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Original Research Paper

Pollution Load of Four Heavy Metals in Water, Sediment and Benthic Organisms in the Kulti River of Sundarban Fed by Metropolitan Sewage

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ABSTRACT

The degree of heavy metal contamination was estimated in the river water, sediments and benthic organisms in the Kolkata metropolitan sewage outfall zone and downstream areas along the Kulti River track. Four heavy metals namely Cr, Pb, Zn and Cd were studied seasonally. The hierarchy of heavy metals in the water samples and sediments was found in the order Zn>Pb>Cr>Cd and Zn>Cr>Pb>Cd respectively in most of the cases. Among the four heavy metals, Pb was found to be beyond the permissible limit recommended by Central Pollution Control Board of India for inland discharge. The extent of contamination by Cd is very prominent in the sediments followed by Pb, which is observed not only in the outfall region but also found persistent in the downstream stations. On the other hand contamination of Zn and Cr was not found to be widespread. Contamination in sediments of the outfall zone was most pronounced during the monsoon, while in the same season it was observed least in case of water samples. The pollution load index study revealed that the overall metal pollution load depleted towards the downstream. Among the two benthic organisms studied, metals were found to be accumulated more in *Uca rosea* than *Boleopthalmus* spp.

INTRODUCTION

Heavy metals are present in streams as a result of chemical leaching of bed rocks, water drainage and runoff from the banks, and discharge of urban and industrial wastewaters (Soares 1999). Due to rapid industrialization over the past century, heavy metals have been discharged into the major rivers and estuaries of the world (Tam & Wong 2000, Cobelo-Garcia & Prego 2003, Chen et al. 2004, Pekey 2006). Sediments have been widely used as indicators of environmental pollution because of their ability to trace contamination sources (Sayadi et al. 2010, Camusso et al. 2002, Bermejo Santos et al. 2003). The metals can be either adsorbed onto sediments or get accumulated in benthic organisms, sometimes, to toxic levels (Singh et al. 2005).

The city of Kolkata with 141 municipal wards in the core area is inhabited by more than 15 million population. There are approximately 11,516 small and large factories in and around the city, which produce toxic chemicals (Mitra & Gupta 1999). Way back in 1997, it was reported that the Kolkata Municipal Corporation area generates about 750 million litres of sewage and wastewater every day and more than 2500 metric tons of garbage (Ghosh 2005), which is assumed to have increased in the last decade. The wastewater is lead by underground sewers to the pumping stations in the eastern limits of the city, and then pumped into open channels (called dry weather flow or D.W.F. and storm weather flow or S.W.F.). Most of the effluents released from the industrial sector, situated in outskirt of the metropolitan area, pass through the above mentioned drainage system to the Kulti river. The Kulti river lock gate, located 35 km south east of city, is the exit point of all the wastes of the city that generate due to multifarious industrial and anthropogenic activity (Mitra & Gupta 1999). Moreover, this area is the northern limit of Indian Sundarban, demarcated by Dampier-Hodges line with the appearance of mangroves. The present study is an attempt to estimate the pollution load of four heavy metals Cr, Pb, Zn and Cd in the river water, sediment and benthic organisms namely *Uca rosea* and *Boleopthalmus* spp. of Kulti river (also called Bidyadhari River) from the metropolitan sewage outfall zone to downstream areas. These benthic organisms were purposely chosen as they are the most common and abundant dwellers in this region. The work has been comprehensively carried out in three months covering three seasons respectively namely pre-monsoon (April), monsoon (August) and post-monsoon (December) in the year 2009. River water and sediments were collected from the river bank during three seasons, whereas, benthic organisms were collected only during pre-monsoon and monsoon.

Three locations, namely Ghusighata, Malancha and Kanmari Bazar were chosen for sampling, situated at the sewage outfall, 5 km and 10 km distant downstream from the outfall respectively, along the track of the river. Ten samples of each type were randomly taken from each site for analysis. All the data presented in this work are the corresponding mean along with the standard deviation of the 10 replicate samples.

MATERIALS AND METHODS

The water samples were collected in a one-litre nonreactive plastic container and 4 mL of concentrated nitric acid was added to stop further biological activity and prevent degradation. The sediments and benthic organisms were collected in the plastic lock bags, taken in the ice box and sent back to the laboratory within 24 hours for further analysis.

Five mL of aqua regia was added to each water sample of 1-litre and allowed to digest at 75°C. The volume was reduced to 40 mL and filtered through Whatman No. 42 filter paper, and the final volume was made to 100 mL by double distilled water. Each soil sample was digested in a similar way by mixing 5g of homogenous sediment with 50 mL distilled water and 10 mL aqua regia and heated at 75°C. The samples were reduced to 20 mL and then re-digested by adding 5 mL aqua regia. After having digested twice, the final sample solution was prepared by filtering through Whatman No. 42 filter paper and the volume was made up to 100 mL by double distilled water. The benthic organisms were rinsed with distilled water to remove the debris from the body and frozen at 10°C. They were then defrosted for two hours and heated at 80°C and the dry weight was recorded until constant weight was achieved. The dried samples were ground in a clean, dry mortar and sieved through 0.02 mm pore size. Half (0.5) g of each sample was treated with 5 mL concentrated nitric acid and digested. The digested samples were filtered and the filtrate was made up to 50mL (Olowu et al. 2011).

Heavy metals in water were determined by Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES. Model No. ICAP6300DUO (THERMO)) after proper acid digestion (APHA 1993). The heavy metals of the sediment and benthic organisms were analysed with Atomic Absorption Spectrophotometer (Model No. AA50-VARIAN).

In order to understand the magnitude of contamination of trace metals, the observed trace metal values were utilized to find the contamination factor (CF). While computing the CF of sediments of the area, world average concentrations of these elements reported for Shale (Martin & Meybeck 1979) were taken as the background values. The pollution level of trace metals was calculated by a simple method based on Pollution Load Index (Tomlinson et al. 1980). Contamination Factor (CF) and Pollution Load Index (PLI) were calculated by using following formulae:

$$CF = C_{Metal}/C_{Background\ value}$$

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \ldots\ldots\times CF_n)^{1/n}$$

Where CF = Contamination factor

n = Number of metals

C_{Metal} = Metal concentration in sediments

$C_{Background\ value}$ = Background value of that metal

RESULTS ANS DISCUSSION

The hierarchy of heavy metals in river water was present in the order of Zn>Pb>Cr>Cd in all the stations during all the seasons (Table 1), with a solitary exception in the outfall

Table 1: Mean ± S.D. concentrations of heavy metals (mg/L) studied in the river water. BDL = Below dtection limits

Stations	Ghusighat (0 km)				Malancha (5 km)				Kanmari Bazar (10 km)			
Heavy metals	Cr	Pb	Zn	Cd	Cr	Pb	Zn	Cd	Cr	Pb	Zn	Cd
Pre-monsoon	1.09 ± 0.49	0.23 ± 0.11	0.50 ± 0.21	0.01 ± 0.1	0.13 ± 0.06	0.16 ± 0.11	0.18 ± 0.09	BDL	0.05 ± 0.04	0.08 ± 0.02	0.13 ± 0.1	BDL
Monsoon	0.02 ± 0.01	0.022 ± 0.01	0.034 ± 0.02	BDL	0.024 ± 0.02	0.032 ± 0.02	0.034 ± 0.01	0.008 ± 0.002	0.008 ± 0.004	0.018 ± 0.009	0.04 ± 0.013	0.03 ± 0.02
Post-monsoon	0.18 ± 0.09	0.36 ± 0.17	0.55 ± 0.03	0.03 ± 0.01	0.05 ± 0.03	0.38 ± 0.11	0.49 ± 0.21	0.06 ± 0.04	0.07 ± 0.11	0.36 ± 0.14	0.71 ± 0.24	0.06 ± 0.01

Table 2: Mean ± S.D. concentrations of heavy metals (mg/kg) studied in the river bank sediment.

Stations	Ghusighat (0 km)				Malancha (5 km)				Kanmari Bazar (10 km)			
Heavy metals	Cr	Pb	Zn	Cd	Cr	Pb	Zn	Cd	Cr	Pb	Zn	Cd
Pre-monsoon	65.4 ± 5.34	40.70 ± 6.73	87.7 ± 14.5	1.49 ± 0.53	36.7 ± 2.31	55.2 ± 10.9	67.9 ± 15.32	1.3 ± 0.23	40.4 ± 7.68	26.7 ± 8.23	65.6 ± 5.55	0.7 ± 0.23
Monsoon	140.2 ± 23.34	41.7 ± 3.45	106 ± 34.32	2.29 ± 1.10	52 ± 3.35	30.8 ± 12.23	72.4 ± 3.21	1.49 ± 0.09	36.3 ± 10.91	29.0 ± 9.34	64.8 ± 11.17	1.30 ± 0.19
Post-monsoon	91.84 ± 26.78	32.74 ± 8.21	102.97 ± 20.01	1.20 ± 0.34	74.53 ± 8.11	18.39 ± 3.22	72.74 ± 11.29	0.94 ± 0.33	39.8 ± 1.12	24.2 ± 4.27	68.2 ± 5.67	0.94 ± 0.21

station during pre-monsoon where Cr exceeded all the other heavy metal concentrations. In some cases, Pb surpassed the permissible limit (0.1 ppm) of heavy metals of inland discharge recommended by Central Pollution Control Board (CPCB) during pre-monsoon and post-monsoon in all the stations. However, Cr, Zn and Cd concentrations have not crossed the permissible limit of heavy metals during three seasons at all the stations in the river water.

During monsoon, none of the metals were found beyond the CPCB recommended permissible limit at all the stations and showed much less concentration than pre-monsoon and post-monsoon. This may be because of high dilution rate of river water during the monsoon. However, heavy metals did not always show highest values at the outfall station in comparison with downstream stations.

The abundance of heavy metals in the sediments in most of the cases were found aligned in the order of Zn>Cr>Pb>Cd (Table 2). Almost in all the instances, the heavy metals showed significant decreasing trend in the downstream stations. No significant correlation was found between a specific heavy metal concentration in the sediment and that of in the river water.

An important observation of this study is that, concentration of all the heavy metals in sediments is highest at the outfall station during the monsoon, although in most of the cases, heavy metals exhibited lowest value in the river water during the monsoon. Contaminants generally enter the rivers through two pathways: (1) identifiable point sources such as municipal and industrial wastewater effluents, and (2) diffuse sources, closely related to the meteorological factors. Major diffuse sources include surface runoff, erosion and the atmospheric deposition. Both point and diffuse sources contribute to the total contaminant load of the rivers (Barcel'o 2004). So, it is very much possible that the contaminant load from the diffuse sources would increase during the monsoon and being deposited maximum in the sediment of outfall region, but because of high dilution rate, heavy metal concentrations in the river water showed a decline per volume concentration during the monsoon.

Contamination factor (CF) of Cd was observed to be highest among these four heavy metals and much greater than unity in all the cases (Table 3). The CF of Pb was also higher than 1 in almost all the cases except in 5 km downstream during post-monsoon, which might be due to lower dissolution of Pb compounds in water as observed by Sayadi et al. (2010) in riverbed sediment from Chitgar industrial area of Iran. CF of Cr and Zn were greater than 1 only in outfall station during monsoon. This observation clearly indicates that sediment of the outfall and downstream areas are highly contaminated with Cd followed by Pb. Compara-

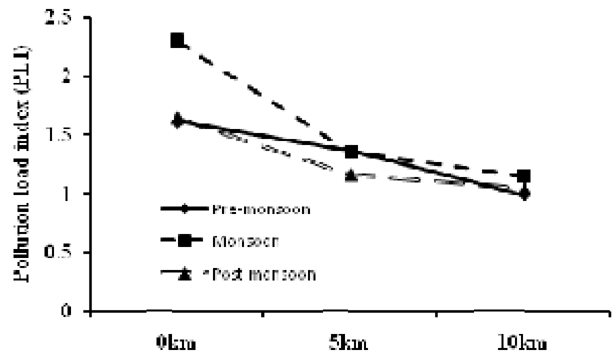

Fig. 1: Variability of pollution load index (PLI) from the outfall zone to downstream stations.

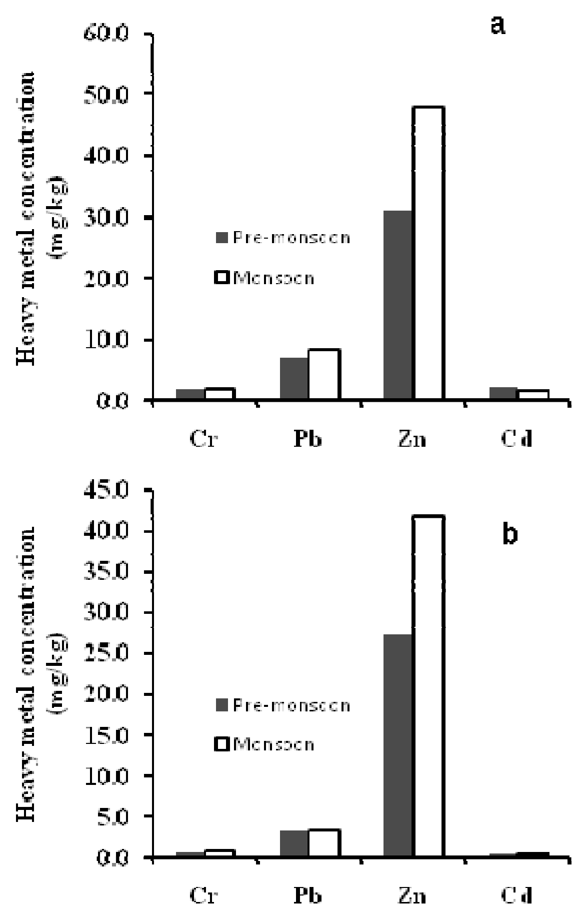

Fig. 2: Seasonal heavy metal concentration level in (a) *Boleopthalmus* spp. and (b) *Uca rosea.*

ble observation was reported by Jain (2004) in case of Yamuna river of India. Contamination of Cr and Zn is much less and not widespread towards downstream areas. Pollution load index (PLI) was (Fig. 1) highest during the monsoon at the outfall station (2.29). Although PLI showed greater

Table 3: Seasonal variability of contamination factor (CF) in the respective stations.

Heavy metals		Cr	Pb	Zn	Cd
World Shale average (mg/kg)		90	20	95	0.3
Pre-monsoon	0km	0.72	2.04	0.92	4.97
	5km	0.4	2.76	0.71	4.33
	10km	0.45	1.34	0.69	2.33
Monsoon	0km	1.55	2.09	1.12	7.63
	5km	0.58	1.54	0.76	4.97
	10km	0.4	1.45	0.68	4.33
Post-monsoon	0km	1.02	1.64	1.08	4
	5km	0.83	0.92	0.77	3.13
	10km	0.44	1.21	0.72	3.13

values than 1 in almost all the stations but it also showed significant decreasing trend towards downstream. Concentration of Cr was found to be highly correlated with concentration of zinc (r = 0.92). This type of correlation (> 0.9) may be due to their common source, mutual dependence and/or identical behaviour during transport as observed by Jain et al. (2005). No other significant correlation was found between the other metals in the sediment.

All the four heavy metals were found to be higher in *Uca rosea* than in the *Boleopthalmus* spp. (Fig. 2), which indicates more reliability of the later regarding membrane permeability (Mitra et al. 2006). In all the cases heavy metals followed the hierarchy of Zn>Pb>Cr>Cd in both the species during the two seasons studied. The only exception was Cd found to be greater than Cr in the pre-monsoon. Cr, Pb and Zn have been observed to be higher in the monsoon than summer, whereas Cd showed a reverse trend.

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