicity in most of the investigated plant species.

Accumulation pattern of heavy metals in root, stem and leaf systems: Applying unilateral F-test on the concentrations of each metal (separately in roots against stems and leaves), indicated significant differences only for Zn (p <0.05) as follows:

Metal:	Cd	Co	Cu	Ni	Pb	Zn
F-value:	0.007	0.160	0.774	0.444	0.288	0.001*

Based on the above results, it is obvious that Zinc seems to accumulate with more tendencies towards roots than stems of the tested species. The output of Pearson correlation coefficient analysis on combinations of different metal-pairs which are present together in either roots, stems or leaves of the tested plant species and showed medium + ve correlation (r = 0.5-0.7) between only a single metal pair (Cu and Ni), high + ve correlation (r = 0.7-0.9) between Cu and Cd, Ni and Cd, Pb and Cd, and Cu and Pb metal pairs, and very high + ve correlation (r > 0.9) between Ni and Pb metal pairs (Tab. 6). These results indicated that both root and stem systems may have a kind of natural controlling mechanism regarding the quantity of specific metals taken from the ambient environment, but they don't have controlling mechanism to suppress the combination between specific metal-pairs in their tissues (Ravera *et al*. 2003).

Tab. 6. Correlation coefficient between concentrations of heavy metal-pairs in root, stem and leaf systems of plant species. * Medium Correlation (r = 0.5-0.7); ** High Correlation (r = 0.7-0.9); *** Very High Correlation (r >0.9).

Analysis metal-pair	Correlation Coefficient (r) Root system	Stem system	Leaf system
Zn x Cd	-0.387	0.339	0.274
Cu x Cd **	0.890	0.754	0.597
Ni x Cd **	0.496	0.841	0.702
Ni x Zn	-0.279	0.459	0.864
Co x Cd	0.639	-0.906	-0.860
Pb x Cd **	0.721	0.675	0.296
Zn x Cu	-0.710	0.326	0.416
Zn x Ni	-0.279	0.459	0.864
Zn x Co	-0.644	-0.589	-0.727
Zn x Pb	-0.053	0.276	0.714
Cu x Ni *	0.548	0.556	0.494
Cu x Co	0.777	-0.846	-0.647
Cu x Pb **	0.689	0.242	0.874
Ni x Co	0.905	-0.889	-0.960
Ni x Pb ***	0.588	0.932	0.569
Co x Pb	0.503	-0.664	-0.590

3.2.3. Overall chain-transport mechanism of metals

Overall study reflects the transport mechanism of metals from abiotic environment (soil) to biotic environment (macrophyte) and their accumulation in various parts of aquatic plants. The transport mechanism and accumulation pattern of heavy metals (mean concentration) can be elaborated as follows: Sediment > Root system > Stem system > Leaf system (Fig. 6).

Species proposed as biomonitors / biofilters for heavy metals: The information of metals *versus* species (arranged in a decreasing order) containing metals higher than the minimum critical limits (Kabata-Pendias & Pendias 1992) is as follows.

Metal proposed for biomonitors / biofilters

Zn (*Ipomoea* > *Najas* > *Vellisnaria*)
Cu (*Vellisnaria* > *Najas* > *Typha*)
Ni (*Typha* > *Vellisnaria* > *Najas*)

Based on the above results, it was concluded that the three native aquatic plant species (*Ipomoea*, *Vellisnaria*

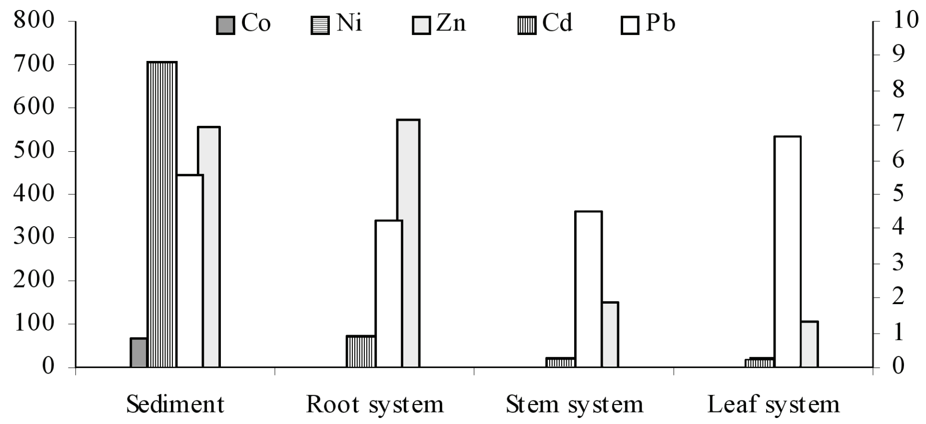

Fig. 6. Mean concentration (mg l^{-1}) of six heavy metals in sediment and plan parts from NSBS.

and *Typha*) accumulated heavy metals in much higher concentrations. Perhaps, it might be the reason that these three species are more efficient than the other native species in uptake of metals. Such aquatic macrophytes could also be used as "biomonitors / biofilters" as compared to other native aquatic macrophyte species.

4. DISCUSSION AND CONCLUSIONS

The aquatic plants growing in the study area exhibit different trace element concentrations, depending on the plant organ, and both the sampling time and the sampling site (Baldantoni *et al*. 2005). Roots of aquatic plants absorb heavy metals from the interstitial water (or pore water) and accumulate high concentrations (Baldantoni *et al*. 2004). Similarly our findings reveal the higher concentrations of all the studied heavy metals in roots of *Ipomoea* and *Phragmites* spp. The stems and/or leaves of submerged plants accumulate lower concentrations of trace elements than roots. The results of the present work are also well-coincided with this, elaborated by low metal concentrations in stem and leaf systems of the plants (Nirmal Kumar & Kumar 1989; Baldantoni *et al*. 2005). Thus among the investigated species, *Ipomoea* and *Phragmites* spp. appears to be the best monitoring species due to their availability throughout the year in NSBS.

The present study shows that the concentrations of the metals (in sediments and plant tissues) could be arranged in a decreasing order as follows: Zn > Cu > Ni > Co > Pb > Cd. The ratio of these metals was two times higher in the sediments than in studied aquatic macrophytes. This agrees with previous findings of Ramdan (2003). Accordingly, the studied samples from NSBS could be arranged in a decreasing order based on their content of heavy metals as follows: Sediment > Root system > Stem system > Leaf system. Lovett-Doust *et al*. (1994) estimated that the accumulation levels of organochlorine pollutants (PCB) in aquatic ecosystems may be higher in sediments than in plants. The highest level of Cu in our study might be due to downstream flow of River Brahmani at north-west coming through sewage outfall from upstream, which is an important source of contamination in the lake, which agrees with the findings of Jones *et al*. (1991) for a lake in Wales, emphasizing that existing agricultural practices on soils around the lake may also be responsible for high Cu concentration measured in the sediments of Lake. This also largely agrees with the findings of Siegel *et al*. (1994) on Ginka sub-basin, south of Lake Manzala. Thus, the following decreasing order of the studied metals in Lake NSBS was based on the degree of toxicity level in both cases of plants and sediments: Zn > Cu > Ni. The above sequence agrees with the findings of Ramdan (2003) and Siegel *et al*. (1994), who have worked on Lake Manzala, Nile Delta, Egypt. The native species may become tolerant to heavy metals and they may metabolize and secrete them (Abdel Moati 1985). We obtained results interpreting that the concentrations of heavy metals were much lower in tissues of the native aquatic plant species than in the sediments.

Although our results showed that the toxicity status of the studied heavy metals (except Zinc) are not very alarming at Lake NSBS in the present time, as outlined by Ramadan & Mekki (1996). We recommend that combating all kinds of pollution in Lake NSBS through prevention, controlling or by applying fine treatments on the drainage loads which discharge into the lake. Well-designed action plans should be developed, strongly supported and strictly executed within intensive rehabilitation programs. Because of the great importance of Lake NSBS, the threatened components of its food web should immediately be saved, starting by its physical elements and primary producers and terminating by man. That is because human populations of the twelve surrounding villages depend mostly on the food and fish produced from Lake NSBS.

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