Evaluation of water quality of Bhitarkanika mangrove system, Orissa, east coast of India

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The nutrient and dissolved metal concentration in Bhitarkanika mangrove system, Orissa, east coast of India had been examined. Surface water samples were collected from the different regions of mangrove-estuarine complex during the post monsoon season. There was distinct variation in chemical constituents of water among the estuarine, mangrove and bay region. Physicochemical parameters like pH, EC and TDS and nutrients like NO$_3^-$, PO$_4^{3-}$ varied significantly among three sectors. The cations like K$^+$, Ca$^{2+}$, NH$_4^+$ and anions like SO$_4^{2-}$, HCO$_3^-$, SiO$_2$ didn’t showed any significant variation. There is high concentration of dissolved metal in this mangrove system. The above fact will reveal that mangrove is facing severe threat due to industrial pollution. The metals, Cu, Zn and Co showed higher affinity, while Pb and Cr also result in strong coupling with each other.

Keywords — Bhitarkanika mangroves, water quality, heavy metal, pollution.

Introduction

Mangroves represent highly dynamic and fragile ecosystem. It occupies a large fraction of the tropical coastline, dominating the intertidal zone of diverse environmental settings. The potential role of mangrove ecosystems as sinks for anthropogenic contaminants in tropical and subtropical areas has been widely recognized$^{1, 2}$. India has a total area of 4461 sq. km under mangroves. It is 0.14% of the country’s total geographic area. It account for about 5% of the world’s mangrove vegetation$^3$. Bhitarkanika mangrove ecosystem flourishes in the deltaic region, formed by the rich alluvial deposits of Brahmani and Baitarani River. Brahmani has a drainage basin of 8570 km$^2$, length of 365 km, and peak discharge of 14150m$^3$s$^{-1}$, while Baitarani River, has a drainage basin of 8570 km$^2$, a length of 365 km, and a peak discharge of 14150m$^3$s$^{-1}$. It receives inputs of untreated domestic and industrial wastes (including organic matter, oil and heavy metals). These mangroves have being considered attention for its floristic and faunal diversity$^4$. The present study was undertaken to understand the prevailing situation of the water quality and the impact of the anthropogenic input on this mangrove dominated estuarine ecosystem. The investigations consists major hydrogeochemical process controlling water chemistry and the status of water quality in mangrove ecosystem.

Study site

Geographically Bhitarkanika is located between $20^\circ$4'-20$^\circ$8' N Latitudes and $86^\circ$45'-87$^\circ$50' E longitudes in the Kendrapara district of Orissa. It is the second largest mangrove ecosystem of India which and consists mangrove forests, rivers, creeks, estuaries, backwater, accreted land and mud flats. Bhitarkanika mangroves were declared as Wildlife Sanctuary with an area of 672 sq. km in 1975. The core area (145 sq. km) of the sanctuary has been declared as Bhitarkanika National Park in 1992. It is a tide–dominated mangrove with areas of high tidal range of semi-diurnal; with mean tide level 1.5 to 3.4 M. These area exhibit bidirectional tidal fluxes and thus forms extensive, low gradient inter-tidal zones available for mangrove colonization$^4$. It supports a rich floral diversity with about 62 species of mangroves.

The average annual rainfall is about 1670mm of which ~70% is received during August and September. In summer, the temperature ranges from 30°C to 20°C (day and night respectively) whereas during winter it is 20°C to 15°C (Meteorological Department, 2006). The relative humidity remains between 75 - 80% throughout the year. The sediments are divided into two categories, ‘newer alluvium’ and Pleistocene forms named as ‘older alluvium$^5$. The recent sediments are represented by sand, silt, and clay with assorted boulders and pebbles, which are dark and
loosely compacted with high moisture content. The Pleistocene deposits comprise of clay, sand, silt, and ‘kankar’, with locally cemented pebbles and gravels. These are reddish brown due to high degree of oxidation.

Materials and Methods
The samples were collected during the post-monsoon period of year 2005 from three zones—estuarine, mangrove region and bay region. Fifteen samples were collected.

Water samples were collected at low tide so as to minimize the tidal fluctuations. The average of the measurements was considered for data interpretation. Thermo-Orion water analysis kit (Model Beverly, MA, 01915) was utilized to examine pH, electrical conductivity (EC), and total dissolved solids (TDS). Bicarbonate (HCO$_3^-$) was measured by titration at the time of sampling. Samples were collected in pre-washed polypropylene bottles separately for nutrient and heavy metal analysis. Samples for metal analysis were filtered through 0.45µ glass fiber Whatmann filter paper and acidified to preserve dissolved metals. The collected samples were stored in ice-chest during sampling and were transferred to the laboratory and stored at 4°C until further analysis.

Analysis of water samples was carried out as per the standard procedures mentioned. Dissolved metal was measured by using an (Shimadzu-AA-6800) Atomic Absorption Spectroscope. The instrument was standardized using multi-elemental standard MESS 2 (Merck). The percentage error for all sample examined was within 5%.

Statistical calculation was done using MS Excel ver 2003 and Statistica 5.5.

Result and Discussion
The Bhitarkanika estuary system is tide nominated. The environmental parameters showed wide variations as per the topography and geomorphic setting of the ecosystem. The three regions viz. estuarine, mangrove and bay are well marked in the system. Estuarine region is the regions with entry point of Brahmani–Baitarani Rivers to mangrove area and is area of intermixing of freshwater with the tidal area. Mangrove area represent, the area dominated dense mangrove vegetation. The Bay region represents the area close to Bay of Bengal i.e., the entry point of tidal water (Fig. 1).

A large variability in all parameters was observed within all the three regions as depicted by Table 1. The pH of water was highest as 8.0 in Bay regions, which represent the pH of typical seawater, while the pH of estuarine area is next in line, as represent the mixing of freshwater with sea water (Table 1). The physicochemical parameters of water such as pH, EC, TDS differ significantly among three regions (Table 2). The EC showed a large range of 3200 - 33750 µS.cm$^{-1}$, along the gradient from estuarine area to bay region, which is primarily due to mixing of seawater with river water.

The estuarine and mangrove region represent a similar average chloride (Cl$^-$) concentration (5870 mg l$^{-1}$), while it was gradually increased to 12200 mg l$^{-1}$ for the bay region. Bicarbonate (HCO$_3^-$) concentration showed a decreasing tendency along the estuarine to bay region. The bicarbonate and calcium (Ca) values are indicative of intense chemical weathering in the Indian subcontinent. The high sulfate (SO$_4^{2-}$), chloride, and sodium (Na) values are largely due to the proximity of the sea (Table 1).

The present data also reveals that Potassium (K) was lower in concentration than Na. This may be due to preferential absorption and incorporation into silicate minerals. Ca and K concentration is highest in estuarine region, due to the more influx of riverine source. Baitarani and Brahmani river catchments are characterized by Precambrian granites, gneisses, and schists of the Eastern Ghats. There is local basic intrusive and volcanic lithologies; limestone, sandstones, and shale of the Gondwana; and recent deltaic alluvium deposits at the river mouths on the Bay of Bengal. However, no distinct variation was observed for K, Ca and SO$_4^{2-}$ among the three regions (Table 2).

Generally, estuarine mangrove waters have relatively low content of dissolved inorganic phosphorus and nitrogen. In some cases, the degree of human impact seems to control nutrient profiles, while in others the degree of upland influence and the hydrology of the ecosystem appear to be of greater importance. The entire mangrove system of the study area had shown significant variation in nitrate and phosphate (Table 2). Higher nitrate and phosphate concentration in estuarine water is mainly due to intense agricultural activities. The agricultural activity involves extensive usage of urea and diammonium phosphate fertilizers. In mangrove region, the rich microbial community utilizes nitrate.
and phosphate for their metabolism\textsuperscript{15}. In bay region, nitrate and phosphate content is higher. This is due to intense Damra port activity as well as agricultural runoff from nearby villages (Table 1). The Gibbs diagram of the source of total dissolved material in the mangrove water gives the impression of salinity dominance. This is essentially due to tidal influence from nearby Bay of Bengal (Fig. 2).

**Heavy metal in Bhitarkanika mangrove**

A large variability was observed in the concentration of heavy metal in water from all three sectors. The estuarine region represents the highest concentration for all the selected heavy metal, which is confluence/entry point of Brahmani and Baitarani River with mangrove area.

The heavy metal concentration was lowest in the bay regions (Table 3). This is due to pioneer function of mangrove i.e. mangrove forest act as filter for the ecosystem. The coastal region receiving water from mangrove is almost devoid of heavy metal\textsuperscript{16}. Major source of heavy metal pollution in the mangrove system are the two rivers, Brahmani and Baitarani. These two rivers were shown to have extremely

Fig. 1 — Location map of study area representing various sampling locations of three regions — Mangrove, Estuarine and Bay sites.
Table 1 — Physicochemical constituents of water in different sectors of Bhitarkanika mangrove average concentration of heavy metals for all sampling sites

<table>
<thead>
<tr>
<th>Concentration**</th>
<th>Estuarine Mean*</th>
<th>SD</th>
<th>Mangrove Mean*</th>
<th>SD</th>
<th>Bay region Mean*</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.6</td>
<td>0.2</td>
<td>7.5</td>
<td>0.3</td>
<td>8.0</td>
<td>0.3</td>
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<tr>
<td>EC (µS.cm⁻¹)</td>
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<td>337</td>
<td>13438</td>
<td>4419</td>
<td>33750</td>
<td>14820</td>
</tr>
<tr>
<td>Na</td>
<td>393</td>
<td>83</td>
<td>575</td>
<td>102</td>
<td>739</td>
<td>215</td>
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<tr>
<td>K</td>
<td>147</td>
<td>35</td>
<td>133</td>
<td>39</td>
<td>131</td>
<td>35</td>
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<tr>
<td>Ca</td>
<td>166</td>
<td>95</td>
<td>110</td>
<td>45</td>
<td>101</td>
<td>70</td>
</tr>
<tr>
<td>SO₄</td>
<td>346</td>
<td>58</td>
<td>370</td>
<td>73</td>
<td>475</td>
<td>220</td>
</tr>
<tr>
<td>PO₄</td>
<td>0.3</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>NO₃</td>
<td>1.2</td>
<td>0.3</td>
<td>1.0</td>
<td>0.2</td>
<td>1.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Cl</td>
<td>5870</td>
<td>199</td>
<td>5900</td>
<td>278</td>
<td>12200</td>
<td>626</td>
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<tr>
<td>HCO₃</td>
<td>74</td>
<td>14</td>
<td>69</td>
<td>26</td>
<td>56</td>
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<tr>
<td>SiO₂</td>
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<td>12</td>
<td>27</td>
<td>3</td>
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<tr>
<td>NH₄</td>
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<td>0.13</td>
<td>0.16</td>
<td>0.17</td>
<td>0.17</td>
<td>0.19</td>
</tr>
</tbody>
</table>

(*- mean of five replicates).

**All concentrations are in mg/l except EC, where it is µS.cm⁻¹.

variable trace element concentrations, which is consistently higher than the world river average\(^1\)\(^7\). The impact of pollution on river chemistry is most evident in the Brahmani River, where high elemental concentrations correspond to the presence of... industrially areas\(^3\). River Brahmani receives aqueous effluent discharged by NALCO (National Aluminum Company), FCI (Fertilizer Corporation of India), and TTPS (Talcher Thermal Power Plant Station). These industries utilize coal and are active source of fluorides, nitrogen compounds, cyanide, chromium, fly ash, and other suspended solids. The end result of all three industries is a collective discharge of effluent, in which the concentrations of most elements are, enriched over 10 times the upstream values\(^1\)\(^7\).

Correlation analysis depicted a positive and significant (P<0.05) correlation of Fe and Mn (0.7). The Zn also observed positive correlation with Co (0.94) and Cd (0.94). Pb and Cr also revealed positive and significant correlation which shows the strong affinity for each other (Table 4). The Table 5 will ascribe the factor analysis that had been carried out to delineate the sources and interrelationships between the heavy metals Factor 1 is statistically dominant and accounts for 37 percent of variance. This factor is characterized by strong loading of Zn, Co and Cd, due to industrial pollution in the upstream of two rivers. Factor 2 accounts for 26 percent of variance with

Fig. 2 — Gibb’s diagram showing the dominance of salinization process by means of Evaporation/Crystallization dominance.
positive loadings of chromium and lead, which is derived from port activities. Factor 3 accounts for 22 percent of variance and depict the strong biogeochemical affinity of iron and manganese. In the deep reducing part of the sediment iron and manganese hydrous oxides are dissolved and migrate upward through the sediment column and are subsequently precipitated in the oxidizing sediment surface or lost to the overlying water and thus added to water column.

Conclusion

The present water quality of Bhitarkanika mangrove ecosystem reveals that salinity plays a dominant role in controlling the water chemistry. In addition, intense pollution from both agricultural inputs and industrial pollution deteriorate the water quality of mangrove ecosystem.

Acknowledgements

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