IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

PHYSICOCHEMICAL CHARACTERISTICS OF WATER AT ADAYAR ESTUARY, TAMIL NADU, INDIA

S. Nandini[1], M.C. John Milton[2] and J.J.Arockia Rita[3]

1 Assistant Professor, Department of Advanced Zoology and Biotechnology, Quaid-E-Millath Govt. College, Chennai, Tamil Nadu, India

2 Assistant Professor, PG and Research Department of Advanced Zoology and Biotechnology, Loyola College, Chennai, Tamil Nadu, India

3 Assistant Professor, Department of Advanced Zoology and Biotechnology, Quaid-E-Millath Govt. College, Chennai, Tamil Nadu, India

Abstract: Present study was carried out to determine the important physicochemical parameters of water of Adayar estuary. Adayar river is principally used for sewage discharge from Chennai, which adversely affects the river's self-purification capacity. A cluster of industries, such as chemical factories, a battery company, plastic and rubber factories are situated on the riverbanks. The continuous discharge of effluents, which invariably contain heavy metals, tends to elevate the concentration of these in the river water. These heavy metals are transported downstream and either precipitated within the river system or washed into the sea. Present study was carried out from March 2016-February 2017 to study the impacts of discharges on physicochemical characteristics of Adayar Estuary water.

Key words: Adayar Estuary, Physicochemical characteristics, Heavy metals.

I. INTRODUCTION

Chennai, the capital city of Tamil Nadu, is situated at the Coromandel Coast of the Bay of Bengal. The city is located near equator it experiences hot and humid climate during major seasons (summer, winter and monsoon).

The summer season, begins from March and spreading till October, has scorching days. The duration of late May to early June records the highest temperature of 45^{o}C. This duration is recognized by the inhabitants of Chennai as the Agni Natshatram, literally 'Fire Star'. The places near the sea coast persist warm and humid. The cool breeze is during the night.

During the monsoons (June to September) Chennai receives ample rainfall. The prevailing winds of Chennai are the South-westerly winds (April to October) and North-easterly winds (November to March). Since the city is located near the sea side; it receives adequate rainfall of about 140 cm throughout the year. (Indian Meteorological Department, Chennai 2012).

The winters are very short and occur during the months of November to February with January being the coolest month of the year. The temperature of the city fluctuates from 15^{o}C to 22^{o}C. Winters too receive moderate rainfall. The seasonal rainfall, resulting from the north-east monsoon winds, is experienced during mid-October to mid-December (Chennai Metropolitan Development Authority, 2012).

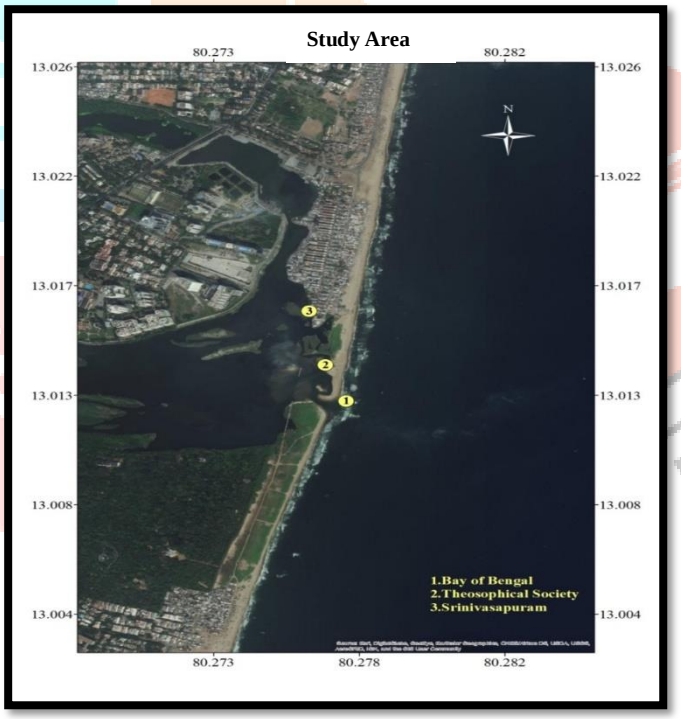
The physical and chemical properties of water immensely influence use of a water body for the distribution and richness of biota and each factor plays its own role. These factors provide as a source for the richness or otherwise biological productivity of any aquatic environment.

II. Materials and Methods

The methods used for the analysis of various physico-chemical parameters were the same as given in Standard Methods for the Examination of water (APHA 2012).

Water Sampling

Water samples were collected from 3 different stations of the Adayar estuary at various seasons (S1, S2 and S3) for a period of one year, March 2016 to February 2017. Access to the individual sites was accomplished by boat. For physico-chemical analysis, water samples were collected in one litre polyethylene bottles. All the sampling bottles were labelled properly. All the samples were collected one foot below the surface of the estuarine water by plunging the open end of each sterile bottle before turning it upright to fill. Temperatures of the water samples were noted at the site by using a mercury bulb thermometer and for further analysis the samples were then transported to the laboratory. Standard procedures recommended by APHA, 2012 were followed during the sample collection, preservation, handling and analysis to ensure data quality and consistency.



Statistical analysis

To find out the significance in physico-chemical parameters between stations and between seasons, two-way ANOVA was performed using the software SPSS version 18. The Pearson correlation coefficient and Hierarchal Cluster analysis using Ward's method and Squared Euclidean was performed.

III. Results and Discussion of Adyar Estuary Water Samples

Samples collected from the study site were analyzed to determine the physico-chemical properties of the estuary. On the basis of the analysis, the mean values and standard deviations were calculated. The results are summarized in Table 1, 2 and 3.

Temperature: Temperature in the present study ranged from 26.3ºC to 27.67º C in the surface waters. Minimum temperature was recorded during the monsoon season (July 2016 to October 2016) and maximum during the post monsoon (November 2016 to February 2017). In general, all the stations showed similar seasonal changes. Seasonal variation of temperature of water samples is represented in Figure 1.

Water temperature is always influenced by the intensity of solar radiation, evaporation, inflow of fresh water and flow from adjoining coastal waters. Similar observations were observed by Govindasamy *et al*., (2000); Anitha and Kumar, (2013); Anitha and Sugirtha, (2013).

Variations in temperature are one of the major factors in the coastal and estuarine system, which may influence the physico-chemical characteristics and also the dispersal and richness of flora and fauna. In the dry months the values of the temperature recorded were high and this may because of the heat from sunlight. Similarly, low temperature values in wet season months are attributed to substantial rainfall. This is in accordance with the works done by Rajkumar *et al*., 2011, Vijayakumar *et al*., 2014 and Abowei, 2010; and also, commendable works are available on Vellar estuary (Nedumaran, *et al*., 2001); Parangipettai coast (Santhanam and Perumal, 2003; Sundaramanickam *et al*., 2008) Point Calimere costal water (Damotharan *et al*., 2010); and Muttukadu backwaters (Prema and Subramaniam, 2003).

pH of Water Samples: The pH is the measure of hydrogen ion (H^+) concentration of a solution. It is the measure of the acidity or alkalinity of a fluid. The pH values were recorded between 7.27 to 7.73 in water samples. Fresh water is mixed with the sea water and because of this the estuary shows slightly alkaline pH, the highest value is observed in post monsoon season (Station I: 7.33, Station II: 7.27 and Station III: 7.73) and lowest were observed in monsoon season (Station I: 7.33, Station II: 7.27, Station III: 7.27), this is in accordance with the work carried out by Aquiline *et al*., (2017); Lola Catherine and Mary Helen, 2018; Kurma Rao and Ramesh babu, (2017), Vasanthi and Sukumaran, (2017). Figure 2 represents seasonal variation of pH of water samples.

The lowest pH value could be because of the fresh water discharge from Adayar river waters due to the influence of Monsoon. The observed insignificant variation in pH may be due to insignificant terrestrial runoff and rainfall during the pre-North east monsoon period together with the extensive buffering role of the sea water that causes pH change within a very narrow limit. Similar observations were recorded by Barath kumar *et al*., (2018) along Tamil Nadu coastal waters.

pH of water is an important environmental factor, the fluctuation of pH could be linked with chemical changes, species composition and life processes. The findings of the study are in accordance with the results observed by Vasanthi and Sukumaran, (2017) in having lowest pH in monsoon and highest value in post monsoon.

Total Dissolved Solids in Water Samples: Total dissolved solids are a measure of the dissolved combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular suspended form.

The TDS values for the three seasons are represented in the Tables 2, 3, and 4. For Pre monsoon season it was recorded as 28135 ± 4.12, 28135 ± 4.12, 28586.17 ± 2.86, for Monsoon season it was 27135.17 ± 3.71, 26423 ± 4.05, 27425.17 ± 4.07, for Post monsoon season it was 26234.67 ± 3.78, 27145.17 ± 5.46 and 26424.5 ± 3.51 in station I,II and III respectively. In the present study the highest values were observed in Pre monsoon season and values of the Post monsoon season were less, this may be due to the heavy rainfall in monsoon season and in summer due to low inflow of fresh water. Thommai Arockia Gaspar and Lakshman, (2014) have reported the similar range of TDS in their study and it is also in accordance with the work by Muduli Bipra Prasanna and Panda Chitta Ranjan (2010). Figure 3 shows the seasonal variation of TDS of water samples.

Electrical Conductivity of Water Samples: Electrical conductivity (EC) highly depends on the amount of dissolved solids in water and it varies with season (Murugan and Anandhi Usha, 2016). In the present study values of EC for three seasons is represented in the Tables 2, 3, 4 and Fig 4. For Pre monsoon season it was recorded as 454.17 ± 0.27, 453.03 ± 0.25, 454.23 ± 0.48, Monsoon season it was 424.2 ± 1.34, 423.75 ± 1.12, 425.17± 1.52 and for

Post-monsoon season it was 482.32 ± 0.49, 483.65 ± 0.45 and 483.65 ± 0.72 for Station I, II and III respectively. The maximum electrical conductivity was recorded in Post monsoon season, followed by Pre-monsoon season and Monsoon season. This is in accordance with the work carried out by Vasanthi and Sukumaran, (2017), Sophia *et al*., (2017) Surana Ranjana *et al*., (2013) and Narendra Babu *et al*., (2009).

Higher value of conductivity recorded in post monsoon is attributed to low mixing of fresh water from river causing more ionic concentration and lower value in monsoon may be due to rain and mixing of more fresh water from river. The results obtained goes in line with the work done by Surana Ranjana *et al.*,

Table 1: Physico-Chemical analysis of Water at Adayar Estuary - Pre-Monsoon (Mar 2016 to June 2016)

S.No	Parameter	Station I	Station II	Station III	**USEPA (2000, 2006)** permissible limits for Estuary
1	Temperature	26.65 ± 0.52	26.43 ± 0.58	26.78 ± 0.54	< 40.00
2	pH	7.32 ± 0.02	7.45 ± 0.04	7.69 ± 0.02	6.50 – 8.50
3	Total dissolved solids mg/L	28135 ± 4.12	28242.8 ± 4.83	28586.17 ± 2.86	2000.00
4	Electrical conductivity (μScm^{-1})	454.17 ± 0.27	453.03 ± 0.25	454.23 ± 0.48	4000
5	Salinity (PSU)	34.52 ± 0.37	33.37 ± 0.76	33.7 ± 0.39	NA
6	Total alkalinity as mg/L	242.63 ± 0.54	240.7 ± 1.44	239.3 ± 0.68	30 - 90
7	Total hardness as mg/L	3553.7 ± 1.09	3548.4 ± 0.73	3558.67 ± 1.05	NA
8	Nitrate as NO_3 mg/L	43.42 ± 0.51	44.57 ± 1.09	42.42 ± 1.41	0.03 to < 1
9	Phosphate mg/L	28.28 ± 1.45	28.27 ± 1.17	26.98 ± 2.18	0.03 to < 1
10	Dissolved Oxygen O_2 mg/L	4.26 ± 0.03	3.98 ± 0.07	3.62 ± 0.23	40 - 60
11	BOD mg/L	2.72 ± 0.13	2.72 ± 0.12	2.65 ± 0.11	10.00
12	COD mg/L	22.76 ± 0.30	21.83 ± 1.47	21.70 ± 0.82	0.10–0.15

*Correlation was significant (α=0.05) at the $P<0.0001$between stations of all parameters, highly significant; USEPA - United States Environmental Protection Agency (permissible limits for Estuary 2000 and 2006) NA-Not available; Values are mean and standard deviation of n = 6

Table 2: Physico-Chemical analysis of Water at Adayar Estuary - Monsoon Season (July 2016 to October 2016)

S.No	Parameter	Station I	Station II	Station III	**USEPA (2000, 2006)** permissible limits for Estuary
1	Temperature	26.45 ± 0.79	26.45 ± 0.59	26.3 ± 1.20	< 40.00
2	pH	7.33 ± 0.06	7.27 ± 0.05	7.27 ± 0.18	6.50 – 8.50
3	Total dissolved solids mg/L	27135.17 ± 3.71	26423 ± 4.05	27425.17 ± 4.07	2000.00
4	Electrical conductivity (μScm^{-1})	424.2 ± 1.34	423.75 ± 1.12	425.17± 1.52	4000
5	Salinity (PSU)	32.45 ± 0.34	30.48 ± 0.25	27.5 ± 0.35	NA
6	Total alkalinity as mg/L	243.47 ± 2.39	248.53 ± 1.16	247.6 ± 0.57	30 - 90
7	Total hardness as mg/L	3585.2 ± 1.80	3574.88 ± 1.09	3579.97 ± 1.45	NA
8	Nitrate as NO_3 mg/L	46.35 ± 1.72	45.45 ± 1.41	45.32 ± 0.80	0.03 to < 1
9	Phosphate mg/L	29.72 ± 0.78	28.78 ± 0.78	28.88 ± 1.85	0.03 to < 1
10	Dissolved Oxygen O_2 mg/L	4.91 ± 0.05	4.44 ± 0.04	4.21 ± 0.02	40 - 60
11	BOD mg/L	3.65 ± 0.09	3.32 ± 0.10	3.78 ± 0.14	10.00
12	COD mg/L	23.82 ± 0.14	23.8 ± 0.41	23.5 ± 1.87	0.10–0.15

*Correlation was significant (α=0.05) at the $P<0.0001$between stations of all parameters, highly significant; USEPA - United States Environmental Protection Agency (permissible limits for Estuary 2000 and 2006) NA-Not available; Values are mean and standard deviation of n = 6.

Table 3: Physico-Chemical analysis of Water at Adayar Estuary - Post Monsoon (November 2016 to February 2017)

S.No	Parameter	Station I	Station II	Station III	**USEPA (2000, 2006)** permissible limits for Estuary
1	Temperature	27.67 ± 0.10	27.33 ± 0.15	27.4 ± 0.14	< 40.00
2	pH	7.34 ± 0.05	7.46 ± 0.06	7.73 ± 0.14	6.50 – 8.50
3	Total dissolved solids mg/L	26234.67 ± 3.78	27145.17 ± 5.46	26424.5 ± 3.51	2000.00
4	Electrical conductivity (μScm^{-1})	482.32 ± 0.49	483.65 ± 0.45	483.65 ± 0.72	4000
5	Salinity (PSU)	31.77 ± 0.21	32.73 ± 0.76	30.5 ± 1.14	NA
6	Total alkalinity as mg/L	240.3 ± 0.67	238.68 ± 0.42	237.27 ± 0.71	30 - 90
7	Total hardness as mg/L	3549.42 ± 0.57	3547.37 ± 0.78	3543.27 ± 0.73	NA
8	Nitrate as NO_3 mg/L	45.3 ± 1.53	44.6 ± 0.52	45.17 ±0.87	0.03 to < 1
9	Phosphate mg/L	28.38 ± 1.36	28.53 ± 1.15	28.5 ± 1.16	0.03 to < 1
10	Dissolved Oxygen O_2 mg/L	4.07 ± 0.01	3.85 ± 0.69	3.24 ± 0.04	40 - 60
11	BOD mg/L	2.89 ± 0.08	2.83 ± 0.07	2.90 ± 0.03	10.00
12	COD mg/L	24 ± 2.37	24.17 ± 0.27	25.43 ± 0.62	0.10–0.15

*Correlation was significant (α=0.05) at the *P*<0.0001between stations of all parameters, highly significant; USEPA - United States Environmental Protection Agency (permissible limits for Estuary 2000 and 2006) NA-Not available; Values are mean and standard deviation of n = 6

(2013). Higher EC may be due to the high amount of dissolved inorganic substances in ionized form as been also emphasized by Murhekar Gopalkrushna, (2011).

Salinity of Water Samples: The salinity values for Pre monsoon season were 31.77 ± 0.21, 32.73 ± 0.76, 30.5 ± 1.14, for Monsoon season 32.45 ± 0.34, 30.48 ± 0.25, 27.5 ± 0.35 and for Post monsoon season 34.52 ± 0.37, 33.37 ± 0.76 and 33.7 ± 0.39 for the stations I, II and III respectively (Figure 5). In the present study salinity was high during post monsoon and low during the Monsoon season. Present findings are in agreement with Vasanthi and Sukumaran (2017); Mohan Raj *et al*., (2013) and Naseema Shaikh *et al*., (2017).

High salinity in Post monsoon may be due to high rate of evaporation, and absence of river discharge. Thus the 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. Similar observations were also reported by Gibson, (1982); Naseema Shaikh *et al*., (2017); Kurma Rao and Ramesh Babu, (2017); Santhosh Kumar and Ashok Prabhu (2014); Balasubramanian and Kannan (2005) and Raju *et al.*, (2017).

The salinity variation in the exchange of ions and nutrients is because of the tidal flow and low during the monsoon in the Adayar estuary. The present study is in conformity with the earlier reports from Arasalar estuary (Raju *et al.*, 2017), Vellar estuary (Palpandi, 2011).

Alkalinity of water is its acid neutralizing capacity and it is primarily a function of carbonate, bicarbonate and hydroxide content of water. It is taken as an indication of the concentration of these constituents in water. The Alkalinity for Pre monsoon was observed to be 242.63 ± 0.54, 240.7 ± 1.44, 239.3 ± 0.68, for Monsoon 243.47 ± 2.39, 248.53 ± 1.16, 247.6 ± 0.57 and for Post monsoon 240.3 ± 0.67, 238.68 ± 0.42 and 23.27 ± 0.71 for the Stations I, II and III respectively (Figure 6). Alkalinity value reserve as an index of productive potential of water (Mariappan *et al*., 2000). It is considered as a measure of the buffering capacity of the water (Rao, 2001). It is commonly used as an index of potential sensitivity because; alkalinity stands for the relative tolerance of potential sensitivity to acidic inputs in to the water body (Jothivel and Paul, 2014).

High values of alkalinity during monsoon may be due to surface water runoff in to the estuary as well as due to the churning currents and mixing of benthic sediments in the sea (Jothivel and Paul, 2014). Such high values were recorded in the present study and the reasons hold good in the current scenario too.

Total Alkalinity of water samples: High values of TDS were observed in monsoon season and lesser in post monsoon season. Similar study by Sreekala and Mary Helen (2017) has recorded the lesser levels of TDS in post monsoon season. During wet seasons high surface runoffs occurs and discharge organic waste into the river and finally into the estuaries takes place. This may be the reason for high levels of TDS in monsoon seasons. Similar observations were made by Onojake *et al*., (2015) in New Calbar river estuary, Nigeria.

Total Hardness of water samples: Hardness of water is not a specific constituent but it is a variable and complex mixture of cations and anions. It is caused by dissolved poly-metallic ions. In water the principle hardness causing ions are calcium and magnesium (Mohan Raj *et al*., 2013). Total Hardness recorded for Pre monsoon were 3553.7 ± 1.09, 3548.4 ± 0.73, 3558.67 ± 1.05, for Monsoon 3585.2 ± 1.80, 3574.88 ± 1.09, 3579.97 ± 1.45 and for Post monsoon season 3549.42 ± 0.57, 3547.37 ± 0.78 and 3543.27 ± 0.73 from three stations I, II and III respectively (Figure 7).

Nitrate: The Nitrate concentration levels during Pre monsoon were 43.42 ± 0.51, 44.57 ± 1.09, 42.42 ± 1.41, Monsoon 46.35 ± 1.72, 45.45 ± 1.41, 45.32 ± 0.80, and Post monsoon the values were 45.3 ± 1.53, 44.6 ± 0.52 and 45.17 ± 0.87 from the three station I, station II and station III respectively (Figure: 8). Maximum levels were observed in Monsoon season and low levels were observed in Pre monsoon season. Similar results were recorded by Anitha and Sugirtha, (2013); Anitha and Kumar, (2013) from Thengapattanam estuary; Damotharan *et al.*, (2010) from Calimare coastal waters and Muthukumaravel *et al.*, (2012) from Arasalar estuary, Muduli Bipra Prasanna and Panda Chitta Ranjan, (2010) in Dharma estuary. Nitrate is an essential nutrient but at high concentration it is toxic and is capable of disturbing the aquatic environment (Mohan Raj *et al*., 2013). Studies have shown that excess utilization of fertilizer in agriculture and sewage discharge result in the increase of nitrogen and phosphorous levels in the estuary (Adeyemo, 2003). Increase in the concentration may be due to the anthropogenic sources like domestic sewage, agricultural wash offs and other waste effluents containing nitrogenous compounds. The same trend was observed by Muduli Bipra Prasanna and Panda Chitta Ranjan, (2010).

Phosphate: The Phosphate level observed during Pre monsoon were 28.28 ± 1.45, 28.27 ± 1.17, 26.98 ± 2.18, during Monsoon 29.72 ± 0.78, 28.78 ± 0.78, 28.88 ± 1.85 and during Post monsoon it were 28.38 ± 1.36, 28.53 ± 1.15 and 28.5 ± 1.16 in Stations I, II and III respectively (Figure 9).

Concentration of phosphate in coastal waters is influenced by the concentration in the fresh water that mixed with the seawater within the land-sea interaction zone, Phytoplankton uptake, addition through localized upwelling and replenishment as a result of microbial decomposition of organic matter. Usually seawater functions as the main source of phosphate in estuarine and coastal waters except those receives fresh water contaminated with domestic wastes containing detergent and wastes from agro field rich with phosphate-phosphorous fertilizer (Barath Kumar *et al*., 2018).

The maximum value of Phosphate was recorded in monsoon and minimum value was recorded in Pre monsoon. This may be due to the intrusion of sea water as well as rainfall and also mixing of land run off from the domestic sewage. Same result was reported by Lola Catherine and Mary Helen (2018) from Manakudy estuarine region, Prasanna and Rajan (2010) from Dharma estuary, Naseema Shaikh *et al*.,2017) from Kali estuary, Nair N. Balakrishnan *et al*., (1983) in Ashtamudi Estuary. The recorded low phosphate levels during dry seasons could be attributed to the limited flow of freshwater, high salinity and utilization of phosphate by phytoplankton confirming the earlier reports of Senthilkumar *et al*., (2002) and Rajasegar, (2003) of Vellar estuary, Gupta *et al*., (2017), Raju *et al*., (2017) from Arasalar estuary.

Dissolved Oxygen: The value of dissolved oxygen is remarkable in determining the water quality criteria of an aquatic ecosystem. The Dissolved oxygen is a regulator of metabolic activities of organisms and thus governs metabolism of the biological community as a whole and also acts as an indicator of trophic

Figure: 1 Seasonal variation of Temperature in the Water samples of Adayar Estuary (March 2016 – February 2017)

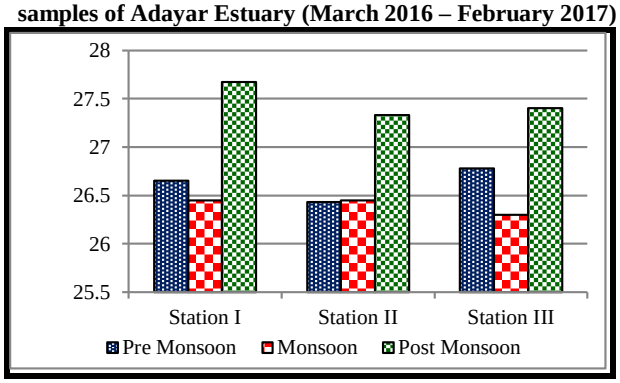


Figure: 2 Seasonal variation of pH in the Water samples of Adayar Estuary (March 2016 – February 2017)

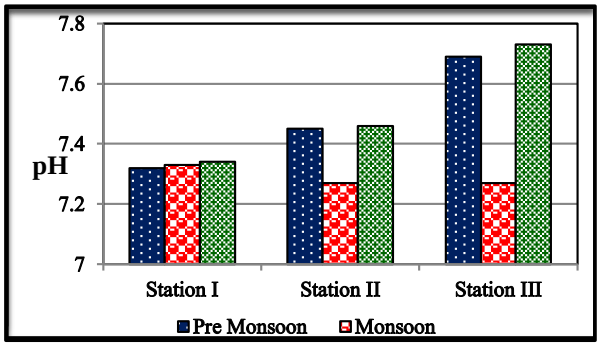


Figure: 3 Seasonal variation of Total dissolved solids in Water samples of Adayar Estuary (March 2016 – February 2017)

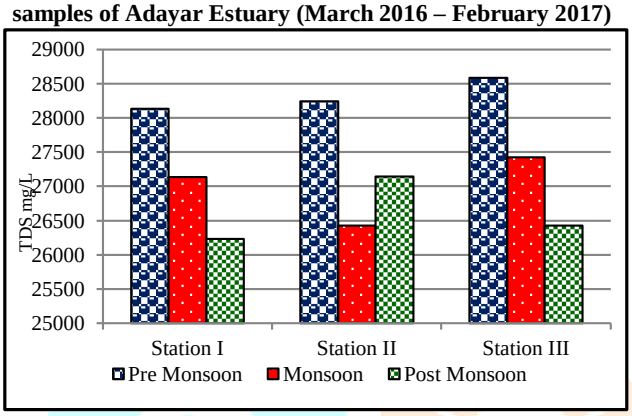


Figure: 4 Seasonal variation of Electrical conductivity in the Water samples of Adayar Estuary (Mar 2016 – February 2017)

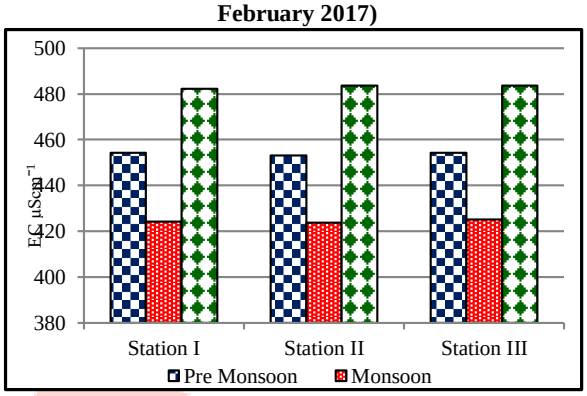


Figure: 5 Seasonal variation of Salinity of in the Water samples Adayar Estuary (March 2016 – February 2017)

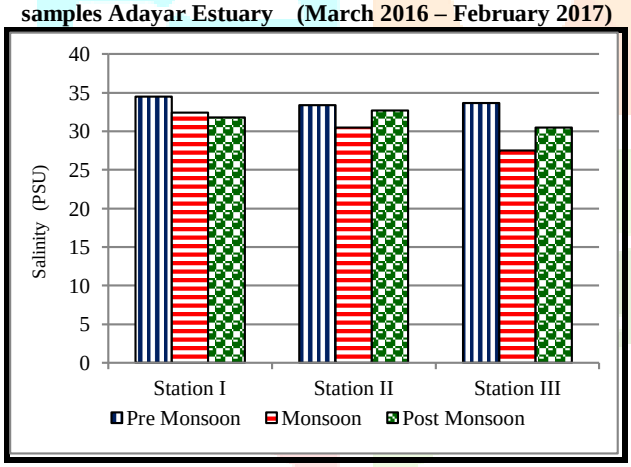


Figure: 6 Seasonal variation of Total Alkalinity in the Water samples of Adayar Estuary (March 2016 – February 2017)

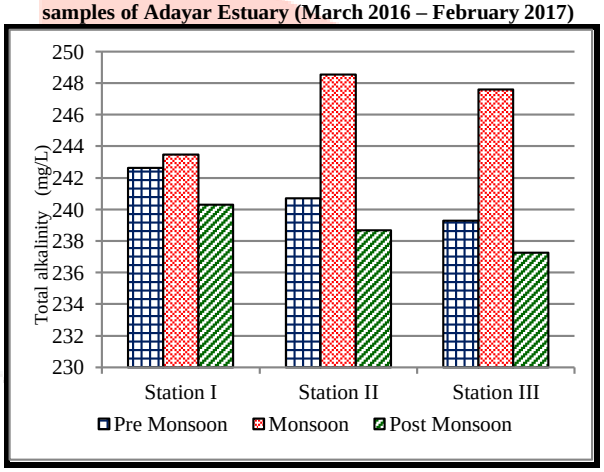


Figure: 7 Seasonal variation of Total Hardness in the Water samples of Adayar Estuary (March 2016 – February 2017)

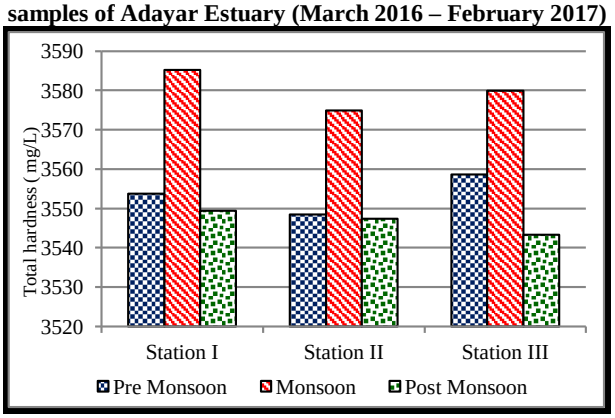


Figure: 8 Seasonal variation of Nitrate in the Water samples of Adayar Estuary (March 2016 – February 2017)

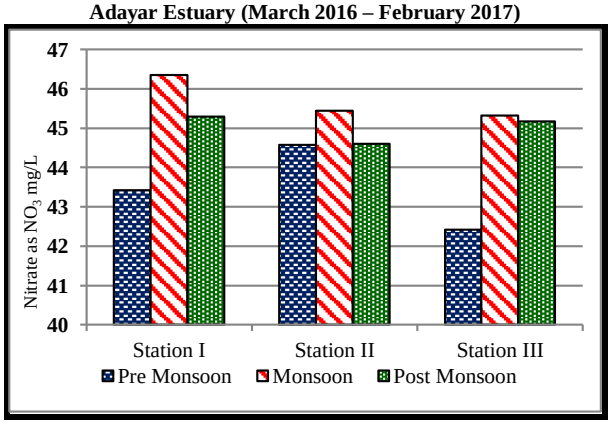


Figure: 9 Seasonal variation of Phosphate in the Water samples of Adayar Estuary (March 2016 – February 2017)

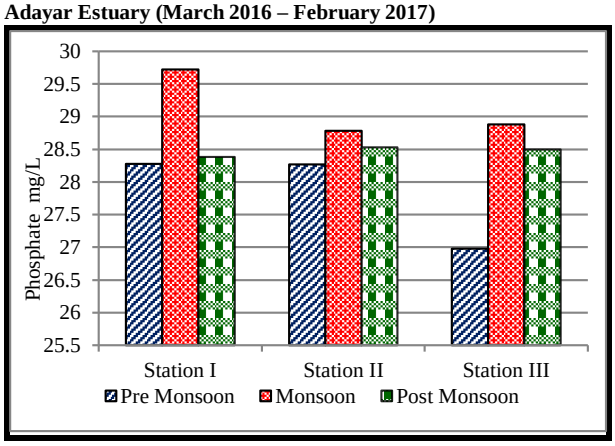


Figure: 10 Seasonal variation of Dissolved Oxygen in the Water samples of Adayar Estuary (March 2016 – February 2017)

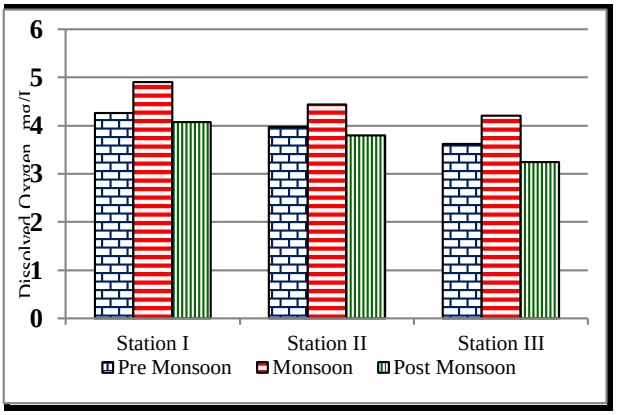


Figure: 11 Seasonal variation of Biological Oxygen Demand in the Water samples of Adayar Estuary (March 2016 – February 2017)

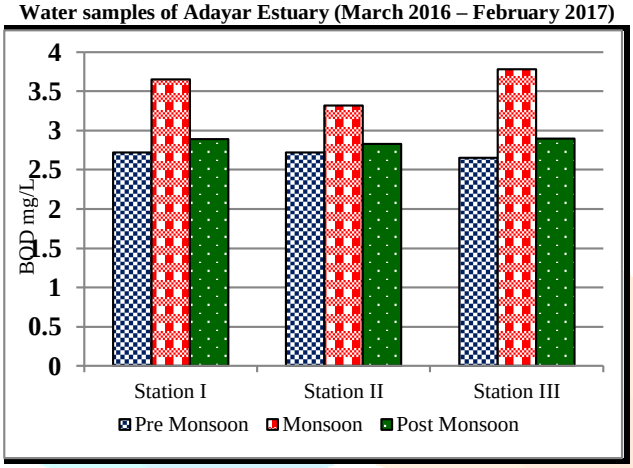
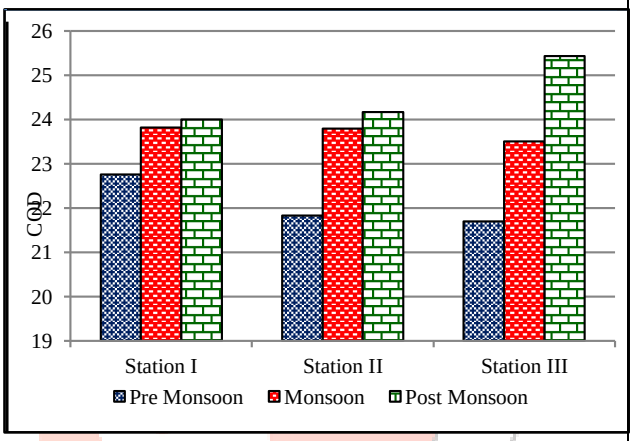


Figure: 12 Seasonal variation of Chemical Oxygen Demand in the Water samples of Adayar Estuary (March 2016 – February 2017)



community and the trophic status of the water body as a whole (Saksena and Kaushik, 1994; Vasanthi and Sukumaran, 2017).

The Dissolved Oxygen in the Pre-Monsoon season were 4.26 ± 0.03, 3.98 ± 0.07, 3.62 ± 0.23, in Monsoon it was 4.91 ± 0.05, 4.44 ± 0.04, 4.21 ± 0.02 and Post monsoon season it was 4.07 ± 0.01, 4.07 ± 0.01 and 3.24 ± 0.04 from the three stations I, II and III (Figure: 10). Maximum value of DO was recorded in monsoon and minimum value was recorded in post monsoon season. Similar results were observed by Lola Catherine and Mary Helen, (2018) in Manakudy estuarine region. The observation noted could be due the turbulence of water facilitating the diffusion of atmospheric oxygen and the increased solubility of oxygen at lower temperature. Similar observations were made by Yadav *et al*., (2013). Study by Vasanthi and Sukumaran (2017) in Muthupet estuary shows maximum dissolved oxygen in monsoon season and minimum DO during Post monsoon which is similar to the results obtained in the present study. It might be due to the cumulative effect of higher wind velocity coupled with heavy rainfall. Similar observations were also drawn by Ravichelvan *et al*., (2015), Naseema Shaikh *et al*., (2017) in Kali estuary, Sahu *et al*., (2000), Arumugam and Sugirtha P. Kumar, (2014) and Kurma Rao and Ramesh babu (2017) in Champavathi estuary.

The low DO concentration observed during the present investigation may be due to waste discharge which is high in organic matter and nutrient near by the river site and also due to increase in microbial activity occurring during the degradation of the organic matter. These current observations coincide with those made by Yisa and Jimoh, (2010), Nidhi Gupta *et al*., (2017) and Raju *et al*., (2017).

Biological Oxygen Demand (BOD): Biological Oxygen Demand (BOD) is the quantity of oxygen required by the living organisms engaged in the utilization and ultimate destruction or stabilization of organic water. It is a very important indicator for the pollution status of the water body (Vasanthi and Sukumaran., 2017). In the present study the BOD recorded for Pre monsoon were 2.72 ± 0.13, 2.72 ± 0.12, 2.65 ± 0.11, Monsoon 3.65 ± 0.09, 3.32 ± 0.10, 3.78 ± 0.14 and for Post monsoon season were 2.89 ± 0.08, 2.83 ± 0.07 and 2.90 ± 0.03 from stations I, II and III respectively (Figure 11).

The maximum BOD was observed in Monsoon season and least in Pre monsoon. Similar results were observed in experiments conducted by Vasanthi and Sukumaran., (2017) in Muthupet estuary. This may be as a result of organic matter into the river mostly from faecal waste deposition by the surrounding urban area and human settlements. The BOD values observed by Nidhi Gupta *et al*., (2017) and Kumari *et al*., (2013) go in line with the present study.

The slightly higher levels in the Monsoon could be attributed to the influence of the municipal activities. Compared to the Pre monsoon season, the BOD of Post monsoon is higher and this could be due to the effect of higher temperature, salinity and putrefaction of substances deposited in the river and this is in accordance with the study by Onojake *et al*., (2015) in Calabar river estuary, Fatema *et al*., (2016), Fianko *et al*., (2009) and Grafny *et al*., (2000).

Chemical Oxygen Demand (COD): The Chemical Oxygen Demand (COD) is an indicative measure of the amount of oxygen that can be consumed by reactions in measured solution. COD is a degree of pollution in aquatic ecosystems. It estimates carbonaceous factor of organic matter (Vasanthi and Sukumaran, 2017). In the present study the COD values of Pre monsoon season were the lowest and were 22.76 ± 0.30, 21.83 ± 1.47, 21.70 ± 0.82, the highest levels were recorded in Post monsoon 24 ± 2.37, 24.17 ± 0.27, 25.43 ± 0.62, and for Monsoon they were 23.82 ± 0.14, 23.8 ± 0.41 and 23.5 ± 1.87 from the three stations I, II and III respectively (Figure: 12). Similar results have been observed by Vasanthi and Sukumaran, (2017) of Muthupet estuary and Surana Ranjana *et al*., (2013) of Tapi estuary. Maximum COD during the Post monsoon season could be due to decrease in freshwater inflow, land drainage, domestic sewage and industrial inputs, increase in salinity, temperature, phytoplankton productivity and microbial consumption of oxygen at the time of decomposition. Similar result has been obtained by Pillai, (1994) and Surana Ranjana *et al*., (2013).

Correlation and Multivariate analysis of water quality: Pearson correlation is a measure of the strength and direction of association that exists between two continuous variables. Pearson correlation among the three stations according to seasons shows

Table: 4 Correlation between the water quality parameters of three stations in Adayar estuary during the Premonsoon season.

Correlations

		Station 1	Station 2	Station 3
Station 1	Pearson Correlation	1	-.032	-.688
	Sig. (2-tailed)		.922	.013
	N	6	6	6
Station 2	Pearson Correlation	-.032	1	-.704
	Sig. (2-tailed)	.922		.011
	N	6	6	6
Station 3	Pearson Correlation	-.688	-.704	1
	Sig. (2-tailed)	.013	.011	
	N	6	6	6

Figure: 13 Multivariate analysis of water quality varaibles for Premonsoon season

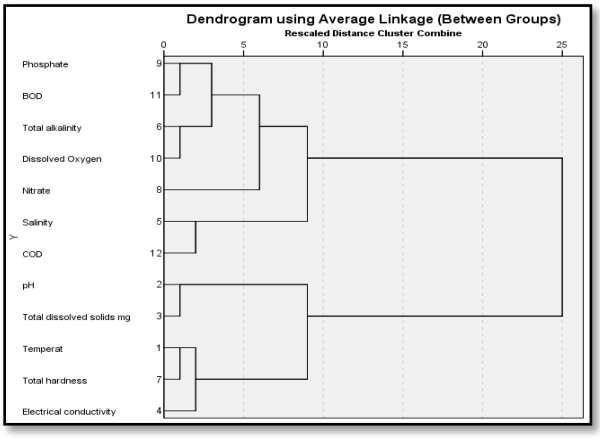


Table: 5 Correlation between the water quality parameters of three stations in Adayar estuary during the Monsoon season.

Correlations

		Station 1	Station 2	Station 3
Station 1	Pearson Correlation	1	-.264	-.621
	Sig. (2-tailed)		.408	.031
	N	6	6	6
Station 2	Pearson Correlation	-.264	1	-.592
	Sig. (2-tailed)	.408		.042
	N	6	6	6
Station 3	Pearson Correlation	-.621	-.592	1
	Sig. (2-tailed)	.031	.042	
	N	6	6	6

Figure: 14 Multivariate analysis of water quality varaibles for Monsoon season

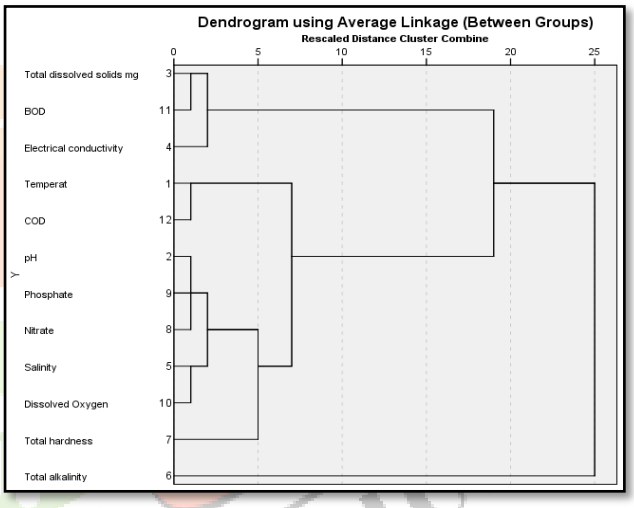
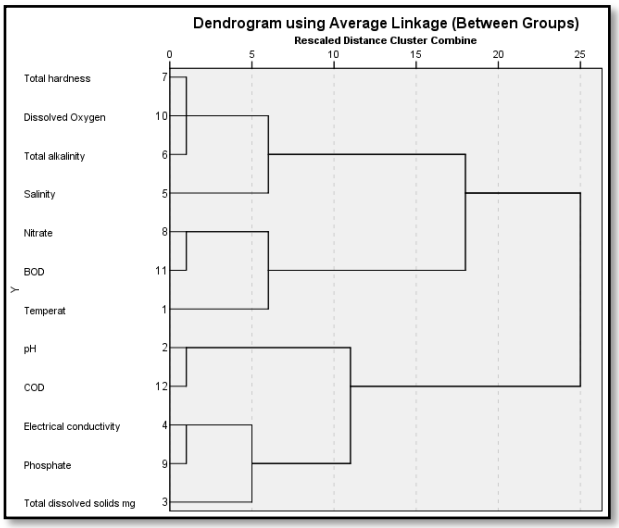


Table: 6 Correlation between the water quality parameters of three stations in Adayar estuary during the Postmonsoon season

Correlations

		Station 1	Station 2	Station 3
Station 1	Pearson Correlation	1	-.467	-.612
	Sig. (2-tailed)		.126	.034
	N	6	6	6
Station 2	Pearson Correlation	-.467	1	-.413
	Sig. (2-tailed)	.126		.182
	N	6	6	6
Station 3	Pearson Correlation	-.612	-.413	1
	Sig. (2-tailed)	.034	.182	
	N	6	6	6

Figure: 15 Multivariate analysis of water quality varaibles for Postmonsoon season



variation. In premonsoon season strong positive correlation was observed whereas for monsoon and postmonsoon seasons the correlation observed was weak.

The use of Cluster Analysis (CA) is to classify variables based on their similarity level. The result is illustrated by dendrogram, presenting the clusters and their proximity. The cluster analysis includes physico chemical parameters according to seasons. For water quality variables for premonsoon season (Figure 13) two clusters

has been formed. Cluster I include phosphate, BOD, total alkalinity, dissolved oxygen, nitrate, salinity and COD. The Cluster II being formed of pH, total dissolved solids, temperature, total hardness and electrical conductivity. The dendrogram for monsoon season shows three clusters (Figure 14). Cluster I is formed of total dissolved solids, BOD, electrical conductivity, Cluster II of temperature, COD, pH, phosphate, nitrate, salinity, dissolved oxygen and total hardness and Cluster III is formed of total alkalinity. For postmonsoon season the number of clusters formed is three (Figure 15). Total hardness, dissolved oxygen, total alkalinity and salinity forms Cluster I. Nitrate, BOD, temperature Cluster II and pH, COD, electrical conductivity, phosphate and total dissolved solids forms Cluster III. The combination of cluster formation for different seasons slightly varies. Similar observations were made by Cieszynska *et al*., (2011) and Simeonov *et al*., (2001). This study is also in consistent with the study carried out by Rajesh kumar *et al*., (2017).

Conclusion:

The monitoring of sediment quality is a very important process in the restoration and protection of the biological integrity of our nation's waters as well as our aquatic/wildlife resources (Adeola Alex Adesuyil *et al.,* 2016). When compared to water, sediments contained very high values of the physico chemical parameters. Concentration of these parameters showed spatial variations at Adayar estuary during the study period. The present baseline information of the physico-chemical parameters, in water and sediments would form a useful tool for further ecological assessment and monitoring of the coastal ecosystems of Adayar estuary. It is concluded that Adayar estuary should be constantly monitored for trends in physico chemical parameters in surface water and sediments.

References:

Abowei, J.F.N., (2010). Salinity, Dissolved Oxygen, pH and Surface Water Temperature Conditions in Nkoro River, Niger Delta, Nigeria. *Advance Journal of Food Science and Technology*, *2*(1), 36-40.

Adeyemo, O.K. (2003), Consequences of pollution and degradation of Nigerian aquatic environment on fisheries resources, *The Environmentalist*,*23*(4), 297-306.

Adeola Alex Adesuyi1, Moses Okafor Ngwoke, Modupe Olatunde Akinola, Kelechi Longinus Njoku and Anuoluwapo Omosileola Jolaos. (2016). Assessment of Physicochemical Characteristics of Sediment from Nwaja Creek, Niger Delta, Nigeria. *Journal of Geoscience and Environment Protection*, *4*, 16-27.

Anitha, G. and Kumar, S. P. (2013). Seasonal variations in physico-chemical parameters of Thengapattanam estuary, Southwest coastal zone, Tamil Nadu, India. *International Journal of Environmental Sciences*, *3*(4): 1253–1261. http://doi.org/10.6088/ijes.2013030400004

Anitha, G., & Sugirtha, K. (2013). Physicochemical characteristics of water and sediment in Thengapattanam estuary, southwest coastal zone, Tamilnadu, India. *International Journal of Environmental Sciences*, *4*(3), 205–222. http://doi.org/10.6088/ijes.2013040300001

APHA, (2012). Standard methods for the examination of water and wastewater, (2012, 22nd edition) edited by E. W. Rice, R. B. Baird, A. D. Eaton and L. S. Clesceri. American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation (WEF), Washington, D.C., USA, pp 1360.

Aquiline Ans, K., & Mendez, D. R. M. (2017). Seasonal Variation in the Physicochemical Characteristics and Microalgae of Selected Mangrove Ecosystems in Ernakulam. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *11*(05), 01–05. http://doi.org/10.9790/2402-1105030105

Arumugam & Sugirtha, P. Kumar. (2014). Evaluation of physico-chemical parameters and nutrients in the Mangrove ecosystem of manakudy Estuary, southwest coast of India. *International Journal of Latest Research in Science and Technology*,*3* (6), 205- 209.

Balasubramanian, R. & Kannan, L. (2005). Physico-chemical characteristic of the coral reef Environs of the Gulf of Mannar Biosphere Reserve, India, International Journal of Ecology and Environmental Science, 31:265-271.

Badarudeen, A., Damodaran, K. T., Sajan, K., & Padmalal, D. (1996). Texture and geochemistry of the sediments of a tropical mangrove ecosystem, southwest coast of India. *Environmental Geology*, *27*(3), 164–169. http://doi.org/10.1007/BF00770428

Barath Kumar, S., Mohanty, A. K., Padhi, R. K., Selvanayagam, M. & Satpathy, K. K. (2018). Coastal water characteristics along Tamil Nadu, east coast of India during pre-northeast monsoon period.*Indian Journal of Geo Marine Sciences*, *47* (02), pp. 308-318

Cieszynska, M., Wesolowski, M., Bartoszewicz, M., Michalska, M., & Nowacki, J. (2011). Application of physicochemical data for water-quality assessment of watercourses in the Gdansk Municipality (South Baltic coast). Environmental Monitoring and Assessment, 184(4), 2017–2029. doi:10.1007/s10661-011-2096-5

Chennai Metropolitan Development Authority. p. 1. Retrieved 28 December 2012.

Choudhury, S.B. & Panigrahy, R. C. (1991). Seasonal distribution and behaviour of nutrients in the creek and coastal waters of Gopalpur, East Coast of India, *Mahasagar*, *24*(2), 81-88.

Damotharan, P., N.Vengadesh Perumal, M.Arumugam, S.Vijayalakshmi & T.Balasubramanian, (2010). Seasonal variation of physico-chemical characteristics in point Calimere coastal waters (South East Coast of India). Middle East J.Sci., Res., 6(4): 333-339

Fatema, K., Omar, W., & Isa, M. (2016). Effects of Tidal Events on the Water Quality in the Merbok Estuary, Kedah, Malaysia. *Journal of Environmental Science and Natural Resources*, *8*(2), 15. http://doi.org/10.3329/jesnr.v8i2.26858

Fianko, J. R., Nartey, V. K., & Donkor, A. (2009). The hydrochemistry of groundwater in rural communities within the Tema District, Ghana. *Environmental Monitoring and Assessment*, *168*(1-4), 441–449. http://doi.org/10.1007/s10661-009-1125-0

Grafny, S., Goren, M. & Gasith, A. (2000). Habitat condition and fish assemblage structure in a coastal mediterranean stream (Yarqon, Israel) receiving domestic effluent. Hydrobiologia. *422*, 319–330.

Govindasamy.C., Kannan.L. & Azariah.J., (2000), Seasonal variation in Physico-chemical properties and primary production in the coastal water biotopes of Coromandel Coast, India journal of environmental biology, 21, pp 1-7

Gupta, B.G., Biswas, J.K. & Agrawal, K.M., (2017). Physico-chemical parameters, water quality index and statistical analysis of surface water contamination by bleaching and dyeing effluents at Kalikapur, West Bengal, India, *J. Env. Sci. Pollut. Res. 3*(2), 177–180

Indian Meteorological Department, Chennai Regional Website. (2012). Indian Meteorological Department. Retrieved 28 December 2012.

Jothivel, N. & Paul, V.I. (2014). Comparitive Physico-chemical analysis of Uppanar Estuary and Killai Back water from Tamil Nadu coasty with special reference to their nutrient status. *International Journal of Current Research*, 6(12), 11218-11225.

Kumari, M., Mudgal, L.K. & Singh, A. K., (2013). Comparative studies of physico-chemical parameters of two reservoirs of Narmada River, MP, India. *Curr. World Environ., 8* (3), pp. 473-478

Kurma Rao, R. & Ramesh Babu, K. (2017). Seasonal Variations in Physico-Chemical Properties of Gosthani Estuary, Northeast Coast of Andhra Pradesh, India. *Int J Curr Microbiol App. Sci*,*6*(6), 443-447. https://doi.org/10.20546/ijcmas.2017.606.0512017

Lola Catherine, V. & Mary Helen, H. (2018). Studies on the seasonal variation of water quality parameters of Manakudy estuarine region, South West coast of India. *International Journal of ChemTech Research*, *11*(02), 394–398.

Mariappan, P., Yegnaraman, V. & Vasudevan, T. (2000): Occurrence and removal possibilities of fluoride in ground waters of India. *Poll. Res*., *19*(2): 165-177.

Mohan Raj V. Padmavathy S, & Sivakumar S. (2013). Water quality Parameters and it influences in the Ennore estuary and near Coastal Environment with respect to Industrial and Domestic sewage. *Int. Res. J. Environment Sci*., *2*(7), 20-25.

Muduli Bipra Prasanna & Panda Chitta Ranjan, (2010). Physico chemical properties of water collected from Dhamra estuary. *International journal of Environmental sciences*, *1*(3). http://doi.org/10.6088/ijessi.00103010006

Murhekar Gopalkrushna, H. (2011). Determination of Physico-Chemical parameters of Surface Water Samples in and around Akot City. *Int. J. Res. Chem. Environ*.*1*(2), 183-187.

Muthukumaravel K., Vasanthi N., Sivakami R., Kandasami D. & Sukumaran N., (2012), Physico-Chemical characteristics of Arasalar estuary Karaikal Southeast Coast of India., *International journal of institutional pharmacy and life sciences*, 2(3), pp 84-93.

Nandini, S and John Milton M.C., (2019). Diversity of edible fish species in Adayar estuary, Chennai, Tamil Nadu, India., *Journal of Emerging Technologies and Innovative Research*, 6(6), pp 1217-1231.

Narendra Babu.K., Omana.P.K. & Mahesh Mohan., (2009), Water and sediment quality of Ashtamudi estuary, a Ramsar site, Southwest coast of India-a statistical appraisal, *Environmental Monitoring and Assessment*, *165*, pp 307-319

Naseema Shaikh, Rathod, J.L. & Raveendra Durgekar. (2017). Seasonal variations in physico-chemical parameters of Kali estuary, West coast of India. *International Journal of Science and Nature*,*8* (3), 489-493

Nedumaran, T., Ashok Prabu, V. & Perumal, P. (2001). Ecology of phytoplankton of Vellar estuary, southeast coast of India. *Seaweed Res. Tiln*., *23* (1&2):157-162.

Nidhi Gupta, Pankaj Pandey, & Hussain, J. (2017). Effect of physicochemical and biological parameters on the quality of river water of Narmada, Madhya Pradesh, India. *Water Science*, *31*(1), 11–23. http://doi.org/10.1016/j.wsj.2017.03.002

Onojake, M. C., Sikoki, F. D., Omokheyeke, O., & Akpiri, R. U. (2015). Surface water characteristics and trace metals level of the Bonny/New Calabar River Estuary, Niger Delta, Nigeria. Applied Water Science, 7(2), 951–959. http://doi.org/10.1007/s13201-015-0306-y

Palpandi, P. (2011) Hydrobiological parameters, pollution density and distribution pattern in the gastropod Nerita (dostia) crepidularia Lamarck, 1822, from mangroves of Vellar estuary, southeast India. *Int J Biodvers Conserv*, *3*(4):121–130

Prema, M. & B. Subramanian, (2003). Hydrobiological parameters of Muttukadu backwater of Bay of Bengal. Indian Hydrobiology 6(1&2): 95-100

Pillai, M.M., (1994). Hydrobiological investigations on the intertidal diatoms of the Cuddalore-Uppanar estuary (India). Ph.D. Thesis, Annamalai University, India.

Rajkumar J.S.I., John Milton M.C. & Ambrose T., (2011). Seasonal variation of water quality parameters in Ennore estuary with respect to industrial and domestic sewage, *Int. Journal of Curr. Res*., *33*(3), 209-218.

Rajasegar, M. (2003) Physico-chemical characteristics of the Vellar estuary in relation to shrimp farming. *J. Environ. Biol,. 24*, 95-101.

Rajesh Kumar M, Olive Eunice P, Sreejani Tp, Sravya Pvr, Srinivasa Rao Gvr., (2017). Multivariate Statistical Analysis of Seasonal Variations of Water Quality In River Godavari at Polavaram, A.P. *International Journal of Environmental Engineering and Management*. 8 (1), 27-38

Raju, C., Sridharan, G., Mariappan, P., & Chelladurai, G. (2017). Physico-chemical parameters and Ichthyofauna diversity of Arasalar estuary in southeast coast of India. *Applied Water Science*, *7*(1), 445–450. http://doi.org/10.1007/s13201-014-0260-0

Rao, A.M. (2001). An environmental assessment on SIPCOT industrial complex, Cuddalore, Tamilnadu in relation to water pollution and its ethical implications. Ph.D. Thesis, Annamalai University, India, 1-7

Ravichelvan, R ., Ramu, S. & Anandaraj, T. (2015). Seasonal variations of water quality parameters in South East coastal waters of Tamil Nadu, India. *Int. J. Modn. Res. Revs.*, *3*(10), pp 826-829.

Sahu, B.K., Rao, R.J., Behara, S.K. & Pandit, R.K. (2000). Effect of pollution on the dissolved oxygen concentration of the river Ganga at Kanpur. In: Pollution and biomonitoring of Indian rivers Ed.: R. K. Trivedy. ABD Publication, Jaipur, India. 168 -170.

Saksena, D.N. & Kaushik, S. (1994). Trophic status and habitat ecology of entomofauna of three water bodies at Gwalior, Madhya Pradesh. In: Perspective in entomological research Ed.: O. P. Agrawal Scientific Publishers, Jodhpur.

Sampathkumar, P. & Kannan, L. (1998). Seasonal variations in physico-chemical characteristics in the Tranquebar-Nagapattinam region, south-east coast of India, *Pollution Research*, *17*(4), pp 397-402

Santhosh Kumar, C. & Ashok Prabu, V. (2014). Physico-chemical parameters in Parangipettai coastal waters and Vellar estuary, Southeast coast of India. *Int. J. Curr. Microbiol. App. Sci., 3*(9) 85-93.

Santhanam, P. & P. Perumal, (2003). Diversity of zooplankton in Parangipettai coastal waters, South east coast of India. J. Mar. Ass. India. 45(2) 144-151

Senthilkumar, S., Santhanam, P. & Perumal, P. (2002) Diversity of phytoplankton in Vellar estuary, southeast coast of India. In: Proc. 5th Indian Fisheries Forum (Eds. S. Ayyappan, J.K. Jena andM. Mohan Joseph). Published by AFSIB, Mangalore, Bhubanewar, India. pp. 245-248

Simeonov, V., Sarbu, C., Massart, D. L., & Tsakovski, S. (2001). Danube River water data modelling by multivariate data analysis. *Mikrochimica Acta*, 137, 243–248

Smith, S. V., & Hollibaugh, J. T. (1993). Coastal metabolism and the oceanic organic carbon balance. Reviews of Geophysics, 31(1), 75–89. http://doi.org/10.1029/92rg02584

Sreekala. S, & Mary Helen, H.(2017). Studies on the Seasonal Variation of Physicochemical Characteristics of Kadiyapattanam Estuary, the South West Coast of India. *International Journal of ChemTech Research*, *10*(6), 980-985.

Sophia, S., Milton, M. C. J., & Prakash, M. (2017). Analysis and Seasonal Variation of Heavy Metals in Water and Sediment from Adyar Estuary., *Journal of r uoJ Environmental & Analytical Toxicology, 1*(2), 1-5. http://doi.org/10.4172/2161-0525.1000457

Sundaramanickam, A., T. Sivakumar, R. Kumaran, V. Ammaiappan & R.Velappan. (2008). A comparative study of physico-chemical investigation along Parangipettai and Cuddalore coast. *J. Env. Sci. and Tech*. *1*, 1-10.

Surana Ranjana, Gadhia Mohini & Ansari Ekhalak, (2013). Assessment of physic-chemical characteristics and pollution status of Tapi estuary at Dumas Jetty, Surat. International Journal of Innovative Research in Science, Engineering and Technology, 2(10), 5351-5357.

Thommai Arockia Gaspar, D. & Lakshman, G. (2014). Water Quality Parameters of Thamirabarani Estuary. *International Journal of Advanced Research*, *2*(4), 380-386.

Vasanthi, P., & Sukumaran, M. (2017). Physicochemical analysis of coastal water of east coast of Tamil Nadu (Muthupet estuary), *2*(5), 15–21. http://doi.org/10.1103/PhysRevLett.78.3390

Vijayakumar, N., Shanmugavel, G., Sakthivel, D., & Anandan, V. (2014). Seasonal variations in physico-chemical characteristics of Thengaithittu estuary, Puducherry, South East-Coast of India. *Pelagia Research Library Advances in Applied Science Research*, *5*(5), 39–49.

Yadav, P., Yadav, A.K. & Khare, P. K. (2013). Physico – Chemical characteristics of a freshwater pond of Orai, U. P., Central India, *Octa Journal of Biosciences*., *1*, 177 -184.

Yisa, J. & Jimoh, T. (2010). Analytical Studies on water quality Index of River Landzu *Am. J. Appl. Sci*.,*7* (4) (2010), pp. 453-458