Summary

The multifarious nature of industrial and domestic pollution of Manakudy mangrove ecosystems and the accumulation of pollutants in the mangrove influences the quality of surface and bottom water and sediment of the study area. The present study provides a scientific data of the region in the proximity of the mangrove ecosystem. In order to achieve the objective, mangrove water, sediment samples were chosen in a grid pattern in the study area. The required physico-chemical parameters and the concentration of trace metals were determined. The present comprehensive investigation on the surface water, bottom water and sediment to this fragile zone is imperative to assess the environmental degradation of the study area and research findings are summarized below:

All the studied physico-chemical parameters depend upon seasonal fluctuation of fresh water input and seawater intrusion. High pH values are due to the mixing effect and birds excreta. High salinity values are due to tidal mixing and dominance of neritic water from open sea. Turbidity was affected by salinity. So salinity was high in monsoon due to the movement of water in and out of the estuary by tides, causing fine particles to mix and be stirred up. Dissolved oxygen contents showed well marked variations in the Manakudy estuary. It seemed to be controlled by various factor such as rainfall, temperature, phytoplankton, photosynthesis and salinity.

Total alkalinity values are high in Manakudy mangrove ecosystem due to the presence of mineral salt. Chloride was high premonsoon due to the sea water intrusion coupled with huge influx of sewage. The distribution and behaviour of nutrients (Phosphate, Nitrate and Nitrite) in the Manakudy mangrove ecosystem
would exhibit considerable seasonal variations. High concentration of nutrients in water during monsoon could be attributed to the heavy rainfall and subsequent river runoff, bringing much land derived materials along with domestic, municipal and agricultural wastes including fertilizers and pesticides. During non monsoon months the disposal of fresh water is meagre, which make less amount of nutrients in this estuary.

Sulphate, sulphide concentrations were high in near the mangrove due to retting processes. Sodium is a dominant cation followed by Ca$^{2+}$, Mg$^{2+}$ and K and it is observed that the concentration increases with increase in salinity. The low N: P ratio indicated potential nitrogen limitation of phytoplankton production. Statistical analysis confirms the multiple sources controlling mangrove water chemistry. Correlation studies demonstrates that the variation of Na$^+$ with Cl$^-$ is related to nitrate reflecting that the contribution from the domestic effluents (sewage water) could be expected much for the water chemistry of the region.

Factor analysis is employed to delineate the sources affecting the mangrove water chemistry. It shows that the Manakudy mangrove forests are affected due to anthropogenic activities. Cluster analysis classifies the elements with similar properties in Manakudy estuary around mangrove forest. The water quality forms the basis for the floral and faunal diversity of the mangrove ecosystems. The results from this study could be used for a better water quality management of Manakudy estuary and the coastal zone. The conservation, management and sustainable development of the Manakudy swamp would depend on the maintenance of the hydrological characteristics without much alteration.
Box plot of calcium carbonate shows the mean, median, and quartiles. Box plots provide to identify outliers. The calcium carbonate values were highly fluctuating, due to the presence of molluscan shells. Anthropogenic activity increases the organic carbon matter in these mangrove sediments and shows the expected positive correlation between organic matter and calcium carbonate. Organic carbon was high in S7. The detritus from the mangrove forest increase the organic carbon content of this station. The Manakudy mangrove sediments are under pressure from the anthropogenic sources like sewage and domestic waste has resulted in initiation of organic load build up in it.

The sulphur content was high in S1. The coir retting pits along the estuary accounts for hydrogen sulphide and subsequently the high sulphur content of this station. Sand is the major fraction and coarsely skewed and very leptokurtic in nature. Sand and silt constitute 70-90% of the mangrove sediments followed by clay.

Chemical and statistical analysis of the sediment suggests that the mangrove is relatively unpolluted, with unique chemical behaviour and a multitude of sources. The study reveals the lesser impact of anthropogenic signatures in the Manakudy mangrove ecosystem. The study also made plans for an alternate use of coastal resources in tune with environmental hygiene in supportive of additional income to the nation/coastal folk, in particular. The recent devastation by tsunami only emphasizes the need to protect the fisher folk and mangroves for the benefit of the entire nation. Hydrodynamic techniques such as artificial retention system, detention system, recharge pits has to be carried out in order to improve the quality of water.
**Water Quality**

Objective of water quality study is to seek to improve the water quality to a level which supports both a healthy estuarine ecosystem and to satisfy the local community’s recreational, aesthetic and commercial needs. Generally, the water quality of any estuary is a potentially limiting factor to the relative health of the estuarine and adjacent habitats.

**Concerns and issues: Threats to water quality**

There are a number of factors that influence estuarine water quality. Key treats to water quality include

- Industrial effluent and sewerage discharge pollution from the urban and industrial sources.
- Erosion and sedimentation.
- High levels of nutrients, which lead to eutrophication and algal blooms.
- Reduced freshwater inflow.

Of late, the coastal ecosystems are highly degraded due to high pollution and industrial growth (Glasby and Roonwal, 1995; UNEP, 1997). Due to various pollution including pesticide poisoning, over exploitation of water resources by the municipal uses and encroachment for urban development force the fishing community to the brink of disappearance (Sen Gupta, 1990). When those natural resources are imperilled, so too are the livelihoods of the many people who live and work here. The environmental abuse and the negligence of the governing body make the matter worse (Sreenivasan and Franklin, 1975).
Water Quality Management

In general, the water quality of any estuary is a potentially limiting factor to the relative health of the estuarine and adjacent habitats. In Manakudy estuary, water quality is affected by (i) the mixing of contaminated water from pazhayar river (ii) Effluents from adjacent small scale industries like coconut husk retting and lime shell dredging. The aim of this work is to improve the water quality to a level which supports both a healthy estuarine ecosystem and local community’s recreational, aesthetic and commercial needs.

Estuary habitats in the study region may be most affected by changes in the timing and persistence of seasonal mouth closure and the intensity and timing of seasonal runoff, as well as the continued rise in sea level. Sediment discovery and availability are projected to strongly influence the ability of estuary morphology to adjust to rising sea level and maintain intertidal estuarine habitat. Also, water properties such as temperature, salinity, dissolved oxygen and pH can be expected to change significantly, as well as patterns of primary production (Largier, 2010) while it is unlikely to predict future states of a system as complex as the coastal ecosystem within the study region, which includes monitoring and adaptive management approaches that can be implemented as the environment continues to change, seeking to maximize benefits of change while mitigating the negative impacts (Largier, 2010).

The results of the study illustrates that the average values of TDS of mangrove water during the studied period ranges from 2.71-3.98 ppt. TDS values also indicates the non-suitability of water for portability. Results of factor analysis and cluster analysis also substantiate the water quality. In this context, better
sustainable management solution to improve the quality of water is necessitated. Public awareness about pollution abatement, particularly about ‘natural diatom scum’ and the difference to sewage related scum.

- Options have to be investigated for improving or removing private discharges.
- Possibilities of quantifying nutrient enrichment and the minimization of the future nutrient input into the estuary have to be explored.
- The impact of estuarine pollution with small scale industries and the local community through the use of code of conduct has to be addressed.
- Regular shoreline litter clean-ups have to be encouraged and the identification of lee shore litter problem areas.
- A comparative plan on surface water body has to be prepared to create a data base with regard to their present status, sustainable use, management and conservation and to formulate strategies for their long term management.

**Sediment Quality**

Most estuaries act as a depositional area, trapping and retaining sediments and organic matter from their catchments, along with associated contaminants such as heavy metals, nutrients, hydrocarbons and redistributed by floods, tides and currents, eventually settling out in lower energy environments. The contaminants associated with estuarine sediments may be re-processes through chemical or biological processes or buried, forming part of the sedimentary record.

The Manakudy mangrove sediment has less contamination. Historical and contemporary land uses within the catchment also influence sediment inputs, grain size, and chemistry. The geochemical cycle of anthropogenic trace metals in the
marine environment is determined to a large degree by the interactions of the metals with sediments (Krumgalz, 1992).

**Future options**

The integration of multiple surveys and use of a standardized assessment framework provided a more comprehensive and robust assessment of Manakudy estuary sediment quality that has been achieved previously. This assessment yielded results that were consistent with expectations based on earlier studies, thus increasing confidence in the overall accuracy of the sediment condition assessments.

Future studies should also include multiple toxicity tests and benthic indices in order to provide greater confidence in the measurement of these lines of evidence. The environmental significance of sediments classified as possibly impacted is uncertain, as this category may indicate a minor level of contaminant effect, or substantial disagreement. Stressor identification studies, such as toxicity identification evaluations are needed as possibly impacted sites to determine whether sediment quality at these sites is adversely impacted by contaminants.

**Concerns and Issues**

Nearby 80% of the population belongs to fishermen community and they settled in this region for generations. Major occupation of these people is fishing and they depend on the Manakudy estuary for their livelihood. Due to pollution, the native fish variety had declined and the fishermen depend on the nearby sea for their fishing activities. The education status reveals that the fisher folks lack higher educational facilities and this has to set back their employability in other fields. Their economical level is very vulnerable. The depletion of fish stock has also reflected in the decline of fish catch by artisan fishes and their income. In fact, the catches from
the artisan sector in India have decreased from 8,70,000 tons in 1971 to 2,97,000 tons in 1997. There are about 0.5 million coastal artisan fishers, which are about 75% of the total active marine fishers. The steep declining growth of marine fishing is mainly attributed to over exploitation and general marine environmental degradation especially in the coastal areas. This has immediate effect on the income of coastal fishers.

**Future implement**

- Programs to monitor the current condition of target fish species of the Manakudy estuary have to be established.

- Fishermen cooperative can be formed which can be vested with the responsibility of protecting the fisheries resources they harvested. They should be made aware of the biological and environmental basis for sustainability of fish stocks by constant interactions with the scientific community.

- Steps should be taken to stop/minimize the discharge of waste from coir retting pits into the estuary.

- Regular environmental monitoring should be undertaken to sustain the health of the estuary for posterity.

- Land use management focusing to reduce the contaminated level of estuary by (i) Removal of shrubs (ii) Removal of waste dumps (iii) Gross over adjacent to the estuary by creating large surrounding parks which will halt the indiscriminate disposal of domestic wastes into the estuary and (iv) Plantation of mangrove trees.