# Introduction

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Water is one of the important constituent of life support system. It is indeed a wonderful chemical medium, which has unique properties of dissolving and carrying in suspension of huge varieties of material with different chemical properties. Water helps in the movement, circulation and cycling of nutrients in the biosphere. Thus, it can get contaminated very easily. Water is the most vital resource and essential to all forms of life on this planet. Conservation and keeping up of the good quality water is of prime importance to face the ecological crises. Surface water is most vulnerable to pollution due to their easy access for the disposal of waste by natural and manmade source. Water resource is under threat due to over utilization from modern society, industrial and domestic sectors.

Water is the most important commodity which man has exploited than any other resource for the sustenance of his life (Mathur, 2004). A study of water quality in any aquatic system is fundamental to understand the water resource as it gives insight into the benefits to be gained from water management and consequence of its mismanagement. One of the striking features of the water bodies is the way in which they interact with and are affected by the surrounding land particularly due to the activities of man in agriculture, urbanization, construction of dams, roads, deforestation and the domestic as well as industrial input (Chattopadhyay and Kushari, 2003).

The Indian ocean region includes 36 littoral and 11 hinterland states, accounting for 30% of the Earths population (Khan and Morugesan, 2005). India has a coastline of 7500 km with an exclusive economic zone of 2.015  $\times 10^{6}$  km<sup>2</sup> which is 61% of the land area. The country has 14 major, 44 medium and 162 minor rivers with a total catchment area of 3.12  $\times 10^{6}$  km<sup>2</sup>, discharging 1645 km<sup>2</sup> of freshwater every year to the seas around the country. There are 11 major, 16 intermediate and 78 minor ports handling about 120 million tones of cargo annually are also located along the coasts (ENVIS, 2002).

The important major rivers are Ganga, Mahanadi, Godavari, Krishna and Kaveri on the east coast and Narmada and Tapi on the west coast. These seven rivers have a catchment area of  $1.83 \times 10^6$  km<sup>2</sup> and discharge 812 km<sup>3</sup> of freshwater transporting 1194 x  $10^6$  tons of silt to the marine waters every year (Zingde, 1989). Coastal ecosystem is under threat due to anthropogenic activities, increased human settlement, agricultural waste and the progressive industrialization, tourism business are posing serious threats to aquatic environment and its resource potential.

Coastal ecosystems are facing broad array of threat today. These threats include replacement of coastal habitat for construction of developmental projects. The coastal environment is an interface between land and marine water. This ecosystem is valuable to human from the dawn of civilization. Human, biological and social needs are readily met by coastal zone and 75% of the population of the world will be living in the coastal zone. This is also true in other developing maritime countries.

The loss of marine biodiversity is highest in coastal areas, particularly in developing countries, where anthropogenic pressure is maximum (John and Irvin, 2005). Human population along the coastal area is 25% of the total population and the population intensity along the coastal region increases pressure on the utilization of resources leading to habitat destruction, degradation and fragmentation. These resources are mismanaged and exploited for meeting the growing demand of food for the increasing human population. The major components of coastal zone are the coastal waters and the coastal land regime, which are subjected to intense pollution.

Estuary is an integral part of the coastal environment. It is the outfall region of the river, making the transitional zone between the fluvial and marine environs. The Concise Oxford Dictionary defines estuary as the "Tidal mouth of a large river". Balsubramnian *et al.*, 2002 defines estuary as "An arm of the sea: a narrow passage of the mouth of a river or lake, where the tides meet the current". "An estuary is a semi-enclosed coastal body of water

which has a free connection with the open sea and within which the sea water is measurably diluted with the fresh water derived from land drainage. Estuaries have been the focal point of the maritime studies and activities. As they are semi-enclosed they provide natural harbor for trade and commerce. Most of the great cities of the world have developed around the estuaries and ten largest metropolitan areas in the world, seven such as New York, Tokyo, London, Shanghai, Buenos Aires, Osaka and Los Angels border the estuarine areas (Zingde, 1989).

In India, the coastal population density has been quite high since many centuries and the metropolitan cities like Mumbai, Kolkata and Chennai are developed around the estuaries. Even at the time of the Harappan civilization, exploitation of estuarine and riverine resources was intensive. Active Graeco-Roman sea trade flourished in the Indus delta (Mohan-jo-daro area), the Ganga-Brahmaputra delta and the harbors in Bengal and South India (ENVIS, 2002).

An estuary is typically tidal 'brain' of a river and often characterized by sedimentation or silt carried in from terrestrial runoff and, frequently, from offshore (Daiber and Beattie, 1969). Estuarine circulation is common in estuaries; this occurs when fresh or brackish water flows out near the surface, while denser saline water flows inward near the bottom (Kena, 2006). Antiestuarine flow is its opposite, in which dense water flows out near the bottom and less dense water circulates inward at the surface, this cycle is called flushing time (Hansen and Rattray, 1966). The estuaries can be classified as salt wedge in which river output greatly exceeds marine input; there is little mixing, and thus a sharp contrast between fresh surface water and saline bottom water. Highly stratified estuary in which river output and marine input are more even, with river flow still dominant; turbulence induces more mixing of salt water upward than the reverse. Slightly stratified estuary in which river output is less than the marine input. Here, turbulence causes mixing of the whole water column, such that salinity varies more longitudinally rather than vertically. Vertically mixed estuary in which river output is much less than marine input, such that the freshwater contribution is negligible; longitudinal

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salinity variation only. Inverse estuary in which located in regions with high evaporation, there is no freshwater input and in fact salinity increases inland; overall flow is inward at the surface, down wells at the inland terminus, and flows outward subsurface. Intermittent estuary is a type of estuary varies dramatically depending on freshwater input and is capable of changing from a wholly marine embayment to any of the other estuary types (Schroder *et al.*, 1990).

The ever-increasing human population, urbanization and industrialization around the coastal ecosystems result in irrational use of estuarine environment and estuaries have for long been important to mankind, either as places of navigation, or as locations on their banks for towns and cities. As many as 33 estuaries are along the coast of India threatened such as Hooghly receiving oil pollutants, Rushkulaya receiving alkali waste, Mahanadi receiving agricultural runoff, Godavari and Krishna receiving shrimp farming waste and Adyar receiving domestic sewage in high concentration (Khan and Morugesan, 2005). Fortunately India is endowed with a number of estuarine systems and many of them are in pristine condition. The tidal and freshwater wetlands of estuaries act as buffers from coastal storms and flooding (Nigam, 1988). Hence, several varieties of fish, prawns, crabs, lobsters, stomatopods, clams, mussels and oysters of commercial significance have been identified from this environment, which provide good breeding grounds.

Estuaries wetlands help to reduce water pollution by trapping and filtering pollutants transported in runoff from the land. The estuaries are thus playing a vital role in the renewing of marine resources. In India 1.5 million ha of brackish water has been identified. 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, and extraction of freshwater and transport, and play a dominant role in the economy of coastal population. These very 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.

In the coastal zone of Indian estuaries and other inshore zones are the preferred destinations for developments, may it be an industry, urban settlement or a port. However, with economy often overriding environment, a good deal of such developments takes place without comprehensive scientific studies to assess probable impacts of a development on the aquatic ecology. They are also significant for human welfare through their role in transportation, production of food, waste disposal and various recreational pursuits. Nowadays, they are under pressure, either as repositories for the effluent of industrial processes and domestic waste, or as prime sites for land-reclaim to create sites for industry or urban development and tourism sector.

The study of estuarine regions plays vital role as they are highly productive and play an important role as nursery ground for many commercially important fishes especially shrimps (Reddy and Reddy, 2004). The estuary ecosystem provides essential habitat for a diversity of plants, animals and microorganisms and supports a complex and vibrant food web. Estuaries are transition zones between rivers and the sea, which differ from both in biotic and abiotic conditions. Marine resources traditionally been a major source of food for local inhabitants and a major economic value in terms of commercial (Venkantraman, 2005). From a biotic viewpoint, estuaries are highly productive ecosystems ranking at the same level as coral reefs and mangrove swamps. An elevated productivity is maintained because of high nutrient levels in both sediment and water column.

The productivity of any aquatic environment depends on many hydrobiological features and the important factor is the availability of inorganic nutrient content for the phytoplankton, which in turn determines the level of animal population and also effective vital source of natural resources. Such dynamic environment provides many ecological niches for diverse biota. The health status and the biological nitrogen and phosphorus are key of water quality parameters in estuaries (James, 2001).

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India is perhaps the only country that has a long record of inventories of coastal and marine biodiversity dating back to at least two centuries and the ocean cover over 70% of the planet surface area and account for 99 % of the volume that is known to sustain life. Estuarine ecosystems are very unique with respect to biodiversity as well as biological community is very impressive in this ecosystem. Coastal ecosystem such as estuaries, coral reefs and mangrove forest are highly valuable for coastal communities and much of the world's wealth of biodiversity is found highly diverse marine and coastal habitats (Chabrie, 2001).

The change in the hydrographic condition of these estuarine systems directly influences the zooplankton abundance. The zooplankton biomass was low in the estuarine system during the low saline period (Selvakumar *et al.*, 1979). Nutrient concentration is important in estuarine system which provides food for many organisms and change in concentration will produce remarkable effect. Nutrient concentrations vary according to surrounding land use, season, and geology. Population growth and human activities in developed and developing countries have lead to widespread eutrophication through the increased and continuous supply of nutrients to river and lake basins (Madgwick, 1999).

Nutrients are chemical substances used for maintenance of growth and that are critical for survival. Plants require a number of nutrients carbon, nitrogen, phosphorus, oxygen, silica, magnesium, potassium, calcium, iron, zinc, and copper for growth, reproduction and prevention of diseases. Nitrates and phosphates are important elements especially nutrient for phytoplankton and phytobenthos of the biogeochemical system of an estuary (Sardesai and Sunder, 2003). They are two of the most important nutrients being delivered to estuaries has increased significantly. Nutrients from these sources may fall to the land or estuary either directly or along with precipitation. Surface water inputs include point and nonpoint source. High nutrient concentrations have also been linked to harmful or nuisance phytoplankton blooms such as "red tides" and "brown tides" some of which produce harmful toxins and levels of

nutrient concentrations are always in flux, responding to changes in water temperature (Votsa *et al.*, 2000).

Biological activity in the estuary and the status of other water quality parameters are showing significant levels for nutrients in estuarine waters. Nutrient concentrations are usually greatest during spring and early summer, when fertilizer use and water flow from tributaries and irrigation activities are high. High nutrient concentrations can also be detected during seasonal lowflow conditions. During winter low-flow periods e.g. the lack of land and aquatic plant uptake combined with contributions from groundwater can result in high nitrogen levels. Nutrient levels downstream from urban areas may also be high during low-flow periods. At these times, contributions from point sources can be greater relative to stream flow. Estuary has no oxygen however, phosphate bound to the sediments is released back into the water. This release can fuel yet another round of phytoplankton blooms. Pollutants are known to deteriorate the aquatic environment by affecting their dissolved oxygen, turbidity, pH and chemical content. This is not only demises their auto regulating and buffering capacity but also influences the inhabiting biota (Gupta and Sharma, 2005).

The physico-chemical characteristics are important for water system. They are changing nature of water quality continuously. Determination of chemical pollutants in the environmental matrices has entered a new phase in the last decade and the subject of environmental analysis has expanded in recent years into a fully grown scientific field on its own merits (Lokhande, 2005). Environmental physico-chemical conditions play a major role in governing the ecological distribution, productivity and health of the organism. An element or compound present in a natural water system will generally distributed between a variety of physico-chemical status (Burton, 1979). High temperature, pungent odour and high level of suspended solid and low dissolved oxygen influence the growth of the algal bloom vigorously and clearly give an indication of eutrophication in that area (Sabata and Nayar, 1987).

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It is important in water management to know the concentrations of the various constituents (natural or pollution) of water. In the most commonly met form of pollution, by organic biodegradable wastes. Physico-chemical assessment of water quality is usually based on five parameters such as Hydrogen ion concentration (pH), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), total solids and salt content. The oxygen uptake is due to the activity of micro-organisms in breaking down the organic matter present in the sample. The greater the rate of loss of dissolved oxygen the greater is the amount of organic matter present. Thus, the test provides a useful general measure of the level of contamination of the sampled water by biodegradable wastes. Some ecological factors such as dissolved oxygen, salinity and detritus have significant effect on both desorption and bioaccumulation of metals (Kardege and Unlu, 2007). The water flowing into the estuaries will convey large quantities of oxygen into the estuary, and additional oxygen will be supplied through the surface of the water and by plant photosynthesis. Other parameters such as pH (which indicates the degree of acidity or alkalinity) and chloride (a major constituent of sewage and other wastes) are all determined almost routinely in river waters.

The Physico-chemical methods have the merit of being precise, discriminatory and quantitative. Water quality parameters should be in prescribed limit and data required by licensing authorities for the assessment of compliance by licensed discharges with prescribed standards (Natrajan, 2000).

Periodical entry and withdrawal of sea water and fluctuations in the fresh water volume cause frequent changes in the level of salinity of water which itself is responsible for several of the physicochemical and biological properties (Reddy and Reddy, 2004). In less saline water having low DO, low pH, high phosphate and low nitrate. The concentrations of nitrate and nitrite decrease, while that of ammonium, nitrogen substantially increases when DO is depleted. By studying the physico-chemical nature we can examine the life of an estuary. The physical and chemical features are mould the estuarine environment. The salts principally sodium and chloride ions, supplemented by

potassium, calcium, magnesium, and sulfate ions are in a continual state of change, so even the topography of estuaries is continuously changing (Voluntary estuary monitoring manual, 2006). Dissolved organic matter may also be higher in river water than the sea and the concentrations of most trace metals are similar in river and seawater and therefore tend to be relatively constant within estuarine water. Presence of large number of heavy metal in ecosystem and their toxicity manifestation, ranging from mildly harmful to lethal has been reported by several researchers (Fugare and Deshmukh , 2004).

However, many organisms living within estuaries, especially in the bottom deposits, rapidly consume the oxygen thus many sediments are anoxic, except for a thin surface layer where excessive organic enrichment occurs the multiplicity of microorganisms so produced may also consume all the oxygen within the water body. A few localized estuarine sediments however, have been reported to accumulate heavy metals Cr, Cu, Zn, Pb, Cd and Hg in Ulhas estuary and Hg in Rushikulya estuary by (Pradhan et al., 1999). Hg concentrations of 60 µg/g have been reported in the sediments of interior in Ulhas estuary. In the absence of sufficient quality-controlled data on dissolved trace constituents such as heavy metals, pesticides and hydrocarbons. The environmental status of our estuaries with respect to these contaminants remains uncertain. Broadly, it may be said that physicochemical monitoring will measure the causes of pollution and the quantity of pollutants, and biological surveillance will measure the effects of pollution. The composition of a community from any given point in a river therefore reflects the average water quality at that particular point.

After the great importance of estuarine system and its relation with physico-chemical properties. The inshore line of India specially Konkan areas now a days is under threat due to effluent discharge from industries, pesticide leaching from agricultural fields, oil spills from oil tankers, small and large trawlers. Sewage and solid waste disposal and retting of coconut husk along estuaries and backwaters. Tourism business is growing at alarming rate. Domestic sewage and industrial effluent are discharged in the water courses in and around estuaries is untreated or partially treated (Sengupta *et al.*, 1989). Greater human activity tends to deplete locally available water supplies and millions of liters of sewage, domestic waste, industrial and agricultural waste containing substances varying in characteristics and nature from simple nutrients to highly toxic substances (Daniel and Mayer, 2002). The majority of pollutants that enter into the coastal ecosystem especially estuaries and backwaters are chemical in nature and range from nutrients to toxic substances. The changing nature of the water quality gives indication of the likely impact on the associated biota (Karthikeyan *et al.*, 2004).

State of Maharashtra has 750 km coast line and great cities like Mumbai, Ratnagiri and Malvan are situated on the bank of estuaries. Sindhudurg district is having coast line of 121 km and five important estuaries are Tarkarli, Aachra, Kolam, Kalawali and Sarjekot. About twenty thousand population is situated on the bank of estuary and 75 % people are directly related to estuary for fishing business (Integrated coastal and marine area management project, 2001). These estuaries are main attraction of tourist and tourism business due to its picturesque value, good vegetation and climatic condition. Malvan is also known for Sindhudurg fort, coral reef and sand dunes and more fish catch. Estuaries of Sindhudurg district are more productive in nature. Coastal zone has different biotopes as estuaries, mangroves, coral reefs and Lagoons endowed with splendid beauty and high productivity. Variety of fishes, crustaceans and molluscan animals are found in large quantity. Major and minor fishery is carried out in the estuary. About five to seven lakh tourist visit per year to Sindhudurg district and their main attraction is coastal line and fish food.

Inshore coast of Malvan is under threat of pollution and coexistence of estuaries threatened by the rapidly growing tourism business and tourist flow. Improper disposal facility and unawareness about water quality, its associated impact on aquatic life and surrounding environment. Human settlement and number of hotels are growing in and around Malvan coast. Solid waste and liquid waste is directly dumped in to the estuary will be changing quality of water continuously. About 80 percent solid and liquid waste is dumped in

estuary. Introduction of modern technology such as trawler, water scooter, scuba driving and water sports are creating continuous change in water quality and chances of oil mixing.

People in and around Malvan coast are unaware about water quality and its consequences. Improper disposal facility of solid and liquid waste leads to continuous change in water quality parameters. Inadequate facility provided by local government is responsible for producing direct and indirect impact on water. Construction of roads and bridge are the depositors of large quantity of sand at the bank of estuary. People are directly dump their waste in to sea and estuary. Human settlement in and around Malvan coast is increasing. Therefore, in the present study social survey was carried out to know methods of solid and liquid waste disposal from surrounding people. Management of estuary and restore its water quality is primary function. Estuary Management Program is the study to define the 'baseline' conditions of the various estuary processes and the interaction between these processes (MoEF annual report, 1998). Before management options for an estuary can be meaningfully considered, it will generally be necessary to undertake an estuary process study.

In designing an estuary process study, it is important that the interactions between physical, chemical and biological processes occurring in the estuary itself, and between estuarine, ocean and upstream catchment processes be studied. A proper monitoring of coastal pollution and enforcement of strict measures to control pollution would help enhancing the productivity of the coastal environment.

The Coastal Regulation Zone (CRZ) notification was issued under the provisions of the Environment (Protection) Act, 1986. It outlines a zoning scheme to regulate development in a defined coastal strip. The Notification defines the coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are influenced by tidal action in the land ward side, up to 500 m from the high-tide line (HTL) and the land between the low-tide line (LTL) and the HTL, as the CRZ. The CRZ has been classified into four

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categories for the purpose of regulating developmental activities. Maximum restrictions apply to the ecologically sensitive areas of CRZ-I. The Notification provides information for setting up coastal management plan.

Authorities at the National and State levels are busy to identify and prepare coastal management plans. The Environmental Impact Assessment (EIA) Notifications of 1994 and 2006 make it mandatory to obtain prior approval of the competent authority for most developments in the coastal zone for which an EIA report is the primary requirement. Such reports tend to assess impacts of a particular activity on aquatic ecology in isolation without giving sufficient consideration to cumulative impacts of developments already existing in the area. Thus, with near absence of basin-level planning, regional EIAs and integrated management strategies, the estuaries are often overloaded with wastes or constructions that modify their dynamics, leading to environmental degradation.

However, scientific studies in most estuaries of India to quantify the nature and extent of damage due to anthropogenic activities are far inadequate and sporadic and the assessment based on the available information can be the most tentative. The important requirements to manage our estuaries in a professional and integrated manner are generation of longterm and systematically collected data to explain, with a certain level of confidence, their dynamics and ecology and use the emerging results in planning developments within their assimilative capacity keeping stakeholders informed.

Therefore, the present study was undertaken with specific objectives in mind. It is observed that there is fragmentary information on estuary water quality, particularly from the Tarkarli, Achara and Kolam estuary.

This study is based on the following hypothesis

• Estuarine waters near Malvan are relatively less polluted at upstream as compared to the downstream locations.

- Polluted waters have direct bearing on fish and shellfish productivity and quality.
- Water pollutants produce harmful effect on aquatic ecosystem.
- Coastal pollution ultimately affected on surrounding biodiversity.
- Aesthetic value of the coast is minimized by coastal pollution which affects the tourism potential.

Following objectives were taken for the study.

- To study the Physico-chemical characteristics of inshore water from different locations around Malvan coast.
- To compare the water quality of different locations i.e. upstream, downstream.
- To identify different sources of water pollution such as domestic, agricultural and industrial from nearby areas.
- To know the possible effects of coastal water pollution on nearby community by questioner survey.
- To study awareness among the people about water pollution and its adverse effects.

The present study on estuarine water quality analysis was undertaken with the objectives of generating baseline data on the quality of estuarine water from different areas and evaluating the likely impact of human activities and tourism on it. Attempt have been made in the present study covering physico-chemical parameters such as Temperature, pH, DO, BOD, COD, Salinity, Nitrates, Chlorides, oil and grease and heavy metals like Cu, Ni, Zn, Fe, Mg, Mn, Pb, Na, K and Ca etc. To find out physico-chemical status and heavy metal level in estuarine water samples were collected during low tide condition. It is essential to obtain information on the range of variation of some of the environmental parameters with the tidal rhythm and the changing nature of the water quality which gives indication of the likely impact on the associated biota. The present study is presented in five chapters. The first chapter gives a detailed introduction of the topic. The second chapter gives detailed materials and methods used in the investigation. The third chapter deals with detailed observations of all the parameters studied. The fourth chapter deals with discussion of all the parameters studied. The fifth chapter gives summary and precise conclusions. The dissertation also gives a detailed bibliography of the references which are directly and indirectly referred for the co-relation of the present investigation.