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Source, distribution and ecotoxicological assessment of multielements in superficial sediments of a tropical turbid estuarine environment: A multivariate approach

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ABSTRACT

The work examined the distribution, possible sources and ecotoxicological assessment of 51 trace elements covering 13 sampling stations in surface sediments of coastal regions of Sundarban mangrove wetland and adjacent Hugli river estuary. The element concentrations exhibited an increasing trend towards downstream of the estuary (except lanthanides) with maximum enrichment for 22 elements at Gangadharpur (Sundarban region). According to Sediment Quality Guidelines (SQGs), the concentrations of Cu, As, Cr and Cd exceeded the Effects-Range-Low values, while Ni at certain stations exceeded the Effects-Range-Medium suggesting adverse effects on the sediment-dwelling organisms. The geoaccumulation index revealed that the stations were unpolluted to moderately polluted. Risk Index (357.61) and Enrichment factor (11.42) depicted that Nimtala station (upstream) was at high ecological risk zone. The result of PCA endorsed that organic carbon and clay fraction play crucial role in accumulating the elements in sediments. This pilot study contributes to a better understanding of the geochemistry of this complex deltaic ecosystem.

1. Introduction

Estuaries are the buffered regions with high productivity and intense economic activity due to the convenient traffic conditions and several natural resources (Oursel et al., 2013). These regions, being transitional zones are influenced by inputs from land, river and ocean, resulting in a dynamic and vulnerable environment (Kharroubi et al., 2012). As a result, the deposited sediments in the estuaries become the important components of the ecosystems (Dong et al., 2012) due to their physical and chemical properties and the accumulation of pollutants in it (Hu et al., 2013). In recent years, sediments were increasingly recognised as a major sink and source of contamination, providing an essential link between chemical and biological processes (Sheykhi and Moore, 2013). Thus, assessments of sediment contamination in estuaries are very crucial.

The toxicity and persistence of metal pollution in the aquatic environment is a critical issue in the natural environment (Gao and Chen, 2012), posing potential threats to ecosystems, due to their non-biodegradable nature and long biological half-lives for elimination from the body (Radha et al., 1997, Li et al., 2004). Metals in estuaries originate from both natural processes, such as weathering and erosion (Liaghati et al., 2003) and anthropogenic activities that include industrial and domestic effluents containing toxic metals as well as metal chelates (Amman et al., 2002), urban storm, water runoff (Lantzy and Mackenzie, 1979; Nriagu, 1979), landfill leachate and boating activities (Forstner and Whitman, 1979). After being introduced into the aquatic environment, total metals from the aqueous phase are eventually deposited to sediments through physical, chemical or biological mechanisms (Yuan et al., 2012). The distribution and accumulation of metals are influenced by complex factors, such as sediment composition and structure, grain size, and hydrodynamic conditions (Christophoridis et al., 2009; Qiao et al., 2013). Due to these multiple factors, metal concentrations in sediment changes partially and temporally (Liu et al., 2011).

In the last two decades, the productive mixohaline positive Hugli river estuary (HRE) (Pantalu, 1966) has experienced increasing pollution from anthropogenic activities (Chatterjee et al., 2007; Chowdhury et al., 2016). The estuary collects and transports natural weathering products as well as potentially harmful elements derived from anthropogenic sources. Abbas and Subramanian (1984) calculated that at Kolkata (former Calcutta), the Hugli annually supplies 411×10^6 t (i.e. 328×10^6 t sediment + 83×10^6 t solute load) of total load to the Hugli estuary. Bioaccumulation of metals by biota of different tropic levels in the lower stretch of the Hugli estuary has been widely reported (Sarkar et al., 2004; Watts et al., 2013; Chatterjee et al., 2014).

This region has seen transformational changes in industry, shifted in population and social structure over the last few decades. A significant ecological change is pronounced in the Hugli estuarine environment due to large scale discharge of domestic and industrial wastes. The measurement of elemental concentrations and distribution in the marine

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environment will improve the understanding of their characteristics in the aquatic environment and is important to identify sources of pollution (Chatterjee et al., 2007; Forstner and Whitman, 1979). This study presents sediment-elemental data along the lower stretch of the HRE and adjacent Sundarban mangrove wetland (SMW). The sediment samples were analyzed for key parameters and elemental concentrations to evaluate the geochemical processes, including possible anthropogenic influences. The main objectives of the present paper are: (a) to establish the spatial variation of 51 elements covering 13 stations, (b) to analyse the geochemical properties of the sediments, (c) evaluation and identification of potential sources of contamination, and (d) assessment of the extent of metal pollution in the environment using several indices.

2. Methods and materials

2.1. Sampling stations

A total of thirteen sampling stations was selected, with five sampling stations along the main course of the HRE namely; Barrackpore (S1), Dakhineswar (S2), Nimtala (S3), Babughat (S4) and Nurpur (S5) and the remaining eight sampling stations in the Sundarban wetland region namely; Lot 8 (S6), Phuldubi (S7), M.G.Ghat (S8), Chemagari (S9), Gangasagar (S10), Chandanpiri (S11), Gangadharpur (S12) and Patharpratima (S13) covering the length of approximately 140 km along the stretch (Fig. 1).

Descriptions of the sampling sites and their respective anthropogenic stresses have been stated in Table 1. Situated within the same broad setting of tropical meso-macro tidal amplitude (2.5 to 6 m), the stations are situated along different salinity gradients, wave and tidal environment, energy regimes, distance from the sea, dispersion of the sediments and diverse anthropogenic input with a variable degree of exposure from elemental concentrations. Various physicochemical processes such as suspension-resuspension, lateral and vertical transport by biological activities (bioturbation), flocculation and deflocculation of mud clasts, atmospheric deposition, organic carbon (*Corg*) content and grain size of the sediments are influential again in the distribution of elements. The estuary, from Barrackpore to Gangasagar is a wide divergent one with eroding banks, submerged flats and unstable mid-channel islands. The estuary receives 11×10^6 m^3 of sediment from upland flow and the suspended load varies from 1 to 3 g/L (Sarkar et al., 2004). Multifarious industries namely, paper, tanneries, textile, chemicals, pharmaceuticals, plastic, shellac, leather and jute are situated on both banks of the Hugli estuary, leading to significant inputs of organic contaminants, heavy metals along with agricultural and aqua-cultural waste. The Indian Sundarban, formed at the estuarine phase of the Hugli River over an area of approximately 9600 km^2, is a mangrove wetland belonging to the low-lying coastal zone. This is one of the most dynamic, complex and vulnerable bioclimatic zones in a typical, tropical geographical location in the northeastern part of the Bay of Bengal. The wetland is characterized by a complex network of tidal creeks, which surrounds hundreds of tidal islands exposed to different elevations at high and low semi-diurnal tides.

2.2. 2.2. Collection and preservation of the sediment samples

The surface sediment samples weighing 10 g were randomly collected in triplicate from the top 3–5 cm of the surface from each sampling station during low tide using a grab sampler, pooled and thoroughly

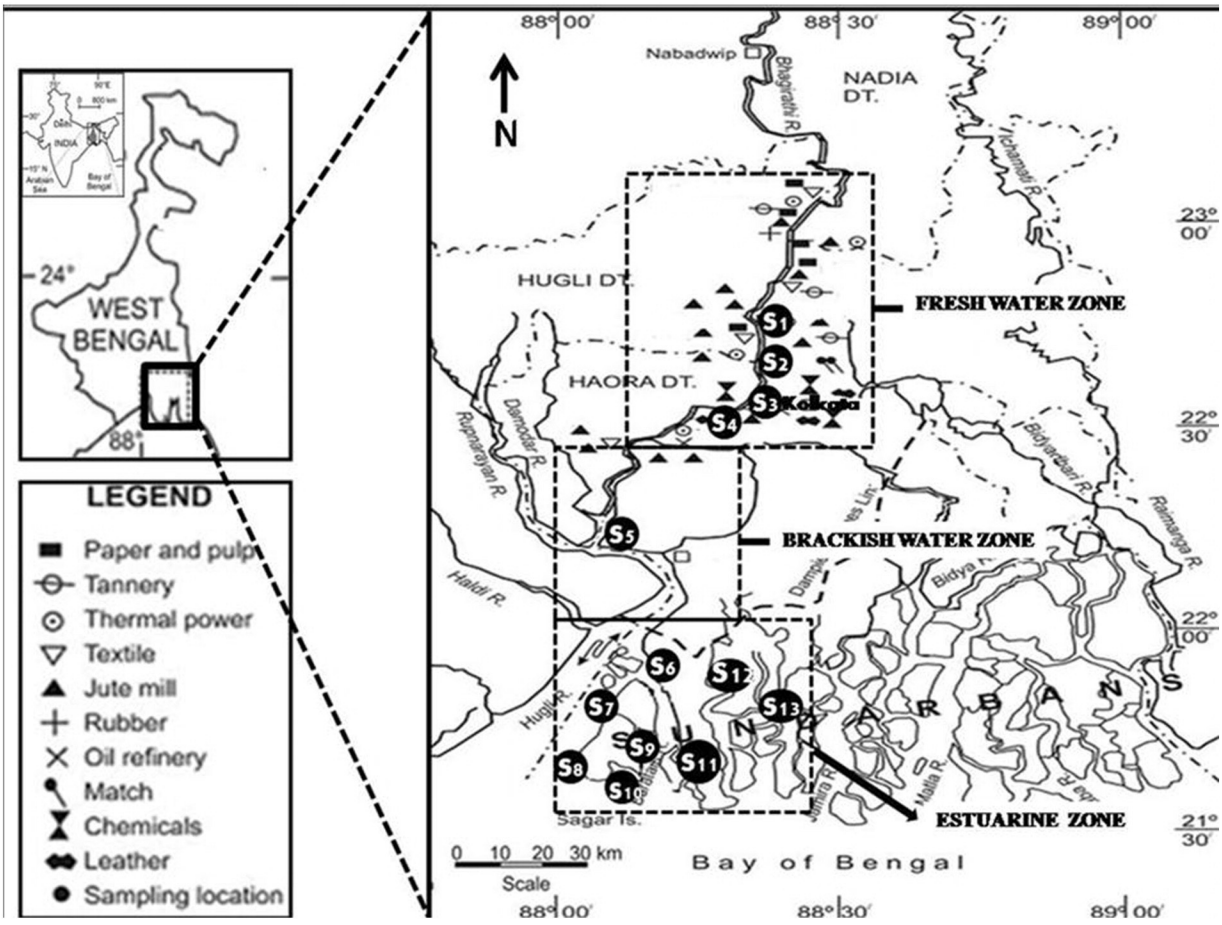

Fig. 1. Map showing the location of the sampling sites (S1–S13) covering Hugli River Estuary and Sundarban mangrove wetland. The location of multifarious industries along with the intricate network of rivers and their tributaries are also shown.

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