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Baseline

Trace metal distribution, assessment and enrichment in the surface sediments of Sundarban mangrove ecosystem in India and Bangladesh

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ABSTRACT

Comparative study of trace metals distribution in the surface sediment of Sundarban mangrove ecosystem in India and Bangladesh is one of the primary baseline study done so far. Trace metal distribution assessment covering lower salinity zone to higher salinity zone was done along Matla River (tidal river) in Indian side and freshwater zone to higher salinity zone along Passur River in Bangladesh side of Sundarban; representing anthropogenic influenced area, agricultural area, tourist site and pristine area. Trace metals distribution in the surface sediments of Sundarban mangrove ecosystem shows relatively higher value of trace metals, Co, Cr, Cu, Fe, Ni, Pb and Zn in Indian part when compared to Bangladesh. Enrichment factor shows the highest enrichment of Pb in both parts of Sundarban mangroves. Co, Cr, Cu, Pb and Zn show EF > 1 indicates sediment contamination from anthropogenic activities. Cr, Ni and Pb were found to have moderate accumulation in geoaccumulation index with Fe showing high accumulation. Normalized data of trace metals shows 87.5% from Indian site and 80% of Bangladesh site as outlier, indicating anthropogenic influence. Out of total sampling site 50% of Indian and 40% of Bangladesh site show trace metal values enriched more than predicted value of trace metals indicating Indian part have more polluted sites than Bangladesh side of Sundarban, which is also confirmed by enrichment factor, I-geo and normalization values in both the sides.

Trace metals are one of the most severe pollutants of mangrove ecosystem due to their toxicity, non-biodegradable nature and bio-accumulation (Macfarlane and Burchett, 2001). Sediment are the most significant component of the ecosystem, where trace metals accumulation and distribution occurs through various complex physical, chemical processes like adsorption, desorption, diffusion and biological activity, etc. (Bayen, 2012). Sorption of trace metal is promoted by different component of sediment like humic substance, carbonate, phyllosilicate and variable charged minerals. Trace metals shows ions exchange behaviour on silicate layer of clay particle having permanent charge. Clay mineral carrying different oxides and humic substances form organo-metal complexes (Violante et al., 2010), which enhance trace metal accumulation in sediment. Micro-organism like free living bacteria and their extra-cellular macromolecule products also accumulate trace metal forming a mineral coating on their surface (Beveridge, 1989; Jackson and Leppard, 2002). Trace metals desorption from sediment and forming of soluble complex with organic and inorganic ligands causes secondary release of various trace metals bounded to sediment into water (Krishnamurti et al. 1997; Mishra, 2014) helping in trace metal distribution. Sometimes, due to some physical disturbance and diagenetic process, pH or redox changes, mangrove sediment known as a sink of trace metals, starts releasing trace metals and act as a source (Jones and Turki, 1997).

Sundarban mangrove formed on Ganga-Brahmaputra delta is a tide-dominated mangrove surrounding hundreds of Island spread through India and Bangladesh. It covers an area of 10,200 km^2 of which 60% lies in Bangladesh and rest 40% in India (Fig. 1). It is a tide-dominated mangrove with many water channels bringing tonnes of sediment (Gurmeet, 2009; Mitra, 1998). Latest FSI report on mangrove cover shows a loss of 131 km^2 of mangrove since 1999 to 2015 (Forest Survey of India, 2015). During last four decades, Bangladesh has lost 66 to 127 km^2 of mangrove forest (Aziz and Paul, 2015).

A total number of 18 samples were collected in January–February 2015. Ten samples were collected from Bangladesh part of Sundarban and eight samples from Indian part of Sundarban. Samples were collected from freshwater zone (B-10) or lower salinity zone (I-1) to higher

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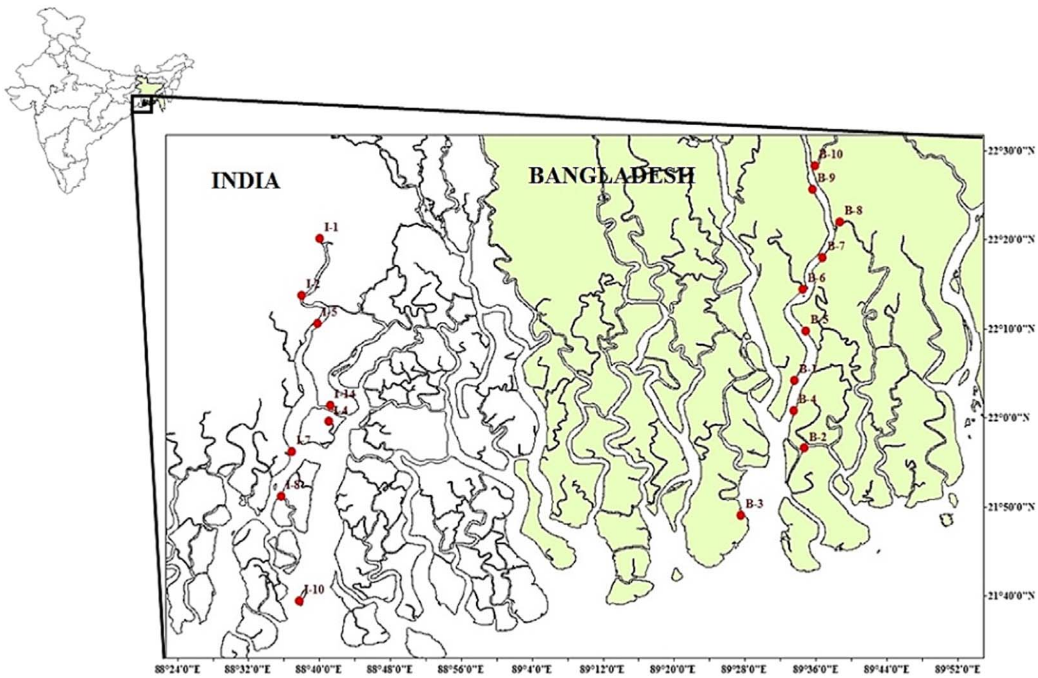

Fig. 1. Study area map showing sampling locations in Sundarban mangrove ecosystem (India and Bangladesh).

saline water zone (I-10, B-3). Sampling represents samples from each site of anthropogenic disturbance, human settlement, aquaculture and pristine mangrove forest to get the broad perspective of change in trace metal pollution with respect to anthropogenic changes.

Grain size analysis was done by Microtrac S3500 laser particle analyser (Konert and Vandenberghe, 1997). Organic carbon was analysed following WALKLEY and BLACK (1934).

Dried and grinded (< 63 μ) sediment samples were digested following method of Kulkarni et al. (2007). Prepared samples were analysed by ICP-OES (iCAP 6500, Thermo Scientific). Sediment standard reference material, NIST SRM 1646a and BCR 320R with certified concentrations for individual metals were used to validate our results (Table 2).

Quantification of trace metal alone does not infer the anthropogenic pollution from natural concentration. So, normalization was used to detect and quantify anthropogenic metal pollution from natural variability of trace metals (Loring, 1990). Many conservative elements have been used previously for normalization like Al (Bertine and Goldberg, 1977; Bruland et al., 1974; Calder et al., 1990; Trefry et al., 1985); Fe (White and Tittlebaum, 1985); Li (Loring, 1990) etc. In present study, Fe is taken as reference element as aluminium does not fulfill the criteria. Al does not show any correlation with sediment texture and trace metals, which is better fulfilled by Fe in both the parts of Sundarban mangroves.

EF is a geochemical index used to distinguished between the crustal and non-crustal sources or to estimate the anthropogenic source of trace metals using normalization of metal by uncontaminated background values (Dickinson et al., 1996). In the present study, we have used Fe as reference element as it shows significant correlation with other trace metals and inverse correlation with grain size. Element like Al, sometime give overestimation of EF (Mil-Homens et al., 2006; Zhang, 1995). EF is calculated using the equation:

$$\mathbf{EF} = \frac{\left(\frac{\mathbf{M}}{\mathbf{Fe}}\right)\mathbf{S}}{\frac{\mathbf{M}}{\mathbf{Fe}}\mathbf{B}}$$

EF < 2	Deficient to Minimal enrichment
EF = 2–5	Moderate enrichment
EF = 5–20	Significant enrichment
EF = 20–40	Very high enrichment
EF > 40	Extremely high enrichment

Where, $(M/Fe)_S$ is metal to Fe ratio in the sample of interest, and $(M/Fe)_B$ is geochemical background value of metal to Fe ratio.

The EF can be used to distinguish between the crustal and non-crustal source of trace metals as EF < 1 indicates crustal origin while EF > 1 are considered to be non-crustal (Nolting et al., 1999).

Trace metal accumulation in sediment is quantified in terms of geo-accumulation index given by Muller, 1969 with respect to background value of upper continental crust by following equation:

$$I = \log_1\left(\frac{Cn}{1.5Bn}\right)$$

Igeo ≤ 0	Practically uncontaminated
0 < Igeo < 1	Uncontaminated to moderately contaminated
1 < Igeo < 2	Moderately contaminated
2 < Igeo < 3	Moderately to Heavily contaminated
3 < Igeo < 4	Heavily contaminated
4 < Igeo < 5	Heavily to Very Heavily contaminated
Igeo ≥ 5	Very Heavily contaminated

Where, C_n = Observed Concentration of element.
B_n = world's average UCC value.

Sediment texture and organic carbon (OC %) of India and Bangladesh Sundarban is shown in Table 1. Both parts of Sundarban show lower value of OC, lower than world average value of 7.9% for estuarine tropical mangrove ecosystems (Rogers et al., 2013). Low OC recorded on both side may be attributed to high tidal activity results in flushing, sedimentation and mixing processes and higher rate of degradation of organic matter by microbially mediated processes (Canuel and Martens, 1993), as well as poor adsorbability of organic matter on negatively charged quartz (Sarkar et al., 2004). High value of OC at I-10