CHAPTER VII
SUMMARY AND CONCLUSION

7.1. Summary

Coastal environment represents only 7% of the total oceanic surface area; however, they are biogeochemically more dynamic and probably more vulnerable to climate changes than the open ocean. Pollution of coastal systems is an inevitable consequence of urban, rural and industrial development. Pollutant types and sources are diverse and include rural, agricultural and industrial practices. The present study is focused on the understanding of the two ecologically different major estuaries in Kanyakumari district, Manakudy estuary and Thengapattinam estuary in the South-west coast of India. To achieve the goal, quantitative flux measurement of various sediment characteristics and their source-sink behaviour were studied. Several natural and anthropogenic activities regulate sediment characteristics and the present study highlights the ‘cause-effect relationship’ in these coastal ecosystems.

The sediment samples were analyzed for texture, pH, electrical conductivity, redox potential, total soluble salts, moisture content, bulk density and particle density, cation exchange capacity, nutrient elements (OC, N, P), major elements (Na, K, Cl), carbonate elements (Ca, Mg), mobile elements (S, Fe, Mn) and trace metals (Cd, Cr, Cu, Pb, Zn). The results of these analyses were subjected to statistical assessment viz., correlation, two-way ANOVA and t-test to determine their significance. To infer anthropogenic input from geogenic input, different environmental indices (Geo-accumulation index, Contamination factor, Degree of contamination and Modified degree of contamination, Enrichment factor, Pollution load Index) were calculated.
based on both global shale values and world surface rock average values in order to assess the degree of contamination. Considering geochemical background value in average shale of element, all the environmental indices were observed to have low values because in the shale, average trace metal concentrations are much higher than those found in the present study stations in Manakudy and Thengapattinam estuaries. According to USEPA/WHO, in both the estuaries, high level of contamination by Fe and Mn was observed whereas in Manakudy estuary, in addition to Fe and Mn, Cr and Cu were also present in a considerable amount affecting the ecosystem. These metals may pose an eco-toxicological risk through biomagnification ultimately causing severe health risks to the humans. Hence, there is a need for continuous monitoring of the trace metal concentrations and pollution abatement measures to protect these sensitive ecosystems and also its inhabitants as in near future these would lead to unpredictable changes in the chemical composition of these two major ecosystems in Kanyakumari district.

7.2. Conclusion

7.2.1. Sediment Characteristics

- Sediment Texture - The sediments were mostly a mixture of sand, silt and clay. In Manakudy (68.06% sand, 13.22% silt and 18.72% clay) and Thengapattinam (69.39% sand, 14.74% silt and 15.87% clay) estuaries, the overall texture of sediment was sandy loam.

- pH for all the sediment samples in Manakudy estuary were found to be slightly alkaline (7.68 - 8.16; av. 7.97) while in Thengapattinam estuary, the mean pH was slightly acidic (4.67 - 7.62; av. 5.74).
The mean EC of Manakudy estuary was 2.93 mS/cm (0.35 mS/cm to 4.93 mS/cm) while the mean EC of Thengapattinam estuary was 2.07 mS/cm (0.763 mS/cm to 4.22 mS/cm).

Sediments of Manakudy estuary showed a negative $Eh$ of - 60.06 mV (-73.17 mV to -41.5 mV) whereas the mean $Eh$ value of Thengapattinam estuary was 74.13 mV (19.81 mV to 125.67 mV).

The average TSS of the Manakudy estuary was 0.132% ranging from 0.0160% (station 1) to 0.2246% (station 6) whereas for Thengapattinam estuary the average TSS was 0.0589% ranging from 0.0246% (station 10) to 0.09967% (station 3).

The mean moisture content of Manakudy estuary was 33.74% (16.49% - 56.95%). In Thengapattinam estuary, it was 28.59% (14.30% - 44.58%).

The mean bulk density and particle density values of the sediments of Manakudy estuary were 1.495 g/cc (1.273 g/cc - 1.677 g/cc) and 2.697 g/cc (2.634 g/cc - 2.830 g/cc) whereas the mean bulk density and particle density values in Thengapattinam estuary were 1.504 g/cc (1.457 g/cc - 1.603 g/cc) and 2.68 g/cc (2.653 g/cc - 2.741 g/cc).

The mean CEC of the sediments of Manakudy estuary was 42.99 meq/100g (25.91 meq/100g - 59.66 meq/100g). Unlike Manakudy estuary, the average CEC of the sediments of Thengapattinam estuary was 31.39 meq/100g (14.22 meq/100g - 48.54 meq/100g).

In the present study the measured nutrient concentrations varied as follows.

- In the Manakudy estuary, the mean value of organic carbon content varied from 0.0903% (station 3) to 0.6103% (station 6) with an overall mean 0.363% and in Thengapattinam estuary, it varied from 0.0633% (station 10) to 0.5424% (station 3) with an average 0.3587%.
The mean nitrogen content of the sediment samples of Manakudy estuary varied between 96.49 ppm (station 3) and 756.1 ppm (station 6) with an overall mean of 360.7 ppm while in Thengapattinam estuary, the mean nitrogen content of the sediment samples varied from 81.41 ppm (station 10) to 734.6 ppm (station 3) with an overall mean of 405.0 ppm.

In Manakudy estuary, the mean phosphate concentration was 89.55 ppm and it varied between 56.20 ppm (station 3) and 127.2 ppm (station 6) whereas in Thengapattinam estuary phosphate concentration ranged from 45.02 ppm (station 10) to 134.6 ppm (station 3) with a mean value of 77.92 ppm.

The concentrations of major elements are as follows.

- The mean sodium content of the sediment samples of Manakudy estuary was 746.7 ppm (35.08 ppm - 1460 ppm) whereas in Thengapattinam estuary, the mean sodium content was 478.6 ppm (78.68 ppm - 595.9 ppm).

- In Manakudy estuary, the mean potassium concentration was 72.61 ppm (8.002 ppm - 131.4 ppm) while in Thengapattinam estuary, it was 37.50 ppm (6.938 ppm - 54.87 ppm).

- The mean chloride content of the sediment samples in Manakudy estuary was 2004 ppm (93.44 ppm - 3950 ppm) whereas in Thengapattinam estuary, the mean chloride content was 937.9 ppm (216.6 ppm - 1581 ppm).

The carbonate element, Calcium of Manakudy estuary ranged from 93.41 ppm (station 3) to 390.2 ppm (station 4) with a mean value of 209.5 ppm whereas in the sediment samples of Thengapattinam estuary, it ranged from 86.14 ppm (station 10) to 233.9 ppm (station 7) with a mean value of 176.8 ppm. The mean magnesium content of the sediment samples of Manakudy estuary varied
from 43.80 ppm (station 1) to 194.1 ppm (station 6) with an overall mean of 91.17 ppm and the mean magnesium content of the sediment samples of Thengapattinam estuary varied from 47.97 ppm (station 10) to 180.5 ppm (station 7) with an overall mean of 131.9 ppm.

- The mean sulphate concentration of the sediment samples of Manakudy estuary was 165.8 ppm (18.63 ppm - 266.2 ppm) whereas the mean sulphate concentration of the sediment samples of Thengapattinam estuary was 265.1 ppm (34.09 ppm - 348.6 ppm)

- In Manakudy estuary, the estimated mean heavy metal concentration is as follows:
  - Cadmium - 0.3443 ppm (below detectable level to 0.8027 ppm).
  - Chromium - 26.82 ppm (12.60 ppm to 38.70 ppm)
  - Copper - 36.52 ppm (15.86 ppm to 69.79 ppm)
  - Iron - 6699 ppm (2854 ppm to 17461 ppm)
  - Lead - 7.383 ppm (below detectable level to 16.86 ppm)
  - Manganese - 159.2 ppm (36.27 ppm to 251.2 ppm)
  - Zinc - 37.88 ppm (24.22 ppm to 67.79 ppm)

- In Thengapattinam estuary, the estimated mean heavy metal concentration is as follows:
  - Cadmium - 0.080 ppm (below detectable level to 0.494 ppm).
  - Chromium - 21.82 ppm (13.10 ppm to 27.06 ppm).
  - Copper - 24.15 ppm (15.99 ppm to 33.56 ppm)
  - Iron - 5378 ppm (921.6 ppm to 14111 ppm)
  - Lead - 6.833 ppm (2.447 ppm to 21.56 ppm)
  - Manganese - 54.59 ppm (9.962 ppm to 136.1 ppm)
  - Zinc - 52.19 ppm (28.34 ppm to 132.8 ppm)

- In both the estuaries, the most occurring heavy metal was iron and the least occurring heavy metal was cadmium. The order of abundance of metals in the
The strong positive correlation of clay with all nutrients indicate that the latter was associated with clay minerals in both the estuaries.

In both the estuaries, pH showed a strong negative correlation with Eh and the variation of pH was significant between seasons and stations.

EC and TSS showed strong positive correlation with clay in both the estuaries. In Manakudy estuary, the variation of EC and TSS were significant between seasons and stations whereas in Thengapattinam estuary, the variation of EC was significant only between seasons.

The variation of moisture content, bulk density and particle density were significant between stations and insignificant between seasons in Manakudy estuary whereas in Thengapattinam estuary, the variation of these parameters were significant between both stations and seasons.

The variation of CEC was significant between stations and seasons in Manakudy estuary whereas in Thengapattinam estuary, the variation of CEC was significant between stations and insignificant between seasons.

In both the estuaries, OC showed a significant positive correlation with nitrogen indicating fine sediments were nitrogenous organic matter.

The variation of OC and nitrogen were significant between stations in Manakudy estuary whereas in Thengapattinam estuary, the variation of OC and nitrogen were significant between stations and seasons.

The strong positive correlation of phosphorus with OC in Manakudy estuary indicates that phosphorus fixation was by organic matter. In both the
estuaries, the variation of phosphate-phosphorus was significant between seasons and insignificant between stations

- The C/N, N/P and C/P values indicate that in Manakudy estuary, these nutrients were of abiogenic origin i.e., agricultural or sewage discharge whereas in Thengapattinam estuary, these nutrients were due to the combined effect of planktonic and agricultural discharge.

- The variation of the major elements sodium and potassium were significant between stations and seasons in both the estuaries. The variation of chloride was significant between seasons and insignificant between stations in Manakudy estuary, but in Thengapattinam estuary, it was significant between stations and seasons.

- The variation of the carbonate elements, calcium and magnesium were significant between stations and seasons in both the estuaries. $\text{Ca}^{2+}/\text{Mg}^{2+}$ ratio indicates unlike Manakudy estuary, Thengapattinam estuary was slightly affected by sea water intrusion.

- In both the estuaries, the variation of sulphate-sulphur was significant between stations and seasons.

- In Manakudy estuary, no significant positive correlation between Fe, Cd and Zn indicates that there is no mutual relationship among these metals. Since significant positive correlation was found to exist between all the metals under study in Thengapattinam estuary, it can be concluded that they may have the common pollution source i.e. agricultural or sewage discharge.

- In both the estuaries, low positive correlations of OC with all metals under study except Fe indicated all metals except Fe have low association with organic carbon.
TEC/PEC guidelines showed that Manakudy estuary is under stress with the metal copper whereas Thengapattinam estuary is not affected by the presence of small quantities of these heavy metals.

USEPA/WHO guidelines indicate that Cd, Pb and Zn in both the estuaries were below the USEPA /WHO standard value. Cr in Manakudy estuary exceeded the regulating limits while in Thengapattinam estuary, Cr was below the WHO/USEPA standard value. Cu in Manakudy estuary was above the WHO standard values while in Thengapattinam estuary, Cu was below the standard value. In both the estuaries, the concentration of Fe and Mn were above the standard value of WHO/USEPA but they were below the average shale concentration.

According to $I_{geo}$, Manakudy sediments were enriched with metals in the order: Cd > Cu > Pb > Zn > Cr > Mn > Fe whereas Thengapattinam sediments were enriched with metals in the order: Cd > Cu > Zn > Pb > Cr > Fe > Mn. On the basis of the mean values of $C_f$, Manakudy sediments were enriched with metals in the order: Cd > Cu > Zn > Pb > Cr > Mn > Fe while Thengapattinam sediments were enriched with metals in the order: Zn > Cu > Pb > Cd > Cr > Fe > Mn.

$mC_d$ for all the stations in Manakudy and Thengapattinam estuaries were found to lie below 1.5 indicating 'nil to very low degree of contamination.'

In both the estuaries, the mean enrichment factors for Cr, Cu, Fe, Pb, Mn and Zn vary between 0 and 10, indicating that the estuaries are not much affected by anthropogenic influences.

PLI value of the analyzed samples in Manakudy estuary was 0.1983 whereas in Thengapattinam estuary, it was 0.0949. At all sampling stations in both the estuaries, the PLI value was less than 1. Hence it can be concluded that all sampling stations represented perfection (or no overall pollution).
7.3. Pollution Status of Manakudy and Thengapattinam estuaries

Manakudy and Thengapattinam estuaries exhibited marked seasonal as well as locational variations in the sediment quality parameters. The degree of fluctuation was more in the case of Manakudy estuary compared to the Thengapattinam estuary. A comparative evaluation of the sediment quality parameters between Manakudy and Thengapattinam estuaries reveals that the former is contaminated more due to influx of considerable quantity of industrial, agricultural, domestic and municipality wastes. Introduction of industrial effluents into Thengapattinam estuary is very less compared to Manakudy estuary as large number of industries like sand mining industry, coconut husk retting, lime-shell dredging and salt pan are situated on either side of Manakudy estuary. Out of these two estuaries, contamination rate is several fold higher in Manakudy estuary than Thengapattinam estuary. The impact of anthropogenic pollution is severe during the non monsoon compared to the monsoon period as there is no dilution or washing of contaminants during the non monsoon period. Monsoon flood imparts marked changes in the sediment quality of both estuaries. The nutrient species of nitrogen and phosphorus have exhibited an increase during this season compared to non monsoon in Thengapattinam estuary. The major sources are land runoff through agricultural areas, urban / domestic wastes as well as monsoon floods over contaminated lands.

Assessment of sediment trace metal contamination in these systems, gave an important insight into the status of pollution. Fe-Mn oxy-hydroxides along with clay content played a major role in accumulating trace metals from the overlying water column in both the systems. To summarize, it can be stated that on the basis of the values of degree of contamination and PLI, among all the stations in Manakudy
estuary, station 6 was identified as highly contaminated “hot spot” with pollutants as this station was influenced by pollutants from a nearby riverlet into the estuary, coconut husk retting pits and salt pan. This was the station where the sewage drains directly into the estuary and the texture of the sediment was clay. In Thengapattinam estuary, station 3 was the “hot spot” where the AVM canal drains its water.

To sum up, the analysis of nutrient and heavy metal fluxes in Manakudy and Thengapattinam estuaries reveals that the quantity of nutrients and heavy metals discharged through Thengapattinam estuary is low and have a wide seasonal difference than the Manakudy estuary. Thus by this investigation, pollution threats as well as other anthropogenic stresses on the sediment quality of the two estuaries has been brought out.

7.4. Recommendations

- An environmental monitoring system should be established in the industrially affected Manakudy estuary in order to give timely warning to the concerned stakeholders. The system should have the capability of monitoring water (surface and ground water), sediments and liquid and solid industrial effluents of the area on regular basis.

- Strict measures are to be taken to pretreat the solid and liquid wastes as per standard norms of Central Pollution Control Board (CPCB), Government of India, before discharging to the estuary.

- Measures are to be taken to establish an integrated waste treatment / management system in the industrially affected stretch of the Manakudy estuary.
7.5. Scope for Future Studies

- Quantification of the pollution history through geochronological studies to determine the age of the sediment at the time of deposition. Sequential extraction and speciation studies of metals to understand the binding fractions and mobility of metals to the surrounding environment.

- Assessment of the heavy metals in water, sediment and fish samples

- Isolation of bacteria and determination of metal resistance or sensitivity.

- Investigation of probable natural radionuclides, their activity concentration levels in the sediment samples and determination of the radiological effect on the environment due to those radionuclides.