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Geochemistry and bioavailability of mudflats and mangrove sediments and their effect on bioaccumulation in selected organisms within a tropical (Zuari) estuary, Goa, India

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ABSTRACT

Metals are non-degradable in the aquatic environment and play a vital role in estuarine biogeochemistry but could also be detrimental to associated biota. A comparative evaluation of the trace metal concentrations (Fe, Mn, Zn, Cu, Ni, and Co) was carried out in the Zuari estuary, Goa during the post-monsoon season of 2013 at six locations, each representing three mangrove and three mudflat regions. In addition, fractionation of trace metals in sediments was performed to provide information on the mobility, distribution, bioavailability and toxicity. Special attention was paid to the marine mollusks viz. bivalves and gastropods that are extensively used as bio-indicators in coastal pollution. Considering the percentage of metals in the sequentially extracted fractions, the order of mobility from most to least bioavailable forms was Mn > Zn > Cu > Ni > Co > Fe. Mn maintained high bioavailability (average around 60%) in Fe–Mn oxide and carbonate bound forms indicating that Mn is readily available for biota uptake. The bioavailability of Fe was on an average of around 6% whereas other metals like Cu, Zn, Ni and Co were around 19% to 34%. When the bioavailable values were compared with standard Screening Quick Reference Table (SQUIRT), Zn showed higher toxicity level and bioavailability in the lower estuary. On the basis of calculated Bio Sediment Accumulation Factors (BSAF's), overall trend in bioaccumulation was in the order of Cu > Zn > Mn > Ni > Co > Fe. Metal Pollution Index (MPI) computed was higher for gastropods than bivalves.

1. Introduction

In recent decades, there have been increasing concerns about pollutants entering the aquatic environment which can have detrimental effects by finding its way into estuarine waters and affecting biotic communities. Despite high hydrodynamics, estuaries are preferential sites for accumulation of fine grained sediments, organic matter and metals originated from numerous marine and terrestrial sources including those of anthropogenic origin. After discharge to an aquatic environment but before uptake by organisms, metals are partitioned into five phases, viz. Exchangeable, Carbonate, Fe–Mn oxide, Organic and Residual (Elder, 1989; Salomons, 1995). A chemical contaminant that is tightly bound to sediment particles may not be available into the organism exposed to that sediment, regardless of the concentration of contaminant in the sediment. However, a physical disturbance resulting in sediment resuspension may increase desorption of that contaminant from sediment particles to water and thus increase the bioavailability of contaminant to water column organisms. Marine bivalves and gastropods are sedentary, filter-feeders, feeding on suspended particles coupled with their ability to accumulate metals have made them as important candidates to study metal pollution (Phillips, 1980). Most importantly, the concentration of many pollutants in the tissue of bivalves appears to be proportional to the concentration of pollutants in the surrounding water (Amiard, 1987).

Several authors have reported trace metal concentration in estuaries and studied bioaccumulation in tissues of bio-indicator organisms. The behavior of trace metals in an environment is critically dependent on their chemical form, which influences mobility, bioavailability and toxicity to the organisms (Passos et al., 2010). Although time consuming, the use of sequential extraction provides detailed information concerning the origin, mode of occurrence, biological and physico-chemical availabilities, mobilization and transport of trace metals. However, there are gaps in information related to bioavailability and bioaccumulation where the organism accumulates more than the bioavailable forms. These facts have led many to recognize that both the sediment geochemistry and biology of the particular organism must be understood in order to explain the mechanisms that control metal bioaccumulation (Griscom and Fisher, 2004).

Based on studies conducted in Zuari estuary, Mesquita and Kaisary (2007) noted higher values of Fe and Mn in water, suspended particulate matter and sediments in the middle estuary and related the concentrations to mining activities. Panchang et al. (2005) found that there is reduction in pollution in the Zuari estuary due to reduced mining activity in the catchment area. Dessai Deepti and Nayak (2009) studied speciation of

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metals in Zuari estuary and reported that Mn and Co are higher in concentration in exchangeable fraction.

Accumulation in mullet fish *Laurata*, edible bivalve oyster *Crassostrea madrasensis* from Gosthany estuary, east coast and edible clam *Polymesoda erosa* from Mandovi estuary, west coast of India studied by Gawade et al. (2013) showed that bivalves accumulate higher metal concentration compared to fish indicating that feeding habits, habitat, size and regulatory ability play important roles in bioaccumulation. The Fe concentration in clams in the sediments of the Volta estuary, studied by Adjei-Boateng et al. (2010) showed significant variation in concentration between tissues and sediments. Therefore, it is important to monitor concentration of metals in water, sediments and marine organisms especially in areas largely subjected to anthropogenic activities. Estuarine ecosystems yield a rich variety of fishery resources providing breeding and nursery grounds for more than 200 species of marine fishes and shellfishes (Sreekanth et al., 2015). The Zuari estuary is lined with dense mangrove vegetation filled with silt, clay and detritus that has been transported by riverine influx from upper reaches. Traditional fishery comprising of motorized and non-motorized boats operate gillnets and hooklines exist in this estuary serving an important purpose to the society. A lot of fishing activities take place in this estuary as this region is very important to a number of finfishes and shellfishes of commercial significance with highest catches during post-monsoon (October to January) and lowest catches during pre-monsoon (April and May). The Zuari estuary has inputs coupled with shipping activities, mining transport, input from agricultural practices and boat building yards handling large quantities of metals. Effort to establish a relation between bioavailability and bioaccumulation therefore is important in tropical areas where large human population is directly dependent on fish and fishery products for daily diet. In view of the above, the present study makes an attempt to assess the variation in physico-chemical and geochemical characteristics to understand the relation between bioavailability in sediments and bioaccumulation of metals in tissues of mollusks along the Zuari estuary.

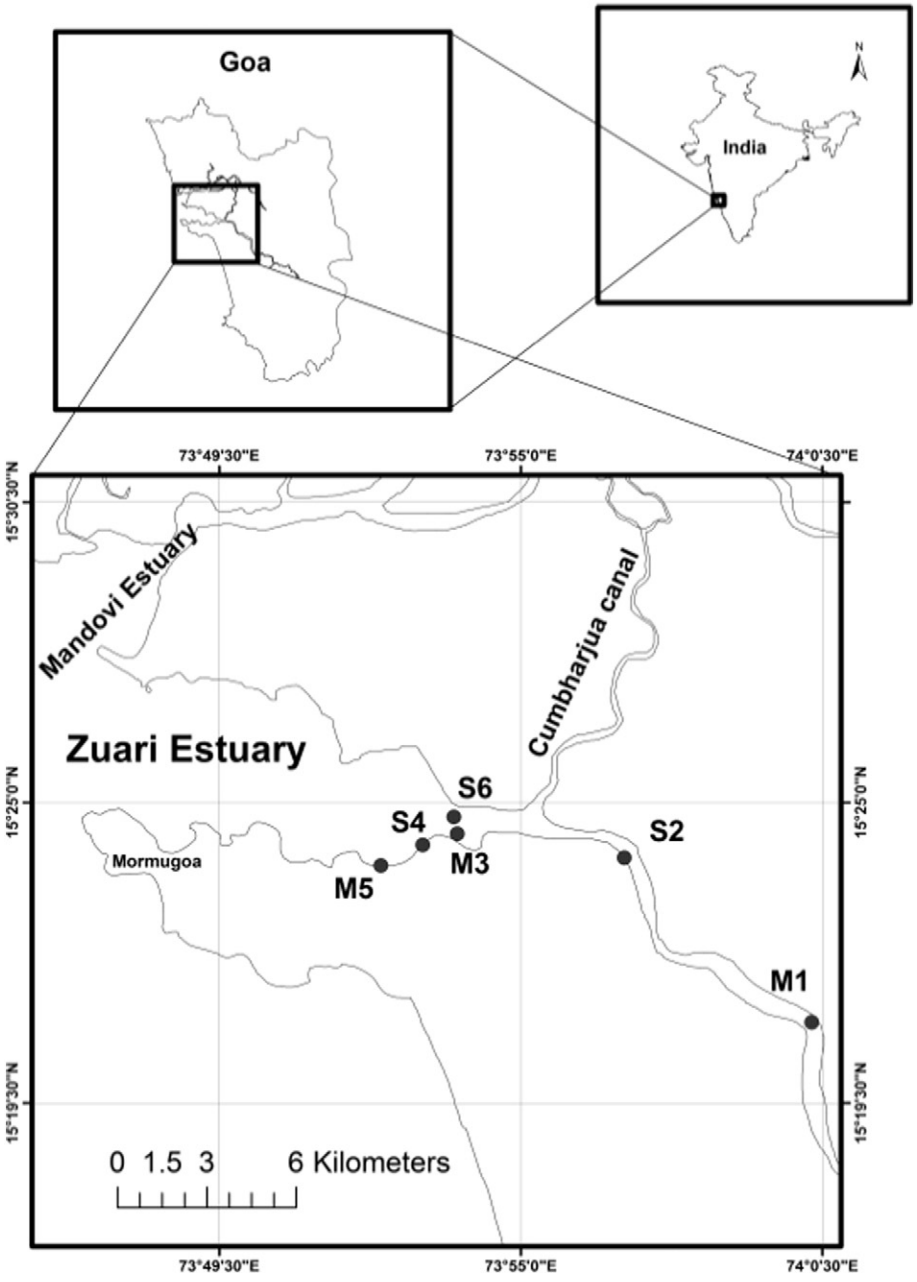

Fig. 1. Map showing the core locations along the study area.