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Distribution of Metals in Representative Biota of Sundarban Mangrove Wetland, Northeast India

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The effect of metals – among other contaminants – on aquatic organisms are of increasing concern as greater amount of potential pollutants are mobilized to the environment by human activities. Anthropogenic sources of metals, including urban runoff, sewage, traffic emissions, coal and oil combustion, industrial production, mining and the smelting of ores (Eisler 1981; Moore and Ramamoorthy 1993), have lead to a significant enhancement of metal concentrations in coastal areas with its inherent toxic threat. The present collaborative work has been set out to evaluate the status of metal concentrations in the representative biota inhabiting the Sundarban wetland environment (NE India) and to assess their potential for the biomonitoring of metal contamination.

MATERIALS AND METHODS

The Indian Sundarban (Figure 1), the largest delta (4267 km^2) in the estuarine phase of the river Ganges, is a unique bioclimatic zone in a typical geographical situation in the coastal region of Bay of Bengal. It has the potential for being a global biodiversity 'hotspot' as it is a reservoir of very rich and diverse faunal and floral communities (Bhattacharya and Sarkar 2003). This coastal environment suffers from environmental degradation due to rapid human settlement, tourist activities, deforestation, and increasing agricultural and aquacultural practices. Multifarious industries namely, paper, tanneries, textile, chemicals, pharmaceuticals, plastic, shellac, leather, jute etc., are situated on both the banks of the Ganges estuary. In addition to the untreated wastes from these "point sources", the estuary also receives the raw sewage from 85 km upstream, discharge from the highly urbanized metropolitan mega city of Calcutta (population 14.5 million) as well as Howrah city.

During November 2002, the bivalves and gastropods indicated in Table 1 were sampled at low tide level from the intertidal zone of a mud flat embracing the eastern and western part of Sagar Island (22^{0}19'N; 80^0 03'E, Figure 1). Fishes

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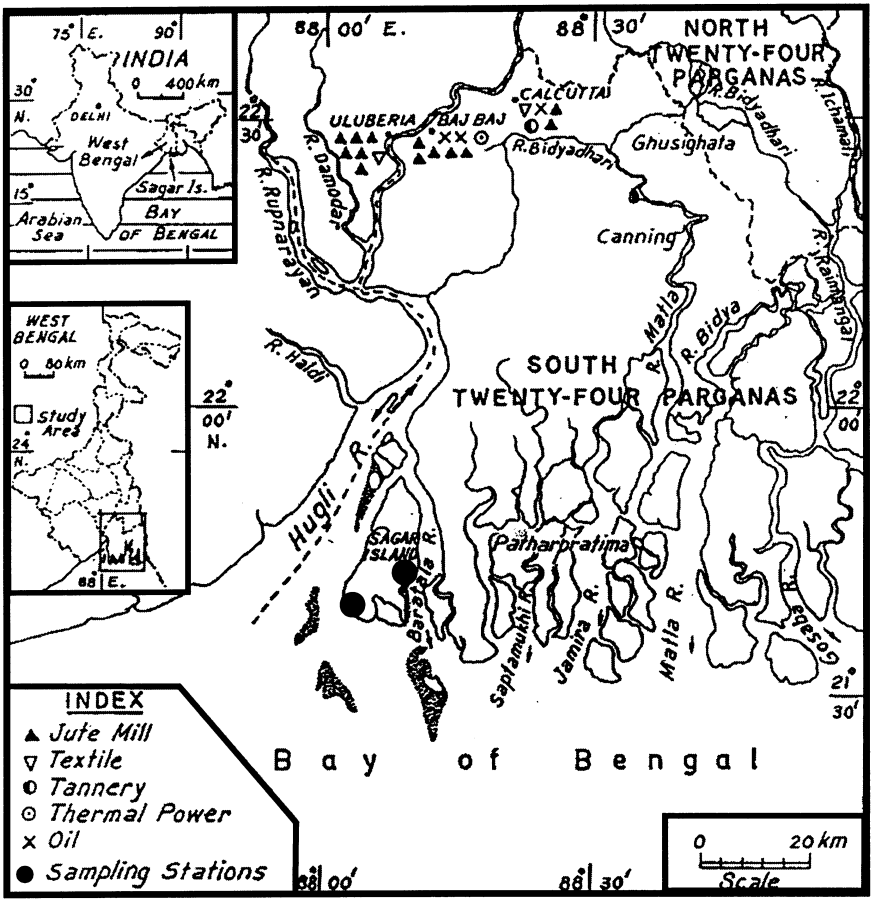

Figure 1. Map of the Indian Sundarban showing the location of sampling stations.

(Table 1) were collected either from the fishermen or by netting. Collection and handling of the samples was carried out according to well-established methodology (Simpson 1979; NAS 1980). All the samples were oven-dried at 60°C until constant weights were obtained, and then ground in a agate mortar in order to homogenize the sample. Prior to metal determination samples were microwave-digested in Teflon bombs using a HNO_3/H_2O_2 (Merck Suprapur) mixture. Samples were then determined by means of GF-AAS. Blanks of the analytical procedure were run and results were blank corrected. The accuracy of the analytical procedure was checked analyzing a dogfish muscle certified reference material (DORM-2, NRC Canada) finding good agreement with the certified values (Table 2).

Table 1. Summary of the key features of the species investigated (mean values ± standard deviation).

Species	Family	Common name	Range of body/shell(cm)
Macoma birmanica	Tellinidae	Mussel	6.85 ± 0.95
Meretrix meretrix	Veneridae	Mussel	6.54±0.87
Saccostrea cucullata	Ostreidae	Rock oyster	7.29±0.95
Cerithidea cingulata	Potamididae	Gastropod	2.32 ± 0.01
Thais lacera	Muricidae	Gastropod	3.38 ± 0.08
Telescopium telescopium	Potamididae	Gastropod	6.98 ± 0.95
Nerita articulate	Neritidae	Gastropod	2.38 ±0.36
Harpodon nehereus	Harpodontidae	Bombay duck	17.28±1.88
Trichiurus sp.	Trchiuridae	Ribbon fish	24.66± 1.08
Boleopthalmus sp.	Gobidae	Gobid fish	11.64± 0.98
Daysciaena albida	Sciaenidae	Bhola bhetki	10.26± 0.85
Coila reynaldi	Engraulidae	Amedi	8.88± 1.02

Table 2. Concentrations ($\mu g\ g^{-1}$) of elements obtained for dogfish muscle certified reference material (DORM-2, NRC Canada).

Metal	Obtained value	Certified value
Pb	0.063 ± 0.018 (*n*=5)	0.065 ± 0.007
Cu	2.41 ± 0.28 (*n*=5)	2.34 ± 0.16
Cr	26.1 ± 4.3 (*n*=8)	34.7 ± 5.5
Cd	0.042 ± 0.003 (*n*=4)	0.043 ± 0.008
Fe	140 ± 19 (*n*=6)	142 ± 10
Zn	28.8 ± 5.9 (*n*=4)	25.6 ± 2.3

RESULTS AND DISCUSSION

The concentrations of the different metals in the organisms under study are shown in Table 3. Copper concentrations ranged from low levels in the dorsal muscles of the fishes *Boleopthalmus sp.* and *Coila reynaldi* (3-5 $\mu g\ g^{-1}$) to values up to 2000 $\mu g\ g^{-1}$ in the bodymass of the gastropod *N. articulata* and the gill of the oyster *S. cucullata*. Cd showed a similar behavior than Cu, with lowest concentrations (down to 0.03 $\mu g\ g^{-1}$) in fishes and highest in *N. articulata* (37 $\mu g\ g^{-1}$) and *S. cucullata* (13-57 $\mu g\ g^{-1}$). Zn ranged from <100 $\mu g\ g^{-1}$ in the fishes and bivalve *M. meretrix*, reaching the highest values (as for Cd and Cu) in the *S. cucullata* and *N. articulata*. Fe also showed a high variability among species and organs, but following a different trend than Cu, Cd and Zn; accordingly, highest concentrations were found in the mantle of the *M. birmanica* (2096 $\mu g\ g^{-1}$) and the gill, mantle and visceral mass of the *M. meretrix* (1915-3310 $\mu g\ g^{-1}$), and the lowest values were found in *N. articulata* (58 µg g^{-1}) and the fishes *Tricurus sp.* and *Boleopthalmus sp.* (50-96 µg g^{-1}). Pb (0.1-10.0 µg g^{-1}) and Cr (1.1-13.6 µg g^{-1}) did show low concentrations, even lower than those found in the neighboring sediments (17 µg g^{-1} for Pb and 37 µg g^{-1} for Cr; Sarkar et al. 2004), indicating that the net uptake of these elements was very limited. Unlike Cu, Cd and Zn, however, highest Pb concentrations were found in the gill and mantle of the bivalves *M. birmanica* and *M. meretrix*. A different bioaccumulation pattern was also found for Cr, with the highest concentrations in the fishes *D. albida* and *C. reynaldi* (10.3-13.6 µg g^{-1}), and the gill and mantle of *M. meretrix* (10.0-13.4 µg g^{-1}).

These results clearly indicate the different selectivity of the different organisms on the bioaccumulation of every different metal, as well as on the different organs of the same specimen. Cu, Cd, Zn and Fe showed a high variation among different species and different organs, whereas Cr and Pb showed a lower variability with typical background values, showing no important net uptake by these metals or no Cr and Pb bioavailability. The high Cu, Zn and Cd concentrations found in the bivalve *S. cucullata* and the gastropod *N. articulata* are in agreement with the findings by Blackmore (2001) who showed the bioaccumulation of the oyster *S. cucullata* was considerably greater than the rest of invertebrates. The high accumulation capacity of oysters is well known (Phillips 1979; Phillips and Yim 1981); taking the typical metal concentrations in sediments of Gangasagar (Sarkar et al. 2004), i.e. 68 µg g^{-1} (Zn), 28 µg g^{-1} (Cu) and <0.1 µg g^{-1} (Cd), a bioaccumulation factor in the gill of the *S. cucullata* is as high as 49 for Zn, 71 for Cu and >130 for Cd. These results are in agreement with the previous study by Sarkar et al. (1994) who found a selective enrichment of these three metals (Cu, Zn and Cd) in *S. cucullata* from the lower part of Ganges estuary with the highest concentrations, 610 µg g^{-1}, 4100 µg g^{-1} and 40 µg g^{-1} respectively, in the vicinity of Sunderban mangrove wetland.

A marked organ-specific bioaccumulation was found in the three bivalves studied, the concentrations following the trend: mantle-gill > visceral mass-siphon-podium-adductor muscle. This elevated level of metals in gill and mantle may be attributed to (i) the mucous layer covering these organs which facilitates rapid accumulation of metals because of its ion-exchange properties and (ii) their close contact with the surrounding water giving rise to greater and faster accumulation (Pringle et al. 1968). The podium and adductor muscle were found to be poor reflectors of metals in the environment; these organs have no absorptive or secretary function and hence lower levels of metals were recorded when compared to other tissues.Among gastropods, highest concentrations of Cu, Cd and Zn were found in *N. articulata*. However, a considerably high concentration of Cu was also found in the *T. telescopium* (405 µg g^{-1}) and *C. cingulata* (331 µg g^{-1}), which may suggest the presence of the respiratory pigment haemocyanin (White and Rainbow 1985) which requires a high concentration of this element.

Table 3. Metal concentrations in different organs of biota species collected at Sagar Island, Sundarban mangrove wetland.

Name of specie	Organ/Body tissue	Pb	Cu	Cr	Cd	Fe	Zn
Macoma birmanica	Gill	8.9	40.5	3.6	1.6	909	259
	Mantle	10.0	117	5.3	1.7	2096	143
	Podium	0.1	12.4	4.3	0.6	203	128
	Siphon	3.9	17.2	4.7	2.4	712	148
	Adductor muscle	1.3	16.9	1.1	0.7	317	128
	Visceral mass	1.5	35.5	4.8	1.1	634	228
Meretrix meretrix	Gill	8.3	61.1	13.4	2.0	2840	92.8
	Mantle	4.5	49.6	10.0	1.6	1915	64.5
	Podium	2.6	37.9	6.7	1.6	344	5.6
	Adductor muscle	2.0	56.4	2.2	1.6	779	24.9
	Visceral mass	1.6	192	6.3	1.6	3310	87.7
Saccostrea cucullata	Gill	2.8	1986	3.1	13	435	3317
	Mantle	2.0	1466	2.3	47	805	3091
	Adductor muscle	1.2	688	1.4	57	296	1787
	Visceral mass	1.1	750	1.7	48	262	2809
Cerithidea cingulata	Whole body mass	1.1	331	4.0	0.7	754	176
Thais lacera	Whole body mass	0.8	25.5	4.8	16	249	106
Tel. telescopium	Whole body mass	0.7	405	1.9	0.7	524	131
Nerita articulata	Whole body mass	4.1	2036	2.6	37	58	925
Harpodon nehereus	Dorsal muscle	1.0	38.6	1.1	0.2	164	75.7
Tricurus sp.	Dorsal muscle	0.7	31.4	2.4	1.0	96	131
Boleopthalmus sp.	Dorsal muscle	0.6	3.0	2.8	0.03	50	42.9
Daysciaena albida	Dorsal muscle	1.0	23.6	10.3	0.7	459	95.1
Coila reynaldi	Dorsal muscle	3.2	4.6	13.6	0.09	428	35.3

Values expressed as $\mu g\ g^{-1}$ (dry weight basis).

Difference in metal accumulation was also found between the different species of fishes. Highest dorsal muscle Cu concentration was observed in *H. nehereus*, whereas for Zn it was found in *Trichiurus sp*. Elevated Cu concentrations was also observed in muscle tissue of *H. nehereus* from Bombay creek waters (W India; Krishnamurti and Nair 1999). The low concentration of heavy metals in finfishes was also observed by Bhattacharya et al. (1994) from Sagar Island (Sundarban) and a general affinity for accumulation of heavy metals (Fe, Zn and Hg) in *H. nehereus*. It is interesting to note that the levels of metals in fishes, as shown in Table 3, were far less compared to that in shellfish. This difference may arise from different factors such as the specific organs and species, feeding diet and environmental factors such as temperature, salinity and pH (Hakanson 1984; Badsha and Goldspink 1988) and also to the ability of fishes to move from place to place avoiding contaminated areas.

The present study represents a baseline contribution on concentrations of metals in species from the Indian Sundarban that is important, both in terms of ecology and human consumption. Results have shown that the bioaccumulation of metals in organisms is metal, organ, and organism specific. The oyster *S. cucullata* are widespread throughout the tropics and subtropics, occurring in the Indo-Pakistan sub-continent, eastern Africa, northwest Australia, New Zealand, the Philippine Islands, and Hawaii, amongst other areas (Ahmed 1975). The high Cu, Cd and Zn concentrations found in this oyster makes it – in terms of its distribution and bioaccumulation potential – to be prime candidates for the biological monitoring of pollutants in the tropical and subtropical coasts (Paez-Osuna and Ruiz-Fernandez 1995). On the other hand, it is necessary to continue this study in order to obtain information about other aspects related to metal speciation and bioavailability.

It is also worth noting that the high accumulation of several metals in some species (e.g. *S. cucullata*, *N. articulata*) needs the implementation of suitable contamination control and regular monitoring programme in order to avoid any potential threat for humans. The coastal areas of West Bengal are in a stage of rapid development and new mining, dredging and chemical activities are being undertaken to keep pace with development schemes. These processes may mobilize these metals in these coastal areas and expose the biota to a chronic contamination, impacting the marine environment in this location, as well as causing public health and economical hazards. Systematic mapping of sources of pollution and assessment of the heavy metal inputs into the Ganges estuary are recommended with a view to implement various pollution control measures by the environmental managers, public health officials and persons responsible for enforcing policy standards (Sarkar et al. 2004).

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