CHAPTER I
INTRODUCTION

Awareness on environment and related issues has given tremendously all around the world in the recent years. Increasing human population resulted into expanding needs of man. With scientific progress and technological development, man started utilizing natural resources at a larger scale. Conservation is concerned with complete elimination of some unique species. Hence there is an urgent need to check the degradation scale of the environment. Maintain or restore the nature’s balance is the most important challenge to mankind. Present generation has the responsibility to leave a better world with enriched natural resources for the present as well as the future generation. The environment in general is imperative to adopt a comprehensive and integrated view in space and time for the development process. Being an integral part of the global sustainable development process oceans, coasts and islands support a diverse array of activities yielding enormous oceanic and social benefits.

Estuaries are the most productive, diverse, economically important, and hydrologically variable ecosystems on Earth. An estuary is a partially enclosed water body along the coast where freshwater from rivers and streams meet and mix with salt water from the ocean. Estuaries are places of transition from land to sea and freshwater to salt water. The inflow of both sea water and fresh water provides high levels of nutrients both in the water column and in sediment, making estuaries among the most productive natural habitats in the world. Although influenced by the tides, they are protected from the full force of ocean waves, winds, and storms by barrier
islands or peninsulas. Estuarine environments generate more organic matter each year than forest, grassland or agricultural land. The tidal, sheltered waters of estuaries also support unique communities of plants and animals especially adapted for life at the margin of the sea. Different types of habitat are found in and around the estuaries, including shallow waters, freshwater and salt marshes, swamps, sandy beaches, mud and sand flats, rocky shores, oyster reefs, mangrove forests, river deltas, tidal pools and sea grasses.

1.1. Importance of Estuaries

Estuaries provide many resources for the benefits of mankind and water related services. Estuaries are nowadays very popular for recreational activities, scientific study and aesthetic enjoyment. So it must be managed carefully without any deterioration. Estuary is the place where thousands of species such as birds, mammals, fish and other wildlife habitats live, feed and reproduce. Many marine organisms, including most commercially important fish, depend on estuarine condition during their development. Estuaries are important for the development of infrastructure, serving as harbours and ports. Water draining from uplands carries sediments, nutrients and other pollutants to estuaries. As the water flows through wetlands such as swamps and salt marshes, much of the sediments and pollutants are filtered out. This filtration process creates clear water, which benefits both people and marine life. Wetland plants and soil act as natural buffers between the land and ocean, absorbing flood waters and dissipating storm surges. This protects upland habitat as well as valuable one from storm and flood damage. Salt marsh grasses and other estuarine plants help to prevent erosion and stabilize shorelines. Natural beauty and bounty of estuaries are part of the economic growth of any nation.
So, countries with long coast are growing three times faster than countries elsewhere in the nation. Unfortunately, increasing population upsets the ecological balance of estuarine ecosystems, threatens their integrity and imposes increased pressure devastating natural resources. In addition to economic, cultural and ecological benefits to communities, they also deliver valuable ecosystem services which are fundamental life-support processes upon which all organisms depend. They stabilize shorelines and protect coastal areas, inland habitats and human society from floods and storm surges from hurricanes. When flood occurs, estuaries often act like huge sponges, soaking up the excess water.

1.2. Geological Classification of Estuaries

Estuaries are typically classified based on their geologic origins. The five major types of estuaries classified by their geology are coastal plain, bar-built, deltas, tectonic and fjords. Coastal plain estuaries are formed when rising sea levels invaded low-lying coastal river valleys. Bar-built estuaries are characterized by barrier beaches or islands that form parallel to the coastline and separate the estuary from the ocean. Barrier beaches and islands are formed by the accumulation of sand or sediments deposited by ocean waves. A delta, characterized by large, flat, fan-shaped deposits of sediment at the mouth of a river, occurs when sediments accumulate more rapidly than ocean currents can carry them away. When the Earth’s tectonic plates run into or fold up underneath each other, they create depressions and form tectonic estuaries. Fjords are steep-walled river valleys created by advancing glaciers, which later became flooded with seawater as the glaciers retreated.
1.3. Estuaries in Tamil Nadu

Tamil Nadu situated on the south-east of Peninsular India is about 1,30,000 sq.km. The length of the coast line of Tamil Nadu is about 1050 km, with its significant portion on the east coast of India. The coast line starts from Pulicat along the east coast and extends up to Neerodi in Kanyakumari district and consists of estuaries of ecological importance, major and minor ports, fishing harbours, monuments of international heritage, tourist locations, pilgrimage centers etc. Tamil Nadu is influenced by the prevailing seasons, South-west monsoon (June to September), North-east monsoon (October to December) and Non monsoon (January to May).^6^  

There are 46 rivers that drain into the sea of Tamil Nadu coast. Out of the 46 rivers, the important river mouths are Pulicat, Ennore, Cooum, Adayar, Vellar, Vellaiyar, Punnakayal, Manakudy and Thengapattinam. The nature of coast line is generally classified as

- Coast line from Pulicat to Vedaranyam
- Coast line from Vedaranyam to Mandapam
- Coast line from Mandapam to Kanyakumari
- Coast line from Kanyakumari to Neerodi.

1.4. Estuaries in Kanyakumari District

Kanyakumari, the smallest district in Tamil Nadu, with a land spread of 1,684 sq.km. has almost all ecosystems - forests, wetlands, freshwater resources, marine, etc. Agricultural plantation crops (spices, rubber), banana, coconut, paddy, etc. are commonly produced. Apart from this, coastal environment is very important with respect to fish production and fisher folk's employment. The coastal ecosystem of this
The coastal landscape of Kanyakumari district encompasses a diverse range of features including beach terraces, low cliffs, sandy beaches, dunes, rocky shores, estuaries, wetlands and forests. The 68 km long coast has thickly populated fisher-folk, almost one village per 1.5 km. Chinnamuttom harbour and Vattakottai (circular fort), a historically important place are located on the eastern end of the coast. Colachel Port and Muttom harbour are found along the western side of the district. The coast extends up to Neerodi, a coastal village.

Fig. 1.1. Location map of the Area of Study
Nowadays, the estuaries are exploited due to many activities. The estuaries and coastal waters are more productive during monsoon as rain water brings enormous quantities of nutrients as a result of its dynamic nature. The presence of several varieties of finfish, prawns, crabs, lobsters, stomatopods, clams, mussels and oysters of commercial significance in this environment is a clear evidence that the estuaries are functioning as good breeding grounds. The estuaries are thus playing a vital role in renewing marine resources. In India 1.5 million ha of brackish water has been identified. In Kanyakumari District nearly 1000 ha of estuarine environment has been identified as potential area for fisheries resources.

There are three important riverine ecosystems, which confluence with Arabian sea. They are

1. Thengapattinam estuary formed by the confluence of river Tamiraparani in between Thengapattinam and Erayamanthurai.
2. Valliyar estuary formed by the river Valliyar near Kadiapattinam.
3. Manakudy estuary formed by the confluence of river Pazhayar in between East and West Manakudy villages.

Apart from these, there are two minor estuaries also: they are

- Pambar estuary near Colachel and
- Pantri estuary near Rajakkamangalam. These are formed by the drainage canal, when excess water during monsoon and the water drained from the irrigational fields.

1.5. Pollution in Manakudy and Thengapattinam Estuaries

Estuarine pollution may be defined as the human introduction of any substance such as chemicals and waste products that are hazardous or potentially
harmful to estuarine ecosystem. This includes pollutants that are directly toxic to plants and animals and materials that overload the estuary's capacity to assimilate wastes which ultimately deplete essential oxygen. Toxic substances commonly found in estuaries are heavy metals, pulp-mill effluents, insecticides, herbicides and petroleum products. Also the contaminants such as sewage, slaughterhouse and seafood-processing wastes, tree bark and sawdust from sawmills, wood fibres from log-rafting operations, phosphates and nitrates from detergents and fertilizers and livestock wastes degrade the estuarine ecosystem. Introduction of pollutants to estuaries is one of the greatest threats to our marine environment. The major activities responsible for coastal pollution in Tamil Nadu are discharge and disposal of untreated domestic and industrial wastes, discharge of coolant waters, harbour activities such as dredging, cargo handling, dumping of ship wastes, spilling of cargo’s chemicals and metal ores, fishing activities etc. The shoreline along the coast of Tamil Nadu is subjected to oscillation due to natural and man-made activities. The development of ports and harbour lead to erosion of the coast and create an open access to inland waterway. The shoreline along the coast is enclosed by wave induced littoral drift leading to accretion and erosion. In general, dredging and disposal of dredged material affect sediment transport. The disposal of industrial waste coupled with domestic waste into inland estuaries and waterways may lead to deterioration of creek water quality. The sediment depletion due to port structures causes erosion, loss of coastal properties and compulsory rehabilitation of native fishermen.

The Pazhayar river starts at Shurlacode, about 18 km north-west of Nagercoil. The Manakudy estuary is one which naturally connects the Arabian sea and the Pazhayar river. The estuary gets the pollutant load from Thovalai, Ananthanar and
Nanjilnadu Puthanar channel passing through Thazhakudi and Vellamadam villages. The deterioration of estuary can be attributed to the inflow of water from agricultural fields, coconut husk retting, lime-shell dredging, salt pan and untreated domestic sewage. Water is always present in the estuary and the monsoons result in high flow of water through the river raising the water level in the estuary.

The river Tamiraparani originates from Kodayar hills, which is situated in the southern part of Western Ghats. It mixes with the Arabian sea after traversing a distance of about 45 km across the district. The river receives water from the heavy rainfall during the monsoon months. Thengapattinam estuary is connected with the Arabian sea thereby Tamiraparani river flows through this estuary. Water from paddy fields, coconut plantations and AVM canal (Anandan Victoria Marthandavarman Canal) are entering the estuary through Tamiraparani river. A huge quantity of untreated sewage leaches into the estuary through the AVM canal. On the banks of the estuary large scale coconut husk retting activity is being carried out throughout the year.

1.6. Description of the Study Area in Manakudy and Thengapattinam Estuaries

Manakudy estuary is the confluence of river Pazhayar and it is the second largest estuary in Kanyakumari district. The tail end of Pazhayar river merges with the Arabian sea at Manakudy. It is a bar-built estuary and has a total area of 145 hectares extending over 4 km bordered with vast stretches of salt pans on either side. It is situated about 8 km north-west of Cape Comorin, falling within the latitude 8°09’ N and longitude 77°48’ E on the south-west coast of Kanyakumari district. The climate in this region is greatly influenced both by the south-west and north-east monsoons.
Large scale sand mining industry activity is on a full swing in the estuary. Along the banks of the estuary there are small scale industries like coconut husk retting, lime-shell dredging and salt pan.

![Location Map of Manakudy Estuary](image)

**Fig. 1.2. Location map of Manakudy estuary**

The estuary is connected with the sea during the rainy season and the rest of the year it is locked by sand bar. The formation and closure of the sand bar at the mouth of the estuary leads to pronounced changes in the composition of sediment nutrients of the estuary and hence continuous ecological assessment and monitoring is required.

Ten stations with different ecological conditions were chosen for the collection of sediment samples in the estuary from estuarine mouth bed to river basin. The location of the stations is shown in Fig. 1.2.
Station 1: River Basin (Near Mission Dam)

This station is a fresh water zone, which is 4 km before the main estuary and is shown in Plate - 1(a). This station is comparatively free from sewage pollution but has inflow of water from the nearby paddy fields and coconut plantations.

Station 2:

This station is located about 0.5 km before the bar mouth in the estuary. When the bar mouth remains open, the mean depth is about 1.5 metres. This however, increases considerably when the estuary is land-locked. In the bottom of the estuary, the sediment is mud mixed with sand.

Station 3: Bar Mouth

The third station is the estuarine mouth near the sand bar. It is connected with the sea on most of the days during the rainy season due to the influx of fresh water from river Pazhayar. In summer months it generally remains land-locked. This is shown in Plate - 1 (b).

Station 4:

This station is located upstream from station 2. Lime shell dredging is being carried out in this station. This station is constantly polluted by effluents brought out from nearby coconut husk retting pits and lime shell dredging areas [Plate - 2 (a)]

Station 5:

This station is located upstream from station 4. There is a small mud flat with clayey soil and plenty of dead shells are found in this station.
Station 6:

This station is located upstream from station 5 [Plate - 2 (b)]. This station is influenced by pollutants from a nearby riverlet into the estuary, coconut husk retting pits and salt pan. This is the station where the sewage drains directly into the estuary, resulting the station a highly polluted one. The soil is exclusively clay in this station.

Station 7:

This station is situated upstream from station 6. There is inflow of domestic sewage, and water from coconut grooves and salt pan.

Station 8:

This station is located upstream from station 7. It represents the interior segment of the estuary where the sewage is comparatively diluted.

Station 9:

This station is situated near the mangrove forest, which receives heavy inflow of water from the neighbouring salt pan.

Station 10:

This station is located upstream from station 9. Here again the pollutants are from the nearby coconut grooves and salt pans.

Thengapattinam estuary (8° 14’ N latitude and 77° 10’ E longitude) on the south-west coast of India (Fig. 1.3) is situated in Paimkulum village of Vilavancode Taluk of Kanyakumari district. It is the first largest estuary in Kanyakumari district and situated at a distance of about 35 km from Nagercoil. The estuary spreads over an area of 400 hectares and extends over 5 km. It is also a bar-built estuary formed by the
confluence of river Tamiraparani with the Arabian Sea at Thengapattinam. The climate of this region is greatly influenced both by the south-west and north-east monsoons. Along the west coast line, the AVM canal with water inflow from nearby land and streams, is used for coconut husk retting activities. The estuary is connected with the sea during the rainy season and land locked for the rest of the year by sand bar. Similar to Manakudy estuary, ten stations were selected based on different ecological conditions for the collection of sediment samples from estuarine mouth bed to river basin. The stations are shown in Fig. 1.3.

Fig. 1.3. Location map of Thengapattinam estuary

Station 1: River Basin (Parakani)

This is a riverine zone, which is 4 km before the main estuary and is shown in plate - 4 (a). There is heavy inflow of water from the nearby paddy fields and coconut
plantations into the river and large scale coconut husk retting is being carried out throughout the year.

**Station 2:**

This station is about 2 km, downstream from station 1. This represents a station between the head and mouth of the estuary. The sediment in this station is sandy clay.

**Station 3:**

This station is about 2 km from the bar mouth of the estuary. The mean depth is about 2 metres when the bar mouth remains open. However, this increases considerably when the estuary is land-locked. AVM canal drains its water near this station. The nature of the sediment is muddy and large number of molluscs is found in this station [Plate - 4 (b)]

**Station 4:**

This station is situated about 0.5 km, downstream from station 3. There is heavy inflow of water from the neighbouring coconut grooves.

**Station 5:**

This station is located downstream from station 4. Here the pollutants are from the nearby coconut grooves and tapioca fields.

**Station 6:**

This station is located downstream from station 5. This station is constantly polluted by domestic sewage and effluents brought from nearby coconut grooves.
Station 7:

This station is located downstream from station 6. There is a small rock with sandy clay and plenty of molluscs are found in this station. There is a riverlet in this station [Plate - 5 (a)]

Station 8:

This station is located, downstream from station 7. There is inflow of domestic sewage through a riverlet and water from the nearby coconut fields. Here again, molluscs are found in abundance. The sediment is found to be sandy clay in this station.

Station 9:

This station is situated upstream from station 10 [Plate - 5 (b)]. There is inflow of domestic sewage and water from coconut grooves.

Station 10: Bar Mouth

The last station is the estuarine mouth near the sand bar. It is connected with the Arabian sea on most of the days during the rainy season due to the influx of fresh water through river Tamiraparani. In summer months it generally remains land-locked, but occasionally gets connected with the sea when the local people remove the narrow sand bar to avoid damage to the neighbouring areas by flood caused by the inflow of river water. This is shown in Plate - 6 (a).
1.7. Objectives of the Study

The objectives of the study are

1. Periodical sampling of the sediments in Manakudy and Thengapattinam estuaries and their characteristic analysis.

2. Characterisation of metals and nutrients in the sediment samples and their interpretation with statistical application.

3. Assessment on the impacts of contaminated sediments on the environment and

4. Suggesting suitable management measures to reduce the pollution load in Manakudy and Thengapattinam estuaries.

1.8. Relevance of the Present Study

Studies on the physico-chemical aspects and textural characteristics have been made in the sediments of different Indian estuaries and also in Tamil Nadu. Important works on the physico-chemical factors on sediments along the west coast of India have also been done. Considering the paucity of information available on various estuaries in Tamil Nadu, an attempt has been made to assess the physico-chemical and textural characteristics of the sediments of Manakudy and Thengapattinam estuaries. Sediment samples were collected monthly from ten ecologically different stations in Manakudy and Thengapattinam estuaries for a period of one year from April 2011 - March 2012 and then quarterly for a period of one year from April 2012 - March 2013. The samples were analyzed for the assessment of nutrients and metals like Cu, Zn, Cd, Cr, Pb, Fe and Mn in the sediments and also the impacts of contaminated sediments on the environment.
Three seasons are considered for the study based on the south-west monsoon and north-east monsoon prevailing in Kanyakumari District and the data are grouped into three categories as

Pre monsoon season (April, May, August and September),
Monsoon season (June, July, October and November) and
Post monsoon season (December, January, February and March).

So far, no comparative study was made on these two estuaries and this study may provide a base line data for future ecological assessment and monitoring of these estuaries. Further the Government of Tamil Nadu has constructed a new bridge over the Manakudy estuary and a fishing harbour in Thengapattinam estuary during the study period. Therefore the observation will be more useful to monitor the possible ecological changes during and after these constructions.