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# Monthly Variations of Water Quality along South East Coast of India

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Abstract: ***The environmental factors of coastal areas are very important, because the variations in the Physico-chemical properties, such as temperature, salinity, pH, dissolved oxygen and nutrients will impact the life span of the fauna and flora in the sea. It regulates the species richness in the coastal area. If the Physico-chemical parameters are not suitable, it will affect the distribution and the life style of the Biota. The variations in the nutrients load along the coastal waters is due to the natural weathering, riverine, land and anthropogenic input .However, the natural seasonal changes keep the coastal waters well mixed and aerated, which help to scatter the nutrients useful for the Biota. In the present study the environmental parameters such as temperature, DO, salinity, pH, Nutrients and Chlorophyll-a were recorded from January 2014 to December 2014. The data suggests that during the monsoon period, a significant increase of fresh water and land side input into the coastal area and have elevated nutrient concentration compared with other seasons. The qualitative study showed the present status of the Physico-chemical parameters, which is very useful to evaluate the health of the coastal system and also to take precautionary measures to save the coastal environment.***

**Keywords:** Monthly Variations, Coastal waters, Water quality, South East coast of India.

## 1. Introduction

Water quality is well-defined by the chemical, physical and biological contents of water. Coastal Zone is the area of interaction between land and sea and both land-dwelling as well as marine environments influence this zone. Coastal areas and estuarine are complex and dynamic aquatic environment [1].In India the coastal zone is more significant because of renewable and non-renewable natural resources discharge of waste effluents and also polluted by municipal sewage, industries and of recreational activities. From this time forth, the protection of the coastal environment and continuous monitoring is needed. Coastal Zones includes bays, estuaries, backwaters, and creeks, etc. which are influenced by wave action.

Physico-chemical monitoring generally provides stable information about the incoming offensive effluents, which ultimately gives idea about the probable sources of pollutants [2]. By a well-planned water quality monitoring system we can predict the variations in the water quality and hence we can take the preventive measures to maintain the ecological balance in the coastal water [3]. The coastal marine environment forms an essential constituent of the global life. In all the countries, the human activities can affect the physical characteristics of the coastal water. The discharge of municipal sewage and industrial effluents, impact the environment on the coastal side which can further affect the aquatic biota as well as the health of the marine environment [4]. The Coastal ecosystem is the vibrant host for fauna and flora and it is the most important resource to provide a good plat-form for the coastal life. There are various sources which are responsible to change the biodiversity of the coastal ecosystem. The modern urbanization is the root cause for the coastal water pollution [5]. In the near shore waters and estuaries, exhibit considerable seasonal variations depending on the local conditions of rainfall, tidal incursions, various abiotic and biotic processes, quantum of fresh water inflow affecting the nutrient cycle in the coastal environments [35]. The availability of nutrients plays a significant role in the phytoplankton diversity which can reflect the environmental conditions of the ecosystem [6].

Rapid industrialization along the coastal areas made substantial deterioration in the water quality. They cause a variety of socio-economic problems, and producing increased environmental stress along the coastal environment [7, 8]. Such problems leads to excessive input of nutrients, associated with industrial and municipal wastewater [9]. The consequent variations in the Physico-Chemical parameters produce an ecological impact over biological communities associated mostly with eutrophication process [10, 11].Hence it is essential to know the interrelationships between the organisms and Physico-Chemical parameters to assess the stability and function of the Coastal ecosystem.

## 2. Description of the Study Area

The study area Mandapam (latitude 9°16'14"N; longitude 79°7'10"E), Thoothukudi (latitude 8°46'26"N; longitude 78°10'9"E), Arumuganeri (8°59'40"; 78°13'71") Kanyakumari (latitude 8°4'45"N; longitude 77°32'38"E) are located in the Gulf of Mannar zone along the South East Coast of India. Mandapam (nearby by Rameswaram) is situated near to Bay of

Bengal and close to Gulf of Mannar Biosphere. The closest tourism destination of Mandapam is Rameswaram. Thoothukudi and Arumuganeri are the major industrial areas contains major chemical industries like SPIC, Copper smelting plant, Dharangadhara chemicals ,salt pans, Thermal power station, several small scale industrial units in Thoothukudi SIPCOT complex. Thoothukudi is traditionally known for its pearl fishery and shipbuilding. Now Thoothukudi is one of the important major Port having a number ship movement. The Thermal power station directly dumps its ash into the coastal sea. The effluents from industries in Thoothukudi and Arumuganeri coastal region are discharged directly or indirectly into the sea. Kanyakumari (formerly known as Cape Comorin), lies at the southernmost tip of East coast of India, where the three seas meet. Part of the charm, it is the end point of the Indian peninsula where the confluence of the Bay of Bengal, the Arabian Sea and the Indian Ocean. It is one of the important Tourist Spot as well as Pilgrim place (Figure 1).


Figure 1. Sampling Locations and Sampling Points

## 3. Materials and Methods

The Temperature (surface and water) was measured using a standard centigrade mercury thermometer. Salinity was measured with the help of a Digital Refractometer PR-100SA (ATAGO) and the seawater pH was measured using HACH portable pH meter. Dissolved oxygen was estimated by the modified Winkler's method and expressed as mg/l. For the analysis of nutrients, surface water samples were collected in clean polyethylene bottles, kept in an ice-box, and transported immediately to the laboratory. The water samples are filtered through the Millipore filtering system (MFS) for required filtered sample.

The Nutrients and Chlorophyll-a were determined by the standard methods prescribed by Strickland and Parsons (1972) [12] and Grasshoff et al (1999) [13], further the sample were analyzed using SHIMADZU (UV-2600) UV-VIS Spectrophotometer. Nutrient concentrations were expressed in µMoles/L. Monthly variations of Physico -chemical parameters viz., temperature, salinity, pH, dissolved oxygen, nitrite, nitrate, ammonia, total phosphate, reactive silicate and Chlorophyll –a are recorded from January 2014 to December 2014.

## 4. Results and Discussion

Temperature variations in the coastal and estuarine system can influence the other Physico-chemical characteristics. Atmospheric temperature ranges were 27.2 to 36.7 (°C) respectively (Figure 2).

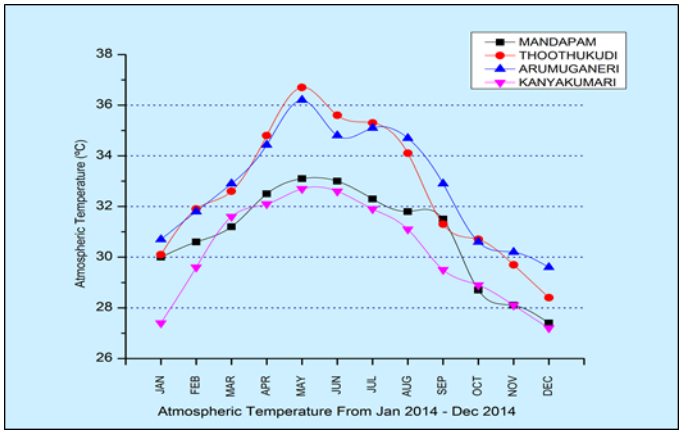


Figure 2. Atmospheric Temperatures at Different Stations (January 2014 – December 2014)

During the present study, the coastal surface water temperature varied from 24.1 - 34.2 (°C). The minimum (24.1°C) was recorded at Mandapam during January and the maximum (34.2°C) was observed in May at Thoothukudi coastal waters (Figure 3). Less solar radiation with cloudy sky and moderate rain fall during the monsoon season may greatly reduce the water temperature [14].

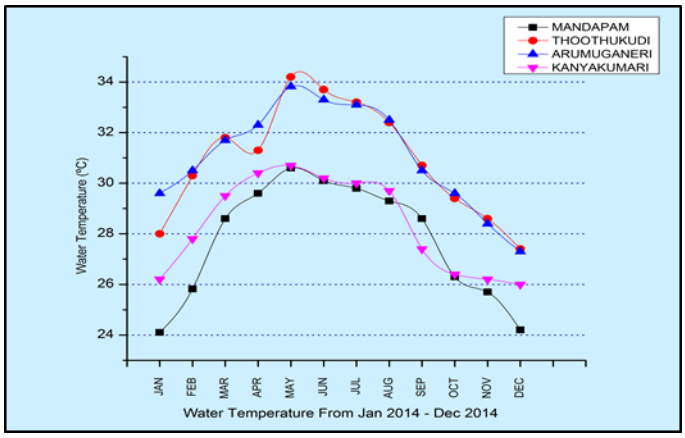


Figure 3. Water Temperatures at Different Stations (January 2014 – December 2014)

The surface water temperature largely depends upon the intensity of solar radiation, evaporation, freshwater influx, cooling and mixing due to currents and tidal flow. The gradual increase in water temperature is directly related to atmospheric conduction and radiation [15, 16].

The pH value depends upon the salinity and temperature of the water and the climatic condition present in that area. The chemical and biological condition of water also places a role in the control of pH concentrations. The pH of the natural water system depends on the concentration of carbonate, bicarbonate and hydroxyl ion present. The high buffering activity of sea water often checks wide variations of pH in coastal waters. Fluctuations of dissolved oxygen content, and $CO_2$ influence the pH in coastal water bodies [18]. In the present study, pH ranges from 7.96 to 8.30. The minimum (7.96) was recorded in Thoothukudi during December, Monsoon Season and the maximum (8.30) was observed in Kanyakumari during June, summer season (Figure 4).

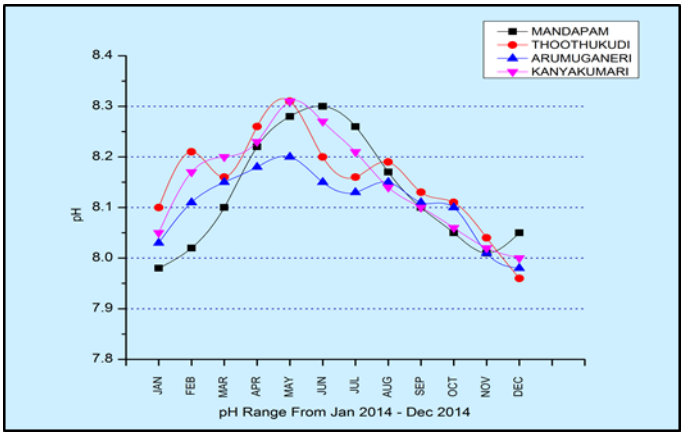


Figure 4. Hydrogen Ion Concentration (pH) at Different Stations (January 2014 – December 2014)

The higher phytoplankton production and greater the photosynthetic activity may cause high pH, because of bicarbonate degradation by carbonic anhydrase associated with photosynthesis process [19].

Salinity acts as a limiting factor in the distribution of living organisms, and its variation caused by dilution and evaporation is most likely to influence the fauna in the intertidal zone. The observed salinity variations could be related to the influx of freshwater from land runoff, caused by monsoon or tidal variations [17]. The freshwater inflow imparted significant influence on lowering salinity during monsoon season (October to December), while seawater influx exhibited overall control of high salinity values in the non-monsoon period. In the present study, the salinity was ranged from 31.54 (‰) to 36.07 (‰). The minimum 31.54 (‰) was recorded during December at Mandapam and the maximum 36.07(‰) was observed in June at Kanyakumari Coastal waters (Figure 5).

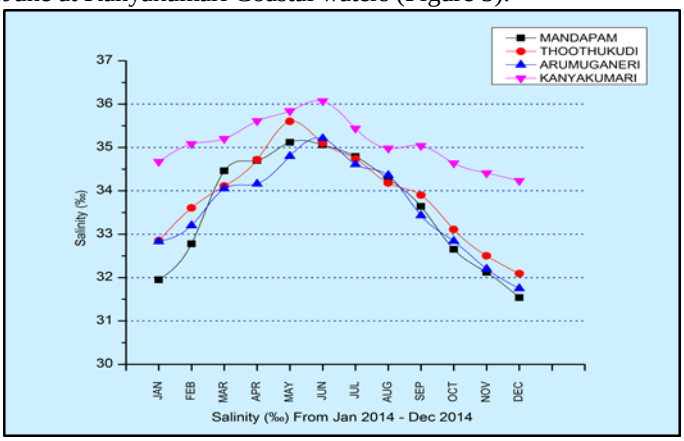


Figure 5. Salinity (‰) Different Stations (January 2014 – December 2014)

The salinity is an ecological master factor in the distribution of living organisms, likely to influence the biota distribution and the production of the coastal ecosystems.

Dissolved Oxygen is the indicator of aquatic system health. The vital metabolism of aerobic organisms depends purely on the amount of oxygen dissolved in the water. Season-wise observation of dissolved oxygen showed an inverse trend against temperature and salinity. It is well known that temperature and salinity affect dissolution of oxygen in seawater [20]. It is also depending on a considerable degree on the quantity of organic matter present in the aquatic environment. If the decomposition of organic matter is in great proportion, it will absorb too much of the dissolved oxygen in water [21]. In the study areas, Dissolved oxygen varied between 4.27 to 5.95 mg/l. It was found minimum (4.27 mg/l) at Thoothukudi during May and maximum (5.95 mg/l) at Kanyakumari during December, monsoon period (Figure 6).

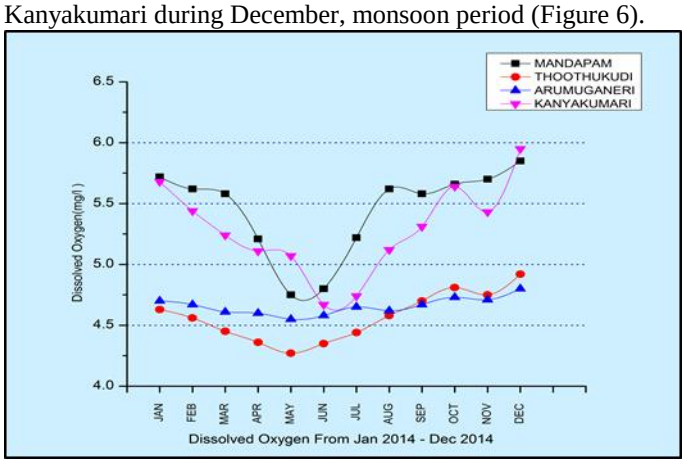


Figure 6. Dissolved Oxygen Different Stations (January 2014 – December 2014)

In the present investigation, higher values of dissolved oxygen were recorded during monsoon months(October –December) in all the stations and relatively lower values found during summer(April –June) could be mainly due to reduced agitation and turbulence of the coastal waters. Higher dissolved oxygen concentration observed during the monsoon season might be due to the cumulative effect of higher wind velocity coupled with heavy rainfall and the resultant freshwater mixing [22, 23]. The hike in the DO level during monsoon may be due the effect of climatic conditions such as low solar radiation prohibited by the clouds, runoff and high turbulence induced by the wave action, although the rate of photosynthesis was reduced [24].

Nutrients are the important parameters in the Coastal Waters which influence the growth, reproduction and metabolic activities of biotic components. Distribution of nutrients is mainly based on season, tidal conditions, freshwater inflow and land runoff, chemical effluents and flushing of fertilizer used in the agricultural fields. During the present study, all the nutrients were found to be high during monsoon season and low during summer at all the stations. Behavioral and distribution of nutrients such as nitrate, nitrite, phosphate and silicate in the coastal waters would exhibit considerable seasonal variations depending on the local conditions of rain fall, quantum of freshwater in flow, tidal incursions and nutrients consumption by phytoplankton biomass and regeneration. Low concentration of nutrients observed during the summer season may perhaps, due to a decrease in fertilizer waste disposal from the terrestrial region and consumption of nutrients by phytoplankton biomass [25, 26].

The dissolved inorganic nitrite concentration values ranged from 0.31 to 1.28 µM/l. It was found minimum (0.31µM/l) Arumuganeri during June, summer season and maximum (1.28 µM/L) in Thoothukudi during December, Monsoon season (Figure 7). The higher value of nitrite recorded during monsoon season could be due to variation in phytoplankton excretion, oxidation of ammonia and reduction of nitrate and by recycling of nitrogen and bacterial decomposition of planktonic detritus and also due to denitrification and air-sea interaction [27,28].

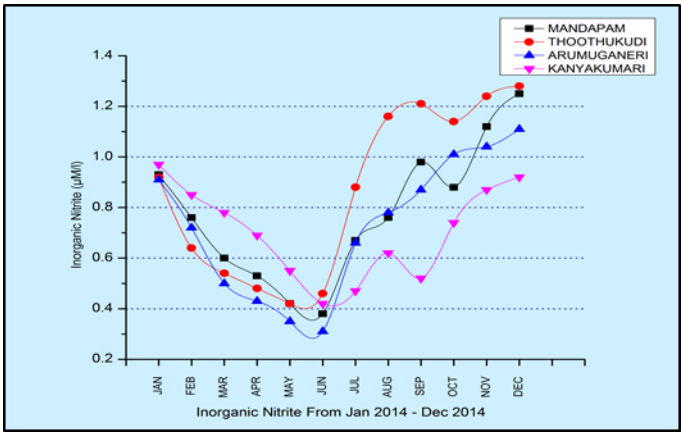


Figure 7. Dissolved Inorganic Nitrite Different Stations (January 2014 – December 2014)

The recorded low value during summer seasons (April –June) could be related to less freshwater inflow and high salinity [23]. Nitrite is to form nitrosamines which are carcinogenic. This was due to the addition nitrogenous nutrients mainly terrestrial runoff like break down of vegetation, use of chemical fertilizers in agriculture and oxidation of ammonia from of nitrogen to nitrite [23].

The dissolved inorganic nitrate concentration values ranged from 2.45 to 10.17 µM/l. It is found minimum (2.45 µM/l) at Mandapam during June, summer season and maximum (10.17 µM/L) in Kanyakumari during December, Monsoon season (Figure 8).

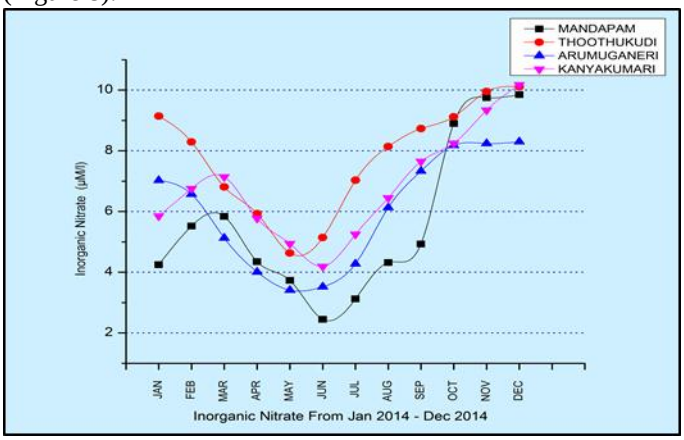


Figure 8. Dissolved Inorganic Nitrate Different Stations (January 2014 – December 2014)

The recorded low values during non-monsoon period may be due to utilization by phytoplankton as evidenced by high photosynthetic activity and the dominance of neritic seawater having negligible amount of nitrate [29, 30]. The recorded highest monsoonal nitrate value could be mainly due to the organic materials received from the catchment area by ebb tide. Another possible way of nitrate input could be through oxidation of ammonia form of nitrogen to nitrite formation [31].The high nitrate content observed during monsoon periods is mainly due to the river water discharge from agricultural fields containing nitrogenous particles of various origins. Low values of nitrate observed during summer seasons might be due to the lesser amount of freshwater inflow and higher salinity [32, 33].

The dissolved inorganic Phosphate concentration values ranged from 0.35 to 1.91 µM/l. It is found minimum (0.35 µM/l) at Mandapam during June, summer season and maximum (1.91 µM/L) in Kanyakumari during December (Figure 9).

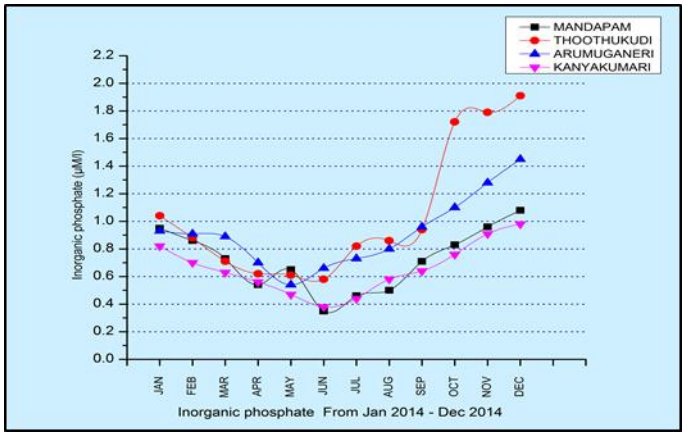


Figure 9. Dissolved Inorganic Phosphate Different Stations (January 2014 – December 2014)

High concentration of inorganic phosphates observed during monsoon season might possibly be due to intrusion of upwelling seawater [16]. The recorded low phosphates value during dry seasons could be attributed to the limited flow of freshwater, high salinity and utilization of phosphate by phytoplankton [34, 31]. The addition of super phosphates applied in the agricultural fields as fertilizers and alkyl phosphates used in households as detergents can be other sources of inorganic phosphates by land run-off during the Rainy season [35, 36]. The low phosphate value could be attributed by the adsorption and desorption of phosphate and buffering action of sediment under varying environmental conditions. The observed high monsoonal phosphate value might be due to the regeneration and release of total phosphorus from bottom mud into the water column by turbulence and mixing [23]. Moreover, due to the weathering of rocks soluble alkali metal phosphates in the upstream area are carried into the Coastal water [29].

Reactive Silicate content was higher than that of the other nutrients and the recorded high value during monsoon season. The Reactive silicate concentration values ranged from 7.10 to 41.33 µM/l. It is found minimum (7.10 µM/l) in Arumuganeri during May, summer and maximum (41.33 µM/L) in Kanyakumari during November, Monsoon season (Figure 10).

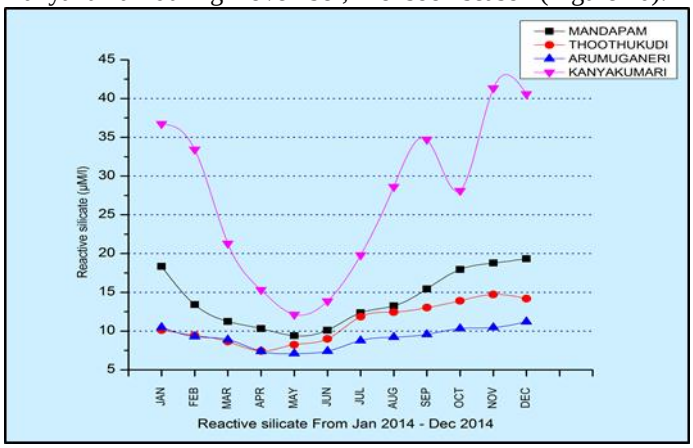


Figure 10. Reactive silicates Different Stations (January 2014 – December 2014)

The recorded high monsoon values may be due to heavy inflow of freshwater derived from land drainage carrying silicate leach out from the bottom, rocks and sediment might have been exchanged with overlying water in the coastal environment[31,29]. The observed low summer and post monsoonal values could be attributed to uptake of silicate by

phytoplankton for their biological activity [27]. The removal of silicates by adsorption and co-precipitation of soluble silicate silicon with humic compounds and iron also reduce silicate levels [31].

The level of ammonia depends on the activity of the nitrifying and denitrifying bacteria. Ammonia is important as the predominant excretory product of aquatic animals and the high ammonia levels can develop, through biota excretion, degradation of excreta, and uneaten feed. In the study areas, the concentration of ammonia ranges from 0.62 to 6.78 (µM/l). It was observed that the lower values of ammonia (0.62 µM/l) at Mandapam during May, summer season and higher value (6.78µM/l) was found at Thoothukudi coastal waters during December, Monsoon season (Figure 11).

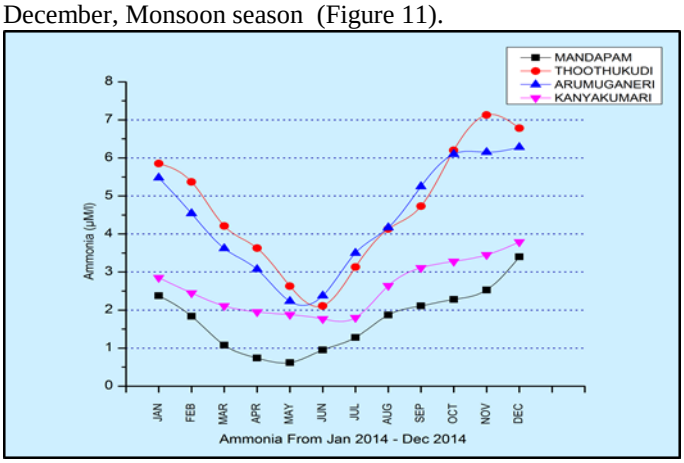


Figure 11. Ammonia Different Stations
(January 2014 – December 2014)

The surface runs off wastes, agricultural wastes gives maximum value in monsoon. Excess ammonia indicates polluted water and maximum algal growth. The recorded higher concentration could be partially due to the death and subsequent decomposition of phytoplankton and also due to the excretion of ammonia by planktonic organisms [37, 40]. Ammonium is the nitrogenous end product of the bacterial decomposition of natural organic matter containing nitrogen.

Chlorophyll -a is the main photosynthetic pigment essential for the primary production in the marine ecosystem [38]. Chlorophyll -a concentration values ranged from 2.93 to 17.27 mg/m3. It is found minimum (2.93 mg/m3) at Arumuganeri during December and maximum (17.27 mg/m3) at Kanyakumari during May, summer season (Figure12).

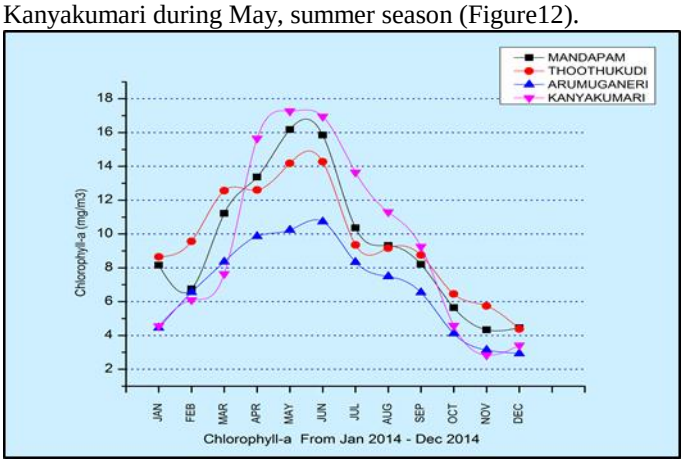


Figure 12. Chlorophyll –a Different Stations
(January 2014 – December 2014)

The recorded low monsoonal values may be due to anthropogenic effects, and also due to freshwater discharges from the rivers causing turbidity and less availability of light penetration [37, 39, 40]. A higher value of Chlorophyll-a was recorded during summer season shows high level photosynthetic activity.

## 5. Conclusion

The observations made during the present study clearly indicate that there is marked difference in the water-quality based on seasons and anthropogenic inputs. The freshwater inflow due to monsoon has a major influence on the nutrient load along the coastal waters. The pre-eminent nutrient levels during the monsoon period of the present study shows that the riverine and land run-off collects rich load of nutrients along the coastal area. The seasonal fluctuations in Physico-chemical parameters depends upon the seasonal tidal amplitude and fresh- water influx resulting in the continuous exchange of organic, inorganic, plant and animal matters in the coastal water. In a coastal ecosystem, zooplankton forms an important link in the food chain, from primary to tertiary level. The present study shows temperature, pH, DO and salinity fluctuations in all seasons. They mainly influence the Physico-chemical characteristics and stimulate the distribution of flora and fauna. The seasonal variations affect the nutrients distribution also. The increase of chlorophyll-a during the summer season shows the dominant saline conditions and higher photosynthetic activity. Present information and study on water quality variables is useful for further monitoring the anthropogenic levels and evaluate the health of the Coastal ecosystems.

## References


[1] A.W.Morris, J.I Allen, R.J Howland, R. J. M., and R.G.Wood," The estuary plume zone: source or sink for land derived nutrient discharges-Estuarine", Coastal and Shelf Science 40: 387-402, 1995.

[2] G.N.Pandey,and G.C.Carney, G.C., "Environmental Engineering",Tata Mc Graw-Hill publishing Company Limited, New Delhi,1989.

[3] H.P.Singh, J.H. Mishra, and L.R.Mahaver, L.R., "Observation on biochemical and chemical oxygen demands of certain polluted stretches of river Ganga", J. Environ. Biol., 20(2): 111-114,1999a.

[4] R. Pai and M. P. M. Reddy, "Distribution of Nutrients of Malpe, South Kanara Coast," Indian Journal of Marine Science, Vol. 10, No. 4, pp. 322-326, 1981.

[5] A.K.Sinha, and A.K.Shirvastava, "Impact of industrialization and urbanization on water quality of lake at Rae Bareli (India)" – A Case Study. Proc. National Symp. On Environment: 25-26, 1992.

[6] J.H.Rhyther, W.M. Dunstan, "Nitrogen, phosphorous and eutrophication in the coastal marine environment" Science 171, 1008–1013, 1971.

[7] M.J.Belzunce, O. Solaun, V. Valencia and V. Perez, "Contaminants in estuarine and coastal waters. In: Oceanography and Marine Environment of the Basque country", Elsevier Oceanography Series, A. Borja and M. Collins (Eds). Amsterdam, 70: 33-51, 2004.

[8] A.Sundaramanickam, T. Sivakumar, R. Kumaran V. Ammaiappan and R. Vellapan, "A comparative study of physicochemical investigation along Parangipettai and Cuddalure coast", J. Env. Sci. and Technol., 1(1): 1-10, 2008.

[9] P.R.F.Bell, "Status of eutrophication in the great Barrier Reef Lagoon" Pollut. Bull., 23: 89-93, 1991.
[10] K.R.Karlson, Rosenberg and E. Bonsdorff, "Temporal and spatial large-scale effects of eutrophication and oxygen deficiency on benthic fauna in Scandivian and Baltic waters", A review.Oceanogr. Mar. Bio. Ann. Rev., 40: 427-489, 2002.
[11] P.F.Wang, J. Martin and G. Morrison, "Water quality and eutrophication in Tampa Bay, Florida. East. Coast", Shelf. Sci., 49: 1-20, 1999.
[12] J. D. H. Strickland and T. K, Parsons "A Practical Hand Book of Seawater Analysis," Bulletin. Fisheries Research Board of Canada, Vol. 167, 1972.
[13] K. Grasshoff, M. Ehrhardt and K. Bkremling, "Methods of Seawater Analysis," Wiley-VCH, Hoboken, pp. 159-226, 1999.
[14] R.Karuppasamy, Alokam Mohan Rao and C.Elanchezhiyan, "Seasonal variations of nutrients in the Uppanar estuary, Cuddalore, South East coat of India", Proc. Intl. Sem. Appl. Hydrogeochem., Annamalai University, 269-274, 1999.
[15] A. Sundaramanickam A ,"Distribution of finfish larvae in relation to hydrographical parameters in parangipettai coast and adjacent water (South East Cost of India)" Ph.D. Thesis, Annamalai University, India,2004.
[16] I.Ganesan I," Ecobiology of seaweeds of the Gulf of Mannar with special reference to hydrography and heavy metals", Ph.D. thesis, Annamalai University p162,1992
[17] R.N Gibson, "Recent studies on the biology of intertidal fishes", Oceanogr. Mar. Biol. Ann. Rev.20: 363-414, 1982.
[18] J.H.Martin,"Phytoplankton-zooplankton relationship in Narrangansett. Bay IV. The seasonal importance of grazing", Limnol. Oceanogr, 15: 413-418, 1970.
[19] F.Ruttner, Fundamentals of limnology. University of Toronto Press, 1953.
[20] S.K.Vijayakumar, K.M. Rajesh, R.Mridula, Mendon and V.Hariharan," Seasonal distribution and behaviour of nutrients with reference to tidal rhythm in the Mulki estuary, southwest coast of India" J. Mar. Biol.Ass. India, 42, 21-31, 2000.
[21] L.Shakweer, L., "Ecological and fishery investigations of Nozha Hydrome near Alexandria 2000–2001", Bull. Natl. Inst. Oceanogr. Fish. 29, 387–425, 2003.
[22] J.Das, S.N. Das and R.K. Sahoo,"Semidiurnal variation of some physicochemical parameters in the Mahanadi estuary, east coast of India", Ind. J. Mar. Sci.26: 323-326, 1997.
[23] A. Saravanakumar, M. Rajkumar, J. Sesh Serebiah and G.A. Thivakaran.," Abundance and seasonal variations of phytoplankton in the creek waters of western mangrove of Kachchh-Gujarat", Journal of Environmental Biology, 29(2) 271-274, 2008.
[24] R. Kannan, and L. Kannan, "Physiochemical characteristic of seaweed beds of the palk bay. South East coast of India", Indian J. Mar. Sci., 25: 358-362, 1996.
[25] Pillai, M. Mathevan, "Hydrological investigations on the inter-tidal diatoms of the Cuddalore – Uppanar estuary (India)", Ph.D. Thesis, Annamalai University, India, 1994.
[26] K.R.Reddy, N. Jayaraju, I. Suriyakumar and K. Sreenivas, "Tidal fluctuation in relation to certain physico-chemical parameters in Swarnamukhi river estuary, East coast of India", Ind. J. Mar. Sci., 22, 232-234, 1993.
[27] V.Ashok Prabu, P. Perumal and M. Rajkumar," Diversity of microzooplankton in Parangipettai coastal waters, southeast coast of India" J. Mar. Biol. Ass. India, 47: 14-19, 2005.
[28] P.S .Asha and Diwakar. "Hydrobiology of the inshore waters off Tuticorin in the Gulf," J. Mar. Biol. Ass. India, 49: 7-11, 2007.
[29] C. Govindasamy, L. Kannan and Jayapaul Azariah," Seasonal variation in physico-chemical properties and primary production in the coastal water biotopes of Coromandel Coast", India. J. Environ. Biol., 21: 1-7, 2000.
[30] R.Rajaram, M. Srinivasan and M. Rajasegar," Seasonal distribution of physico-chemical parameters in effluent discharge area of Uppanar estuary, Cuddalore, Southeast coast of India" J. Environ. Biol., 26: 291-297, 2005.
[31] M.Rajasegar," Physico-chemical characteristics of the Vellar estuary in relation to shrimp farming", J. Environ. Biol. 24: 95-101, 2003.
[32] S.N.De Souza, "Monitoring of some environmental parameters at the mouth of the Zurai river, Goa", Indian J. Mar. Sci., 6: 114-117, 1977.
[33] Hari Muraleedharan, Abhilash and R. Ramasubbu, "Physico-chemical parameters and planktors analysis of seawater of Thondi of Palk Bay, Tamil Nadu', J.Biosci. Res. 1(1): 20-24, 2010.
[34] S.Senthilkumar, P. Santhanam and P. Perumal,"Diversity of phytoplankton in Vellar estuary, southeast coast of India", In: Proc. 5th Indian Fisheries Forum (Eds. S. Ayyappan, J.K. Jena and M. Mohan Joseph). Published by AFSIB, Mangalore and AeA, Bhubanewar, India. pp. 245- 248, 2002.
[35] L.R.Tiwari and V.R. Nair, "Zooplankton composition in Dharamtar creek adjoining Bombay harbor", Indian J. Mar. Sci. 22: 63-69, 1993.
[36] S.Bragadeeswaran, M. Raja Segar, M. Srinivasan and U. Kanagarajan: "Sediment texture and nutrients of Arasalar estuary, Karaikkal, southeast coast of India", J. Environ. Biol., 28, 237-240, 2007.
[37] Z. Kawabata, A. Magendran, S. Palanichamy, V. K. Venugopalan and R. Tatsukawa, " Phytoplankton biomass and productivity of different size fractions in the Vellar estuarine system, southeast coast of India", Ind. J. Mar. Sci., 22, 294-293, 1993.
[38] N.Godhantaraman, "Seasonal variations in species composition, abundance, biomass and estimated production rates of tintinnids at tropical estuarine and mangrove waters, Parangipettai, Southeast coast of India", J. Mar. Syts., 36, 161-171,2002.
[39] K.Thillai Rajasekar, P.Perumal, P.Santhanam, "Phytoplankton diversity in the Coleroon estuary, Southeast coast of India", Journal of Marine Biological Association of India, 47: 127–132, 2005.
[40] M.Rajkumar,P.Perumal , V.Ashok Prabhu ,"Diversity of phytoplankton in Pichavaram mangrove waters, southeast coast of India", Journal of Environmental Biology, 30: 489–498,2009.