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MINING AND ITS EFFECT ON COASTAL / ESTUARINE ENVIRONMENTS, CENTRAL WEST COAST OF INDIA

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BACKGROUND

Over two third of the world's population live either at the coasts or in adjacent coastal low land areas. Coastal lands and water also comprise substantial quantities of the nations agricultural, mineral and living resources.

The coastal zone is characterized by variety of land forms like estuaries, lagoons, beaches, islands etc., in and around them, a number of specific biological communities develop within marsh, mangrove, sea grass, coral reefs, and inter-tidal. Each of these communities live in these well defined coastal environments.

Human interference along the coast and in the catchment area of rivers in the recent years has become responsible for releasing additional load and therefore, in changing the processes in the associated environs, leading to degradation problems such as erosion and destruction of living resources, which are issues of major concern. A survey was conducted by IOI, India (Rajagopalan, 1996) on coastal zone management and sustainable development of the coastal zone. Coastal degradation, is one among them. The causes of degradation should be ascertained first. The data on various parameters associated with water, sediment and biota, on the real state of the coastal environment over time and space is a prerequisite.

Milliman (1991) has discussed the discharge of water and sediment from rivers of the globe to the ocean. Sediment discharge had also been estimated by number of authors, based on either erosion rates (Fournier, 1960) or sediment loads measured near river mouths (Holeman, 1968; Lisitzin, 1972; Milliman and Maede, 1983). As the data is available only for large rivers, all the estimates are based on these data sets. However Milliman and Meade (1983) did point out that small rivers have greater sediment yields (load per unit drainage basin area) than large rivers and according to Milliman and Syvitski, (1992) there are over 20,000 rivers with drainage basins smaller than 10,000 sq. km. They also stressed the need of estimation of yield of small rivers to get actual data on sediment discharge. Elevation, climate, geology and also human impact primarily control the sediment yield of river. It is presumed that high yield of Asian rivers is due to the monsoonal rains. Recent human activities like deforestation and associated mining and agricultural activities have enhanced the release of material many folds. It is also argued that river discharge has decreased due to damming or diversion and that caused major impact upon coastal zone.

It is understood from the available literature that the studies involving material transport from land to sea and its impact on the associated environs on regional scale are rare in India.

CENTRAL WEST COAST OF INDIA

The Central West Coast of India can be classified as bold coast due to the presence of rocky promontories with intermittent pocket beaches and small river mouths. The coast here is different from southern as well as northern West Coast of India in geomorphic set up and oceanographic processes owing to the indented coast. The coast under discussion however has similar geomorphic setup and climate but vary in human interference in the catchment area.

The Central West Coast of India includes three regions namely (1) the southern part of the Maharashtra State. Along this stretch, hitherto no destructive and developmental activities have been taken up unlike the northern part of

Maharashtra coast. (2) The coastal stretch along Goa, which covers two rivers – Mandovi and Zuari. The catchment area of these rivers is known for extensive mining activity, giving rise to anthropogenic stress on the coastal environments. (3) The area in the northern coastal Karnataka. The stretch in Karnataka, includes Rivers like Kali, which is interrupted by many dams, reducing the discharge of the sediment from land to sea affecting the coastal processes. It may be important to note that, the coastal stretch under discussion, in the recent years with the facilities of Konkan railway, is gaining much importance towards development both urbanization and industrialization and also for nuclear power plants at Kaiga. The three regions in general are different in respect of human interference.

The natural ecosystem is being affected in recent years due to human interference in these areas. It is necessary to understand the impact of human interference due to mining activity, dam construction, deforestation in the catchment area of rivers, which join the Arabian Sea along the Central West Coast of India.

Earlier studies:

The efforts to understand the material transport from land to sea and human interference in this process are rarely studied in the Central West Coast of India. However, studies are available on individual estuaries, beaches and such other environments.

Some of the important works carried out on estuaries, during the last decade and a half, basically deal with bio-geochemical, geochemical, physico-chemical and geological aspects. Important contributions are those of Borole et al. (1982); Zingde and Singbal (1983); Nayak (1993); Nayak and Bukhari (1993); Bukhari (1994); Bukhari and Nayak,(1996); Nayak (1998); Nayak, (1999); Bukhari and Nayak, (2000); Nigam et al (2002); Nayak, (2002). An important contribution to estuarine research in India, is a volume edited by Nair which comprises of contributions related to suspended sediment distribution, sediment texture, pollution by metals, physico -chemical aspects and also estuarine management.

Studies are also available on coastal processes. Major contributions along the central West Coast has come from research Institute, viz. National Institute of Oceanography, Goa along with its regional centers. Universities - Pune, Kolhapur, Dharwad, Goa, and Mangalore, have also carried out significant research on the beaches of Maharashtra, Goa and Karnataka.

A case Study on Impact of Mining on Estuaries:

One of the important aspects of environmental management, particularly coastal zone involves the preservation of its quality. Because of rapid economic development, increase in human population, urbanization, industrialization, the stress on the environment is increasing day by day. This requires environmental assessment which would concentrate on short and long term monitoring of various pollutants in coastal waters resulting from human settlement, industrial and agricultural activities. Domestic sewage, industrial effluents and mining are recognized as the concerned on the Central West Coast of India.

Qualitative and quantitative analysis of material transport from land to sea with reference to sediment transport, and also sediment composition and processes involved in their accumulation, are of vital importance. In this present case, mining as a man made activity and its impact on estuarine ecosystem is taken as an example.

The state of Goa is rich in minerals such as iron ore, manganese ore, bauxite, silica sand, high magnesia limestone and clay. At present, iron and manganese mining are the major extractive industries of Goa. Iron ore mining is predominant in terms of production and export. Annual production of iron ore during 1994 was around 13.5 to 15 million tonnes. Mining industry here is mainly export oriented and it contributes to about 10% of the state's economy. Estimated iron ore reserves were 1400 million tonnes (Nayak, 1994) and with the existing rate of production, mining can continue at least till 2030.

An estuary is a transitional ecotone at the confluence of rivers and sea, and one of the most complex environments. The chief factors that determine the estuarine process are the fresh water influx / the river discharge, tides, waves and meteorological forces associated with the latitudinal climatic regions. The processes are rendered more complex in case of tropical estuaries, especially those that are geographically located within the belt of monsoon influence. Heavy influx of fresh water during the monsoon plays an important role in defining and redefining estuarine limits & dynamics and the resultant changes are imprinted on distribution of sediments within the system.

Mandovi is a funnel shaped estuary. At the mouth, it measures 3.2 km, but within 4 km upstream it narrows down to less than 1 km, thus forming a bay. Further upstream it narrows to a mere 0.25 km. Water depth is about 7.5 m at mouth and 2.5 m at upstream end. The river is navigable up to 42 km upstream, which also marks the estuarine limits. River Khandepar and River Madei are the two main feeding rivers.

The tributaries of Mandovi are run across a terrain characterized by Pre- Cambrian rocks of Dharwar super group. The geology of Mandovi basin comprises of iron and manganese ore bearing formations. Other lithological units that cover the basin to varying degree are argillites, metagreywackes, quartz – chlorite schist and variegated phyllite, granitic and felspathic gneiss, tilloid, banded ferruginous quartzite, pink ferruginous phyllite and limestone. The formations have been intruded by basic dykes and quartz – pegmatite veins. The rocks belong to the Goa Group of the Dharwar Super Group.

It needs to be specially mentioned, here, that for most of their length, river Mandovi and its tributaries pass through regions of extensive mining activity basically iron and manganese ore. Mandovi basin houses 27 major mines besides a number of small scale mines. The river provides a cheap and effective means of transportation of iron ore from hinterland to Marmagoa harbour.

Increase in suspended matter

The research work carried out (Nayak 1993, Bukhari 1994), on Mandovi, 1989 onwards shows large increase in the values of suspended sediment. These studies based on monthly collection of data for over a period of one year, have reported the total suspended matter values between 2.22 mg/l and 60.49 mg/l in pre-monsoon, 10.54 mg/l and 166.03 mg/l in monsoon, 1.06 mg/l and 56.48mg/l in post monsoon for Mandovi. The changes have been interpreted as mainly due to additional input of both suspended and bed load that has linked to release of material from open cast mining activities. Further they have stated that during fair weather season, sea acts as a source and during monsoon hinterland for these estuaries. The studies have also revealed that the geomorphic set up of the estuary also plays an important role in defining the parameters / characteristics of the estuary. For example the waters of Zuari estuary are more saline than Mandovi. These studies have shown that the concentration of total suspended matter in bottom waters is always higher than that of surface waters in the estuarine region. They have also interpreted that factors like tide/tidal currents control the estuarine region. They have also interpreted that the factors like tide / tidal currents control the estuarine processes during fair weather season and land runoff during monsoon season. Monsoon rain as explained earlier, acts as a main agent in the process of transport of mine-waste to the Mandovi estuary. It seen that there is a direct relation between rainfall and total suspended matter in the estuary. Studies (Nayak,1993) have shown that the tributaries those pass through the mining zones contain very high concentration of total suspended matter and the estuarine waters hold extremely high concentration of suspended matters.

Due to heavy southwest monsoon rains, part of the mining is washed into the sea through rivers. Thus with increasing mining activity, large part of the mining rejects result in a considerable increase in suspended load. The data of the suspended load recorded in 1972 (2 to 4 mg/1) and in 1982 (4.5 to 8 mg/1) by Parulekar et al. (1986) and in 1990 very high values (as mentioned above) by Bukhari (1994) showed a considerable and continuous increase in suspended load in waters of Mandovi estuary during the last 18 years and thus confirmed the mining effect on the estuary. The increase in suspended load creates turbidity leading to reduction in light penetration and finally affecting foraminiferal population.

Decrease in foraminifera

Rao(1974) had reported presence of 32 species of foraminifera in Mandovi – Zuari sediments. However only 14 species were reported by Nigam et al. (2002) in Mondovi sediments. Similarly, the estimates of total foraminiferal number (TFN) had shown considerable decline. TFN in 1 gm of dry sediment revealed a variation from 10 to 139 specimen/ gm in 1974 whereas, only 2 to 42 specimen / gm were recorded in the 2002 study. Decline in foaminiferal assemblage has been well correlated to increase in suspended load and further to mining activity in the catchment area by Nigam et al.(2002).

Elemental enrichment

Bed load sediments for three seasons in Mandovi estuary and the bed load of tributaries were analysed for 16 elements including major and trace. Bottom and surface suspended sediment samples of post-monsoon were also analysed at selected stations for selected elements. The results obtained were used to compute enrichment factor and index of geoaccumulation and viewed in terms of anthropogenic effects and environmental impact.

For most part of their length, the tributaries of Mandovi pass through active mining and mineralized zones as mentioned earlier. Considerable amount of the material and metals are released into the sediments of these tributaries from washings / tailings and runoff from mines in addition to weathering of the exposed surface. Hence it is obvious that there could be a significant enrichment of metals in the sediments of estuary. The elemental distribution revealed that stations in close proximity of mines show considerably high concentration of trace elements.

To understand the extent of enrichment in these sediments of the river and its tributaries, the concept of enrichment factor was used. Enrichment factor (EF) is given by

$$EF = \frac{\text{(Metal / Al) Sediment Sample}}{\text{(Metal/Al) Background}}$$

The geochemical data of the post Archaean average shale (PASS) were used as the background.

Enrichment factor is remarkably high for manganese and iron followed by high factor for Cr, Ni,V,Cu,Pb,Mo and Zn in sediments of Mandovi and its tributaries. Enrichment of these elements is of great magnitude in the tributaries than in the estuary.

To assess the impact and extend of pollution, the Index of Geo-accumulation was computed for those elements that show a high enrichment factor.

Index of Geo-accumulation (Igeo) is given by the formula $Igeo = \frac{\log Cn}{1.5\ Bn}$

Cn is the measured concentration of the element and Bn is the background value, again the PAAS values are considered as background. The index of Geo-accumulation consists of 7 grades, whereby the highest grade reflects 100 fold enrichment above the background values.

The results show that the estuary and tributary sediments fall in grade O to 1 i.e. practically unpolluted to moderately polluted with reference to Zn, Cu, Co, V, Ni and Pb. With reference to Fe, the estuary in all the seasons is moderately strongly polluted within Igeo grade 2. In most tributaries, the sediments are strongly polluted falling in grade 3 i.e. 24 fold enrichment. The pollution effect is perhaps the greatest from Mn, in pre-monsoon it shows 8 to 12 fold enrichment between Igeo grade 2 and 3. During monsoon and post-monsoon, the sediments are moderately to very strongly polluted showing 12 to 48 enrichment. In tributaries level of Igeo grade was from 1 to 3 indicating about 12 fold enrichment.

The Igeo grade obtained for the estuary and tributaries indicates that these environments are polluted to varying degrees to high levels at certain zones. From the studies on suspended matter, Foraminiferal assemblage and Elemental concentration it is clear that there is an impact of mining on Mandovi estuary and its tributaries.

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