CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusion

The texture and grain size of the estuarine sediments have signified to evolve the depositional environments and distribution of metals therein.

The clayey sediments of pre-monsoon season and the silty sediments of post-monsoon period have been deposited under violent hydrodynamic conditions at the upstream region of the estuary in a shallow water environment. The sediments are found to be mostly bimodal during pre-monsoon and a few locations exhibit polymodal behaviour during post-monsoon as inferred from the frequency curves. The number of modes are also on the increase from zone I towards zone III. The grain size is predominantly fine under both seasons. Sorting of the sediments considered to be one of the most useful textural attributes, has revealed (from the standard deviation values) that the sediments are moderately sorted. The 'near symmetrical' (skewness) nature of the distribution between coarse tail and fine tail is an indication of the hydrodynamic regimes in the estuary and the high energy conditions
prevailing under zone I, II and III especially under post-monsoon period. The plalikurtic behaviour of the sediments of zone I is in tune with their bimodal nature and the leptokurtic nature of a few sediments has established the mixed population in the estuary, one derived from the fluvial and the other from marine environment. The transportation mechanism of the sediments explained by the C:M pattern, has proved the existence of more tidal action in the central part of the estuary. Turbulant conditions prevail during the posts-monsoon period. Visher's log probability curves have also confirmed the turbulent condition and tidal action. Heavy mineral analysis has indicated the presence of rutile, glaucophane, garnet, chlorite, tourmaline, staurolite, hypersthene, zircon, and epidote, besides the opaques ilmenite, haemetite and magnetite. Quartz and plagioclase feldspar are the light minerals present. The clay minerals such as kaolinite, vermiculite, illite, bidelite, and corrensite have been distributed in the decreasing order in the estuarine region.

Accumulation of nitrogenous organic matter along the industrial transect (zone I) has led to anoxic conditions during the pre-monsoon period. The decreasing grain size of the sediments and high rate of sedimentation during major flood events have retained the organic carbon in the sediments. The enhanced preservation of organic carbon in fine grained sediments has led to enriched concentration of trace metals due to the preferential adsorption of metal scavenging phases like Fe/Mn hydrolysates in view of the higher surface area provided by the fines. However, most of the trace elements have not correlated themselves with the finer sediments, as there is considerable desorption of the metals from the clay mineral sites on entering the saline estuarine region. This has been proved in the case of copper whose concentration is minimum where the salinity is maximum during the pre-monsoon period. Most of the trace
metals studied have indicated that their concentrations are higher during the pre-monsoon period except for nickel. Nickel, lead and copper are found to exhibit a 'mid-estuarine maxima' in their concentration in sediments during post-monsoon period.

In general, the zone I is found to be concentrated maximum with respect to most of the trace metals, including zinc, cadmium and mercury. However for trace metals Pb, Cu, Ni, Co and Cr, their concentration levels are found to remain below the natural background levels and the estuary could be declared pollution free with reference to these metals, as their enrichment factors are found to be low thereby confirming the lesser anthropogenic input. But Zn, Cd and Hg have high to extremely high enrichment factors, revealing a proportionately high anthropogenic contribution. This has been further confirmed from their 'Geo Accumulation Indices which remain very high.

The anthropogenic contribution of various trace elements to the Tambraparni estuary from different sources, has been identified and confirmed through factor analysis. Zinc, cadmium and mercury are not organically bound to the sediments and found to exhibit excellent correlation, but have been derived from different sources. Whereas Zn and Cd are having dual sources, Hg is derived from zone I region through the effluents discharged from the industrial complex, where a chlor-alkali plant is functioning and PVC powder is also manufactured, thereby contributing to the mercury content. But Zn and Cd have their fluvial and marine contribution from external sources too and enter the zone I region from zone III through waves and tides. A part of Zn and Cd is also contributed by Hg to which they are chemically associated.
The degree of leaching, the metals have been subjected to even under extreme conditions within the estuary, has unravelled the distribution of cadmium in an active state in the estuarine sediments, very much exposed to the marine organisations. However the other two metals Zn and Hg with high accumulation index, are found to remain inactive in the residual fraction of the sediments, and there is no threat to the marine organisms at present. Among the other trace metals Cu, Pb and Ni whose enrichment factors and geo accumulation indices are low, Pb is found in an active state in certain regions of the estuary, (zone III under both seasons) in a mixed carbonate phase, representing the bio-available part of the metal, while the entire Ni and most part of Cu are in the residual phase.

7.2 Recommendations

The inferences made above are only based on preliminary studies on the estuarine system. In order to arrive at the actual impact of the prevailing anthropogenic pollution over the system and the surroundings, further studies have to be undertaken. Hence it is recommended to attempt the following studies:

1. A vertical distribution pattern of trace metals by effecting sediment core analysis on the samples, to measure the rate of accumulation of pollutants.

2. A speciation study on the different textural attributes (sand, silt and clay) of the sediments as well as the suspended particulate matter, to better understand the transportation mechanism of various contaminants.

3. Distribution of trace metals as well as the dissolved organic matter
and various nutrients in water and the sediment-pore water to reveal the adsorption desorption processes taking place between sediment and water under different saline conditions, and

4. A continuous assessment of the pollutants flowing into the estuary during the months of an year to determine the seasonal and temporal impact on their accumulation rate.

7.3 Suggestions for Monitoring the Estuarine System and Remediation

Installation of modern sewerage systems and processing of waste water through efficient sewages treatment plants, are measures which reduce the nutrient load as well as the discharge of metals into the estuary. Such installations, though mandatory for any industry, the proper monitoring system must be entrusted with environmentalists instead of government agencies. Moreover, removal of huge deposits of sand and sediments at the mouth of the estuary that obstruct the free mixing of the estuary with sea especially during pre-monsoon period (Fig. 1.6) when pollution levels are high, would lead to a significant dilution of the contaminants in the estuary.

Remediation of heavy metal – contaminated sediments by solid-bed bioleaching studies (Lozer et al., 2001) have established the possibility of solubilizing metals in freshly dredged sediments and removal through bio-oxidation using elemental sulphur. However, dredging of sediment deposits within the estuary, is no solution as it would result in large scale resolubilization of the pollutants, exposing them to the living resources, the resettling velocity being too small especially for toxic metals like mercury.

Better is the end of a thing than the beginning thereof