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BIOMONITORING OF FRESHWATER MACROPHYTES AND BENTHIC ORGANISMS TO ASSESS TRACE ELEMENT CONTAMINATION: A CASE STUDY OF RIVER CAUVERY KARNATAKA, INDIA

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Abstract: The study focused on assessment of trace element accumulation in certain aquatic macrophytes and benthic organisms to be used as biomonitors. The macrophytes (*Nymphae stellata*, *Vallesnaria spiralis, Pistia stratioles,* and *Aqatic neam)* and benthic organisms (Crustacean, Mollusca and Annelida) collected during November 2011–April from river Cauvery, one of the main fresh water aquatic systems in the south of India. Microwave digested samples of discrete organs of macrophytes and the whole body of benthic organisms were analyzed for metal concentration using AAS-6300. Among the eight metals investigated, six (Fe, Pb, Ni, Cr, Cu, and Cd) were showed higher degree of accumulation in the root whereas, remaining (Mn and Zn) showed in stem and leaf respectively. *Vallesnaria spiralis* shows the greatest potential to acumulate Fe, Mn and Cu while *Nymphe stellata* showed the better ability to accumulate Zn and Cr. Cadmium found in *Aquatic neam* and *Vallisnaria spiralis* with very negligible concentration at downstream stations. Based on the accumulation, the eight metals were arranged in the following order: Fe> Mn> Zn> Cu> Pb> Cr> Ni > Cd. The metal concentrations in the macrophytes were found within the limits of Indian Standards. Among benthos, mollusca have showed a more accumulation capacity fallowed by crustacean and annelid. Bioaccumulation factor for benthos were observed in the sequence of Cu>Mn>Zn>Ni>Fe>Cr>Pb>Cd.

Key word: Heavy metal, Macrophytes, Benthos, Accumulation.

INTRODUCTION

Aquatic macrophytes are unchangeable biological filters and they carry out purification of the water bodies by accumulating dissolved metals and toxins in their tissue (Lilit and Baban, 2006). They are considered as important component of the aquatic ecosystem not only as food source for aquatic invertebrates, but also act as an efficient indicator of accumulation of heavy metals (Nirmal *et al.,* 2006). Many of the macrophytes found to be the potential scavengers of heavy metals from aquatic environment and are being used in wastewater renovation systems (Abida, 2009).

The biomonitoring of heavy metals using macrophytes has several advantages and is the most significant in the study of sublethal levels of bioaccumulated metals within the tissues of organisms, which indicates the net amount of pollutants integrated over a period of time. It provides time integrated information about the quality of the aquatic system (Ravera *et al*., 2003; Baldantoni *et al*., 2005).

The literature survey suggests that investigations on the heavy metals accumulation in lake system is very frequent compare to river system and have probably no studies on metals in macrophytes of Cauvery river in Karnataka stretch were reported. Hence, the present study has greater significance; especially as the water from river is being used for drinking and irrigation in larger extent.

Several investigators have revealed that aquatic benthic organisms are better accumulator of metal than ambient (water) and are good bioindicator of Heavy metal pollution in river ecosystem (Qi sang *et al*., 1985; Kiffney and Clements, 1993; Brandt, 1995). Stoykov and Uznova (2001) suggested that if benthos occurs in a density of 100–999 individuals/m^2, the water is unpolluted; 1000–5000 individuals/m^2, moderately polluted; and more than 5000 individuals/m^2 shows heavy pollution.

Crabs (crustacean) are detrivorous animals that occur mostly on the mudflats of littoral zones in the aquatic system. They are sedentary and do not migrate. Therefore, the crab is an excellent candidate for serving as a biomonitor (Falusi and Olanipekun, 2007) The fleshy tissues of the crab are good accumulator of heavy metals and the nutritional implication of this is that consumers of the animal may be exposed to heavy metal toxicity and bioaccumulation results due to regular consumption (Hsiao-Chien, 2009). Molluscs, due to their filtration activity, sedentary, detritus-feeding style of life and weak metabolizing systems can accumulate higher amounts of heavy metals. Molluscs are capable of achieving tissue concentrations of metals that are 100 to 1000 times higher than the background concentrations (Oyedepo *et al*., 2007). The accumulation rate is more among the bottom dwellers. Gopinathan and Sobhana, (2003); Ali and Fisher, (2005) concluded that molluscs are useful indicators of the abundance and spatial distribution of metals in aquatic ecosystems.

STUDY AREA

This investigation was carried out in river Cauvery from Kushalnagara to Arkavathi Sangama of Karnataka (Fig.1) stretch during dry season of April-2011. Three upstream and five downstream to Krishnaraja Sagar reservoir were chosen as sampling sites for effectual research.

METHODOLOGY

Sampling, Preservation and Preparation

Macrophytes: Sixteen macrophytes belonging to four species from eight stations were used to determine the heavy metals concentration in their different body organs. Healthy macrophytic plants were collected by hand once during the study period according to the nature of plant (floating or submerged). Floating macrophytes were collected from 1.0 X 1.0 m quadrant, while the submerged plant species were collected using a known volume of grab sample and washed with the surrounding water to remove the periphyton and sediment accumulated on them. Therefore, the element concentrations in the plant parts refer not only to tissue concentrations but also to adsorbed elements on plant part surfaces. Plastic bags were used to store the samples. These samples were thoroughly washed once again in the lab with distilled water to remove adsorbed elements on the plant surface and cut into small pieces of leaf, stem and root separately, air dried for 2days and dried at 100±1°C in an hot air oven for 4hr. Dried samples were grounded to powder and passed through a 1mm sift.

Benthic/Bottom dwellers: Twenty four samples of benthic organisms including crab (Crustacean), mussel (Mollusca) and cheatogaster (Annelida), one each from eight stations. Sampling was performed during dry season because of less flow rate and low depth.

Crabs were collected directly, by hand picking, from their holes on the bank of river with the help of localites. The crabs were kept in a bucket containing river water and transported to the laboratory until dissection. The crabs were washed with tap water, and then rinsed thoroughly with distilled water, fleshy tissues was dissected out from the chest and the appendages using surgical knife and placed on clean watch glasses. It was oven dried at 105°C for 1h and cooled in a desiccator (Faulsi, 2007).

The mussel and cheatogaster were sampled using nylon fish net. The samples were separated from the sediment using a 0.5 mm sieve and encrusted algae were scraped from shells (Locarnini and Presley, 1996). Samples were rinsed, dried at 50 °C in an oven and homogenized. Mollusca and crustacean species were removed from their shells during sample preparation but Cheatogaster were analyzed without modification.

Microwave Digestion

Macrophytes: A powdered plant samples of 0.5g was introduced into the reference vessels, 4 ml HNO_3 and 0.2 ml H_2O_2 were added, and the carousel was positioned into the microwave unit. The system was pre-programmed for 1 min of microwave digestion at 250 W power and another 5 min at 500 W power and left for automatic ventilation for 10 min. The digested solution was cooled, filtered using Whatman filter paper No. 40, and made up to 100 mL with Milli-Q distilled water and stored in special containers ready for analysis.

Biological (Crustacean/Mollusca/ Annelida) samples: 1g dry weight of the discrete regions of sample (organ) were introduced in to Teflon reaction vessel and 5mL of 65% Nitric acid was added, the vessel was inserted into microwave chamber and subjected for digestion program as follows

Step-I : 5 minute at 20% power (240W); 1 minute at 30% power (360W); 5 minutes at 25 % power (300W), cooled and the digester was reopened.

Step-II: 1mL of 30% Hydrogen peroxide was added and set to 25% power 3 minutes, 50% power (600W) for 3minutes, cooled and the digester was reopened.

Step-III: 1mL of (20%) Perchloric acid was added and power set to 50% (600W) for 2 minutes, cooled and the digester was reopened.

The resulted sample was cooled and appropriately diluted using deionised water.

Heavy metal analysis

Atomic absorption spectrophotometer (AAS-6300, Shimatzu) with Wizard software was used to estimate the heavy metals viz., Fe, Pb, Zn, Mn, Ni, Cu, Cr, Co and Cd. Two types of atomizers viz., flame and graphite furnaces were functioned to evaluate the metal concentrations at ppm and ppb levels respectively. The sample whose metal concentration was below the detection limit in flame furnace was subjected to graphite furnace analysis.

RESULTS AND DISCUSSION

Heavy metal concentration in Macrophytes

The concentration of heavy metals in sixteen aquatic macrophytes of four different species from eight locations of Cauvery river was presented in Table 1. As depicted in Table 1, distribution of different elements in the macrophytes was similar and interesting.

In general concentration of Fe was observed more (1375.6 μg g^{-1}) in roots of *Nymphae stellata* collected from station V7 whereas, stem of the *Aqatic neam* collected from station V4 showed lesser accumulation of 137.34 μg g^{-1}. Highest concentration (0.98 μg g^{-1}) of Pb was found to be accumulated in *Vallisnaria spiralis* roots of station V8. While, *Pistia stratioles* leaf collected from station V1 recorded lowest concentration (0.11 μg g^{-1}). Zn was observed highest accumulation (44.12 μg g^{-1}) in stem of *Nymphae stellata*, collected from station V7 and lower concentration (1.86 μg g^{-1}) in *Pistia stratioles* of V2 station. Among the plant organs, only root of all the species showed considerable Ni accumulation with highest concentration (1.05 μg g^{-1}) in *Aqatic neam* root of station V8. Although leaf samples of *Vallisnaria spiralis* and *Aquatic neam* from V6 and V8 stations accumulated insignificant concentrations of Ni. *Nymphae stellata* root collected from V7 station recorded maximum concentration of Cr (0.96 μg g^{-1}) but, lowest concentration (0.12 μg g^{-1}) for stem of *Aqatic neam* from V4 station. Maximum Mn concentration (52.34 μg g^{-1}) was observed for *Vallisnaria spiralis* leaf sample of station V8 and minimum concentration (2.39 μg g^{-1}) for leaf of the same plant from station V1. Root of *Valisnaria spiralis* collected from station V6 showed highest Cu concentration (9.14 μg g^{-1}). In contrast lowest (0.17 μg g^{-1}) was observed for leaf sample of *Pistia sratioles* collected from station V2. Incredibly trifling concentrations of Cr was observed for root samples of all the macrophytes except *Pistia stratioles*.

Among the eight metals investigated, six (Fe, Pb, Ni, Cr, Cu, and Cd) showed higher rate of accumulation in the root whereas, remaining Mn and Zn showed more accumulation in stem and leaf respectively (Table 1). Further no such spatial variations were found in metal accumulation by macrophytes. Even though, downstream stations (V4-V8) managed to accumulate moderately higher metal concentrations than upstream stations (V1-V3) of the study area. A plant with numerous thin roots would accumulate more metals than one with few thick roots. Factors such as light intensity, oxygen stress and temperature are known to affect the uptake of minerals (Devlin, 1967). Moreover, the energy derived from photosynthesis and the oxygen released can improve conditions for the active absorption of elements. However, interactions between metals are often complex, and they are dependent on the metal concentration and pH of the water body (Balsberg-Pahlsson, 1989).

From the present observations it is documented that there is a uniform pattern of heavy metal variation in the macrophytes of the river Cauvery (Table 1). However the accumulation of a particular metal depends to a large, on the presence of the metal in the water column and sediment (Lilit and Baban, 2004). Of the four macrophytes *Vallesnaria spiralis* shows the greatest ability to accumulate Fe, Mn and Cu up to 914.94 µg g^{-1}, 41.08 µg g^{-1} and 5.20 µg g^{-1} respectively. *Nymphe stellata* showed the better ability to accumulate Zn (34.25 µg g^{-1}) and Cr (0.49 µg g^{-1}). The role of Zn and Mn in respiration as activators of enzymes involved in glycolysis and Krebs' cycle has been documented. *Vallisnaria spiralis* accounted for significant level of accumulation up to 0.65 µg g^{-1}. High Cu content is known to reduce photosynthesis and respiration rates in aquatic macrophytes (Vazguez *et al*., 2000). Cadmium was almost absent in freshwater macrophytes collected from whole study area. However, very least Cd concentration was recorded in *Aquatic neam* and *Vallisnaria spiralis*, of stations V6, V7 and V8. The presence of Cd in the macrophytes suggests the possible accumulation of cadmium in river environment (Zakova and Kockova, 1998). When arranged according to their accumulation, the following order was observed for the eight elements - Fe> Mn> Zn> Cu> Pb> Cr> Ni > Cd. In comparison with Indian standards for food (Awashthi, 2000) concentrations of all metals were well within the prescribed limits (Table 1).

It is a fact that aquatic plants due to photosynthetic activity change the oxygen regime of the rivers, which in turn has great importance for the growth and multiplication of the hydrobionts (Butterworth *et al*., 1972; Khosravi *et al.,* 2005). These macrophytes offer good condition for sediment, which in turn plays a very important role in proliferation of benthic community (Gopinathan and Sobhana, 2003). However, the positive role of aquatic macrophytes may become reverse in case of their massive growth.

The effects of trace elements in an aquatic ecosystem can be assessed by changes in the community structure, physiological activity and ultra structural components of macrophytes (Bradford, 1976; Patricia *et al.,* 2004). However, comparison of metal content in macrophytes is often difficult because of differences in sampling time (ageing of plants) and presence of pollution sources. Moreover, the metal data cannot be extrapolated from one species to another or even within the same species, largely due to differences in the rate of accumulation. The low availability of heavy metals in the river system could be due to the flow and its rate compare to stagnant lake system. As the concentration of highly toxic metals like – Cr, Cd, Pb and Ni was lower compared to the essential metals like Fe, Mn and Zn therefore, high metal concentrations in aquatic macrophytes observed in the study area may not directly reflect on the pollution level of these areas. Driel and Groot (1974) and Bower *et al.* (1978) have studied the metal uptake, translocation and effects in plants growing on naturally polluted and unpolluted river sediments. Their results suggest that aquatic plants may facilitate the transportation of metals from sediments up into shoots. The metals are thereby made available to grazing molluscs and, thus, reintroduced into the food web via fish to birds and humans (Arnulf, 1999). In addition, macrophytes in shallow coastal zones function as living filters for nutrients and metals that become bound to living plant material and remain in the inner archipelago areas (Sawidis *et al.,* 1995).

Heavy metal concentration in Benthos

Fe and Mn

Fe and Mn showed a similar distribution profiles which suggests that these metals were derived from the same source. Fe content in the benthos showed their highest values in station V6 (20.56 µg g^{-1} for mollusca) and station V8 (20.02 µg g^{-1} for crustacean and 16.37 µg g^{-1} for annelida) while, lowest values were recorded in station V2 (10.85 µg g^{-1} for mollusca, 11.42 µg g^{-1} for crustacean and 10.15 µg g^{-1} for annelida) (Table- 2). Mn concentration showed to more extent a similar distribution and spatial trend as iron for all benthos with highest value for mollusca (4.62 µg g^{-1}) and lowest for annelida (1.42 µg g^{-1}).

Table 1. Heavy metal concentrations (µg g^{-1}) in Aquatic macrophytes (dry weight) of Cauvery river

Location	Aquatic Macrophyte	Plant organ	Fe	Pb	Zn	Ni	Cr	Mn	Cu	Cd
Kushalanagara (V1)	*Valesnaria spiralis*	Root	928.24	0.49	16.42	0.21	0.47	9.68	1.05	BDL
		Leaf	229.31	0.19	10.21	BDL	0.18	2.39	0.46	BDL
	Pistia stratioles	Root	796.33	0.45	15.62	0.86	0..77	15.29	0.75	BDL
		Leaf	268.61	0.11	12.37	BDL	0.34	4.10	0.37	BDL
Ramanathapura (V2)	*Valesnaria spiralis*	Root	857.49	0.55	8.62	0.88	0.46	4.38	0.89	BDL
		Leaf	305.24	0.15	3.25	BDL	0.15	15.13	0.52	BDL
	Pistia stratioles	Root	1015.33	0.59	6.52	0.21	0.68	19.58	0.44	BDL
		Leaf	285.67	0.18	1.86	BDL	0.21	7.19	0.17	BDL
Hampapura (V3)	Nynpheae stellata	Root	1218.65	0.73	40.57	0.15	0.82	19.87	3.25	BDL
		Stem	572.30	0.21	43.37	BDL	0.20	43.77	0.85	BDL
		Leaf	321.87	0.20	21.47	BDL	0.29	51.25	1.29	BDL
		Flower	185.37	0.27	31.60	BDL	0.23	40.25	2.17	BDL
	Pistia stratioles	Root	867.65	0.53	39.65	BDL	0.68	38.74	0.95	BDL
		Leaf	285.44	0.19	19.27	BDL	0.22	15.64	0.24	BDL
Srirangapatna (V4)	*Valesnaria spiralis*	Root	892.43	0.88	21.44	0.98	0.53	18.67	5.14	0.12
		Leaf	210.82	0.56	8.17	BDL	0.19	32.45	1.29	BDL
	Aquatic neam	Root	596.54	0.94	15.28	0.97	0.62	16.43	3.85	0.10
		Stem	137.34	0.19	5.36	BDL	0.12	30.07	0.82	BDL
		Leaf	284.37	0.55	7.18	BDL	0.19	42.17	0.75	BDL
Bannuru (V5)	*Valesnaria spiralis*	Root	794.92	0.92	18.45	BDL	0.55	16.37	6.64	BDL
		Leaf	358.06	0.13	7.64	BDL	0.22	23.53	0.86	BDL
	Aquatic neam	Root	823.38	0.62	2.98	0.35	0.74	9.37	2.83	BDL
		Stem	295.34	0.12	6.98	BDL	0.15	13.55	0.91	BDL
		Leaf	315.40	0.37	9.73	BDL	0.26	17.29	0.97	BDL
Thirumakundlu Narasipura (V6)	*Valesnaria spiralis*	Root	1268.50	0.81	32.48	0.87	0.69	26.75	9.14	0.18
		Leaf	561.39	0.28	12.33	0.05	0.27	41.28	1.27	BDL
	Aquatic neam	Root	802.40	0.89	16.05	0.96	0.82	20.05	7.25	0.13
		Stem	214.22	0.22	8.46	BDL	0.20	17.38	0.95	BDL
		Leaf	295.20	0.28	8.24	0.09	0.28	27.22	0.53	BDL
Harale (V7)	*Nynpheae stellata*	Root	1375.61	0.87	39.74	0.93	0.96	15.60	1.39	BDL
		Stem	317.58	0.59	44.12	BDL	0.27	30.45	0.75	BDL
		Leaf	460.07	0.93	16.17	BDL	0.39	41.57	1.07	BDL
		Flower	192.35	0.81	35.18	BDL	0.36	27.88	1.09	BDL
	Pistia stratioles	Root	849.00	0.53	28.46	0.29	0.80	30.08	0.68	BDL
		Leaf	313.16	0.15	16.38	BDL	0.27	22.49	0.37	BDL
Arkavathi sangama (V8)	*Valesnaria spiralis*	Root	1185.90	0.98	30.58	0.67	0.75	29.82	6.16	0.21
		Leaf	507.36	0.32	17.34	0.04	0.30	52.34	0.96	BDL
	Aquatic neam	Root	957.64	0.93	21.28	1.05	0.83	12.31	5.33	0.19
		Stem	255.48	0.29	6.18	BDL	0.25	20.07	0.62	BDL
		Leaf	316.34	0.37	8.19	0.07	0.37	29.57	0.45	BDL
Indian Standards for food (Awashthi, 2000)			-	2.5	50	1-5	20	-	30	1.5

Table 2. Heavy metal concentrations (µg g-1) in fish and benthic organisms (dry weight) and their bioaccumulation factor (BAF) of river Cauvery

Location	Metal	Crustacean		Mollusca		Annelida	
		Crab	BAF	Mussel	BAF	Oligo chaeta	BAF
Kushalanagara (V1)	Fe	11.35	0.006	13.23	0.008	11.85	0.007
	Pb	BDL	0.000	0.15	0.000	BDL	0.000
	Zn	3.73	0.094	3.49	0.088	2.83	0.071
	Ni	1.75	0.029	1.93	0.043	1.58	0.070
	Cr	0.10	0.000	BDL	0.000	BDL	0.000
	Mn	1.84	0.215	2.01	0.235	1.42	0.166
	Cu	0.65	0.492	0.72	0.545	0.55	0.417
	Cd	BDL	0.000	0.11	0.000	BDL	0.000
Ramanathapura (V2)	Fe	10.85	0.002	11.42	0.002	10.15	0.002
	Pb	BDL	0.000	BDL	0.000	BDL	0.000
	Zn	3.14	0.185	4.10	0.241	2.48	0.146
	Ni	0.84	0.091	1.63	0.176	1.25	0.135
	Cr	BDL	0.000	BDL	0.000	BDL	0.000
	Mn	1.75	0.083	1.93	0.091	1.50	0.071
	Cu	0.82	0.287	0.69	0.241	0.61	0.213
	Cd	0.00	0.000	BDL	0.000	BDL	0.000
Hampapura (V3)	Fe	15.65	0.001	16.27	0.001	12.39	0.001
	Pb	BDL	0.000	0.11	0.042	BDL	0.000
	Zn	5.10	0.041	5.14	0.041	3.11	0.025
	Ni	1.01	0.050	1.79	0.089	1.52	0.075
	Cr	BDL	0.000	0.13	0.009	BDL	0.000
	Mn	2.31	0.028	2.45	0.029	1.98	0.024
	Cu	1.07	0.162	1.09	0.165	0.85	0.129
	Cd	BDL	0.000	BDL	0.000	BDL	0.000
Srirangapatna (V4)	Fe	14.66	0.001	16.82	0.001	13.09	0.001
	Pb	BDL	0.000	0.12	0.025	BDL	0.000
	Zn	4.87	0.042	5.24	0.054	3.48	0.036
	Ni	1.29	0.036	1.85	0.051	1.25	0.035
	Cr	BDL	0.000	0.13	0.006	BDL	0.000
	Mn	2.52	0.018	2.60	0.018	2.14	0.015
	Cu	0.98	0.038	1.13	0.044	0.96	0.038
	Cd	BDL	0.000	BDL	0.000	BDL	0.000
Bannuru (V5)	Fe	13.57	0.002	16.66	0.002	13.04	0.002
	Pb	BDL	0.000	BDL	BDLo	BDL	0.000
	Zn	4.62	0.106	5.08	0.117	4.10	0.094
	Ni	1.65	0.037	1.70	0.038	1.33	0.030
	Cr	BDL	0.000	0.17	0.009	BDL	0.000
	Mn	2.39	0.019	2.86	0.023	2.41	0.019
	Cu	0.79	0.041	1.21	0.062	0.70	0.036
	Cd	BDL	0.000	BDL	0.000	BDL	0.000
Thirumakundlu .Narasipura (V6)	Fe	20.02	0.001	17.52	0.001	15.64	0.001
	Pb	0.10	0.011	0.17	0.018	BDL	0.000
	Zn	7.33	0.071	7.45	0.072	5.93	0.057
	Ni	2.01	0.029	2.25	0.032	2.03	0.029
	Cr	0.11	0.001	0.27	0.004	BDL	0.000
	Mn	3.26	0.015	3.95	0.018	2.87	0.013
	Cu	1.42	0.027	1.68	0.032	1.20	0.023
	Cd	BDL	0.000	0.10	0.029	BDL	0.000

Location	Metal	Crustacean		Mollusca		Annelida	
		Crab	BAF	Mussel	BAF	Oligo chaeta	BAF
Harale (V7)	Fe	18.69	0.003	19.56	0.004	14.92	0.003
	Pb	0.13	0.019	0.14	0.021	BDL	0.000
	Zn	6.62	0.061	7.58	0.070	5.43	0.050
	Ni	1.85	0.060	1.96	0.063	1.81	0.059
	Cr	BDL	0.000	0.20	0.003	BDL	0.000
	Mn	3.28	0.027	3.42	0.028	2.55	0.021
	Cu	1.29	0.036	1.33	0.037	1.17	0.033
	Cd	BDL	0.000	0.11	0.029	BDL	0.000
Arkavathi sangama (V8)	Fe	19.63	0.001	20.56	0.001	16.37	0.001
	Pb	0.13	0.012	0.20	0.019	0.10	0.009
	Zn	6.91	0.108	7.22	0.112	5.24	0.082
	Ni	2.26	0.029	2.88	0.037	1.93	0.025
	Cr	0.20	0.002	0.32	0.004	0.13	0.002
	Mn	4.58	0.012	4.62	0.013	3.24	0.009
	Cu	1.21	0.017	2.01	0.029	1.54	0.022
	Cd	0.12	0.036	0.17	0.051	0.10	0.030

Zn and Cu

Zn stands next to the iron in terms of benthos accumulation. As essential element, Zn content among the benthos has not expressed much variation. However, spatial distribution was appeared to be at substantial extent. Comparatively Zn concentration was high in mollusca (7.58 µg g^{-1}) followed by crustacean (7.43 ìg g^{-1}) and annelida (5.93 µg g^{-1}). Cu concentration was elevated towards the downstream stations. Highest concentration was recorded for mollusca (2.01 ìg g^{-1}) and lowest for annelida (0.55 µg g^{-1}).

Ni and Cr

The concentrations of Ni in mollusca are usually higher than that of crustacean and Annelida in all sampling localities (Table 1). The values varied from 1.63 to 2.88 µg g^{-1} (mollusca), 0.84 to 2.26 µg g^{-1} (crustacean) and 1.25 to 2.03 µg g^{-1} (annelida). Negligible extent of concentrations was observed for all the benthos with highest value (0.32 ìg g^{-1}) for mollusca collected from station V8. In case of annelida only station V8 has showed Cr accumulation at very lesser extent. Station V2 of the study area has not recorded chromium content in its benthos samples.

Pb and Cd

It is evident that, as the nonessential elements Pb and Cd accumulation in benthos was very insignificant. Mollusca collected from downstream station (V8) showed highest concentration for Pb (0.20 µg g^{-1}) and Cd (0.17 µg g^{-1}). In annelida except station V8 all other exhibited below detection limit (BDL).

The benthic studies highlighted their ability to detect temporal changes in metal availabilities. Downstream stretch of the study area usually has high concentrations of most metals. Such differences were apparent for almost all metals. These differences may well be attributable to changes in anthropogenic input of metals or to changes in physicochemical factors which affect the uptake of many trace metals (Rainbow, 1997). From the present investigation, it is obvious that mollusca have showed comparatively higher accumulation capacity among the benthic organisms for almost all the metals followed by crustacean and annelida. Similar results have reported by Mohamed (2005) in their studies on benthic invertebrates. Molluscs have the ability to filter large volume of water, uptake and accumulate metals in their bodies without noxious effects (Lobel *et al.*, 1990; Metcalfe- Smith *et al.*, 1992; Byrne and Vesk, 2000). The results of current study indicate that mollusca have the highest concentrations of most trace metals measured. This accumulation of several metals is due to the low capacity of the mollusca for discriminating

among metals which are similar in some characteristics such as ionic radius (Metcalfe-Smith, 1994). Mollusca also possess a variety of effective detoxification mechanisms to reduce the toxicity of the metal uptakes (Byrne and Vesk 2000).

Bioaccumulation factor (BAF)

The bioaccumulation of all eight heavy metals in different samples of fish and benthic organisms in the river Cauvery was quantified with a bioaccumulation factor (BAF).

In the present study bioaccumulation factor (BAF) (Table 2), showed increase trend from upstream to downstream for all the metals i.e. the downstream of the river has high values of most metals which can be explained on the basis of anthropogenic pollutants income to the Cauvery in the downstream stretch. Also, the BAF values showed elevated trend in case of essential trace metals (Fe, Mn, Zn, Ni and Cu), while they showed an obvious decrease in nonessential trace metals (Pb and Cd).

BAF for benthos in the study area is in the sequence of Cu>Mn>Zn>Ni>Fe >Cr>Pb>Cd. The BAF values for different heavy metals from water to benthos or sediment to benthos are a key component of human exposure to the metal through food chain. The lowest BAF value in this study is for Cd; one of the likely reasons is being that it is more mobile in the natural environment than the other metals.

CONCLUSIONS

This study concludes that *Vallesnaria spiralis* showed significant biomonitor for the trace metals in the fresh water river system and accumulation is in the order of Fe>Mn> Zn>Cu>Pb>Cr>Ni>Cd. Among benthos mollusca have showed more accumulation capacity fallowed by crustacean and annelida. Bioaccumulation factor for benthos observed in the sequence of Cu>Mn>Zn>Ni>Fe>Cr>Pb>Cd. Elevated trend was noticed among the essential metals and decreased trend among the non essential metals in both macrophytes and benthos. Samples from downstream stations with high degree of metal accumulation compare to upstream stations revealed odds of pollutants from nonpoint sources too.

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