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Dynamics of metal ions in suspended sediments in Hugli estuary, India and its importance towards sustainable monitoring program

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SUMMARY

Metal contamination in a river has often been assessed based on total metal ion concentrations without relating them with the amount of suspended solids. This approach masks lot of important dynamics of metal ions in water. This is first time in India, a study has been undertaken to present how the level of metal ions in river water is influenced by suspended solids in response to spatial and seasonal conditions in Hugli estuary, India and to focus necessity of harmonizing science and policy. This study presented extent of metal pollution and distribution pattern over the stations, seasons, tides and depth. Major fraction of metal ions is associated with suspended sediments and discharges into the largest alluvial fan, Bengal fan, in the world. Enrichment factors indicated that major source of metal contamination is large influx of sediment due to strong natural activities and moderate anthropogenic activities over the years strong seasonal change, variable tidal energy level and irregular estuarine geometry play crucial role in maintaining metal concentrations in water column. Findings of this study would help to refine existing monitoring practice and to understand its importance in water quality management.

1. Introduction

Metal pollution in estuaries has adverse impact on coastal ecosystem (Morillo et al., 2004). All metals ultimately accumulate in sediment (Burton, 2002; Dassenakis et al., 2003). To understand the extent of metal pollution in an aquatic system, monitoring is the only means to know the contents of metals in sediments, as well as the distribution patterns and processes controlling their dispersion and disposal. The demands of monitoring system for representative and meaningful assessment of metal pollution in estuary have remarkably increased to provide important decision support. The estuary is a complex and dynamic environment (Liu et al., 2003) that suffers from intense anthropogenic perturbation and has been acting as a regulator of contaminant inputs to coastal areas (Chapman, 2002). In aquatic environments, metals are considered to be frequent and important contaminants, because they are transported as either dissolved species in water, or as integral parts of suspended solids (Garbarino et al., 1995). Once a contaminant is bound to particulate material, knowledge of particle dynamics is very important in determining its fate (Dyer, 1989; Balls, 1990). In estuaries, influence of suspended sediments on distribution of metal ions in water column is particularly significant because of regular (tidal) and sporadic (wind- or river flow-induced) variations in particle concentration and character (Lindsay et al., 1996; Ridderinkhof et al., 2000; Fain et al., 2001) and the modification of chemical and particle reactivity by abrupt changes in salinity, pH, redox conditions, and concentration of dissolved organic matter (Beckett and Le, 1990; Herman and Heip, 1999; Mannino and Harvey, 1999). In India, monitoring of total concentrations of metal ions is being carried out since last three decades but metal contamination in a river has often been assessed using restricted datasets that mask lot of important dynamics of metal ions in water despite huge financial investment particularly in developing countries like India. The important role that suspended particles play in contaminant transfer over the continental areas and finally to the oceans has recently been recognized by many researchers (Owens et al., 2008; Taylor and Owens, 2009; Viers et al., 2009; Mukherjee, 2012; Stummeryer et al., 2002; Nriagu and Pacyna, 1988). In India, the regulator namely Central Pollution Control Board is quite reluctant in evaluating the sediment associated contaminants and its consequences on river water quality. Now an emergent need is to focus the dynamics of metal ions in suspended sediment in rivers and estuaries. The main objectives of this study are to describe the spatial and temporal distribution of metal ions (Al, Fe, Mn, Cr, Co, Hg, Cd, Cu, Zn, As and Ni) in the suspended sediments of Hugli estuary and to

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investigate the limitations in reporting total metal ion concentration in estuarine water without relating them to the amount of suspended solids in water. This study also aims to investigate metal interrelations and determine the factors that affect their distribution. Investigation of metal concentrations in the entire estuary was also made to bridge the gap between science and policy for cost effective monitoring of metal ions.

2. Literature review and thought process

The River Ganga is responsible for the creation of the world's largest delta plain (Singh et al., 2003) the Ganges–Brahmaputra delta and the world's largest deep sea fan, the Bengal fan (Fig. 1). By discharge (15,646 $m^3 s^{-1}$) Ganga is the fifth largest river in the World (Milliman and Meade, 1983). The land use pattern of this river basin has been vastly modified by dense human settlement and industrialization (Ansari et al., 2000) leading to pollution in estuary. Metals are of particular concern due to their environmental persistence and biogeochemical recycling and ecological risks (Forstner and Wittmann, 1983; Liu et al., 2003). The Ganga enters the basin from the northwest after draining Himalayas and most of north India for about 2500 km. The river after bifurcation below Farakka, flow southwards down the deltaic plain of West Bengal as the river Hugli and then empties into Bay of Bengal. The hydraulic character of the Ganga suddenly changes on entry into the tidal zone of the gangetic delta. The tidal stretch of river Hugli is up to Triveni from the Sagar islands. The tidal influence varies depending on upland flow with maximum amplitude of 5.5 m. The Hugli estuary is a well mixed type and vertically homogenous throughout the year except with slight stratification for a short period during south west monsoon (June–September) due to fresh water discharge (Mukhopadhyay et al., 2002). The large tidal variation, irregular estuarine geometry, the presence of island and presence of navigation channel separated by shallow zone make the flow quite complicated. The Ganges river has a discharge of 24,000 million m^3 annually at Balawali (near Haridwar) and 459,000 million m^3 annually at Farakka. Discharges from Faraka Barrage are 2975 ± 1144 $m^3 s^{-1}$ during monsoon with highest value (4000 $m^3 s^{-1}$) during September, 1000 ± 81.6 $m^3 s^{-1}$ during pre-monsoon with minimum value (900 $m^3 s^{-1}$) during May; and 1875 ± 985.5 $m^3 s^{-1}$ during post-monsoon (Mukhopadhyay et al., 2002). Surface runoff ($km^3 month^{-1}$) was reported to be 0.88, 4.02, 18.7, 8.47, 20.47 and 1.93 during May, June, July, August, September and October respectively (Biswas et al., 2004). This large volume of freshwater influx that transports agricultural runoff, storm water and wastewater supplies metals both in dissolved and solid state to this estuary. The relative distribution of these metals between dissolved and particulate phases in the river depends on the nature and concentration of mineral and organic matter originating from the basin (Viers et al., 2009). The metals

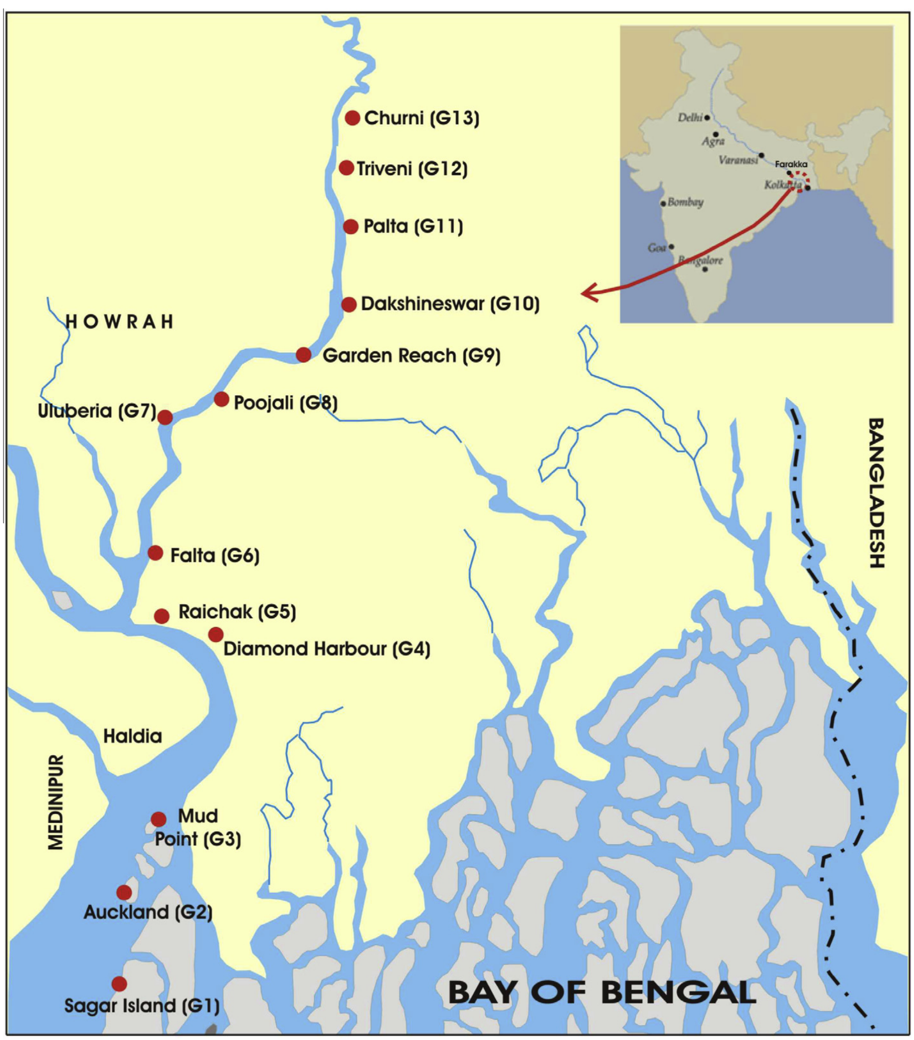

Fig. 1. Study stretch of River Ganga.