CHAPTER 1
INTRODUCTION

Water is one of the most essential inexhaustible basic natural resources needed by all living beings for their survival. Indeed, the economics of whole life processes and living communities are linked to this most vital element. It maintains an ecological balance between the biotic and the abiotic components of the environment. This most precious resource covers more than seventy percent of the earth’s surface. India has a great potential of water resources both marine and fresh water. The intermixing of marine and freshwater systems often creates another arena, the estuary, which is brackish in nature.

1.1. Estuarine Process

Estuary is defined as a semi-enclosed body of water, which has a free connection with the open sea and within which the sea water is measurably diluted with fresh water derived from land drainage (Pritchard, 1967). This unique biotope can be considered as a transition zone or ecotone between fresh water and marine habitats (Odum, 1971).

The estuarine water is of mixed origin with fresh water supplied by the river and the land runoff and the sea water by the state of tide. The water of this mixed origin does not occupy a constant position. The zone of mixing can
remain static if the freshwater discharge is fairly constant throughout the year and the tidal incursion is negligible. These two important variables are not strictly applicable to Indian conditions where the fresh water regime becomes highly variable with the onset of monsoons and the tidal range becomes dependent with the geographical location of the estuary and the phases of the moon (Qasim, 2003).

The state of Kerala lies between latitude 8° 18’ and 12° 48’ N and longitude 74° 52’ and 77° 2’ E at the south-western border of the Indian peninsula. The 590 km coastline of Kerala is intersected by 30 brackish water perennial estuaries. The outlets of all the estuaries on the coast remain open during the period of heavy river discharge. With the retreat of the monsoon and the cessation of the river discharge, the outlets of most of the estuaries get closed due to deposition of the sea sand (sand bar) by the prevailing waves and currents in the sea.

The estuarine system is dynamic and extraordinarily fertile and is generally accepted that the first sign of life evolved from it (Ganapati, 1975). The two major sources of organic materials in an estuary are terrestrial run-off and autochthonous production. Strong chemical reactions, interactions and transformations take place between sediments and water in an estuary. These interactions are particularly apparent in the redistribution of nutrients. This type of exchange between sediments and overlying water plays a major role in regulating the nutrient dynamics in the estuaries.

Nearly 82% of the world’s estuarine zone is open water, while the rest is marsh and swamp. Mainly three habitats are recognizable within the tropical estuarine zone, the wet-lands, the pelagic and the benthic regimes. The biological properties of these three habitats are profoundly different.
Wet lands are the most productive ecosystems which include lakes, marshes and mangroves. Wet lands are regarded as hydrological and biogeochemical complexes endowed with specific structural and functional attributes. They play an important role in regulating food and water quality, reducing sediment load, treating ground water, helping agricultural productivity in drought prone areas, pollution abatement and above all, conservation of aquatic fauna and flora and wildlife habitat.

Mangroves are special type of vegetation distributed in marshes and most commonly appeared in estuarine delta and sea coasts.

1.2. Mangroves

Mangroves are termed ‘Tropical tidal wetlands’ with characteristic vegetation distributed along the coastal areas, lagoons, lakes and sea, growing in swampy soils covered by saline water during high tides. They develop under favourable conditions into extensive and protective forests which act as reservoirs of rich and varied flora and fauna. These forests comprised of taxonomically diverse, salt tolerant trees and other plant species that thrive on inter tidal zones of sheltered tropical shores. They are considered as the most productive, self-maintained estuarine components of the biosphere. This coastal vegetation together with algae and sea-weeds play a pivotal role in regulating the physicochemical as well as biological processes operating in the coastal, near-shore environments.

The word ‘mangrove' originated from ‘mangue’, a combination of the Malay, Spanish, French or Portuguese, meaning an individual mangrove tree or wood, with the English ‘groove’ for small wood, although early versions were ‘mangrove' and 'mangrave'. The term ‘mangrove’ may have been
derived from a combination of the Malay word 'manggi-manggi', for a type of mangrove tree, the *Avicennia*, and the Arabic ‘el gurm’ for the same as ‘mangurm’. As a word, it can be used to refer to a species of plant, forest or community.

Blasco (1975) defined mangroves as a ‘type of coastal woody vegetation that fringes muddy saline shores and estuaries in tropical and subtropical regions’. Mac nae (1968) used the term ‘mangrove’ for the individual plant species and ‘mangal’ for the ecosystem. A similar concept is followed in the present study. Mangroves come under the group ‘halophytes’, ‘halo’ relating to ‘salt’ and ‘phyte’ meaning plant having specific characteristics that can thrive well in wide variation of salinity.

A unique characteristic feature of all mangroves is the muddy bottom. It is due to the absence of wave action and strong water currents. The muddy bottom is exposed during the low tides. It contains rich organic matter. A high rain fall is necessary for the development of mangroves. Generally, mangroves develop in coasts where the atmospheric temperature is never below 20°C, even during the winter season. The water of the mangrove shows high salinity due to the concentration of salts such as sodium chloride and magnesium sulphate. Besides, the water contains dissolved ions. The mangroves are always shallow in nature, rarely showing high depth at certain regions. They are provided with water logged, stagnant anoxic sediments with high nutrients brought in by the incoming fresh water. Plant litter, mainly leaves represents about one third of primary production in the mangroves and up to half of this quantity can be exported via creeks to adjacent waters (Robertson *et al.*, 1992). The export of this large quantity of organic matter has a recognizable effect in food webs in coastal waters (Odum and Heald, 1975., Alongi *et al.*, 1989; Alongi, 1990). The extent to which mangroves
exchange dissolved and particulate nutrients with adjacent waters depends on several factors including geomorphology, tidal regime and climate (Alongi, 1996). A large fraction of organic matter produced in the mangroves is deposited on sediment surface and is degraded and re-mineralized by early diagenetic processes near the sediment - water interface (Henrichs, 1992; Canuel and Martens, 1996). The degradation is mediated by an array of aerobic and anaerobic microbial processes in the dynamic interface with a concurrent release of inorganic nutrients (Meckin and Swides, 1989; Canfield et al., 1993). Mangroves form nursery and nutritional bed for several important, valuable prawn and fish species. The roots of mangroves serve as a good shelter for a large number of organisms including mosses, lichens, bacteria, fungi, algae, nematodes, mollusks etc.

1.3. Distribution of Mangroves

**World distribution:** World wide natural distribution of mangrove vegetation has been broadly divided into two (Chapman, 1976). The first group consists of the East African coasts, coasts of Pakistan, India, Malaysia, Burma, Thailand, Philippines, Southern Japan, Southern Pacific Archipelago, Australia and New Zealand. The second group comprises the Atlantic coast of Africa and America including the Islands of Galapagos. Some of the world’s largest mangrove swamps are found along the south-west coast of Florida and Pacific coast of Columbia. About fifty five species are considered as being covered by the term mangrove and of these, a total of forty two are reported from the Indian and Pacific regions (Chapman, 1976). The general distribution of mangroves throughout the world indicates zonal as well as purely individual colonial patterns.

**The Indian Distribution:** The total area of mangrove in India is estimated to be about 6740 km², which accounts for 7% of the world’s total
mangrove spread. The largest among the Indian mangroves is Sunderbans (4200 km²) of West Bengal followed by that of Andaman and Nicobar Islands (1190 km²). The mangroves of the above localities together account for 80% of the total Indian mangroves. The remaining 20% of the mangroves are scattered in Maharashtra, Gujarat, Orissa, Goa, Andra Pradesh, Karnataka, Tamil Nadu and Kerala (Table.1.1).

Table 1.1
Indian Mangroves: A general estimate

<table>
<thead>
<tr>
<th>State / Union Territory and Locality</th>
<th>Total area of mangrove forests (approx km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Andaman and Nicobar Islands- coasts</td>
<td>1190</td>
</tr>
<tr>
<td>2. West Bengal- deltas of Ganges</td>
<td>4200</td>
</tr>
<tr>
<td>3. Orissa- mouth of Mahanadi</td>
<td>150</td>
</tr>
<tr>
<td>5. Gujarat- Saurastra and Kutch coasts</td>
<td>259</td>
</tr>
<tr>
<td>6. Goa- coasts</td>
<td>200</td>
</tr>
<tr>
<td>7. Maharashtra- coasts</td>
<td>329</td>
</tr>
<tr>
<td>8. Karnataka- coasts</td>
<td>60</td>
</tr>
<tr>
<td>9. Tamil Nadu- Cauvery delta</td>
<td>150</td>
</tr>
<tr>
<td>10. Kerala- coasts</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6740</strong></td>
</tr>
</tbody>
</table>


Mangroves in Kerala: (Table 1.2). The mangroves in Kerala are isolated and confined to the upper reaches of estuaries, lagoons, backwaters and creeks (Mohanan, 1999). Ramachandran and Mohanan (1990) reported that Kerala once supported 70,000ha of mangroves along its coast, which has dwindled to 1700ha in recent times due to various anthropogenic activities (Chand, 1992). Kerala, with coast line of 590km, is characterized in having
long stretches of backwaters and estuaries. They can offer convenient and congenial environment for the luxuriant growth of mangroves (Chandni et al., 2006). Ramachandran and Mohanan (1990) reported the occurrence of mangroves in Veli, Kumarakom, Kollam, Kochi, Kannamali, Chetwai, Nadakavu, Edakkad, Pappinisseri, Kungimangalam, Chiteri, Palaiangadi, Kotti, Kavvai, Thalassery, Vadakara, Kallai, Tirur and Edapalli.

Table 1.2
The district wise distribution of mangroves – (Basha, 1991)

<table>
<thead>
<tr>
<th>District</th>
<th>Mangrove area (approx)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Thiruvananthapuram</td>
<td>23</td>
</tr>
<tr>
<td>2. Kollam</td>
<td>58</td>
</tr>
<tr>
<td>3. Alapuzha</td>
<td>90</td>
</tr>
<tr>
<td>4. Kottayam</td>
<td>80</td>
</tr>
<tr>
<td>5. Eranakulam</td>
<td>260</td>
</tr>
<tr>
<td>6. Thrissur</td>
<td>21</td>
</tr>
<tr>
<td>7. Malappuram</td>
<td>12</td>
</tr>
<tr>
<td>8. Kozhikode</td>
<td>293</td>
</tr>
<tr>
<td>9. Kannur</td>
<td>755</td>
</tr>
<tr>
<td>10. Kasarkode</td>
<td>79</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1671</strong></td>
</tr>
</tbody>
</table>

1.4. Importance of Mangroves

Mangroves constitute one of the most productive areas for brackish water fishery development. They are useful in a wide range of economic as well as ecological aspects. The economic values include their production of timber, fire wood and other products (*Acrostichum aureum*, *Bruguiera gymnorrhiza* and *Rhizophora mucronata*). The ecological values are nutrient enrichment, feeding, breeding and nursery grounds for a number of marine
organisms, resorts for migratory birds, shore-line protection, natural land reclamation and pollution sink (Mohanan, 2000). The mangroves create unique environment that host a rich assemblage of flora and fauna (Kathiresan and Bingham, 2001).

The mangrove wetlands were considered as wetlands and so destroyed until 1970's (Kathiresan and Rajendran, 2003). Mangroves are realized as valuable ecological resources only from 1980’s. Studies in 1990’s proposed that the mangroves serve as sources of high value products such as black tea, UV screen compounds, antiviral drugs, microbial bio fertilizers, mosquito-controlling substances as well as fish attractants. Thus mangroves are considered as 'cash crops' (Kathiresan and Rajendran, 2003).

Mangrove leaves (Avicennia and Rhizophora) when dried, smell like tea and can make black tea like beverage and so can be developed as a cash crop in tea plantations along the coastal area (Kathiresan, 1995). Mangroves are capable of radiating high doses of solar UV radiations back to the atmosphere by virtue of accumulating UV screen compounds like flavonoids in their leaves. There is also a possibility of extracting the UV screen compounds for their applications in cosmetics (Sonneratia caseolaris) and pharmaceuticals to deter the harmful effect of UV rays (Moorthy and Kathiresan, 1996). Species of mangroves like Acanthus ilicifolius and Avicennia officinalis are used in the treatment of several deceases, rheumatism and ulcer respectively.

The detritus food web that develops in mangrove ecosystem provides rich food for several species of edible fin fish and shell fish. Mangroves also act as barriers to prevent coastal erosion and protect the estuarine communities from natural disasters like tsunami, cyclones etc (Desa and Desa, 1982). The extend of land under mangrove cover has been rapidly
declining due to excessive deforestation for fuel purposes, reclamation of swamps for agriculture and industrial purposes. Hence there is an imperative need to protect and conserve the mangrove ecosystem which has a direct bearing on production of aqua culturally important organisms.

Scientists have developed techniques for rearing the mangroves at a faster rate through vegetative propagation and hormonal treatment. Using these low cost techniques, mangrove plantations have been established experimentally in two degraded coastal areas along the south-east coast of India (Kathiresan et al., 1996). Further, there are more possibilities of coastline horticulture by cultivation of mangrove halophytes as ‘cash crops’ using seawater irrigation.

1.5. Biogeoorganics

Biogeoorganics is a term coined to represent the entire array of organic compounds in the aquatic realm, which includes compounds with known structures like carbohydrates, proteins, lipids, hydrocarbons etc and other hydrophobic acids of biological origin as well as compounds which have been subjected to geochemical processes like sorption/partition, precipitation, volcanisation, oxidation/reduction etc. The biogeoorganics are found abundant and widely distributed in the sediment and thus exhibit spatial and temporal variations.

Lotic habitats, the rivers form the major nutrient reservoirs of the continents and the oceans, play a pivotal role in the global carbon cycle (Likens et al., 1981). Rivers discharge large quantities of terrestrially derived organic matter to the sea sediments (Degens and Ittekkot, 1984., Ittekkot et al., 1984., Ittekkot and Arain, 1986). This organic matter constitutes
a minor, but important fraction of lake sediments. Sediment organics are considered as the residue of organic life, which tends to become more important and more abundant with the development and diversification of life. The study on biogeoorganics in the sediment provides a deeper insight into the complexities that govern the source, fate and transformations of organic compounds. The determination of the quality and quantity of organic substances in the sediment furnishes information on the nutrient value of the substrate (Pocklington and Leonard, 1979). These compounds also play a major role in biogeochemical cycles, detritus food chains and ecological succession (Odum, 1971).

Sediments act as sink and source of inorganic, organic and bioorganic compounds. Studies on sedimentary organics are relevant in the impact-assessment of pollutants in an aquatic system. Carbohydrates and their derivatives are the most essential organic compounds in the biosphere. Carbohydrate content in the sediments is enhanced by the action of the detritus feeders. Proteins constitute about 70-85% of the nitrogenous substances in marine organisms. Proteins are widely distributed in sediments. Dead remains of plants, animals and microbes are the major source of proteins in aquatic sediments. Proteins and carbohydrates, the substantial portion of the sedimentary organic matter are of vital importance in aquatic systems, as they serve as strong link between several known and unknown phenomena (Degens and Mopper, 1976). Autotrophic and heterotrophic organisms are the sources of lipids in the environment. A certain portion reaches the aquatic environment through allochthonous organic matter comprising of neutral lipids and the oil constituents. The lipids are probably released by plankton during the mineralization of detritus (Kattner et al., 1983).
Tannin and Lignin are high molecular weight organic compounds widely distributed throughout the plant kingdom. These compounds are highly resistant to degradation and have potential to damage the aquatic environment. Tannins can influence the cycles of metals and other elements and can react with proteins inhibiting the performance of many enzymes. The breakdown of mangrove plant tissue produces considerable amount of these compounds.

Benthic animals and microbes depend on organic matter for nutrition, since many components of organic matter are easily oxidized forms of carbon. Organic matter is consequently a dynamic biogeochemical component of sediments that influence both living and nonliving processes.

1.6. Benthos

Benthos constitutes flora and fauna that live in or at the bottom of a water body. The bottom sediments are characterised by fine textural materials that varies with depth and types of organisms in overlying water. Bottom sediments are derived from the weathering of rocks and erosion of land areas along with organic matter from aquatic life. Although these sediments are termed organic, they contain little decomposable carbon, derived largely of skeletal fragments of planktonic organisms. In general, with regional variations, organic deposits down to 400m are rich in calcareous matter.

The sediment is a complex milieu with the overlying water which interacts with benthic community to form a heterogeneous system. Benthos performs a cardinal role in the ecosystem dynamics with multilevel representation in the energy flow by occupying different trophic levels forming a unique food web. The benthic fauna is of considerable importance in aquatic food chains (Mc Intyre, 1971). It plays a significant role in detritus food chain of any aquatic
ecosystem and contributes much to the nutrient cycling process (Forsbeigie, 1989).

1.7. Trace Metals

Trace quantities of certain elements exert a positive or negative influence on living organisms which has been known for several decades. No organic life can develop and survive without the participation of metal ions. Current research has revealed that life is as much inorganic as organic (Forstner and Wittmann, 1983).

The term, trace metal is widely used in scientific literature with reference to several elements beginning with beryllium and going up to actinides (Nair, 1984). The trace metals are those elements with atomic number from 22 to 92 in all groups from period III to VII in the Periodic Table (Waldichuk, 1974).

Trace metals are continuously released into the biosphere through the processes like volcanisation, weathering of rocks, urbanization, industrialisation, agricultural run off and anthropogenic activities such as mining, smelting, burning and combustion of fossil fuels. Concentration of metals in surficial sediments is considered as good index to assess the pollution load, trace the source of their origin, fate and the routes of movement. Metals accumulate in sediments through absorption, adsorption, flocculation, precipitation, sedimentation etc.

Pollution of the aquatic ecosystem due to trace metals has created deep concern among the scientists over the past few years and tactful management of this problem has not been over emphasised.
1.8. Scope of the present study

Mangroves, the highly productive coastal wetlands are the inevitable and important nursery and feeding grounds for marine and estuarine biota. These natural gifts are exploited at an alarming rate for fulfilling the man’s needs, due to lack of proper knowledge. Since the mangrove management has received much attention, this study is expected to make the people aware of the need for sustainable usage of the mangrove ecosystem for a better future and also to give prime importance to afforestation of mangrove.

The distribution of biogeoorganics in the mangrove ecosystem of Ashtamudi Lake is influenced largely by the death and decay of living beings along with the increasing anthropogenic activities viz., waste discharge from major industrial establishments housed on the banks of Kallada River and the sewage disposal through the eight creeks. A large number of industries flourishing on the bank of this water body discharge their effluents at various points into this backwater system. The major river system carrying pollutants to Ashtamudi estuary is the Kallada River. The detrimental effects of pollutants not only affect the water quality but also the quality of the sediment. The bottom sediment of a water body provides a rich substrate for different organisms such as plants, herbivores, carnivores and microbes.

Although various studies have been carried out on the hydrography, trace metal and geochemical aspects of Ashtamudi Lake, no systematic and scientific report is hither to available regarding the biogeoorganics and pigments in the sediments of this mangrove ecosystem. The present study is a modest approach in order to assess the status of this aquatic biotope in terms of its water quality and sediment characteristics.

The work incorporated in this thesis is a comparative account of mangrove and non-mangrove ecosystem of Ashtamudi Lake. It is an attempt
to evaluate the hydrographic parameters, sediment characteristics as well as the abundance, distribution and dynamics of biogeoorganics, benthos and trace metals in the sediments of Ashtamudi Lake. The information investigated is first of its kind and will be useful in assessing, predicting and characterising the source, flux and dynamics of the various biogeochemical compounds.

The thesis comprises seven chapters. Chapter 1 gives a general introduction to the topic of research along with the aim and scope of the present study.

Chapter 2 describes the station locations and the sampling sites and also emphasizes the sampling procedure for water and sediment as well as the analytical techniques adopted for the determination of various parameters.

Chapter 3 deals with the hydrochemistry of water of mangrove and non-mangrove areas of Ashtamudi Lake.

Chapter 4 reports on the sedimentary characteristics comprising textural analysis, sediment organic carbon, nitrogen, phosphorus and their ratios, C: N, N: P and C: P. Besides, a comparative account of the mangrove and non-mangrove is presented. A brief description of the benthos of mangrove and non-mangrove sediments is also included in this chapter.

Chapter 5 depicts the occurrence, abundance and distribution of biogeoorganics, viz., sedimentary pigments (chlorophyll a, b, c, carotenoids and pheopigments), carbohydrates, proteins and lipids as well their inter relationship with other parameters in mangrove and non-mangrove sediments. The concentration level of hydroxylated aromatic compounds (tannin and lignin) in the sediment is also dealt with. The distribution profile is discussed in terms of textural characteristics.
Chapter 6 envisages the distribution of trace metals present in the sediments of the study area.

The salient features of the studies conducted are summarised in chapter 7. The list of references is included at the end.

The monthly values of various parameters, in view of their exhaustive nature are removed from the text and given in Tables, which are appended at the end, while the corresponding figures depicting the seasonal variations and derived parameters are incorporated in the text itself.