The aquatic ecosystem is a major subdivision of the biosphere, and covers almost 71% of the earth’s surface area. Continuous land use results in various kinds of environmental impacts on the aquatic ecosystem. Particularly, these impacts have the potential to significantly affect the interface area between land and sea called the coastal ecosystem. Coastal ecosystems mainly include estuaries, deltas, lagoons, mangrove forests, mudflats, salt marshes, salt pans, other coastal wetlands, ports and marinas, aquaculture beds, sea grass beds, coral reefs, and soft bottom environments above the continental shelf. Although coastal ecosystems represent only a small area of the world’s oceans, they are of great ecological and economic importance. Now-a-days, many of the coastal ecosystems of the world are being exploited for various development projects, resulting in deterioration of habitats and resources. Therefore the present study focuses on two of such important coastal ecosystems such as estuary and mangrove.

1.1. ESTUARINE ENVIRONMENT

An estuary has been defined as "a body of water in which the river water mixes with and measurably dilutes the sea waters" (Ketchum, 1951). Emery & Stevenson (1957) described it as the mouth of a river or an arm of the sea where the tides meet the river currents. Thus, estuary forms natural mixing area between marine and fresh water zones (Fig.1). Estuary is a dynamic area with varying physical and topographical conditions, with neritic province, river delta, lagoon, backwater, mangroves, mudflat and salt marsh, all being part of this vital area. Estuaries are generally regarded as one of the most productive aquatic systems and the nutrient supply through fresh water input is important in sustaining their high rate of primary production. Estuaries also function as important sinks and transformers of nutrients, thus
altering the quantity and quality of nutrients transported from land to the sea. Estuaries are important areas of human use for fisheries, transportation, aquaculture and recreational pursuits. Thus, by virtue of their natural location and easy accessibility, estuaries are more amenable to anthropogenic influences.

![Fig. 1.1. A typical estuarine environment.](image)

Estuaries play a significant role in the natural life cycle of some aquatic organisms and recently they are recognised as areas of industrial, commercial and recreational activities. Even though the development of estuaries has contributed to considerable economic development and social changes, it has also caused severe environmental problems. While a few estuaries have been able to assimilate the pollution load depending on factors like rate of mixing, flushing time and nature of pollutant, many other estuaries are in danger all over the world due to indiscriminate exploitation of the nature by man. Estuaries are suffering degradation by many factors, including sedimentation from soil erosion from deforestation, overgrazing, and other poor farming practices; overfishing; drainage and filling of wetlands; eutrophication due to
excessive nutrients from sewage and animal wastes; pollutants including heavy metals, PCBs, radionuclides and hydrocarbons from sewage inputs; and diking or damming for flood control or water diversion (Fig. 1.2).

Fig. 1.2. Sources of estuarine pollution.

1.1.1. Types of Estuaries

Estuaries may be classified based on the way that water layers are formed within the estuary. Most estuaries have a range of salinity from salty sea water to nearly fresh water. Since the waters flowing into the estuary from land are less salty, they float on top of the sea water when they meet. Some mixing also occurs where the two water masses meet. Physical and environmental factors such as the shape of the basin, tides, river flow, and wind determine how much the water mixes. Estuary classification based on water circulation includes salt-wedge estuaries, partially-mixed estuaries and well-mixed estuaries (Kennish, 1986) (Fig. 1.3).
Salt-wedge estuary is an estuary with a wedge-shaped layer of saltwater which lies below a fresh water layer. A salt-wedge occurs when a rapidly flowing river discharges into an estuary with weak ocean currents. A sharp boundary is created between the salt and freshwater layers. Fresh water floats on top and a wedge of saltwater lies on the bottom because the saltwater has a higher density than the fresh water.

A partially mixed estuary normally has a meso-tidal regime, typified by a range of 2–4 m. The tidal currents are quite strong and the whole water mass in the estuary moves first landward and then seaward with a tidal periodicity. The salt water is mixed upward and fresh water is mixed downward.

Well-mixed estuary has strong tidal mixing and poor river flow that mix the sea water throughout the shallow estuary. The mixing is so complete that the salinity is the same from top to bottom and decreases from ocean to the river.

---

**Fig. 1.3.** Diagrammatic representation of three different types of estuaries.
1.1.2. Estuarine Biota

The organisms permanently dwelling in estuaries are mostly strong, stress-tolerant species able to withstand salinity changes and high levels of suspended solids. Estuarine ecosystems are typically characterised by relatively low species diversity comparing to freshwater conditions. Freshwater species become less abundant with increasing salinity and are gradually replaced by marine organisms moving down the estuary with some truly estuarine species found at intermediate salinities (Fig.1.4). This pattern is reflected by the overall species richness, where the least diverse fauna is found at salinity levels between 5 and 18 PSU (Remane, 1934).

![Fig.1.4. Organisms comprising in a typical estuarine zone.](image)

The biodiversity of estuaries may be affected by a variety of factors including size of the estuary, nutrient supply and retention, the complexity of water circulation, the variety and extent of sediment types on the bottom, the range of habitats available and tidal range. As estuaries receive freshwater inflows from land as well as saline waters from the sea, there are few species
that are well adapted to cope with all the habitats present in an estuary. The minimum number of species occurs wherever the variation in water salinity is greatest. Species which inhabit the seafloor (benthic forms) are largely controlled by the nature of sea floor sediment present (mud, silt, sand, gravel, rock) and the dissolved oxygen status of bottom waters. As estuaries receive nutrients from land drainage they may have high levels of productivity and hence increased biodiversity.

1.1.2.1. Phytoplankton

Phytoplankton have been recognized as an extremely important source of food for larval forms of aquatic organisms, since they constitute the microscopic plant life of the sea. Important components of the phytoplankters are: diatoms, dinoflagellates, blue-green algae, phytoflagellates, coccolithophores and nannoplankters. Diatoms constitute the major part of the phytoplankton. Their importance lies in the fact that they are the photosynthesizing organisms and serve as a vital first link in the food chain, either directly or indirectly of almost every animal in the sea. It is true that at sometimes in the early stage of life cycle all fish, molluscs and crustaceans are diatom feeders, at least in part. Phytoplankton supply both energy and essential nutritional requirements such as protein, carbohydrate and lipids since the phytoplankton form the meadows of the sea. Phytoplankton are used as indicators of water quality.

1.1.2.2. Zooplankton

Zooplankton are tiny animals found in all aquatic ecosystems, particularly the pelagic and littoral zones in the ocean, also in ponds, lakes, and rivers. They are classified by size and/or by developmental stage. According to size, they are picoplankton < 2 µm, nanoplankton 2-20 µm, microplankton 20-200 µm, mesoplankton 0.2-20 µm, macroplankton 20-200 µm, and megaplankton >200 mm (Lynn, 2007). Zooplankton constitute a
fundamental step in the marine food web as they transfer energy from the lower trophic levels to the higher trophic levels. Zooplankton play an important role in aquatic food webs as a resource for consumers on higher trophic levels (including fish) and as a conduit for packaging the organic material in the biological pump.

1.1.2.3. Benthic fauna

The term benthos refers to those organisms which live on or in the bottom of any body of water (Bostwick, 1983). Phytobenthos is the collective name for all plants among the benthos such as the diatoms, macroalgae and higher plants. Zoobenthos comprise of all animals occupying the bottom habitat. Those found on hard substrates such as rocks, wood and shells are very different from those of the soft sediments such as sand and mud. Benthic animals are divided into three categories according to size (1) macrobenthos (2) meiobenthos and (3) microbenthos (Mare, 1942). The most common benthic faunal diversity in estuaries includes mollusca, polychaeta, nematoda and crustacea.

Benthic fauna is important in the energy cycle of the sea by making use of the organic matter draining down from the surface waters. These organisms are important in the recycling of nutrients and oxygenation of sediment substratum. Benthic organisms link the primary producers with higher trophic levels such as fishes, by consuming phytoplankton and then being consumed by larger organisms. Thus, they provide the key linkage between primary producers and higher trophic level animals, in the marine food web. Therefore, benthic productivity of the adjacent seas of any maritime country is of fundamental interest to access the total fishery potential pertaining to that area. Benthic organisms can be used as bio-markers in the assessment of contamination in marine ecosystem.
1.1.3. Significance of estuaries

Estuaries are unique places that are valuable, playing vital roles in the environment and society. Some important features of estuaries are:

- Estuaries are constantly changing and are areas of transition. Life is dynamic and diverse in estuaries. Some animals and plants specialize in, or adapt to, living in the unique conditions of estuaries.
- Estuaries act like huge sponges, buffering and protecting upland areas from crashing waves and storms and preventing soil erosion. They soak up excess water from floods and stormy tidal surges driven into shore from strong winds.
- Estuaries can filter small amounts of pollutants and runoff. Vegetation helps as filter and trap silt. However, too much nutrient or sediment input will create an unbalanced situation causing the health of the ecosystem to decline.
- Each estuary can make up an individual ecosystem. However, estuaries are also interconnected with other surrounding environments (oceans, lakes, forests, grassy plains) and nearby human communities.
- Estuaries are recreational sites for people as they provide the area for sailing, fishing, swimming, and bird watching. An estuary is often the center of a coastal community.
- Estuaries provide a safe haven and protective nursery for small fish, shellfish, migrating birds, and coastal shore animals. In general, estuaries are nurseries over 75% of all fish and shellfish harvested.
1.1.4. Indian Estuaries

India has a coastline of 7500 km with an exclusive economic zone of $2.015 \times 10^6$ km$^2$, which is 61% of the land area. There are 14 major, 44 medium and 162 minor rivers which together discharge $1.56 \times 10^{12}$ m$^3$ run-off every year greatly influencing ecology of their estuaries and coastal areas to which they drain (Fig.1.5). These estuaries with their wetlands, lagoons, mangroves and sea-grass beds are rich in natural resources including fisheries. They also offer tremendous potential for recreation, aquaculture, extraction of freshwater and transport and play a dominant role in the economy of coastal population. These areas are the recipients of liquid and solid wastes emanating from domestic and industrial sectors apart from rampant reclamation of their intertidal segments to provide additional spaces for coastal developments. Over 300 million people living in the coastal zone of India are considered to generate $1.11 \times 10^{10}$ m$^3$ of sewage annually, a considerable fraction; particularly from coastal cities and towns where sewage collection network exists, is released in to estuaries and creeks. Large and medium industries within the narrow coastal belt of 25 km width of India are estimated to generate roughly $1.35 \times 10^6$ m$^3$ d$^{-1}$ of liquid effluents and about 34,500 t d$^{-1}$ of solid waste (Qasim, 2003).
An assessment of the nutrient profile and biotic components of Mahi estuary and Vamleshwar mangrove of Gulf of Khambhat, Gujarat, India

Introduction

Fig. 1.5. Map showing the locations of important estuaries of India.

1.1.5. Estuaries of Gujarat

Gujarat has the longest coastline of 1663 km with a continental shelf of $1.65 \times 10^5$ km$^2$. Gujarat has been profusely endowed with perennial rivers. About 16 large, medium and small rivers flow in the east-west direction in low lying, marshy land of Gujarat state and empty into Gulf of Kambhat. Mahi is a major river passing through the state which is about 800 km long. After traversing through Panch Mahal, Vadodara and Charotar plains, it joins the northern part of the Gulf of Kambhat near Kamboi at Kavi forming a broad estuarine stretch extending up to Mohammadpura, which is about 50
km inland. Because of a sill, the zone downstream of Mohammadpura experiences a typical estuarine condition associated with marked tidal variations. In Mahi estuarine region the main anthropogenic influence is largely related to the industrial effluents and domestic wastewater release from Vadodara town through point discharges.

1.2. MANGROVE ENVIRONMENT

Mangroves are specialized ecosystems developed along estuarine sea coasts and river mouths in tropical and subtropical regions of the world, mainly in the intertidal zone. Hence, the mangrove ecosystem and its biological components are under the influence of both marine and freshwater conditions and have developed a set of physiological adaptations to overcome problems of anoxia, salinity and frequent tidal inundations. This has led to the assemblage of a wide variety of plant and animal species of special adaptations suited to the ecosystem. The carbon fixed in mangroves is highly important in the coastal food webs and the litter from mangroves and the subsequent formation of detritus, and its tidal export has also profound effect on promoting biodiversity richness. Moreover, the detritus and nutrients generated in the mangrove ecosystem form excellent feed for a large variety of organisms which support valuable estuarine and near shore fisheries.

1.2.1. Mangroves in India

Mangroves in India cover an area of 6740 km$^2$ or 7% of the total mangrove area of the world. As per the State of Forest Report (2001) by Forest Survey of India, the actual coverage of mangroves is much less about 4481 km$^2$. The highest mangrove area is in West Bengal in Sundarbans (2081 km$^2$), followed by Gujarat (911 km$^2$), Andaman-Nicobar (789 km$^2$), Andhra Pradesh (333 km$^2$) and Orissa (219 km$^2$). About 9 states and union territories in the country have mangroves in their coastal regions.
1.2.2. Mangroves in Gujarat

Gujarat state, which has about 1650 km long sea coast (about 21 percent of the Indian sea coast) has mangroves spread over an area of 911 km², which comes to about 20 percent of the national mangrove area. About 90 percent of mangroves in Gujarat are located around the Gulf of Kutch while the rest of the mangroves are found in the Gulf of Kambhat and on the South Gujarat coast. The major locations of mangroves in the state are (1) The Rann of Kutch (2) Kutch coast (3) Jamnagar coast of Gulf of Kutch (4) Saurashtra coast – from Dwarka to Khambhat (5) Gulf of Kambhat and (6) South Gujarat. Kutch and Jamnagar together have about 848 km² of mangroves, which constitutes more than 90 percent of the total area under mangroves in the state. Mangroves are dominant near Bhavnagar, Devla in Bharuch, Mangrol, Pardijankri, Dashariphalia and Dandi in Surat (Fig.1.6). The Piram Island, Ghogha and Mahuva showed high density of Avicennia marina. Mangroves in the intertidal mudflats are stunted and sparse particularly near Mahi, Dhadhar, Kim and Sena estuaries. A patch of Avicennia is observed in Aliya Bet at the mouth of the Narmada estuary. At most of the places, the growth is stunted and horizontal. Some tall trees were observed at Piram Island.
An assessment of the nutrient profile and biotic components of Mahi estuary and Vamleshwar mangrove of Gulf of Khambhat, Gujarat, India

Introduction

Fig. 1.6. Mangroves of the Gulf of Khambhat.

1.2.3. Mangrove Biota

1.2.3.1. Phytoplankton

The mangrove waters are more productive than the backwaters and estuaries (Bhattathiri, 1992). This is attributed to high production of plankton in the mangrove waters as the phytoplankton are one of the initial biological components, from which energy is transferred into higher organisms through food web. Biomass and production of phytoplankton of various sizes are important factors in mangroves which regulate the availability and diversity of organisms at higher trophic levels. Amongst phytoplankton, Ceratium sp., Coscinodiscus sp., Pleurosigma sp., Chaetoceros sp. and Tintinids are predominant in mangrove waters.
1.2.3.2. Zooplankton

Zooplankton assume a great ecological significance in mangrove ecosystem as they play vital role in food web of the food chain, nutrient recycling, and in transfer of organic matter from primary producers to secondary consumers like fishes. They are more abundant within mangrove water-ways than in adjacent coastal waters, and a large proportion of the juvenile fish of mangroves are zooplanktivorous. The failure of fishery resources is attributed to the reduced copepod (zooplankton) population. Hence, zooplankton communities based on their quality and species diversity, are used for assessing the productivity vis-à-vis fishery resource, fertility and health status of the ecosystem. Among the zooplankton, copepods, larvae of molluscs and polychaetes contribute to the bulk of zooplankton component among different mangroves studied in India.

1.2.3.3. Benthic fauna

Mangrove fauna are an important and integral component of the mangrove ecosystem. Benthic organisms are of ecological as well as of economic importance in mangroves and adjacent tidal flats. They affect internal nutrient cycling and exchange processes with adjacent ecosystems. Mangroves are directly or indirectly associated with a variety of benthic communities. Benthic fauna is a major food source for numerous juvenile fish and crustacean species and thus crucial for the survival of many commercially harvested species. In addition, benthic crabs and molluscs are important fisheries resources for the local population. Studies on the benthic fauna have attained considerable importance due to the increasing knowledge of their significant role in the trophic cycle. The benthic invertebrates play a very active role in the degradation of leaf material of the mangrove trees. Detritus, together with the benthic fauna becomes food for animals at higher trophic level, either directly or indirectly, through intermediaries.
1.2.4. Importance of mangrove ecosystem

From an ecological perspective, mangroves are a unique and significant ecosystem. They form an important ecological asset and economic resource of the coastal environment. The mangroves are the most productive ecosystems, which can efficiently fertilize the sea, potentially protect the coastal zone and vitally serve as the breeding and feeding grounds of fishes. Mangroves are used by a vast array of organisms as breeding, nursery and feeding areas. They also play a valuable role in foreshore protection, reducing erosion by cyclones and lessening the impact of storm surge. Mangroves maintain coastal water quality by abiotic and biotic retention, removal, and cycling of nutrients, pollutants and particulate matter from land-based sources, filtering these materials from water before they reach seaward coral reef and sea grass habitats.

1.2.5. Threats to mangrove ecosystem

Major threats of mangroves include

- Land reclamations for construction activity, aquaculture, agriculture, tourism.
- Industrial and domestic pollution.
- Port development.
- Dumping of all kinds of waste and debris.
- Deforestation for fuel wood.

1.3. HYDRO-GEOCHEMISTRY IN ESTUARIES AND MANGROVES

Estuarine and mangrove areas are complex and dynamic aquatic environment. When river water mixes with seawater, a large number of physical and chemical processes take place, which may influence water
quality. The natural processes, such as precipitation inputs, erosion, weathering of crustal materials, as well as the anthropogenic influences viz, urban, industrial and agricultural activities, calling for increasing exploitation of water resources, together determine the quality of surface water in a region. Rivers play a major role in assimilation or carrying off of municipal and industrial wastewater and run-off from agricultural land, the former constitutes the constant polluting source whereas the latter is a seasonal phenomenon. The nutrient chemistry of an estuarine/mangrove ecosystem is complex and dynamic due to anthropogenic activities and reactions in the tidally mixed zone of strong redox gradients. An outline of nutrient cycling processes occurring in an estuarine ecosystem is depicted in Fig.1.7.

![Nutrient Cycling in an Estuarine System](image)

**Fig.1.7.** Nutrient cycling in an estuarine system.

1.3.1. *Physico-chemical factors of water*

The pH of natural water can provide the important information about many chemical and biological processes and can indicate indirect correlations to a number of different impairments. The knowledge of pH is important because most aquatic organisms are adapted to live in pH between 5.0 and
9.0. The pH in an estuary tends to remain fairly constant because the chemical components of seawater resist large changes in pH; dissolved carbonate minerals present in seawater tend to minimize or “buffer” pH changes by reacting with the ions that change pH. Biological activity, however, may significantly alter pH levels in an estuary. The process of photosynthesis removes carbon dioxide (CO$_2$) from the water. Since CO$_2$ becomes carbonic acid when dissolved, the removal of CO$_2$ results in a higher pH (i.e., reduced acidity). Therefore, as algal populations increase during the growing season, pH levels tend to rise. During large increases in the populations of planktonic algae (or “blooms”), pH levels may increase significantly. Changes in pH can be indicative of an industrial pollutant, photosynthesis or the respiration of algae that is feeding on a contaminant. Most ecosystems are sensitive to changes in pH and the monitoring of pH has been incorporated into the environmental laws of most industrialized countries.

**Temperature** is the prime hydrographical parameter, which can influence the chemistry of many compounds in natural waters. Temperature is a critical factor influencing several aspects of the estuarine ecosystem. Many estuarine and mangrove organisms are sensitive to changes in water temperature. Biological activities and many chemical variables in the estuary are influenced by variation in temperature. Photosynthetic activity also affected by water temperature. Temperature of estuaries affects the physical properties of water such as density, vapour pressure, surface tension, viscosity, solubility, diffusion of gases etc.

**Salinity** has been recognised as an important parameter in studying the physico-chemical characteristics of estuaries. The salinity distribution in an estuary is mainly governed by factors such as seawater intrusion, river discharge, rainfall and evaporation. The mixing and diffusion phenomena occurring in estuaries are largely influenced by salinity distribution pattern. The relationship with salinity and other physico-chemical parameters such as
temperature, pH and dissolved oxygen is important. Thus in understanding the different processes taking place in an estuary, a study of the salinity distribution during different seasons of the year is a pre-requisite.

**Electrical Conductivity (EC)** in waters is the normalized measure of the water’s ability to conduct electric current. EC is an important physical quality parameter, which explains the ionic status of all waters. The source of EC may be an abundance of dissolved salts due to poor irrigation management, minerals from rain water run-off, or other discharges. EC is also the measure of the water quality parameter “Total Dissolved Solids” (TDS) or salinity. EC also plays a great role in maintaining the biota of any aquatic ecosystem.

**Dissolved Oxygen (DO)** is an important water quality parameter in water quality assessment. Dissolved oxygen in the estuarine environment is chiefly controlled by tidal ingress, freshwater runoff and water temperature. DO is one of the most important factors controlling the presence or absence of estuarine species. It is crucial for most plants and animals except for a small minority that can survive under conditions with little or no oxygen. Oxygen is supplied to estuarine waters through two natural processes: a) diffusion of atmospheric oxygen into the water and b) photosynthesis by phytoplankton and aquatic macrophytes (seaweeds and sea grasses).

The **alkalinity** or acid capacity of water is its capacity to neutralize a strong acid to a designated pH. It is generally imparted by the presence of salts of weak acids such as carbonates, bicarbonates, phosphates, borates, silicates etc. together with free hydroxyl ions in solution. Determination of alkalinity of water is significant in many of its uses and treatment of natural waters and waste waters. Alkalinity may be used in the interpretation and control of waste water treatment processes. Alkalinity is used as criteria for determining the nutrient status of waters.
The **Total Solids (TS)**, as the term implies, includes all of the solid constituents of water. Total solids are the total of the organic and inorganic solids or the total of the suspended and dissolved solids. Anthropogenic activities such as releasing effluents from industries and dumping domestic sewage into estuaries and mangroves can degrade the ecosystem. The major contribution of total solids is from the disturbance of bed and shore sediments and tidal current is one of the vital influencing factors.

**Phosphate** is the major nutrient regulating the growth and production of phytoplankton. Its concentration levels are useful to predict the total biomass of phytoplankton. The major contributors of phosphate are the rivers with enormous loads of weathering products they carry. Phosphate exists in myriad forms in the hydrosphere. Abiotic regulation of soluble phosphate concentration in fresh waters is mainly through adsorption-desorption or through precipitation-solubilization reactions. Estuaries normally mediate phosphate transfer from land to the ocean.

**Nitrate** is the micronutrient that controls the primary production in aquatic systems. It is the final oxidation product of nitrogen compounds in aquatic system and is considered to be the only stable oxidation level of nitrogen in the presence of oxygen in sea water. If oxygen becomes depleted in water as a result of microbial remineralization processes, nitrate may be used as an alternative electron acceptor instead of oxygen. The concentrations of various forms of nitrogen in an estuary at a given time is controlled by factors like input rates, the interconversion reactions occurring within the water column, incoming tides, freshwater discharge, denitrification, deposition etc. Nitrate has a significant role in influencing the growth of biotic organisms especially phytoplankton in an aquatic ecosystem.

**Ammonium** is the most abundant form of inorganic nitrogen in the surface water layers after a period of productivity when phytoplankton blooms have removed the greater part of nitrate and phosphate. In the
assimilation process of phytoplankton, ammonium is preferentially used for synthesizing protein. When organisms decompose as a result of oxidative bacterial action they release nitrate and phosphate. As the water approaches anoxic conditions, bacteria use the nitrate ions to continue the oxidation process. This denitrification leads to the production of molecular nitrogen and ammonium. The concentration of ammonium ions is determined by pH and temperature of the aquatic body and its concentration is found to have a positive effect in regulating aquatic organisms.

The main sources of sulfate into water are decaying plant and animal matter, numerous chemical products including ammonium sulfate fertilizers that contain sulfate in a variety of forms and sulfate may be leached from the soil into water by agricultural run-off. The high concentrations of sulfates in estuaries and mangroves are originated from sea water.

The silicates are important building blocks in the Earth's crust. Silicates form the major part of the frustules of diatoms, skeletons of other protists. Land run-off contributes a lot of silicates into estuaries. Physical and chemical weathering occurring naturally also produce many extremely small particles or colloids of silicate minerals. Thus, silicates are commonly found suspended in most water sources. Silica is of significance as a major nutrient for Diatoms and may become a limiting nutrient during diatom blooms.

Excess amount of sodium in waters produces undesirable effects of changing sediment properties and reducing its permeability. It is one of the most abundant elements present in estuarine water. It is mainly found in the form of chloride and sulfate in marine water. Sodium plays a major role in survival of aquatic organisms by maintaining constant internal ionic concentration relevant to external or environmental ionic concentration (osmoregulation). Osmoregulation tends to buffer cells and tissues against the effects of fresh water or sea water which is important in regulating the distribution of biotic community along estuarine gradient.
Potassium is mainly formed through the weathering processes. It finally reaches in seawater through river waters, where it mainly settles in sediments. However the high concentration of these elements in estuarine ecosystem is derived from sea water due to tidal influences. Potassium is one of the important parameters determine the presence of many aquatic species.

Chlorophyll-a concentration is a measure of the abundance of algae, also called phytoplankton, which account for most of the plant production in the ocean. Chlorophyll-a is capable of channeling the energy of sunlight into chemical energy through the process of photosynthesis. The chemical energy stored by photosynthesis in carbohydrates drives biochemical reactions in nearly all living organisms. Chlorophyll-a value can be used to determine the trophic status of an aquatic body and it is the most commonly used parameter for monitoring phytoplankton biomass and nutrient status, as an index of water quality. Although increasing algae growth tends to support larger fish populations, excessive growth often leads to degraded water quality-for example, decreases in water clarity, noxious odors, oxygen depletion and fish kills and may be linked to harmful algal blooms. Excessive algal growth appears to occur as a consequence of increases in nutrient inputs (especially nitrogen) and in response to declines in the abundance of filter-feeding organisms like oysters, clams, and mussels.

1.3.2. Physico-chemical factors of sediment

In an aquatic system, the sediments act as storage reservoirs of nutrient materials in water. The replenishment of these elements in time of need and the consequent removal greatly helps in the biological cycle of the system. Carbon, nitrogen and phosphorus are the most significant macronutrients in aquatic ecosystems. In the aquatic environment, they are distributed between the water and sediment interface in both dissolved and particulate forms. In a specific aquatic system, nutrient dynamics partition these elements among water, sediment, and biota to attain a natural balance.
Sediment temperature plays an important role in many processes, which take place in the sediments such as chemical reactions and biological interactions. Sediment temperature varies in response to exchange processes that take place primarily through the sediment surface. These effects are propagated into the sediment profile by transport processes and are influenced by such things as the specific heat capacity, thermal conductivity and thermal diffusivity.

Chloride is an ion formed from chlorine (an element) and is considered to be conservative, meaning that it is extremely mobile: It does not biodegrade, does not easily precipitate (react with other ions to form a solid), does not volatilize (turn into a gas), is not involved in biological processes, and does not adsorb (adhere) significantly on mineral surfaces. Chloride is used as a tracer in water because compared to other elements it is not significantly slowed in its passage through sediments. The sources of chloride in estuarine and mangrove environments the chloride are the sea salt.

Naturally phosphate in sediment is derived from the rocks through which the river flows. However, organic loading of sewage water loads anthropogenic phosphorus in sediment. Besides, reduction from ferric to ferrous state takes place to release inorganic phosphorus in anaerobic environment. Settling of particulate matter with attached phosphorus is also important source of phosphorus enrichment of sediment. Disturbance in bed sediment such as tidal ingress, dredging and boating are responsible for release of large amounts of phosphorus into the water column thereby decreasing the levels of phosphorus into sediment substantially. Moreover, some physico-chemical reactions take place at the sediment-water interface which release phosphorus in sediment or overlying water column where it is utilized by primary producers. Diatomaceous plankton, phytoplankton, zooplankton, algae and plants use these dissolved phosphorus in the water as a major nutrient for its growth.
Sodium and potassium in both estuaries and mangroves are coming from ocean waters. These elements can also be brought to oceans by surface run-off water and tend to be accumulated in the sediment. The distribution of sodium and potassium in estuarine sediments is determined by freshwater inflow as well as marine tidal influence experienced at these regions.

Organic Carbon (OC) constitutes an integral part of riverine and estuarine sediments. The increased attention in recent years to the geochemistry of organic carbon in sediments of various aquatic environments is due to its significant role in the biological, chemical and geological processes operating in these environments. The organic carbon in riverine and estuarine sediments may be derived from either autochthonous or allochthonous processes. The relative proportions of its supply are a function of the characteristics of the catchment area in relation to the productivity of the aquatic system. Organic carbon plays a significant role in the genesis of hydrocarbon.

Organic Matter (OM) in surface sediments plays a major role in influencing community structure and metabolism of benthos. In the river the organic carbon content in the bulk sediment is much lower than that of the estuary. This observed low value of organic carbon is due to the abundance of coarser clastics in the bulk sediment. In the estuary, the organic carbon content in the bulk sediment is markedly high and increases toward the mouth. This increase has been resulted from the floc formation followed by faster settling of organic rich suspended particulates as well as the increased productivity near estuarine mouth. In addition to this, substantial amounts of organic carbon rich sewage sludges are disposed (through municipal drainages) near the estuarine mouth.
1.4. SCOPE OF THE PRESENT STUDY

Lagoons, deltas, estuary, mangroves, beeches are some of the coastal environments which are influenced by tides. They are unique habitats varying in nature from each other. Therefore the present study is focused on two of such coastal environments i.e. estuary and mangrove. Now-a-days, many estuaries and mangroves of India face a serious threat of pollution because of the drainage of effluents and domestic wastes from the surrounding industries as well as human dwellings. Estuaries have always been a focus for human settlement and recreation.

Gujarat is one of the most industrialized and urbanized states of the country. Majority of the industries rely upon rivers for their daily usage of water, moreover, they discharge their polluted waters into adjacent rivers which ultimately reaches to the estuary. These waters carry a wide variety of substances like nutrients, toxins, pathogens, physical pollutants, etc. When excessive amounts of nutrients, especially nitrogen and phosphorus, enter the estuary it may suffer from “eutrophication” (nutrient enrichment). Rapid socio-economic development and industrialization in the Gujarat state have led to the establishment of many industries near this river, utilizing freshwater and conveniently disposing their effluent in the river or estuary. Majorities of the industries are chemical, fertilizers and petrochemical based and hence are potential threat to estuarine pollution. Even though, there are several references on hydrographical features of many estuaries in Gulf of Khambhat in general, very little is known about the physico-chemical parameters and the biodiversity profile Mahi estuary, a major river of Gujarat state.

Vamleshwar mangrove is one of the important growing mangrove ecosystems along Gulf of Khabhhat. It has an area of 100 ha with monoculture of *Avicennia marina*. It has been noticed that this mangrove is being affected by serious threat of pollution from many industries located on
the bank of Narmada estuary. Therefore, Vamleshwar mangrove also have been taken into account along with Mahi estuary to study the current status of these two ecosystems.

Due to increased anthropogenic stress on Mahi estuary and Vamleshwar mangrove it is a need of the hour to undertake “An assessment of the nutrient profile and biotic components of Mahi estuary and Vamleshwar mangrove of Gulf of Khambhat, Gujarat, India”.

1.5. OBJECTIVES OF THE STUDY

The following aspect was carried out for four different sites in the Mahi estuary and three different sites in the Vamleshwar mangrove from July 2008 to June 2010:

1. Analysed physico-chemical parameters of surface waters such as pH, Temperature, Chlorinity, Salinity, Electrical Conductivity, Dissolved Oxygen, Total Alkalinity, Total Hardness, Total Solids, Phosphate, Nitrate, Ammoniacal Nitrogen, Sulfate, Silicate, Sodium, Potassium and Chlorophyll-α.

2. Evaluated the magnitude of nutrient budget in the surface sediments such as Temperature, Chloride, Phosphate, Sulfate, Organic Carbon, Organic Matter, Sodium and Potassium.

3. Determined the enormity of plankton as indicators and markers of pollution, periodic changes in density and diversity of phytoplankton and zooplankton.

4. Enumerated the density and diversity of benthic fauna in the estuary and mangrove.

***** *****