

## *Discussion*

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The present study deals with the Physico-chemical study of inshore waters from selected estuaries namely Achara, Kolam and Tarkarli from Malvan taluka of Sindhudurg district. Malvan is a famous tourist place from Sindhudurg district and tourism flow is increasing gradually towards places like Tarkarli, Achara and Kolam. Human settlements, hotels and small scale fish industries are growing along the estuary. Fishing and water sports are maximum and are influencing water quality. Local people around estuary are unaware about the change and its impact on surrounding environment.

Estuary is a part of river and transition zone between river and sea dominated by sea water and found more productive than fresh water. Estuaries in Sindhudurg district are rich in biodiversity. Variety of fishes, crustaceans and molluscan species are found in the estuary. Large quantities of nutrients are transported by river from huge distance to the estuaries. Physico-chemical parameters are important in estuary which governs the whole ecosystem of water body. The productivity of aquatic environment is depends on many hydrobiological features and availability of nutrients. Physico-chemical parameters are continuously changed due to change in incoming source. Water quality assessment is usually based on physico-chemical and biological parameters. These parameters are correlated with one another, means the effect on one parameter is affecting other parameter of same waterbody. Change in physico-chemical nature of water is directly or indirectly affecting on surrounding environment. To understand nature of estuary, physico-chemical parameters like Temperature, Salinity, pH, Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Dissolved Solid, Total Suspended Solid, Chloride, Oil and Grease and Nitrates were investigated at Tarkarli, Kolam and Achara estuary under low tide condition. Heavy metal study was carried out on seasonal basis includes metals like Copper, Nickel, Lead, Zinc, Iron, Calcium, Magnesium, Potassium, Sodium and Manganese.

Temperature is an important physical parameter in water system, which determines the nature of other parameters. Temperature affects biological nature of water. In the present investigation higher temperature was found during premonsoon and post monsoon period. Temperature was found in the summer season ranging from 29 °C to 33 °C. This seasonal variation of temperature was due to the incoming radiations, winds and tidal currents. Vijay Kumar (2000) studied the estuarine water which was generally warmer during the premonsoon period (i.e. Feb-May) and attended peak values during summer in Mulki estuary. Higher temperature in summer season was due to high solar radiations and this leads to change in other parameter of estuary water.

High temperature of estuarine waters were due to solar heating of the land locked estuary and greater variation of temperature than the oceanic waters due to the characteristic features of the estuary where brackish or freshwater influence was dominant in estuarine water (Reddy *et al.*, 1979). Water temperatures are not as easy to interrupt because they are neoconservative, and daily input of solar radiation can alter the structures substantially (Schumann *et al.*, 1997). Present study showed variation in water temperature due to tidal influence. Temperature variations of the estuarine waters clearly indicated the influence of tide and such tide controlled changes in temperature during the monsoon season were observed also in Mandovi and Zuari estuaries (Reddy *et al.*, 1979). Similarly high water temperature prevailed during the month of May as observed in Netravati-Gurupur estuary and subsurface waters were warmer most of the time compared to surface water were due to influx of warmer tide (Nagarajiah and Gupta, 1982). Water temperature in the range of 24°C to 29°C was observed in Murderkill estuary (Piet and Franklin, 1974). In the present study the minimum and maximum temperatures were 24°C and 34°C in the month of April and July respectively. During December the temperature varied within a narrow range of 26°C to 27°C. Similar results were also been reported by Gophinathan and Joseph, 1980.

Water temperature was significantly decreased during rainy season, whereas increased in post monsoon. Temperature of the water attained highest i.e. 33°C in premonsoon and lowest i.e. 24°C during monsoon season. Temperature was decreased during rainy season at all sites and significantly increased from winter to summer season. Similar results were recorded in Zuari estuary by Thomas *et al.*, 1975. In the winter season temperature ranged from 26°C to 27°C at upstream site of Belleau estuary (Rai *et al.*, 1998) and surface water temperature varied from 29°C to 34°C in Kayamkulam estuary (Laluraj *et al.*, 2002). The minimum surface temperature recorded was 26°C at Shrivardan creek (Lokhande *et al.*, 1995).

During rainy season fresh water flow rate is high due to continuous rainfall and continuous change in atmospheric condition and low tidal influence created change in temperature. Water flow of fresh water discharged by rivers and canals during the monsoon has a great influence on tidal currents and temperature of the water may at times be raised or lowered independently of the atmospheric conditions prevailing in the locality (Cheriyen, 1963). It was reported by (Thomas *et al.*, 1975) in Zuari estuary, the temperature was increased towards upstream site during monsoon. Therefore, from the study carried out it can be said that the temperature in all these estuaries remains constant during the summer, fluctuates in winter and decrease in the rainy season.

pH of water determines the chemical nature of water. pH indicates the hydrogen ion concentration in water. Mixing of acidic and alkaline substances in aquatic environment is studied by pH electrode method. In the present study seasonal variation in pH of surface water was studied which determines the concentration of other nutrients in water. pH was found alkaline due to high inflow of sea water in to fresh water. Vimala (2005) studied that natural water is generally alkaline due to presence of carbonates. pH changes seasonally due to variation in photosynthetic activity, which increase pH due to consumption of carbon dioxide in the process. During rainy season pH was neutral at all sites due to high flux of fresh water and

rivers almost flooded. Bhat and Gupta (1987) recorded low pH during monsoon and high values during pre and post monsoon.

The pH did not show much fluctuation seasonally except that the water was alkaline during summer and winter as the influx of fresh water was minimum and the water in the estuary was dominated by seawater. pH for estuary water is 8 to 9 and varied by fresh water (Burton, 2007). Laluraj *et al.*, 2002 of the opinion that the variation in pH can be due to contribution of acidic soil water and acidic ground water into the estuary. High alkaline pH produces adverse impact on aquatic life. Mathur and Maheshwari (2006) studied that the pH values of the water mostly alkaline though it has no direct effect on human health. pH varied between 7.5 to 8.5 in winter and 8.9 during summer at Hooghly estuary recorded by Sadhram *et al.*, 2005. Higher pH in post monsoon period at Ashtamudi estuary was recorded by Nair *et al.*, 1983.

The pH of water varied between 6.9 to 7.5 in rainy season, while 7.9 to 9.0 during summer and winter season. Sadhram (2005) recorded pH of winter season was in the range of 7.2 to 8.9 in Hooghly estuary. Minimum pH was 6.9 at Achara upstream site in the month of July 2007 due to high influx of fresh water as well as tidal influence is responsible for variation in pH. It was also observed by Vijaykumar *et al.*, 2000, the pH of water that varied between 7.3 to 7.9 during high tide and ranges 8.0 - 9.0 during low tide and water was alkaline during summer, when the freshwater was minimum and estuary was dominated by sea water. Similarly Balsubramania and Natrajan, 1987 recorded alkaline pH throughout the year.

The influx of fresh water during monsoon showed neutral pH and high pH observed during winter i.e. during Dec, Jan and summer in the month of May due to the abundance of algae (Nagrajiah and Gupta, 1983). Balsubramanian and Kanan (2005) was of opinion that the pH fluctuates seasonally and higher pH can be seen in summer and it decreases in rainy season. pH was found fluctuated on seasonally and lowered during rainy season.

Salinity is a chemical parameter, which determines the total concentration of salt in water. Change in salinity are also important for estuarine biota (Jerling and Wooldrid, 1994). In the present study salinity was recorded seasonally. Salinity also determines the flow rate of fresh and salt water in to the estuary. Salinity is the well recognized parameter for studying the mixing process and intrusion of saline waters into estuaries by tidal action (Laluraj, 2002). In the present investigation salinity was significantly decreased in rainy season at all sites studied. The period from June to September is considered as the low saline period and October to June is saline period. Verma (1975) studied salinity variation over tidal cycle was considerably high during rainy season compared to winter and summer. Selvakumar (1980) stated that the salinity gradient along the longitudinal axis decreasing from mouth to head of the estuaries occurred during high saline period. Continuous supply of fresh water and mixing of high nutrients from catchment area changes salinity percentage. Salinity is yet another important factor that influences the marine environment much and varies in different ecosystem according to the low and high tide and fresh water inflow (Balsubramania and Kanan, 2005).

Vijaykumar (2000) observed that salinity regulates the quality of water and determines the extent of dissolution of gases, hydrogen ion concentration and other characteristics of brackish water. The penetration of high salinity water in to the Brodkil river at high water is a function of tidal flow, atmospheric conditions, and fresh water runoff (Piet and Franklin, 1973). The change in salinity is associated with dilution due to the freshwater inflow (Iyer *et al.*, 2003). In the present study salinity of water was varied from 17.5 ‰ to 36.9 ‰. The minimum salinity attained was 17.5 ‰ in the month of July 2007 due to fresh water.

Reddy and Reddy, 2004 studied Netravati and Gurupur estuary and nearshore waters showed negative correlation between salinity and nutrients. Distribution of salinity indicates that the estuary is stratified during monsoon

season, partially mixed in post monsoon and well mixed during the premonsoon. The estuaries become seawater dominated during the summer and winter month resulting in high salinity whereas it becomes freshwater dominated during the monsoon. The changing state of the estuary with a changing fresh water input Schroeder (1990) Salinity values were quiet lowered at Kolam station downstream site during rainy season. Rai (1998) stated that the salinity of water, which has a significant influence on the species composition of the resident biota. Cheriyan, 1963 suggested that evaporation influences the salinity and temperature. The changing salinity structures are also important for estuarine biota (Jerling and Wooldridge, 1994). Salinity fluctuation in Gamtoo estuary is due to increased freshwater inflow in catchments area (Schumann and Pears, 1997). In the present investigation salinity showed seasonal fluctuation and rainy season influences on percentage of salinity.

Dissolved oxygen is a crucial biological parameter of water, which determines the status of water and surrounding nature of the waterbody. Oxygen is important factor in water which keeps alive the whole ecosystem and biodiversity. Oxygen level was lowest at low tide in Belle estuary (Ragotatzkie, 1969) Depletion of oxygen level is due to presence of biodegradable substances. Dissolved oxygen indicates the physical, chemical and biological activities in a water body. Dissolved oxygen affects the solubility and availability of many nutrients and therefore controls productivity of aquatic system. In the present study dissolved oxygen was found fluctuated at all sites. Toby *et al.*, 2000 stated that the DO concentration is one of the primary water quality constituent that is used as an indicator of the ecological health of water or ecosystem. In present study low oxygen level was found at Tarkarli upstream during the month of Nov 06 – Feb 07, whereas high levels were found at Achara downstream. Low oxygen was recorded at Karwar (Gopinathan and Joseph, 1980). High oxygen content found at Murderkil estuary (Piet and Franklin, 1974). High oxygen contents suggests well mixed condition in the estuary and flow of fresh water wherein oxygen solubility is greater and oxygen concentration controlled by hydrographical parameters

(Temperature and salinity) in association with physical and biological process in the estuarine environment (Sadhuram *et al.*, 2005).

Temperature and salinity shows negative correlation with oxygen. It is well known that the temperature and salinity affect the dissolution of oxygen and in the estuarine environment is chiefly controlled by tidal ingress and freshwater runoff (Nagrajiah and Gupta, 1983).

In the present investigation the estuaries were found to be well oxygenated during rainy season at all the stations. Similarly higher values of dissolved oxygen were recorded during monsoon month at almost all the stations and are due to the copious supply of low saline and low temperature water from the river (Vijaykumar *et al.*, 2000). Oxygen in water is fixed either due to the direct dissolution from the atmosphere or a result of primary production (Laluraj *et al.*, 2002).

Low DO is a result of additional oxygen demand due to the sinking suspended load of organic brought in by the runoff. Increase or decrease of oxygen level is dependent on productivity of that waterbody. Lower values of dissolved oxygen were recorded during premonsoon month at almost all the stations in Gautami estuary by Tripathi *et al.*, 2005. The lower values during October could be due to utilization of oxygen for decomposition of organic matter in the terrigenous sediment. The data reveals that the dissolve oxygen fluctuated between 2.0 and 3.6 mg/l during low tide. The rising tide raised the oxygen concentration due to the influx of seawater rich in oxygen in Belle estuary (Rai *et al.*, 1998). Present study shows that oxygen was fluctuated on tidal currents. Incoming source is important for oxygen determination. Low oxygen level for long period is harmful to aquatic life. Therefore, in the present investigation dissolved oxygen was a key parameter deciding the livelihoodness of the estuary which is determined by the factors like tourism, household waste, and industrial waste released in the estuary.



Biochemical oxygen demand (BOD) is an important physico-chemical parameter in regulating water quality and suggests quantity of organic matter present and its decomposition level. Microorganisms play an important role in the process of BOD. BOD was found in higher range during the month of March to May. High BOD was observed in upstream site of Tarkarli station, while lowered at downstream site. More dilution was found at downstream site. Productivity is high during the low tide situation, which ultimately affects oxygen level. BOD values were observed in the range of 9.5 mg/l to 80 mg/l in the present investigation.

BOD values are varied due to fluctuation in organic sources. High BOD value found at Thane creek indicates high load of organic matter (Chavan *et al.*, 2005). Tripathi (2005) found that the high BOD and low DO in the river is due to inflow of terrestrial input or anthropogenic source at Gautami estuary. Zingade (1979) observed 82 mg/l of BOD at Mumbai creek due to presence of high sewage. In estuarine sector amount of BOD due to discharge of municipal and industrial waste in Seine estuary (Billen *et al.*, 2001)

BOD was somewhat decreased during month of Jun-Aug. Dissolved oxygen and BOD has a negative correlation with each other. BOD was observed in the range of 14 mg/l to 56.66 mg/l during post monsoon season due to high organic matter received in the estuaries through runoff. Sadhuram (2005) studied BOD ranged between 5 mg/l to 67 mg/l during winter, summer and monsoon season and was considered to be lower than the threshold limits and may not pose any threat to aquatic life. High BOD level in the estuaries is harmful for aquatic organism. In the present investigation BOD was found significantly increased at upstream site suggesting a very high organic load from surrounding added to estuaries.

Chemical oxygen demand (COD) in the estuary, determines the level of inorganic material. Chemical oxygen demand indicates the sources of industrial waste water discharge from the surrounding area. Chemical oxygen

demand was found high during pre and post monsoon season. Variation in Chemical oxygen demand is due to tidal influence in fresh water. COD was found significantly decreased towards upstream site. COD was found higher at downstream site and lowered at upstream due to tidal flow of sea water. Rai *et al.*, 1998 also observed COD values were lowered at downstream site in Belle estuary due to sea water influx. COD was lowered during rainy season due to maximum dilution of fresh water but a very little change was observed at Kolam site due to very less influx of fresh water in the estuary. Sarladevi *et al.*, 1979 observed fluctuation of COD at Cochin back water during all season. Higher values were recorded in the month of Jan 07 while lower values i.e. 99.6 mg/l in the month Aug 2007 in monsoon season. COD was found at minimum range at Shrivardan creek (Lokhande *et al.*, 1995). COD indicates contamination of water with Industrial waste. From the present study it can be said that COD was significantly increased towards downstream site.

Oil and Grease in the aquatic ecosystem system is due to anthropogenic sources like sewage and wastewater as well as boating and local tourism creates oil contamination in estuarine area. Oil and grease were not detected during monsoon season at all station due to high fresh water inflow rate and ban on fishing. Tourism and fishing business through troller and small boats create oil pollution. Thin film of oil is created on water due to leakage from small boats and Troller. Oil and grease was found at upstream site of Tarkarli station is 2.25 mg/l in Jan 2007. Water sports and fishing business is high during winter season. Niles and Jennifer, 2006 found less than 5 mg/l of oil and grease at Crossica river. Lokhande *et al.*, 1995 studied oil and grease and found in a range of 0.99 to 3 mg/l and suggested that proper maintenance of boats and trollers may minimize oil pollution in the estuary.

Total dissolved solid is an important biological parameter in aquatic system. TDS determine the level of dissolved solid in water. TDS is also indicator of source of pollutants from surrounding area. Total dissolved solid is

always high in estuary water, due to continuous inflow of sea water in fresh water. Thomas *et al.*, 1975 suggests saline water entering in estuarine water to produce high TDS. Higher values of TDS recorded in the month of March and April, whereas it was lowered during the monsoon season. Constant values are found at both stations of the Kolam site. TDS was found fluctuating due to tidal influence and TDS was significantly increased at downstream site, whereas increased towards upstream. In present study TDS and chlorides are positively correlated with each other. Mathur and Maheswari, 2006 reported TDS 308 mg/l of TDS in Chambal river. Lokhande *et al.*, 1995 observed TDS in higher concentration at Shrivardhan creek (Lokhande *et al.*, 1995). In the present investigation TDS does not show a particular trend but fluctuated due to tidal currents. Presence of high TDS at upstream site suggests that the higher distance of sea water influx whereas values of TDS were lowered during rainy season suggesting influence of season.

Suspended particulate matter in aquatic environment determines the percentage of suspended material in total solid content. In the present study Total suspended solid showed seasonal variation. TSS was significantly decreased during premonsoon and post monsoon season, while increased in monsoon season. Anilkumar *et al.*, 1999 reported suspended particulate matter 58 – 80 mg/l during rainy season at Beypore estuary. Suspended solids were found around 20 mg/l in rainy season. Variation in particulate matter is due to presence of sedimentation load transported by river and low tide situation is important for deposition of sediment and suspension. Suspended particulate matter was noticed at surface and bottom in Hooghly estuary showing the impact of fresh water and sediment transportation (Sadhuram, 2005). During low tide condition flow rate is constant for sediment deposition and suspension. Therefore, suspended solids were increased during low tide (Das *et al.*, 1997) and maximum found was 4000 mg/l upstream site of Netravati estuary (Gupta *et al.*, 1987).

Total suspended solid found less at all stations of every site but they found increased during rainy season. Water in the upstream region in general

bear less suspended material compared to those at the mouth and the mid reaches of the estuary. High quantity of suspended particulate matter found in Narmada estuary in all season (NIO, 1985). Total suspended particulate matter is high at middle stream of estuary compared to head and maximum amount of sediment encountered during monsoon month at Zuari estuary (Thomas *et al.*, 1975). The concentration of suspended particulate matter is due to natural process (Chester and Stoner, 1972).

Suspended sediment load was always high in the estuary than the sea and was maximum in rainy season (Reddy *et al.*, 1979). High values were found in rainy season because of higher soil and solid waste carried by river. Maximum amount of suspended solid encountered in the estuary was during monsoon season. In present investigation TSS showed similar results.

Nitrates in aquatic system are due to the process of nitrification. Presence of nitrate is an indicator of surrounding domestic and agriculture source. In the present study Nitrate concentration varied from 0.65 to 5.11 mg/l during low tide. Estuarine water present relative stock of nitrate (Alongi *et al.*, 1992). The higher values during monsoon season were attributed to the terrestrial input through river discharge. Higher levels of i.e. 9.4 mg/l nitrates were observed during the monsoon season, which could be due to agricultural runoff due to monsoonal flood. Higher levels of nitrate were observed during the post monsoon season by Balsubramanian and Kanan, 2005.

Sadhuram *et al.*, 2005 suggested that nutrients play a vital role in biogeochemical processes of Hooghly estuary. According to Rai (1998) anthropogenic sources are responsible for nitrate contamination. Nitrate is primarily in oxidized form entered the estuary from different sources both natural and from human activities. Higher value of chloride and nitrates were observed due to sewage discharge from domestic source (Brajesh *et al.*, 2007). The river water probably enriched the nitrate content of the water as observed in the Korpuzha estuary studied by Nair *et al.*, 1983. Maximum nitrates 38 mg/l were observed in Cochin back water (Iyer *et al.*, 2003).

With respect to tides higher values were observed during low tide. As compared to upstream sites the downstream sites showed higher values of nitrates and maximum value was observed at Tarkarli downstream site in Aug 2007. During winter season nitrates were found in a constant range at Tarkarli upstream site. Iyer *et al.*, 2003 suggested that the association between dissolved oxygen and nitrate is understandable as their equilibrium controlled by oxidation reduction process. Comparatively high values of nitrates were observed during the month of January and decreased in the month of February and March (Laluraj *et al.*, 2002). Nitrate concentration regulated other parameters in aquatic ecosystem. Nagarjah and Gupta, 1983 observed that monsoon and fresh water discharge determines different physico-chemical parameters, while temperature salinity decreased during monsoon months while nitrate recorded peak value in Netravati estuary.

High nitrates were found during rainy season due to deposition of sediments. Vijay Kumar *et al.*, 2000 recorded higher values during monsoon months both during high and low tides. The nitrate content were increased gradually from April to September and attended maximum value in October (Chattopadhyay and Kushari, 2003). Karthikeya *et al.*, 2004 observed in Uppnar estuary distribution of sediment with high value of nitrate during monsoon and low values during post monsoon. Maximum level of nitrate observed during northeast monsoon in the Palk bay Madapam (Maruthanayagam and Subramanian, 1999). High nitrate content in estuarine water is due to sea water inflow. Various nutrients in the estuarine system show high value but contribution of river is lowest (Sarladevi *et al.*, 1991). In the present study nitrate was found in higher range during rainy season, whereas lowered in summer season.

Chloride is a wellknown parameter of estuary water that regulates water quality. Chloride is a naturally occurring mineral present in any water body. Lower values were recorded in upstream station of all the sites studied. Lowest values were recorded in monsoon season. Constant values were

found in the month of October to April 07. Chloride concentration gradually increased from 75 to 10000 mg/l at Kaveri estuary (Ramnathan, 1993). Higher concentration will be harmful for aquatic life. Lokhande (2005) showed that Chloride content in reasonable concentration is not harmful to human. Chloride was found in the range of 100 to 27000 mg/l at Tarkarli estuary. Maximum value observed 26900 mg/l at Achara downstream site in the month of November 2006 and lowest value observed was 210 mg/l at Tarkarli upstream site during June, 2007. Lower values of chlorides found at Tarkarli site during rainy season, suggest that the fresh water inflow is high.

Heavy metals are naturally occurring elements but sometimes its concentration gets increased due to human activities. Elements in some proportion are important for human being and aquatic life also for normal growth and development. Copper, nickel and zinc were found in the same range during summer and winter season. In general heavy metals were found significantly increased towards downstream site.

Zinc concentration in the estuaries is only due to human activities in and around estuary. Kumari *et al.*, 2005 observed higher concentration of zinc during the north east monsoon period perhaps due to monsoonal discharges and from the land runoff reaching the coastal area. Nickel, Copper and Lead values were nil during rainy season. Calcium and Potassium were found in a constant range at all stations. Sodium observed high in summer and winter season whereas less during monsoon season. Little change was observed at Kolam site during the study. The levels of Iron, Zinc and Copper were showed a slight seasonal fluctuation with higher concentration during the monsoon months in Ennore estuary and the concentration of Iron, Zinc, Manganese and copper in water exceeded (Rajathy and Azariah, 1997). Magnesium was found in higher range during summer and winter season, whereas lowered in rainy season. Pradhan *et al.*, 1999 in Rushikulya estuary, Nickel was found in more quantity than copper whereas Panda *et al.*, 1999 observed that the availability of Manganese compared to Iron in exchangeable fraction at Bahuda estuary. Nickel values were ranged from 0.092 to 0.183 mg/l whereas

Iron and Magnesium values were observed high in rainy season due to high transportation of sediment. Higher value of Sodium was 6973 mg/l in summer season at Achara downstream site and minimum value found was 210 mg/l at Tarkarli downstream site during rainy season.

Concentration of Lead and Iron in water showed significant variation between premonsoon and post monsoon. Niles and Jennifer, 2006 seen lower values of heavy metals like 0.05 mg/l Cu, 0.1mg/l Pb and 0.4 mg/l Zinc in Crossica river. High concentration of sodium and potassium at Tarkarli upstream site suggests that the sea water influx is high. This is supported by Laluraj et al., 2002 suggesting the distribution pattern of Calcium showed that bottom waters have higher concentration of calcium than that of surface waters due to dissolution of detritus material takes place during the premonsoon season found in Kayamkulam estuary.

There was gradual increase of potassium content from July to September and attained peak values in June and the maximum values of Iron content was exhibited by each water body during July to September. Iron content was found highest at West Bengal (Chattopadhey and Kushari, 2003). Presence of Calcium and Magnesium content in seawater is due to calcareous material supply by crustaceous species. The distribution of total and dissolved Manganese in estuaries is usually nonconservative (Richard, 1989) but its limiting supply for estuarine biological process is specific (Evans et al., 1977) Calcium and Magnesium indicates an increasing trend from riverine to estuarine and shelf regions. Padmavati and Goswami, 1996 observed that Calcium was decreased during rainy season in Godavari estuary. Higher value of Calcium and Magnesium were observed during high tide than low tide in Vellar estuary (Palanichamy and Balasubramanian, 1989).

Sodium, Potassium, Calcium and Magnesium showed conservative behavior in the Kaveri estuary (Subramanian et al., 1989). Levels of lead 67 mg/l and Zinc 38 mg/l were observed in Ashtamudi estuary by Nair and Aziz, 1987. In Cochin backwater Iron and Nickel were stationary at surface whereas

the metals like Copper, Zinc and Manganese showed special variation. Seasonal variations were maximum during August to December which remained almost uniform for all the metals (Sarladevi *et al.*, 1991).

Positive correlation found in all elements except Fe, Mg, Na, and K which were fluctuated in rainy season. Nickel was found in range of 0.41 to 0.92 ppm during rainy season. Lead was detected during rainy season. The level of zinc present in Cochin back water indicates anthropogenic sources (Nair and Balchandra, 1993). Copper, Lead and Zinc seem to undergo adsorption, whereas Manganese shows adsorption during estuarine mixing of physicochemical parameter at Olippuram estuary (Ramkrishna *et al.*, 1987). Zingade *et al.*, 1989 increase of Copper and Zinc increase during low tide because of greater impact of waste water at Kolak estuary. Santoshkumar and Saha, 2004 observed a descending order trend of heavy metals was Zn, Fe, Mn, and Ca in Ganga river. All values of Heavy metal were independent with each other and there was no effect found in one site to other site. All these metals found fluctuating seasonal. Higher concentration of Sodium and Potassium at upstream suggest flow is high and low range of toxic elements indicates that there is no industrial contamination.

Social study was carried out to know the disposal pattern of solid and liquid waste. It was observed that Local people around estuary are unaware about water quality and its consequences. Continuous flow of tourist leads to increase in solid and liquid waste quantity. Human impact on estuarine environment is mainly due to developmental activities like road development, bridges, fishing and recreational and tourism flow (Gophinathan, 2006). It was been also observed from fisherman survey that developmental projects are responsible for unavailability of fishes in the estuary. Sharma, 2007 studied and showed that the rapid growth in human settlement along estuary has led to several problems of water quality management, because of ecological imbalance caused by sewage disposal in the estuary.



The social survey in the estuarine area revealed very important data related to the local people perception towards the waste disposal and awareness. It is striking that even the villages on the outskirts of Malvan city and information that has come from the villages and improvement in the living standard of rural masses does not seem to have much impact on the water quality. Human settlement and Hotel business was gradually increased on the bank of estuary with no disposal provision and therefore large quantity of solid and liquid waste is directly dumped in the estuary. It was also observed that the roads and bridge constructional projects were started on Achara estuary which leads to decreased fish catch.

Fisherman survey revealed that high quantity of sand has deposited on the bank of estuary due to construction of small bridges and this has led to decrease in fish movement. Fishes, crustaceans and molluscs are affected by sewage waste and are indicator of sewage pollution. Achara site fisherman are directly disposing their solid waste in the estuary. Fisherman quote that about 10 species of fish are found rarely in the estuary, whereas 2 to 3 are extinct from last 5 year. Open solid and liquid waste dumping practices leads to ground water pollution. From villagers survey estuary found more turbid during winter season. It is also found that during the winter season have high rush of tourist. Solid and liquid dumped in estuary caused biological changes in estuary (Gross, 1978). Discharge of domestic waste in estuary is caused process of eutrophication. Formation of algal boom is only due to effect of domestic waste. Algal booms are found in some part of Tarkarli estuary.

Dumping of solid and pouring liquid into estuarine water are lead to acutely toxic for plants and animal (Gopinathan, 2006). Pelley (1998) studied that dumping of solid waste in estuary creates decomposition of organic matter, leads to depletion of oxygen level and process of eutrophication. Some fishes breathe oxygen from upper surface of water but due to algal boom they cannot take surface oxygen. High organic waste in water body leads to spread of water born diseases. Dissolved oxygen was extremely low at low tide as a result of large quantities of waste material from domestic

agricultural sector. The major effect of sewage is depletion of oxygen content and stimulates the formation of hydrogen sulphide, which is harmful for biota (Ansari, 1987). High biochemical oxygen demand was due to raw sewage from surrounding area (Karikar, 1997). Presence of pesticides in estuarine water is due to seepage from horticulture area. Mixing of sources of pesticide contamination are closely related to agricultural and domestic sector (Bhattacharya. 1988).

Untreated domestic wastewater is increasing BOD level and decrease oxygen level. Degradation is only due to release of untreated domestic waste water from nearby areas (Zingade, 1999). Excess organic loading often associated with the release of untreated or partially treated domestic waste water create degradation. Unsecured land filling creates viral diseases in surrounding area. Open dumping of solid and release of liquid waste leads to loss of aesthetic value is due to insufficient provision from local government. Continuous releases of domestic waste from nearby areas are affected on tourism potential. Burning of solid waste creates air pollution.

In and around estuary maximum fishermen are not using local disposal facility due to unawareness as well as provision of disposal. Malvan Tourism Developmental Corporation (MTDC) has made some rules of disposal for big hotels around estuary are followed by only few hotel owners. Traditional methods of disposal were used by residential people around estuary. The warning through signs and media indicated better and more transparent public information strategy (Lepestur *et al.*, 2007). Maximum numbers of people are found literate around Tarkarli site and they are using local governmental facility for disposal. Dumping of solid waste in estuary is routine practice found around estuary. According to fisherman main reason of unavailability of fishes during fishing is developmental projects and fishing during rainy season has been reducing further fish catch in winter and summer.

Maximum literacy was found in Tarkarli site due to tourism business was gradually increasing towards Malvan. Kolam area found more illiterate due to traditional fishing and minimum flow of tourist. In the present study maximum respondent are fishermen in age group of 30 - 45 years. Maximum dumping of solid and liquid waste found at Tarkarli site because of insufficient facility provided by local self government. Fishermen around estuary at all sites are unaware about disposal of solid and liquid in the estuary. Female respondent are unaware about environmental concern. Maximum literacy was found in male respondent.

It was revealed from the interaction with the villagers that the people doesnot know about seriousness of disposal of solid and liquid waste in to the estuary and the consequences caused due to it. It was also not tried to literate people about the waste dumping into the estuary, as well they have not provided with the disposal facility to them. If this condition remains for next 10 years it is possible that the fish catch will get dwindled due to drastic change in the quality of water in the estuary. Therefore, it is a time to create awareness amongst the people to protect degradation of estuarine environment.