Spatial variation of Arsenic in the Estuarine Zone of Two Different Tropical Rivers

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Abstract:
This study represents distribution of Arsenic in two different estuaries, one is Himalayan source and another is non-Himalayan source. Arsenic concentration in river water, pore water and ground water was found to be significantly higher in the Mahanadi estuary could be due to fringing mangrove than that of Hooghly-Saptamukhi estuary with thick mangrove ecosystem.

1. Introduction

Arsenic is one of the components of a large number of compounds generated by human activities (precious metals mining, manufacturing, wood preservatives, glassmaking industry, electronics industry, chemical weapons etc.) (Han et al., 2003 & Kohler et al., 2001). About 70% of all arsenic used is in pesticides, principally: HAsO₂₂Na, Na₂AsO₃₂H₂, H₃AsO₉ (CH₃)₁AsOH. Arsenic has been widely used in agriculture: sodium arsenite, which is the only known fungicide available for protecting grapevines from excoriosis, was indeed used until 2001 (Grillet et al., 2004). The main anthropogenic sources of atmospheric arsenic contamination are As-rich fossil fuels producing arsenic oxide (As₂O₃), which is highly toxic. Phytoplankton plays an important role in the conversion of arsenic from dissolved to particulate form. Partitioning of arsenic in the particulate and dissolved form and sedimentation from water column to the sediment could be enhanced by the production of autochthonous organic matter (Faye and Diamond, 1996). Variation of the concentration and speciation of arsenic are significant during eutrophication depending on metabolism of phytoplankton, decomposition of organic matter by bacteria and microbial reduction of ferromanganese oxides in sediment.

The high human population density and rapid economic growth of the countries surrounding the Bay of Bengal make the coastal environment vulnerable to a range of anthropogenic stress factors (Millennium Ecosystem Assessment 2005). The Mahanadi originates from the Baster Hills of Madhyapradesh and passing through the ridges of Eastern Ghats, older than Himalaya opens its mouth into the Bay of Bengal at the False Point. The river segregates into several channels forming a huge delta. The Mahanadi drains an area of 0.14 million km² and basin consists of red and yellow soils. Granite and gneisses found in the upper parts of the basin contain water in the...
weathered mantle and along the rift and horizontal joints. Coastal alluvial tracts have fresh water formation near the surface and depth below 150m. Fringing mangroves are found at the lower stretch of the Mahanadi estuary. The Mahanadi Estuary is affected by the release of urban waste, the drainage of industrial effluent, and runoff from agriculture.

The Ganges originates from the Himalaya and the sea end of the river forms Hooghly-Matla estuarine system dominated by mangroves. The Ganges basin is characterized by verities of soils out of which laterite and lateritic soils are mainly found in the high rain fall (over 120cm) area of the upland belt fringing the Gangetic alluvial plain in West Bengal. The total drainage basin of the Ganges is 1.06 million km². Spatial variability of dissolved As found in shallow aquifers of the Gangetic Delta remains poorly understood (Mertal et al. 2008). These arsenic bearing aquifers are mainly confined to sediments discharged from the rapidly eroding Himalaya, approximately 7,500–10,000 years ago (Acharya et al. 2000; Goodbred and Kuehl 2000). So, arsenic occurring in the sediment of Gangetic Delta is from Himalayan source. Apart from this, suspended sediment could scavenge arsenic from sea water before its deposition in the mangrove system. Banerjee et al. (2011) reported the mass accumulation rates of 0.41–0.66 g cm⁻² year⁻¹ determined from 210Pb geochronology of core sample and concluded that variations in trace metal content with depth result largely from their input owing to anthropogenic activities rather than diagenetic process. Our previous study on the spatial and temporal variation of arsenic in the Indian Sundarban mangrove ecosystem (Mandal et al. 2009) showed significant diagenetic remobilization of arsenic with a dispersal rate between 80.7 and 509 ng m⁻² d⁻¹. Highly productive Sundarbans mangrove ecosystem (4.71–6.54 Mg C ha⁻¹ year⁻¹) with 4.85 Mg C ha⁻¹ year⁻¹ of litter production (Ray et al. 2011) could be a source of organic matter which could accelerate the microbial conversion from oxic to suboxic condition in the deeper layer of sediment column. Mandal et al. (2009) suggest that arsenic could be immobilized during incorporation into the arsenic-bearing initial phase, and unlikely to be released into pore water until mangrove derived organic matter fuels microbial reduction of adsorbate and adsorbent in the Sundarban mangrove ecosystem.

This study aims to collect and to collate the data on the special variation of arsenic in the river, ground and pore water of two different tropical estuaries on the east coast of India.

2. Study area

The study sites were located in the Sundarbans (21°32' and 22°40'N; 88°05' and 89°E), India. The area is covered with thick mangroves and in 1985, it has been included in UNESCO’s list of world heritage site. It is the last frontier of Bengal flood plains, sprawling archipelago of 102 islands out of which 54 are reclaimed for human settlement.

The tidal Islands at the central positions show elevations of the order of 3 to 8 m from mean sea level. Tide in the study area is semidiurnal with tidal amplitude, i.e., 2.5-7 m. Mean current velocities ranges between 117 and 108 cm s⁻¹ during low tide and high tide, respectively [Mukhopadhyay et al., 2006].

Another study sites were also located in the Mahanadi Estuary, part of one of the fourteen major rivers in the peninsula of India (Fig. 1). The river originates from the Baster Hills of Madhya Pradesh, flows over different geological formations in the Eastern Ghats and adjacent areas, and has a total length of 857 km and a basin area of 141600 km². It meets the Bay of Bengal after dividing into different distributaries in the deltaic region, with the main distributary flowing into the bay at Nehru Bungalow, near Paradeep. The tide in the estuary is predominantly semidiurnal. The vertical tide range at the mouth varies from 1.45 to 2.2 m. Climate in the region is characterized by the southwest monsoon (June–September), the northeast monsoon or post-monsoon (October–January) and the pre-monsoon (February–May); 70-80% of annual rainfall occurs during the summer monsoon (southwest monsoon), resulting in high river discharge, which then gradually diminishes during the non-monsoonal months.

Fig.1: Location of the selected stations along the NE coast of Bay of Bengal, India.

3. Material and Methods

Experiments design:

Measurements were carried out in every month from January to December, 2008 at two sites: one located at Lothian Island in the confluence of Saptamukhi River and Bay of Bengal. Samples were also collected at three stations, Beguakhal, Kachuberia and Diamond Harbour of Hooghly estuary.
Second sites were located at Mahanadi Estuary and samples were collected at three stations [Stn.1 (20°17'38.1"N; 86°42'30.3"E), Stn.2 (20°18'29.5"N; 86°41'4.4"E) and Stn.3 (20°20'22.9"N; 86°36'50.8"E)] along the estuary; in the lower (Nehru bungalow), middle (Kaudia) and upper (Chaumohona) reaches.

Different sites of the littoral zone covered with mangrove were selected for monthly sampling of pore water (Schulz, 2006).

Surface water samples were collected using Niskin bottle at 3hr interval from a boat. Tidal and pore water samples were filtered (0.45 µm milipore previously dried and weighed) under nitrogen atmosphere and were stabilized by the addition of H2SO4 to give a leaching 0.1% v:v in acid-washed PP bottles and stored in a ice box for arsenic speciation analysis.

4. Analytical methods:

Total As concentration in the filtered samples was analyzed using the Varian Hydride System-Vapor Generator (serial No. EL0405-314) coupled to Spectr AA 55B true Double Beam Atomic Absorption Spectrometer following methods as described by (Loring and Rantala1992) and (Yamamoto et al., 1985). Measurement of dissolved As (III) was performed by hydride generation at pH 4 using 5% potassium biphthalate (Barman et al., 1977). The analytical methods for arsenic were checked before analyses of each batch of samples against standard samples procured from MERCK K GaA, Germany. Relative accuracy and coefficient of variation were 96.2% and 9.2%, respectively for arsenic.

5. Result and discussion:

Variation of arsenic was found significant in the estuarine zone of Ganges (Sunderbans) and Mahanadi river and its concentration was found lower (237 – 4665 ng L⁻¹ in river water, 310- 19,900 ng L⁻¹ in pore water, 507 – 3552 ng L⁻¹ in ground water) in the western part (Hooghly – Saptamukhi estuary) than that of Mahanadi estuary (Table 1).

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<th>Hooghly – Saptamukhi</th>
<th>Mahanadi</th>
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<tr>
<td>River water (ngL⁻¹)</td>
<td>237- 4665</td>
<td>5882 - 16872</td>
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<tr>
<td>Pore water (ngL⁻¹)</td>
<td>310-19,900</td>
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<td>Ground water (ngL⁻¹)</td>
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<td>11765 - 20000</td>
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Arsenic concentration in tidal water in the Hooghly – Saptamukhi estuary demonstrated strong seasonal variations (Fig.2), with a maximum value of 4532 ng L⁻¹ during the pre-monsoon and minimum value of 995 ng L⁻¹ during the post-monsoon due to spring phytoplankton bloom and incorporated of 1605 ng L⁻¹ during the monsoon due to increasing water discharge in the monsoon season relative to the pre-monsoon.

In the Hooghly –Saptamukhi estuary, As(III): As(V) ratio in mangrove water was found high during the post-monsoon(0.5:1) compare to pre-monsoon(0.09:1) and monsoon(0.38:1) due to spring phytoplankton bloom(Biswas et al.,2004). In the Mahanadi estuary, arsenic concentration was found significantly greater than that of the Hooghly-

Saptamukhi estuarine system and its distribution was found to be 5882-16872 ng L⁻¹ in river water, 15000 -21875 ng L⁻¹ in pore water and 11765 – 20000 ng L⁻¹ in ground water (Table 1). Arsenic concentrations in tidal water in the Mahanadi estuary demonstrated strong seasonal variations (Fig.3), with a maximum of 13412 ng L⁻¹ during monsoon and a minimum of 7647 ngL⁻¹ during pre-monsoon and intermediated of 12750 ngL⁻¹ during post-monsoon.

In consistence with the Mahanadi estuary, the As (III): As (V) was found higher in post monsoon (0.38:1) than in the pre-monsoon (0.36:1) and monsoon (0.35:1) in tidal water. Ganguly et al (2011) showed that net photic zone gross primary production was greater in the post-monsoon (184.07 mMCm⁻²d⁻¹) than in the monsoon (32.46 mMCm⁻²d⁻¹) and in the pre-monsoon (108mMCm⁻²d⁻¹). The Mahanadi estuary is one of the anthropogenically perturbed estuaries in India as a result of urban waste water release, industrial effluent drainage and runoff from agriculture. The use of arsenic containing pesticides in the past could leave large areas of agricultural land contaminated. The use of arsenic as copper chrome arsenate in preservation of timber could also led to contamination of the environment.

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It is evident from the study that the relatively lower concentration of Arsenic in the Hooghly-Saptamukhi estuarine ecosystem could be due to its thick mangrove ecosystem along the lower stretch compared with the Mahanadi estuary with fringing mangrove.
References:


Han, F. X. (2003). Assessment of global industrial-age anthropogenic arsenic contamination. Published online: 15 August.

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