

## **CHAPTER – II**

### **PHYSICO-CHEMICAL PARAMETERS OF SEAWATER**

Coastal waters are one of the nation's most important natural resources, valued for their ecological richness as well as for the many human activities they support. Moreover, seawater is one of the most abundant resources on Earth that turn into hydrogen peroxide ( $H_2O_2$ ) using sunlight, which can then be used to generate electricity in fuel cells ( Petrov, 2011). This adds to the ever growing number of existing alternate energy options as the world continues to move towards green energy. And also, seawater electrolysis is used today to provide on-site hypochlorite for waste water treatment plants, and for coastal power stations and ships where hypochlorite is used to prevent the growth of marine organisms which tend to foul equipment and make heat transfer difficult oxygen evolution is actually the thermodynamically favored anodic reaction, occurring at significantly lower anodic potentials than chlorine in the electrolysis of neutral seawater. However, chlorine is found to be a major anode gas product in the electrolysis of saline water containing chlorides.

#### **2.1 GEOGRAPHIC FEATURES**

The study area for the work is Kanyakumari District, which is one of the 32 districts of Tamilnadu, and is located at the southernmost tip of peninsular India. It is sometimes referred to as "land's End". It lies between  $77^{\circ} 15'$  and  $77^{\circ} 36'$  of the eastern longitudes and  $8^{\circ} 03'$  and  $8^{\circ} 35'$  of the northern latitudes. Its south eastern boundary (coastal) is Bay of Bengal, while on the south and south west, the boundaries are the Indian Ocean and the Arabian sea. The Arabian coast is well known for the rich variety

of fishes. Kanyakumari district was one of the worst affected districts in India in the tsunami that ravaged the coasts of various countries in South and South East Asia, on 26 December 2004. The district's coastal environment forms an interface between land and marine water. This eco-system is valuable to humans from the dawn of civilization. This district in Tamil Nadu with a land mass of one thousand six hundred and eighty four square kilometres has almost all ecosystems; wetlands, forests, freshwater resources, marine, etc. The coastal environment is very important with regard to fish production and fisher folk's employment. The district's coastal ecosystem is sixty eight kilometer in length and is studded with forty four coastal fishing villages. Since this district is located at the extreme south of the Indian subcontinent, the coastline is formed nearly by three seas; the Arabian Sea, the Indian Ocean and the Bay of Bengal while the main part of the coast of Kanyakumari district faces the Arabian Sea.

Sand dunes and Teri soil occur along the coast and away from the coast of Kanyakumari. The southern part of the coast is sandy beaches with beach sands containing heavy minerals on the eastern and western sides of Kanyakumari. The coastal geomorphic features observed along the coast of Kanyakumari district are Beach, Beach ridges, Clifed coast, Sand Dunes and Beach Terraces. The marine landforms along the Kanyakumari district is restricted to the width of less than 1km. There are three important riverine ecosystems, which confluence with Arabian Sea in Kanyakumari. Thengapattinam estuary, formed by the confluence of river Tampirabarani in between Thengapattinam and Eraiummanthurai. Valliyar estuary formed by the river Valliyar near Kadiapattinam. Manakudy estuary formed by the confluence of river Pazhayar in between East and West Manakudy villages. Apart from

these it has two minor estuaries such as Pambar estuary near Colachel and Pantri estuary near Rajakkamangalam. These are formed by the drainage canal excess waste during monsoon and the water drained from the irrigational fields mixing with sea.

Seawater samples from six different stations were collected every month of the study period from June 2014 to May 2015 between 6a.m to 8a.m on fixed date to avoid the fluctuations in the observations. Arabian Sea coastal area receives rain in two monsoons namely, the southwest monsoon from June to September and the northeast monsoon from October to December. The study area receives the bulk of rainfall during northeast monsoon.

The six stations selected for the present study are,

Station I - Kanyakumari

Station II - Manakudy

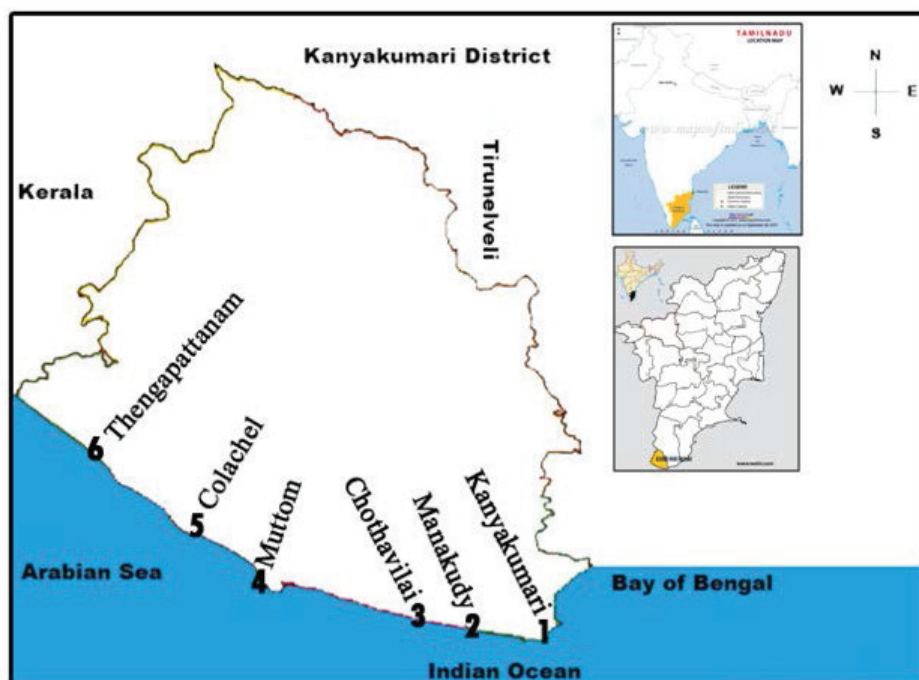
Station III - Chothavilai

Station IV - Muttom

Station V - Colachel

Station VI - Thengapattinam

An integrated study of physico-chemical parameters has not been carried out so far along these regions, which led to take up this study. With a view to delineate environmental changes of such a vulnerable region, detailed chemical oceanographic studies have been undertaken to monitor water quality of coastal waters of south western coast of Kanyakumari District. The survey provides important background information necessary for the study of the coastal processes.



**Fig. 2.1 The sampling stations in Arabian sea in Kanyakumari District**

## **2.2 MATERIALS AND METHODS**

Seawater samples from six different stations were collected every month of study period from June 2014 to May 2015 between 6 am to 8 am on a fixed date to avoid the fluctuations in the observations. The site selection was based on the population/aggregation of fishing families/possible anthropogenic inputs, geographic distribution, catch volume and species diversities in the area.

Water samples from 0.5m depth are collected in polythene bottles. Temperature and pH are recorded in situ and samples for dissolved oxygen and biological oxygen demand are collected in 125 ml stoppered glass bottles without trapping air bubbles and fixed immediately with manganous chloride (Winkler A) followed by alkaline potassium iodide (Winkler B) solution.

### **2.2.1 Multi parameter analyzer**

Some physical parameters like seawater surface temperature, pH, conductivity and turbidity were measured directly in the field using portable multi parameter analyzer.

### **2.2.2 Total dissolved solids**

Parameter TDS was determined gravimetrically.

### **2.2.3 Dissolved oxygen and Biological oxygen demand**

Samples for DO and BOD were collected in BOD bottles. DO and BOD were determined by the Winkler's method in the form recommended by Strickland and Parsons (1972) with standard iodimetric titration. The principle of the determination and the possible sources of systematic errors are discussed by Grasshoff (1983).

### **2.2.4 Total alkalinity**

The total alkalinity was measured by potentiometric titration method following standard operating procedures suggested by the Department of Energy (DOE) (1998).

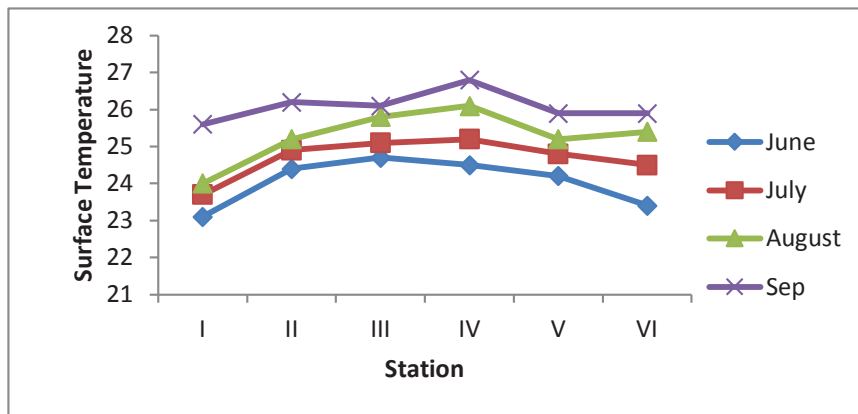
## **2.3 RESULTS**

### **2.3.1 Surface temperature**

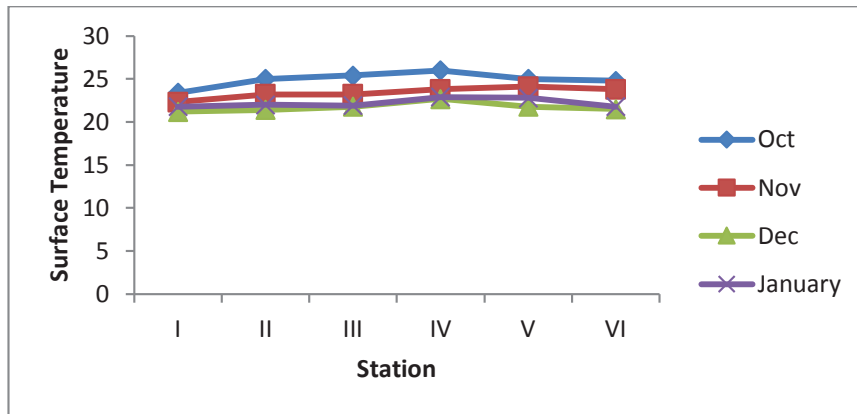
The distribution surface temperature of seawater during the period of study was presented in **Table 2.1**. Its longitudinal variations and annual mean were graphically depicted in **Fig. 2.1 a-d**.

**Table 2.1. Longitudinal variations of seawater Surface Temperature (°C)**

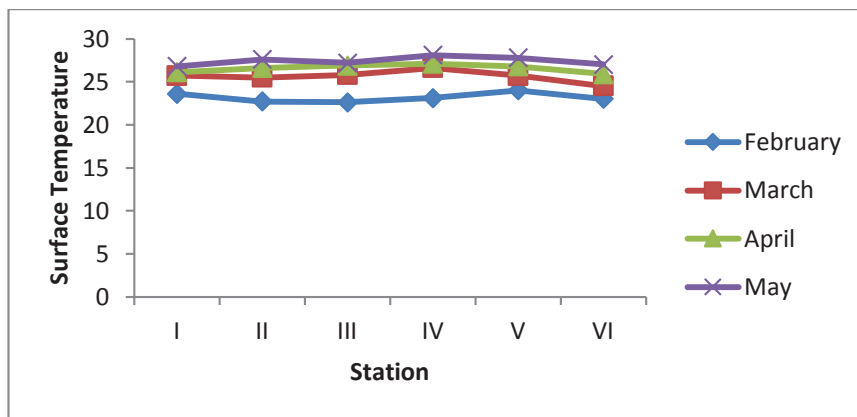
| Station | June  | July | Aug  | Sep   | Oct  | Nov  | Dec  | Jan  | Feb  | Mar  | April | May  | Mean |
|---------|-------|------|------|-------|------|------|------|------|------|------|-------|------|------|
| I       | 23.1  | 23.7 | 24   | 25.6  | 23.4 | 22.3 | 21.2 | 21.8 | 23.6 | 25.7 | 26.1  | 26.8 | 23.9 |
| II      | 24.4  | 24.9 | 25.2 | 26.2  | 25   | 23.2 | 21.4 | 22   | 22.7 | 25.5 | 26.6  | 27.6 | 24.5 |
| III     | 24.7  | 25.1 | 25.8 | 26.1  | 25.4 | 23.2 | 21.8 | 21.9 | 22.6 | 25.8 | 26.9  | 27.2 | 24.7 |
| IV      | 24.5  | 25.2 | 26.1 | 26.8  | 26   | 23.8 | 22.7 | 22.9 | 23.1 | 26.6 | 27.1  | 28.1 | 25.2 |
| V       | 24.2  | 24.8 | 25.2 | 25.9  | 25   | 24.1 | 21.8 | 22.8 | 24   | 25.7 | 26.8  | 27.8 | 24.8 |
| VI      | 23.4  | 24.5 | 25.4 | 25.9  | 24.8 | 23.8 | 21.5 | 21.8 | 23   | 24.5 | 25.9  | 27   | 24.2 |
| Mean    | 24.05 | 24.7 | 25.2 | 26.08 | 24.9 | 23.4 | 21.7 | 22.2 | 23.1 | 25.6 | 26.5  | 27.4 |      |



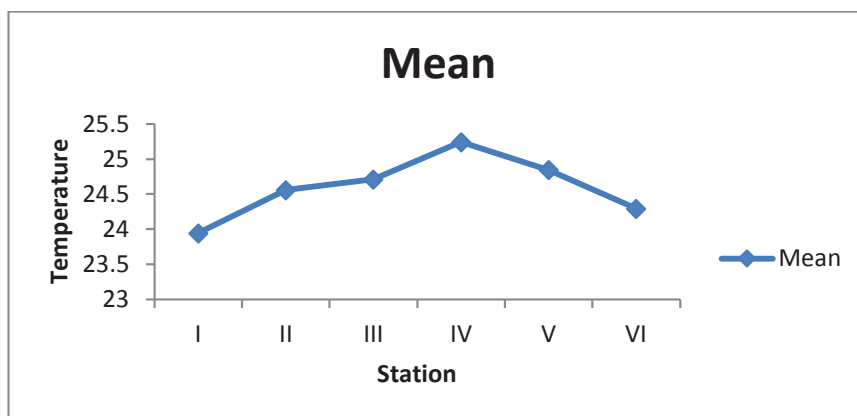
**Fig. 2.1.a. Longitudinal variations of seawater surface Temperature (°C)**



**Fig. 2.1.b. Longitudinal variations of seawater surface Temperature (°C)**



**Fig.2.1.c. Longitudinal variations of seawater surface Temperature (°C)**



**Fig.2.1.d. Annual mean of seawater surface Temperature (°C)**

The surface temperature of seawater at station I ranged between 21.2°C (December, 2014) and 26.8°C (May, 2016) whereas at station II it ranged from 21.4°C (December, 2014) and 27.6°C (May, 2015). Observation at station III was between 21.8°C (December, 2014) and 27.2°C (May, 2015) whereas at station IV it varied from 22.7°C (December, 2014) and 28.1°C (May, 2015). The water temperature at station V ranged from 21.8°C (December, 2014) and 27.8°C (May, 2015) whereas at station VI it was between 21.5°C (December, 2014) and 27°C (May, 2015).

Almost a uniform distribution of low temperature was noticed during December, 2014 and January, 2015 at all stations except station IV. The lowest temperature of 21.2°C was recorded in station I in December, 2014. In December the surface water temperature varied between 21.2°C to 22.7°C. The maximum surface water temperature of 28.1°C was recorded at station IV in May. Also a uniform distribution of high temperature was recorded during April and May, 2015 at all stations except station I and IV. In May the surface water temperature varied between 26.8°C to 28.1°C. The shores are continuous, normal tidal activities occurred all along this coastline. The seasonal variations in the seawater temperature showed similar pattern in all the sampling sites.

### **2.3.2 pH**

The results of sea surface water pH during the period of study were presented in the Table 2.2. Its longitudinal variations and annual mean were graphically depicted in Fig. 2.2.a-d.

The maximum pH of 8.9 was recorded at station II followed by 8.8 in station IV during September, 2014. The minimum pH of 7.6 was noticed in station V in June, 2014.

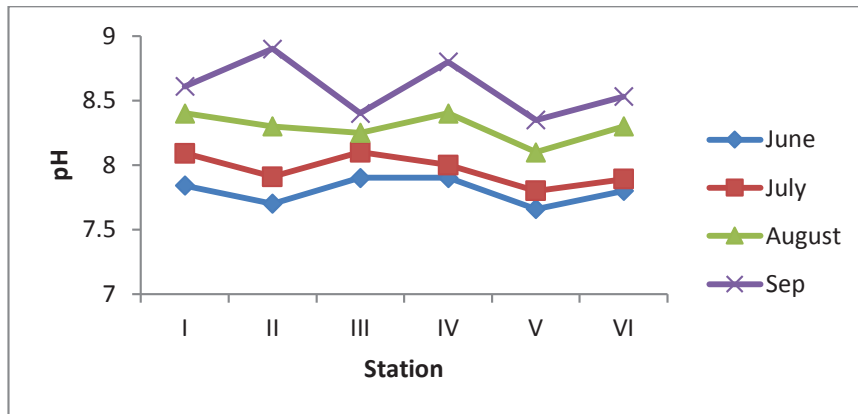


The pH of seawater sample at station I varied from 7.84 (June, 2014) to 8.6 (September, 2014). At station II it was from 7.7 (June, 2014) and 8.9 (September, 2014) whereas at station III, it varied from 7.9 (June, 2014) to 8.4 (September, 2014 and May, 2015). At station IV, the value ranged between 7.9 (June, 2014) and 8.8 (September, 2014) whereas at station V, the value varied between 7.66 (June, 2014) and 8.39 (November, 2014). At station VI, the value ranged from 7.8 (June, 2014) to 8.5 (September, 2014).

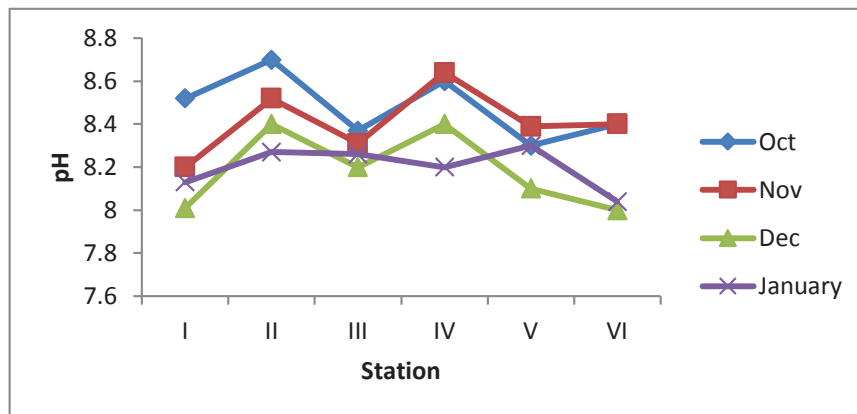
In all the sampling stations minimum pH was recorded in the month of June, 2014 and maximum in the month of September, 2014, except station V. In almost all the stations moderate pH was recorded at both winter and summer season.

**Table 2.2. Longitudinal variations of seawater pH**

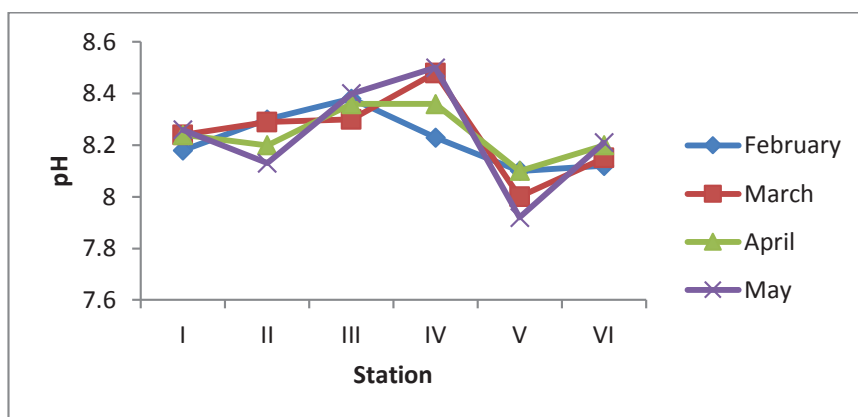
| Station | June | July | Aug  | Sep  | Oct  | Nov  | Dec  | Jan  | Feb  | Mar  | April | May  | Mean |
|---------|------|------|------|------|------|------|------|------|------|------|-------|------|------|
| I       | 7.84 | 8.09 | 8.4  | 8.61 | 8.52 | 8.2  | 8.01 | 8.13 | 8.18 | 8.24 | 8.24  | 8.26 | 8.22 |
| II      | 7.7  | 7.91 | 8.3  | 8.9  | 8.7  | 8.52 | 8.4  | 8.27 | 8.3  | 8.29 | 8.2   | 8.13 | 8.30 |
| III     | 7.9  | 8.1  | 8.25 | 8.4  | 8.37 | 8.31 | 8.2  | 8.26 | 8.38 | 8.3  | 8.36  | 8.4  | 8.26 |
| IV      | 7.9  | 8    | 8.4  | 8.8  | 8.6  | 8.64 | 8.4  | 8.2  | 8.23 | 8.48 | 8.36  | 8.5  | 8.37 |
| V       | 7.66 | 7.8  | 8.1  | 8.35 | 8.3  | 8.39 | 8.1  | 8.3  | 8.1  | 8    | 8.1   | 7.92 | 8.09 |
| VI      | 7.8  | 7.89 | 8.3  | 8.53 | 8.4  | 8.4  | 8    | 8.04 | 8.12 | 8.15 | 8.2   | 8.21 | 8.17 |
| Mean    | 7.8  | 7.96 | 8.29 | 8.59 | 8.48 | 8.41 | 8.18 | 8.2  | 8.21 | 8.24 | 8.24  | 8.23 |      |



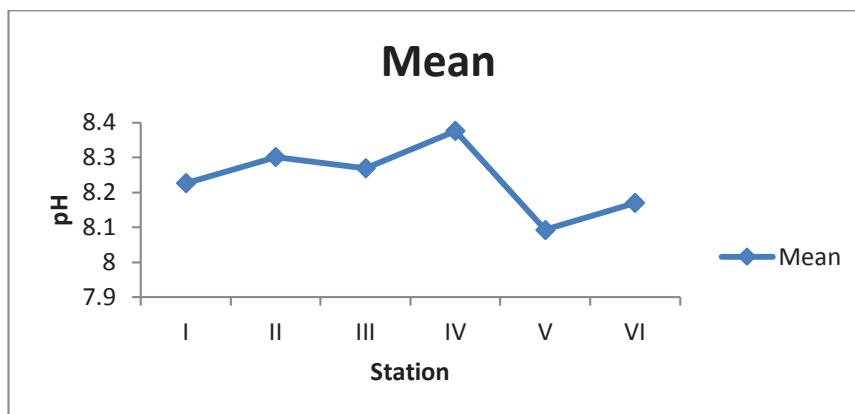
**Fig.2.2.a. Longitudinal variations of seawater pH**



**Fig.2.2.b. Longitudinal variations of seawater pH**



**Fig.2.2.c. Longitudinal variations of seawater pH**



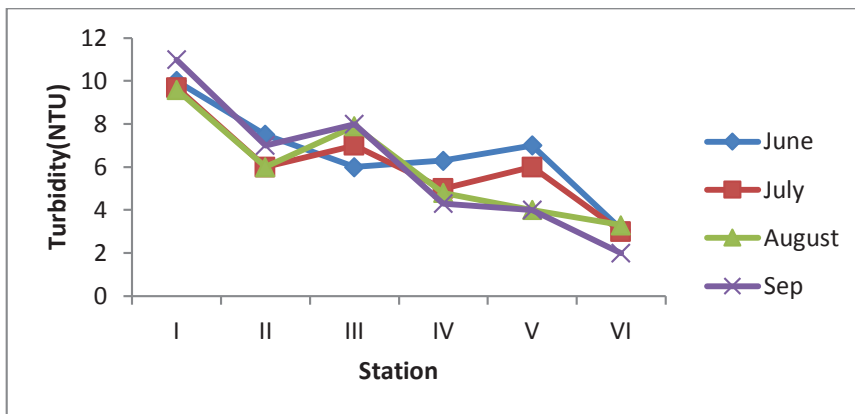
**Fig.2.2.d. Annual mean of seawater pH**

### 2.3.3 Turbidity

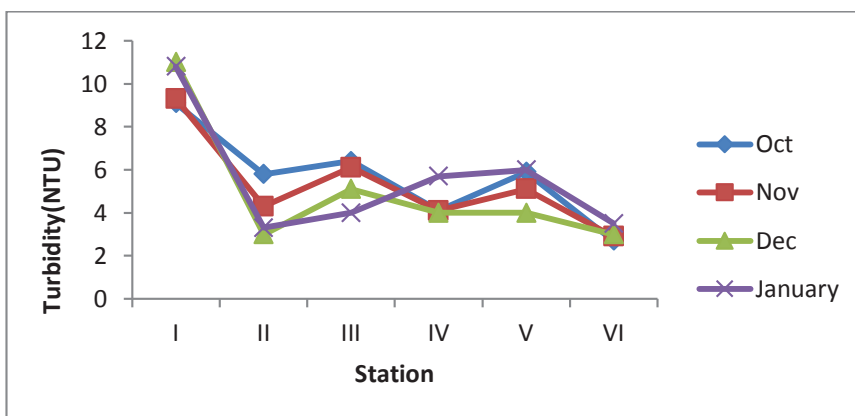
The turbidity of seawater samples during the period of study were presented in **Table 2.3** and its longitudinal variations and annual mean were graphically depicted in **Fig 2.3.a-d**.

**Table 2.3. Longitudinal variations of seawater Turbidity (NTU)**

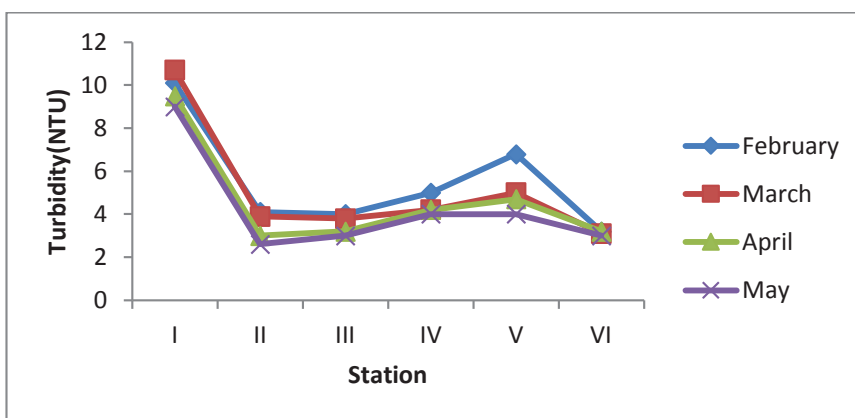
| Station | June | July | Aug | Sep  | Oct | Nov | Dec  | Jan  | Feb  | Mar  | April | May | Mean |
|---------|------|------|-----|------|-----|-----|------|------|------|------|-------|-----|------|
| I       | 10   | 9.7  | 9.6 | 11   | 9.1 | 9.3 | 11   | 10.8 | 10.1 | 10.7 | 9.5   | 9   | 9.9  |
| II      | 7.5  | 6    | 6   | 7    | 5.8 | 4.3 | 3    | 3.3  | 4.1  | 3.9  | 3     | 2.6 | 4.7  |
| III     | 6    | 7    | 7.9 | 8    | 6.4 | 6.1 | 5.1  | 4    | 4    | 3.8  | 3.2   | 3   | 5.3  |
| IV      | 6.3  | 5    | 4.8 | 4.3  | 4.1 | 4.1 | 4    | 5.7  | 5    | 4.2  | 4.2   | 4   | 4.6  |
| V       | 7    | 6    | 4   | 4    | 5.9 | 5.1 | 4    | 6    | 6.8  | 5    | 4.7   | 4   | 5.2  |
| VI      | 3.1  | 3    | 3.3 | 2    | 2.7 | 2.9 | 3    | 3.5  | 3.2  | 3.1  | 3.2   | 3   | 3    |
| Mean    | 6.6  | 6.1  | 5.9 | 6.05 | 5.6 | 5.3 | 5.01 | 5.5  | 5.5  | 5.1  | 4.6   | 4.2 |      |



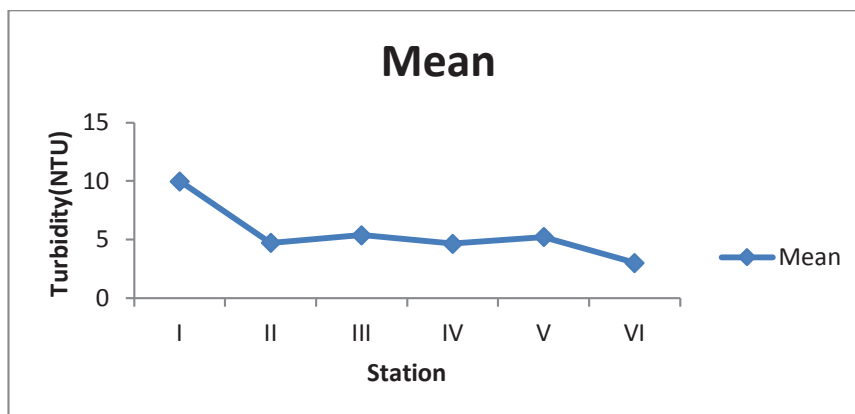
**Fig.2.3.a. Longitudinal variations of seawater Turbidity**



**Fig.2.3.b. Longitudinal variations of seawater Turbidity**



**Fig.2.3.c. Longitudinal variations of seawater Turbidity**



**Fig.2.3.d. Annual mean of seawater Turbidity**

The turbidity of seawater sample at station I ranged between 9NTU (May, 2015) to 11 NTU (September, 2014 and December, 2014). In station II it varied from 2.6 NTU (May, 2015) to 7.5 NTU (June, 2014) whereas in station III it ranged between 3 NTU (May, 2015 and 8 NTU (September, 2014). At station IV it was from 4 NTU (December, 2014 and May, 2015) to 6.3 NTU (June, 2015). In station V turbidity ranged between 4 NTU (August, September, December, 2014 and May, 2015) and 7 (June, 2014) whereas in station VI 2NTU (September, 2014) to 3.5NTU (January, 2015).

Turbidity was maximum in station I in all the months and reaches maximum in September and December, 2014. Minimum turbidity was noticed in station VI in September, 2014 and next in station II in May, 2015. Station VI experiences lowest turbidity in all months. A moderate turbidity was noticed in station II, III, IV and V in all months. Minimum turbidity was noticed in the month of May, 2015 in all stations except Station VI. Similarly maximum turbidity was recorded in stations II, IV and V in the month of June, 2014.

### 2.3.4 Electrical Conductivity

The results of electrical conductivity of seawater samples during the period of study were presented in **Table 2.4.** and its longitudinal variations and annual mean were graphically depicted in **Fig 2.4.a-d.**

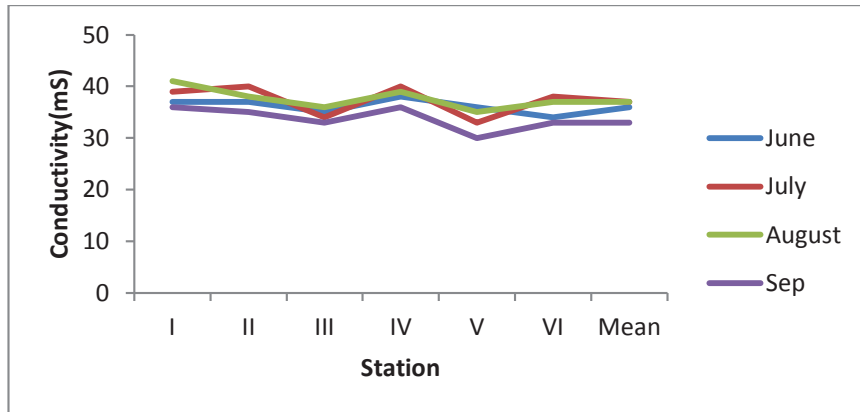
**Table-2.4. Longitudinal variations of Conductivity of seawater (mS)**

| Station | June | July | Aug | Sep | Oct | Nov | Dec  | Jan | Feb | Mar  | April | May | Mean |
|---------|------|------|-----|-----|-----|-----|------|-----|-----|------|-------|-----|------|
| I       | 37   | 39   | 41  | 36  | 40  | 42  | 44   | 45  | 47  | 47   | 48    | 51  | 43   |
| II      | 37   | 40   | 38  | 35  | 39  | 40  | 41   | 41  | 45  | 47   | 47    | 49  | 41   |
| III     | 35   | 34   | 36  | 33  | 36  | 40  | 42   | 40  | 43  | 44   | 48    | 50  | 40   |
| IV      | 38   | 40   | 39  | 36  | 37  | 39  | 41   | 42  | 42  | 43   | 43    | 50  | 40   |
| V       | 36   | 33   | 35  | 30  | 42  | 42  | 44   | 41  | 43  | 44   | 44    | 46  | 40   |
| VI      | 34   | 38   | 37  | 33  | 38  | 41  | 43   | 39  | 38  | 42   | 47    | 48  | 39   |
| Mean    | 36   | 37   | 37  | 34  | 38  | 40  | 42.5 | 41  | 43  | 44.5 | 46    | 49  |      |

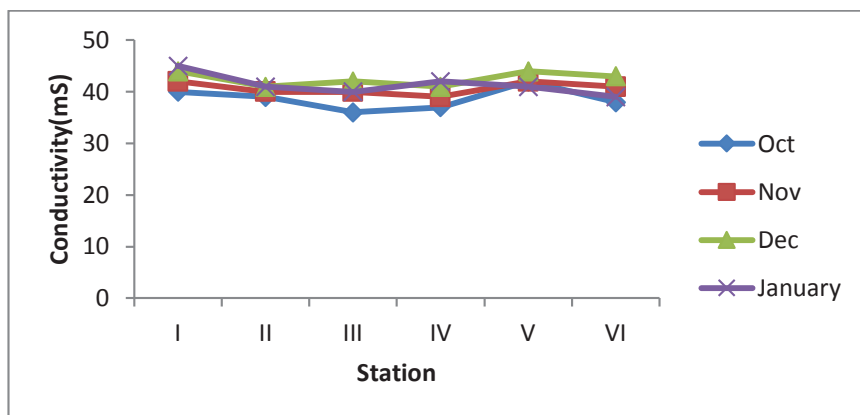
The electrical conductivity of water samples at station I varied between 36mS (September, 2014) and 51mS (May, 2015) whereas at station II it varied from 35mS (September, 2014) to 49mS (May, 2015). At station III it ranged from 33mS (September, 2014) to 50mS (May, 2015). At station IV it ranged between 36mS (September, 2014) to 50mS (May, 2015). At station V it varied from 30mS (September,

2014) to 46mS (May, 2015) whereas at station VI it was from 33mS (September, 2014) to 48mS (May, 2015).

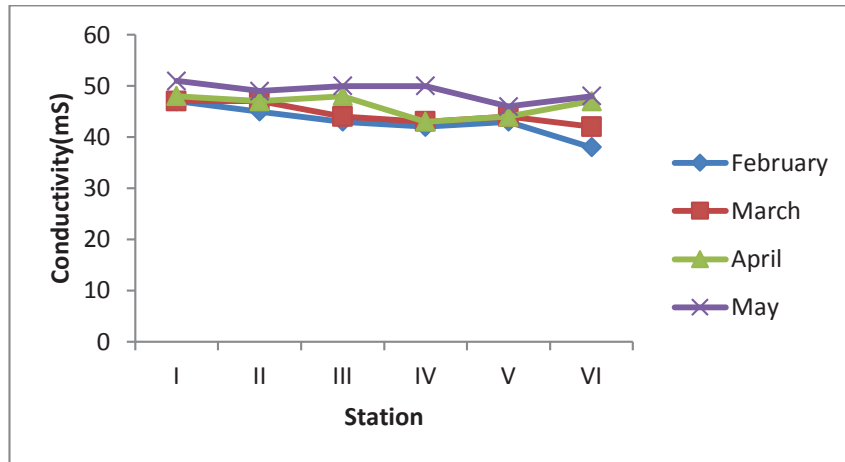
In all the stations minimum electrical conductivity was recorded during the month of September, 2014. Among the six stations the minimum electrical conductivity of 30mS was recorded in station V followed by 33mS in station III and VI in September, 2014. Maximum electrical conductivity was noticed in all stations in May, 2015. In the present study the highest electrical conductivity of 51mS was noticed in station I in May, 2015 followed by 50mS in station III and IV.



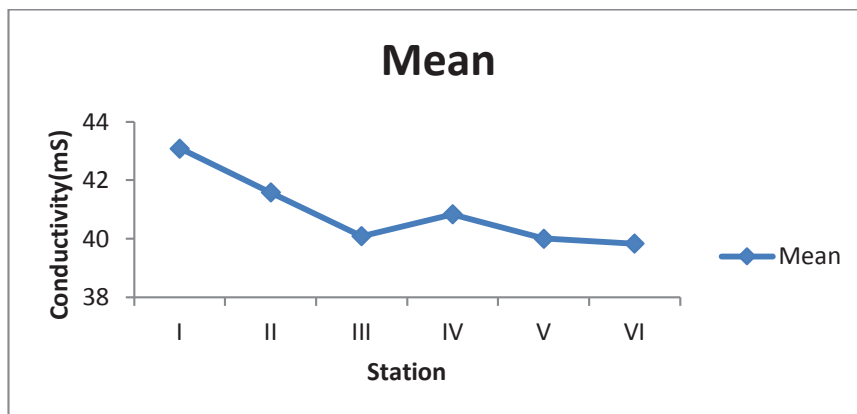
**Fig.2.4.a. Longitudinal variations of conductivity of seawater**



**Fig.2.4.b. Longitudinal variations of conductivity of seawater**



**Fig.2.4.c. Longitudinal variations of conductivity of seawater**



**Fig.2.4.d. Annual mean of conductivity of seawater**

### 2.3.5 Total Dissolved Solids

The results of TDS of seawater samples during the present study period were presented in the **Table 2.5.** and its longitudinal variations and annual mean were graphically plotted in **Fig. 2.5.a-d.**



**Table-2.5. Longitudinal variations of Total dissolved solids of seawater (g/l)**

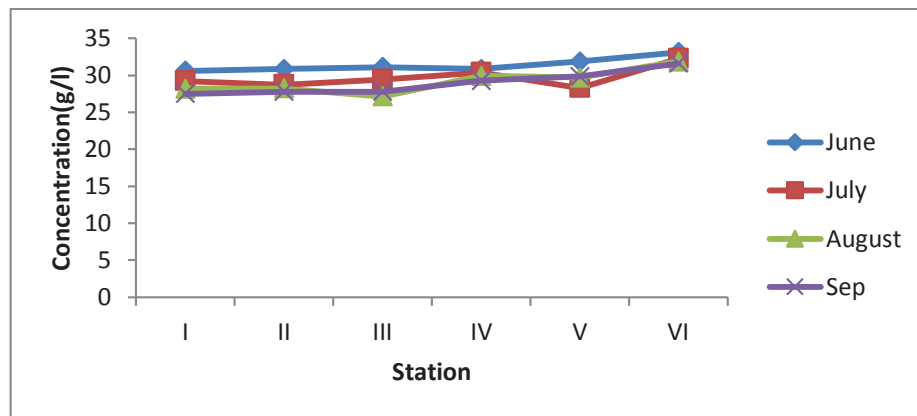
| Station | June | July | Aug  | Sep  | Oct  | Nov  | Dec  | Jan  | Feb  | Mar  | Apr  | May  | Mean |
|---------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| I       | 30.5 | 29.2 | 28.1 | 27.4 | 27.2 | 25.0 | 24.5 | 24.7 | 27.8 | 27.4 | 30.7 | 33.4 | 28.0 |
| II      | 30.8 | 28.7 | 28.2 | 27.7 | 26.5 | 26.3 | 24.8 | 25.1 | 27.8 | 27.9 | 29   | 30.5 | 27.8 |
| III     | 31.1 | 29.4 | 27.1 | 27.7 | 28.8 | 27.1 | 26.6 | 26.9 | 29.5 | 30   | 31.5 | 32   | 29.0 |
| IV      | 30.8 | 30.3 | 29.9 | 29.2 | 27.2 | 26.2 | 24.3 | 25   | 26.8 | 29.9 | 30.0 | 31.7 | 28.4 |
| V       | 31.8 | 28.2 | 29.6 | 29.8 | 29.0 | 26.9 | 25.4 | 27.8 | 28.1 | 28.7 | 28   | 29.6 | 28.6 |
| VI      | 33.1 | 32.2 | 31.8 | 31.6 | 30   | 30.1 | 29.5 | 31.6 | 30.4 | 32.0 | 32.7 | 33.7 | 31.6 |
| Mean    | 31.3 | 29.7 | 29.1 | 28.9 | 28.1 | 26.9 | 25.9 | 26.8 | 28.4 | 29.3 | 30.3 | 31.8 |      |

The TDS of water sample at station I ranged between 24.5g/l (December, 2014) and 33.4g/l (May, 2015) whereas at station II it was from 24.8g/l (December, 2014) to 30.8g/l (June, 2014). In station III it varied from 26.6g/l (December, 2014) to 32.0g/l (May, 2015) and at station IV it ranged from 24.3g/l (December, 2014) to 31.7g/l (May, 2015). In station V it varied between 25.4g/l (December, 2014) and 31.8g/l (June, 2014) whereas in station VI it was from 29.5g/l (December, 2014) to 33.7g/l (May, 2015).

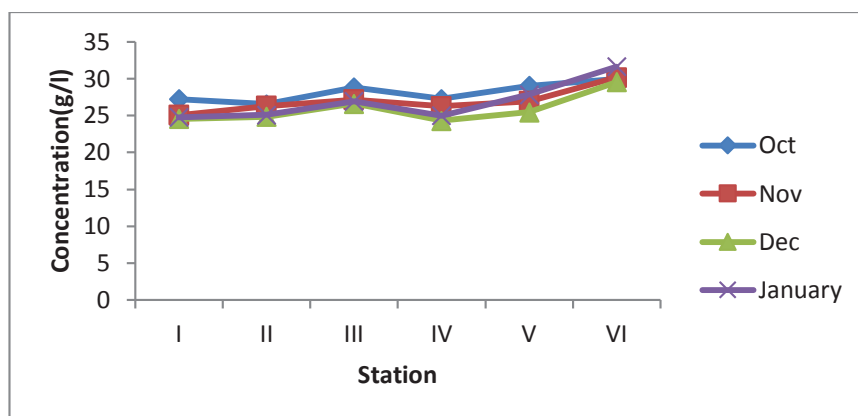
Minimum TDS was noticed in all stations in December, 2014 with least value of 24.3g/l in station IV. In December, 2014 the TDS value in all stations ranged between 24.3g/l to 29.5g/l. Maximum TDS was observed in all stations during the month of

May, 2015 with the highest TDS (33.7g/l) at station VI. In most of the stations moderate TDS was reported.

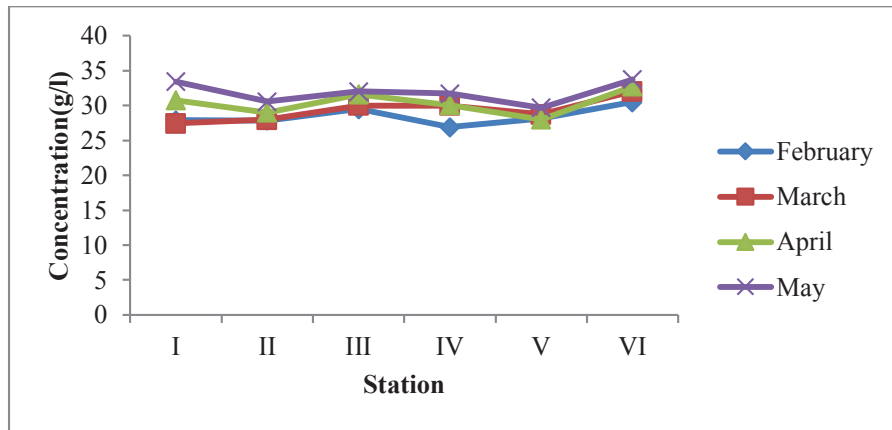
Total dissolved solids did not show any statistically significant spatial and temporal variations between the coasts under study. Among the six coasts, station VI shows maximum TDS in all months.



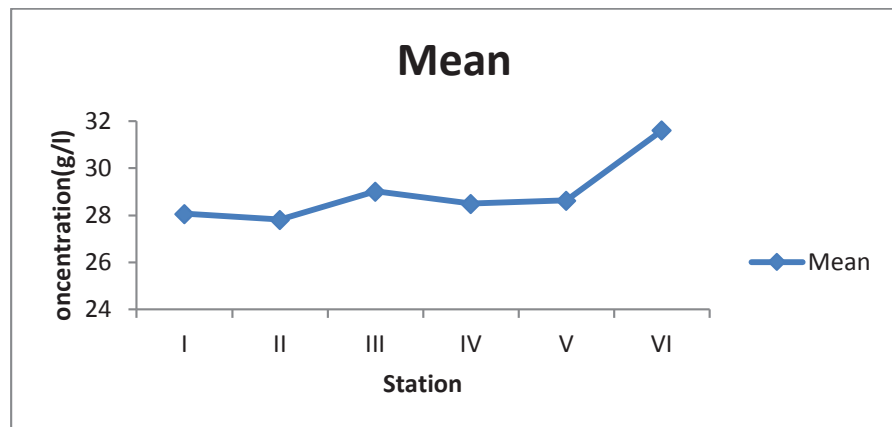
**Fig.2.5.a. Longitudinal variations of total dissolved solids of seawater**



**Fig.2.5.b. Longitudinal variations of total dissolved solids of seawater**



**Fig.2.5.c. Longitudinal variations of total dissolved solids of seawater**



**Fig.2.5.d. Annual mean of total dissolved solids of seawater**

### 2.3.6 Dissolved Oxygen

The data obtained for dissolved oxygen during the period of study was presented in **Table.2.6** and its longitudinal variations and annual mean were graphically represented in **Fig. 2.6.a-d**.

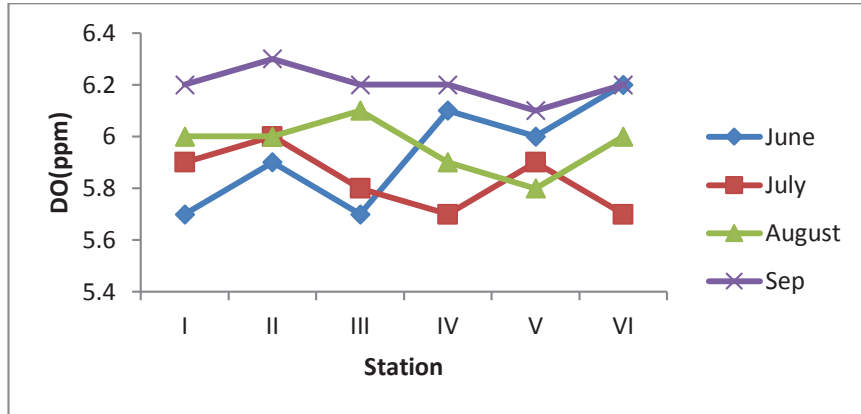
The dissolved oxygen content of seawater sample at station I was ranged between 5.4ppm (May, 2015) and 6.3ppm (December, 2014) whereas at station II it was

from 5.2ppm (May, 2015) to 6.3ppm (September, 2014). At station III, DO varied from 5.2ppm (May, 2015) to 6.2ppm (September, 2014) and at station IV it was between 5.3ppm (May, 2015) to 6.2ppm (September, 2014). At station V, it ranged from 5.1ppm (May, 2015) to 6.1ppm (September, 2014) whereas at station VI it was between 5.2ppm (May, 2015) to 6.2ppm (June and September, 2014).

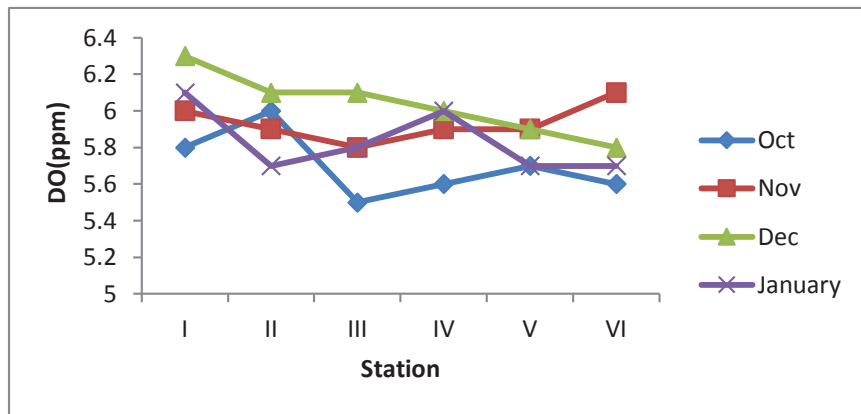
**Table-2.6. Longitudinal variations of dissolved oxygen of seawater (ppm)**

| Station | June | July | Aug | Sep | Oct | Nov | Dec  | Jan | Feb | Mar | April | May | Mean |
|---------|------|------|-----|-----|-----|-----|------|-----|-----|-----|-------|-----|------|
| I       | 5.7  | 5.9  | 6   | 6.2 | 5.8 | 6   | 6.3  | 6.1 | 6.1 | 5.8 | 5.5   | 5.4 | 5.9  |
| II      | 5.9  | 6    | 6   | 6.3 | 6   | 5.9 | 6.1  | 5.7 | 5.7 | 5.6 | 5.4   | 5.2 | 5.8  |
| III     | 5.7  | 5.8  | 6.1 | 6.2 | 5.5 | 5.8 | 6.1  | 5.8 | 5.6 | 5.4 | 5.4   | 5.2 | 5.7  |
| IV      | 6.1  | 5.7  | 5.9 | 6.2 | 5.6 | 5.9 | 6    | 6   | 5.9 | 5.6 | 5.5   | 5.3 | 5.8  |
| V       | 6    | 5.9  | 5.8 | 6.1 | 5.7 | 5.9 | 5.9  | 5.7 | 5.5 | 5.5 | 5.3   | 5.1 | 5.7  |
| VI      | 6.2  | 5.7  | 6   | 6.2 | 5.6 | 6.1 | 5.8  | 5.7 | 5.6 | 5.5 | 5.5   | 5.2 | 5.7  |
| Mean    | 5.9  | 5.8  | 5.9 | 6.2 | 5.7 | 5.9 | 6.03 | 5.8 | 5.7 | 5.5 | 5.4   | 5.2 |      |

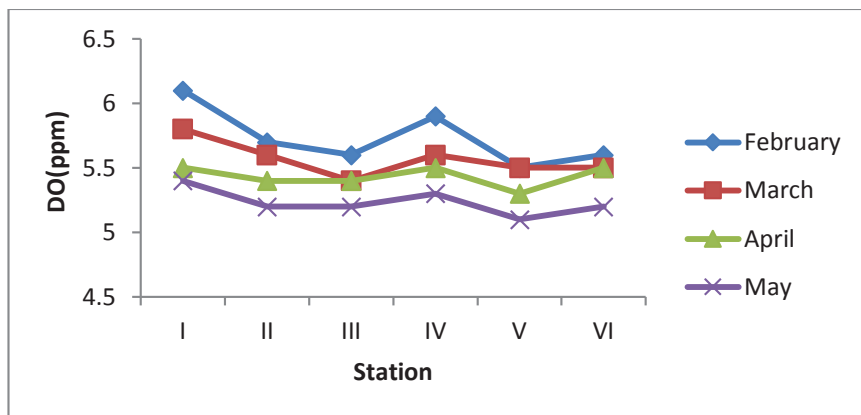
Minimum DO was observed in all stations under study during May 2015 with values ranged from 5.1ppm to 5.4ppm. The lowest DO was noticed in station V during May, 2015. Maximum DO was recorded during the month of September in all stations except station I where maximum DO was observed during the month of December. The highest DO of 6.3ppm was observed in station I in December, 2014 and station II in September, 2014.



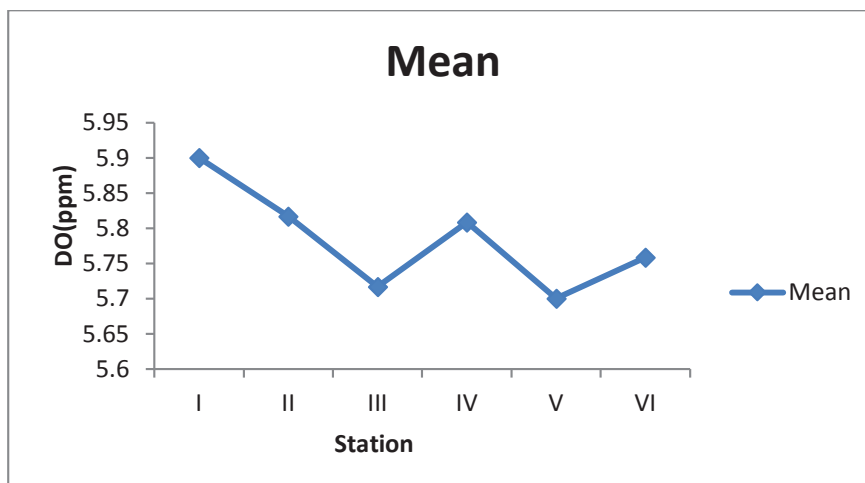
**Fig.2.6.a. Longitudinal variations of Dissolved oxygen (ppm) of seawater**



**Fig.2.6.b. Longitudinal variations of Dissolved oxygen (ppm) of seawater**



**Fig.2.6.c. Longitudinal variations of Dissolved oxygen (ppm) of seawater**



**Fig.2.6.d. Annual mean of Dissolved oxygen (ppm) of seawater**

### 2.3.7 Biological Oxygen Demand

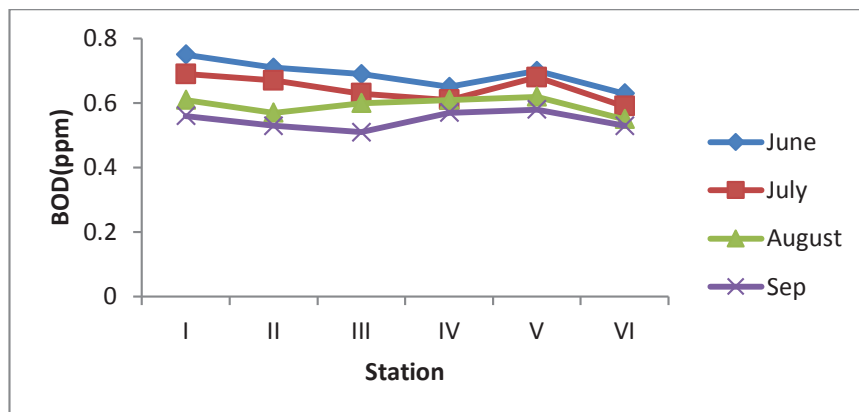
The data obtained for biological oxygen demand during the period of study were presented in **Table.2.7** and its longitudinal variations and annual mean were graphically represented in **Fig. 2.7.a-d**.

The biological oxygen demand recorded at station I ranged between 0.56ppm (September, 2014) and 0.89ppm (May, 2015) whereas at station II it was from 0.53ppm (September, 2014) and 0.74ppm (May, 2015). At station III it was from 0.51ppm (September, 2014) to 0.7ppm (May, 2015) and at station IV it was from 0.52ppm (October, 2014) to 0.71ppm (May, 2015). At station V it ranged between 0.54ppm (October, 2014) and 0.7ppm (June, 2014) whereas at station VI it was between 0.53ppm during both September and December, 2014 and 0.69ppm in May, 2015.

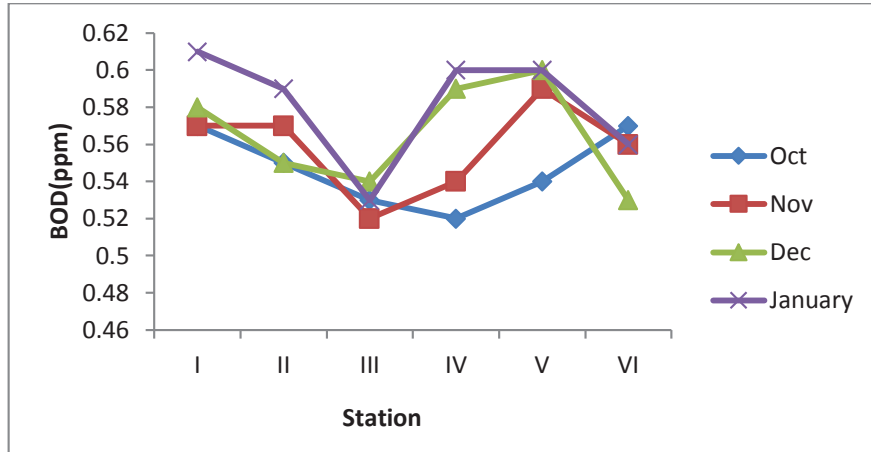
The lowest BOD value of 0.51ppm was noticed at station III during the month of September, 2014 and the highest BOD of 0.89ppm was recorded at station I in May, 2015.

**Table-2.7. Longitudinal variations of BOD of seawater (ppm)**

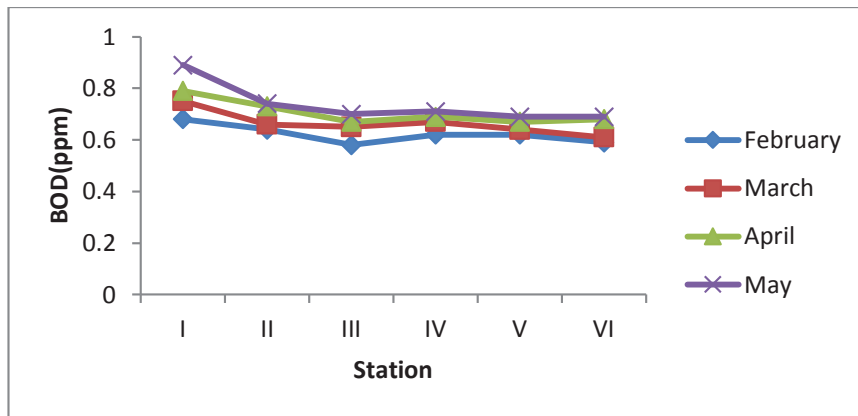
| Station | June | July | Aug  | Sep  | Oct  | Nov  | Dec  | Jan  | Feb  | Mar  | April | May  | Mean |
|---------|------|------|------|------|------|------|------|------|------|------|-------|------|------|
| I       | 0.75 | 0.69 | 0.61 | 0.56 | 0.57 | 0.57 | 0.58 | 0.61 | 0.68 | 0.75 | 0.79  | 0.89 | 0.67 |
| II      | 0.71 | 0.67 | 0.57 | 0.53 | 0.55 | 0.57 | 0.55 | 0.59 | 0.64 | 0.66 | 0.73  | 0.74 | 0.62 |
| III     | 0.69 | 0.63 | 0.6  | 0.51 | 0.53 | 0.52 | 0.54 | 0.53 | 0.58 | 0.65 | 0.67  | 0.7  | 0.59 |
| IV      | 0.65 | 0.61 | 0.61 | 0.57 | 0.52 | 0.54 | 0.59 | 0.6  | 0.62 | 0.67 | 0.69  | 0.71 | 0.61 |
| V       | 0.7  | 0.68 | 0.62 | 0.58 | 0.54 | 0.59 | 0.6  | 0.6  | 0.62 | 0.64 | 0.67  | 0.69 | 0.62 |
| VI      | 0.63 | 0.59 | 0.55 | 0.53 | 0.57 | 0.56 | 0.53 | 0.56 | 0.59 | 0.61 | 0.68  | 0.69 | 0.59 |
| Mean    | 0.68 | 0.64 | 0.59 | 0.54 | 0.54 | 0.55 | 0.56 | 0.58 | 0.62 | 0.66 | 0.71  | 0.73 |      |



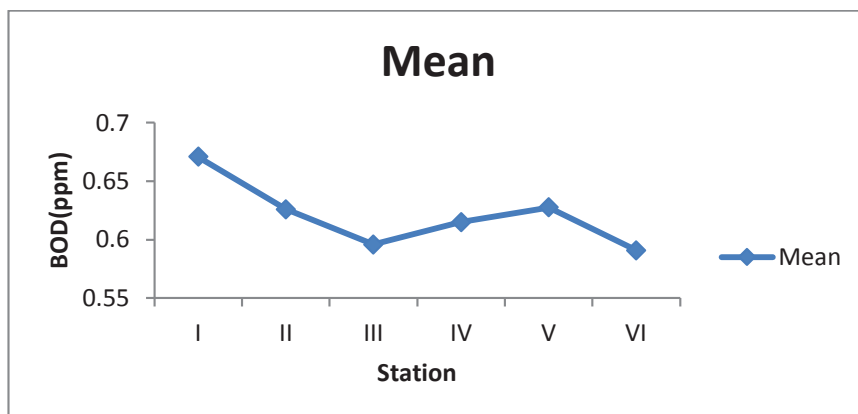
**Fig.2.7.a. Longitudinal variations of BOD (ppm) of seawater**



**Fig.2.7.b. Longitudinal variations of BOD (ppm) of seawater**



**Fig.2.7.c. Longitudinal variations of BOD (ppm) of seawater**



**Fig.2.7.d. Annual mean of BOD (ppm) of seawater**



Low BOD was observed in the months of September, October, November and December in all stations. Maximum BOD was noticed in May, 2015 and April, 2015 and next in June, 2014 in all stations. In the present study period BOD value varied between 0.51ppm to 0.89ppm.

### 2.3.8 Total Alkalinity

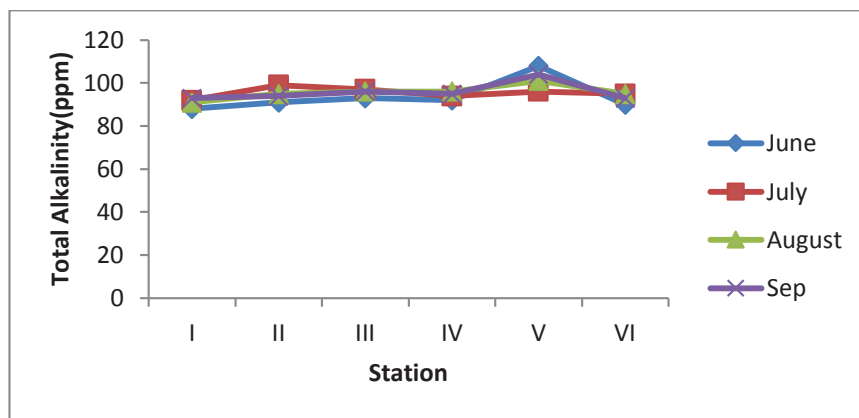
The results of total alkalinity of seawater samples during the period of study were presented in **Table.2.8** and its longitudinal variations and annual mean were graphically represented in **Fig 2.8.a-d**.

**Table-2.8. Longitudinal variations of Total Alkalinity of seawater (ppm)**

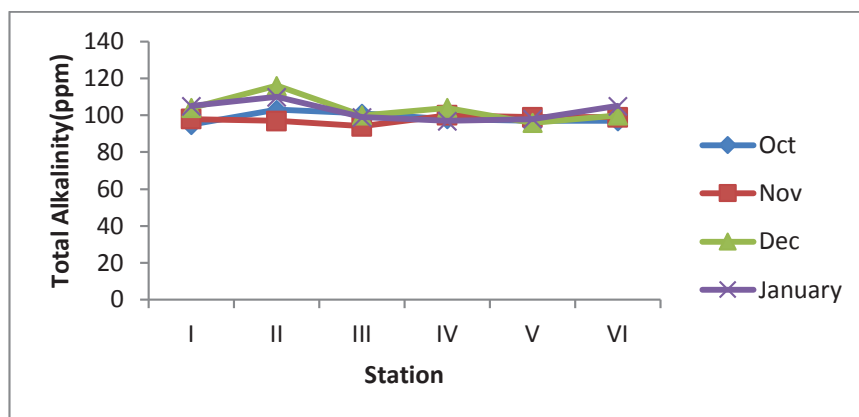
| Station | June | July | Aug  | Sep  | Oct  | Nov  | Dec   | Jan   | Feb   | Mar   | April | May   | Mean   |
|---------|------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|--------|
| I       | 88   | 92   | 91   | 93   | 95   | 98   | 104   | 105   | 107   | 107   | 109   | 112   | 100.08 |
| II      | 91   | 99   | 95   | 94   | 103  | 97   | 116   | 110   | 106   | 102   | 104   | 100   | 101.4  |
| III     | 93   | 97   | 96   | 96   | 101  | 94   | 100   | 99    | 104   | 107   | 105   | 108   | 100    |
| IV      | 92   | 94   | 96   | 95   | 98   | 100  | 104   | 97    | 98    | 100   | 103   | 104   | 98.4   |
| V       | 108  | 96   | 101  | 104  | 97   | 99   | 95    | 98    | 102   | 99    | 99    | 96    | 99.5   |
| VI      | 90   | 95   | 95   | 93   | 97   | 99   | 100   | 105   | 103   | 107   | 110   | 112   | 100.5  |
| Mean    | 93.6 | 95.5 | 95.6 | 95.8 | 98.5 | 97.8 | 103.3 | 102.3 | 103.3 | 103.6 | 105   | 105.3 |        |

The total alkalinity recorded at station I ranged between 88ppm (June,2014) and 112ppm (May, 2015) whereas at station II it was from 91ppm (June,2014) to 116ppm

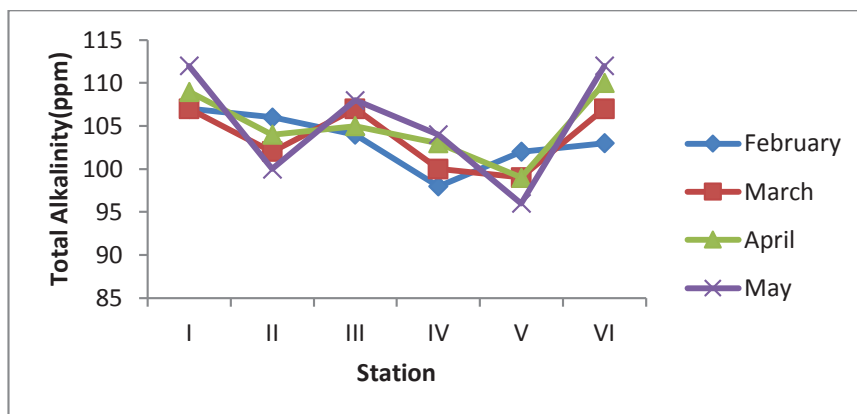
(December, 2014). At station III the value varied from 93ppm (June,2014) to 108ppm (May, 2015) and station IV it was from 92ppm (June,2014) and 104ppm (December, 2014 and May, 2015). At station V the value ranged between 95ppm (December, 2014) and 108ppm (June, 2014) whereas at station VI it varied between 90ppm (June,2014) and 112ppm (May, 2015).



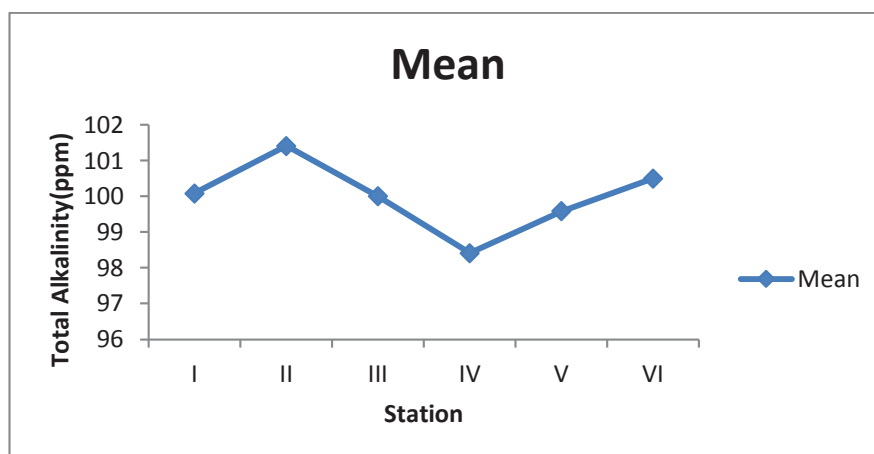
**Fig.2.8.a. Longitudinal variations of Total Alkalinity (ppm) of seawater**



**Fig.2.8.b. Longitudinal variations of Total Alkalinity (ppm) of seawater**



**Fig.2.8.c. Longitudinal variations of Total Alkalinity (ppm) of seawater**



**Fig.2.8.d. Annual mean of Total Alkalinity (ppm) of seawater**

During the present study period the value varied from 88ppm to 116ppm. The lowest value of 88ppm was recorded at station I in June, 2014 and the highest value of 116ppm was recorded from station II in December, 2014.

Minimum total alkalinity was noticed in June,2014 in all stations except station V. Maximum total alkalinity was observed in May, 2015 in all stations except station II and V. In station V, a different statistically significant variation was noted.

## 2.4 DISCUSSION

The physico-chemical characteristics of an ecosystem are highly influenced by various factors. Among these, one of the important factors is the surface runoff which particularly alters the characteristics of an ecosystem.

The area of the present study is located at the southern tip of the west coast of India which experiences both the north east monsoon and the south west monsoon. During winter minimum sea surface temperatures (SST) of about 24 to 25°C (Honjo and Weller, 1997) in the Arabian Sea (NE monsoon) while SST increases southward exceeding 27.5°C to reach its maximum 28°C around 10°N as a result of southward flow (Lee et al, 2000). It is the simplest physical measurement shows more significant variations seasonally than spatially.

The lowest temperature of 21.2°C was recorded in station I in December, 2014 and in other stations it varied between 21.2°C to 22.7°C. Similar observations have been reported by Thangaraj, 1985; Gothandaraman, 1993; Seenivasan, 1998; Mani, 1989; Vasantha, 1989; Kaliyaperumal, 1992; Karuppusamy, 1997 and Saraswati, 1993.

The maximum surface water temperature of 28.1°C was recorded at station IV in May. Also a uniform distribution of high temperature was recorded during April and May, 2015 in most of the stations which coincided with atmospheric maximum which agrees with the observation of Kalaiarasi et al, (2012) and Paldor and Anati, (1979). Solar radiation, tidal currents, incidence of upwelled waters and atmospheric variations were the reasons for the temperature variations (Kannan and Kannan, 1996; Alvarez Borrego and Alvarez Borrego, 1982; Satpathy and Nair, 1990; Richardson et al, 2000).

The range of pH expected for normal seawater is from 8.0 to 8.30 and that for coastal waters is from 7.9 to 8.2. pH remained alkaline throughout the study period. In the present study the highest pH value of 8.9 was recorded at station II during September, 2014. The higher pH values observed suggest that carbon dioxide, carbonate-bicarbonate equilibrium is affected more (Karanth, 1987). High pH was recorded during summer seasons, which might be due to the high biological activity (Das et al, 1997).

The minimum pH of 7.6 was noticed in station V in June, 2014 which agrees with Pazhanisamy, 2014. Monsoon season recorded low pH values while summer and pre monsoon recorded high pH values (James Balgan Anand, 2015). Generally, fluctuation in pH values during different seasons of the year is attributed to factors like removal of CO<sub>2</sub>, dilution of seawater, low primary productivity, reduction of salinity and temperature and decomposition of organic materials (Rajasegar et al, 2002).

Turbidity is a measure of water clarity and how much the material suspended in water decreases the passage of light through water. Turbidity was maximum at river mouth due to the movement of water in and out of the estuary by tidal influence. Turbidity values varied from 2 to 16 NTU. Least amount of turbidity indicates bright sunshine, clear water condition, removal of suspended materials, thereby reducing turbidity (Anitha et al, 2013).

High turbidity value may be due to fresh water discharges and low solar radiation (Kalaiarasi et al, 2012). Turbidity was maximum in station I in all months and reaches maximum in September and December, 2014. Maximum turbidity observed in monsoon and postmonsoon seasons is possibly due to rain water runoff during

southwest monsoon season prevailing in this area (Misra et al, 2005). Land runoff, silt, organic matter, and other microscopic organisms increase the turbidity of the water (Kishore et al, 2005).

In station I, higher values of turbidity in all months which may be due to higher human interference in this place which is maximum in December. In station I turbidity is maximum in monsoon too possibly due to rainwater runoff during south west monsoon prevailing in this area. Bathusha and Saseetharan, (2007), Garg et al, (2006), Prasad and Patil, (2008), Saravanakumar et al, (2008) and Upadhyay et al, (2010) have also observed high turbidity during monsoon season. Minimum turbidity was noticed in the month of May. Similar observations were made by Jothivel and Paul, (2014).

Conductivity is the ability of water to conduct an electric current and the dissolved ions are the conductors. Conductivity of seawater is due to ionizable ions. Seawater's conductivity is one million times higher than that of deionized water.

In the present study maximum conductivity (51mS) at station I was recorded during summer season especially in the month of May and minimum conductivity (30mS) at station V was recorded during the post monsoon season particularly in the month of September, 2014. The reverse was reported by Jothivel and Paul, (2014).

Conductivity prevailing minimum in post monsoon season and next in monsoon season may be due to rain water runoff which decreases conductivity. Similar observations were made by Hallale et al, (2012) who stated that evaporation of water, lack of dilution and presence of high dissolved salt content in water are the reasons for higher value (Badge et al, 1985).

Kumara Vijaya et al, (2002) and Gupta et al, (2009) pointed out that the maximum electrical conductivity was because of the manifestation of dissolved salts. This was supported by Abdulla and Musta, (1999). It is also an indicator of pollution which shows the presence of more inorganic ions in the effluent discharges received by the water body (Dar et al, 2012).

Total dissolved solids (TDS) combine the sum of all ion particles that are smaller than 2 microns (0.0002 cm). Total dissolved solids (TDS) is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular suspended form. In waste water or polluted areas, TDS can include both organic solutes as well as the salt ions (Thompson, 2006). TDS is directly related to the amount of pollution (Singh and Singh, 1990).

According to Water Quality Association, TDS value for seawater is 30,000-40,000 ppm. Minimum TDS was noticed in all stations in December, 2014 with the least value of 24.32g/l in station IV. Maximum TDS was observed in all stations during the month of May, 2015 with the highest TDS (33.74g/l) and next in June, 2014. TDS was comparatively more during the months of April to June which might be due to evaporation of water and low rainfall (Soundarapandian, 2009). Higher TDS values were observed during summer months (Madhura Mukadam, 2015). Similar observations were made by Jothivel and Paul (2014) and Ramalingam Manikannan, (2011).

However, irrespective of the diluting effect, the rain runoff may be bringing in large amounts of various pollutants that would have otherwise remained in the adjoining land areas. Higher TDS is reported in Station I in April and May, 2015 where human

interference at the coastline is high because it is an international tourist centre. However TDS did not show any significant variations between the coasts and well within the acceptable range.

DO is one of the most important parameter. In the present study, dissolved oxygen content varied from 5.1 to 6.3. Minimum DO was observed in all stations under study during May 2015 with values ranging from 5.1ppm to 5.4ppm. Maximum DO was recorded during the month of September. Jothivel and Paul, (2014), Sundaramanickam et al, (2008) and James Balgan Anand et al, (2015) agreed with the present findings.

Higher range of DO might be due to the influence of fresh water flow (Madhura Mukadam, 2015). In contrast, according to Krishnamurthy R, (1990), the high DO in summer is due to high temperature and bright sunlight which accelerates photosynthesis by phytoplankton, utilizing CO<sub>2</sub> and giving off oxygen. The observed DO was above 5mg/l which was also reported earlier in the Arabian sea (Raghunathan et al, 2004). The DO was lower during summer when the temperature was high and maximum during postmonsoon and winter when the temperature was low and high tidal activity due to windy monsoon conditions (Faragallah et al, 2009).

The inverse relationship between temperature and DO is a natural process (Sheathe et al, 2007) which coincides with the present study. Dissolved oxygen concentration varies due to photosynthesis and respiration by aquatic organisms (Hetal Parekh and I. R. Gadhvi, 2015). Minimum value recorded at station V coast might be due to the disposal of domestic sewage and coconut husk retting wastes through Pampar estuary. At higher temperature the capacity of water to hold oxygen decreases



(Murugesan and Rajakumari, 2005) and this might also have contributed to the reduced oxygen content during the summer season which also agrees with the present report. Dissolved oxygen concentration calculated in the monsoon season may be due to heavy rainfall and freshwater mixing (Ramaraju et al, 1987; Zingde et al, 1985; Mitra et al, 1990; Nandan and Abdul Azis, 1993 and Rajasegar, 2002).

Biological oxygen demand denotes the content of micro organisms present in the water and its organic matter load. It gives negative correlation with DO (Anitha et al, 2013). Maximum BOD was noticed in May, 2015 and April, 2015 and next in June, 2014 in all the stations. In the present study period, BOD value varied between 0.51ppm to 0.89ppm. Minimum value was recorded during postmonsoon and winter months (especially September, 2014) in station III and maximum during summer season (especially May, 2015) in station I where DO is minimum in that season. Similar observations were made by Ahmed Salah Abdelmongy and Khalid Mohamed El-Moselhy, (2015). They stated that the highest levels during summer were due to the effect of warm temperature on account and activity of water content of microorganisms. Subramanian and Mahadevan, (1999) also agrees with the present findings.

Low BOD was observed in the months of September, October, November and December in all stations. Kathiravan et al, (2014) pointed out a negative correlation between BOD and DO during summer and high BOD with low DO is observed during summer, due to activity of tourism in addition to the domestic pollution. Ghavzan et al, (2006) noted that the maximum values are due to the maximum biological activity at elevated temperature and reduced flow of water. According to Martin, (1970) waters with BOD less than  $3.0 \text{ mg l}^{-1}$  are known to have received less pollution discharges.

Overall BOD level is below 1ppm which indicates less amount of biodegradable pollutants in these coasts.

Total alkalinity is composed primarily of carbonate, bicarbonate and hydroxide in water. It represents the buffering capacity of water and its ability to resist changes on pH. The Arabian Sea, lie in the tropics where the largest changes of TA due to anthropogenic calcification changes. (Llyina et al, 2009; Schulz et al, 2009; Zondervan et al., 2001). Goyet et al, (1999) states that changes in marine calcification due to ocean acidification can lead to changes in TA, which is an indicator for the capacity of seawater to dissolve and hold CO<sub>2</sub>.

Brewer et al, (1986) pointed out that total alkalinity in the surface ocean is controlled mainly by freshwater influx. Lee et al, (2006) pointed out that larger amplitudes of the seasonal variability are observed in areas where fresh water inputs through rivers occurs. According to Millero et al, (1998) higher alkalinity values were reported in upwelling areas. In Kim et al, (2009) statement, formation and destruction of organic matter also affect surface total alkalinity.

During the present study period, the value varied from 88ppm to 116ppm. The lowest value of 88ppm was recorded at station I in June, 2014 and the highest value of 116ppm was recorded from station II in December, 2014. Minimum total alkalinity was noticed in June, 2014 in all stations except stationV. Maximum total alkalinity was observed in May, 2015 in most of the stations which agrees with Salma Kh. Elageed, (2010). Similar observations were recorded by Balakrishnan et al, 2015. According to Kitack Lee et al, (2006), larger amplitudes of seasonal variability are observed in areas where freshwater inputs through rivers. The present study agrees with the findings of

David J. Hydes and Susan E. Hartman, (2012) which states that higher concentration of total alkalinity during periods of low influx are likely to contribute in part to the observed change in total alkalinity between winter and summer.

## **2.5 CONCLUSIONS**

The west coast of India is environmentally highly sensitive when compared to east coast of India mainly due to the Arabian Sea. The area of the present study is located at the southern tip of the west coast of India which experiences both the north east monsoon and the south west monsoon. In general the physico-chemical parameters of coastal waters are highly influenced by monsoon rains. Analysis of my data sets revealed that the Arabian Sea does not exhibit a large-scale spatial variability. All the physico-chemical parameters showed clear seasonal patterns, and were typical to the tropical marine environment without any marked variation between the stations. pH remained alkaline throughout the study period. Relatively high levels of turbidity were observed in the surface layer of station I during the period of study. DO and BOD values calculated in these coasts indicate that they have received no significant pollution discharges and less amount of biodegradable pollutants present in these coasts. Also interestingly, it is noted that, a uniform electrical conductivity was observed in all the six stations. Station I coast has slightly higher degree of pollution due to pilgrimage and tourism in addition to the domestic pollution. The water quality of all the coastal stations was almost nearer to ideal conditions possibly due to less anthropogenic activities.

## REFERENCES

- 1) **Abdullah, Musta, 1999**, 'Histopathological lesions induced by copper sulphate and lead nitrate in the gills of fresh water fish', *Nandus nandus. J. Ecotoxicol. Environ. Monit.*, Vol.12 (2), p. 105-111.
- 2) **Ahmed Salah Abdelmongy, Khalid Mohamed El-Moselhy, 2015**, 'Seasonal Variations of the Physical and Chemical Properties of Seawater at the Northern Red Sea, Egypt', *Open journal of Ocean and Coastal Sciences*, 2(1).
- 3) **Alvarez Borrego J, Alvarez Borrego, 1982**, 'Temporal and spatial variability of temperature in coastal lagoons', *Cal. COFI Rep.*, XXIII, 188-197.
- 4) **Anitha G, Sugirtha P.Kumar, 2013**, 'Physicochemical characteristics of water and sediment in Thengapattanam estuary, southwest coastal zone, Tamilnadu, India', *International journal of environmental sciences*, Vol.4(3), p. 205-222.
- 5) **Badge US, Varma AK, 1985**, 'Physico chemical characteristics of water of JNU lake at New Delhi', *Indian J. Ecol.* Vol.12(1), p.151-156.
- 6) **Balakrishnan S, Chelladurai G, Mohanraj J, Poongodi J, 2015**, 'Seasonal variations in physico-chemical characteristics of Tuticorin coastal waters, southeast coast of India', *Applied Water Sci*, p. 1-6.
- 7) **Bathusha MI, Saseetharan MK, 2007**, 'Physico-chemical Characteristics and Correlation, and Regression Study on Ground Water of Coimbatore North Zone', *J. Environ. Sci. Eng*, Vol.49(3), p. 215- 224.
- 8) **Brewer PG, Bradshaw AL, Williams DRT, 1986**, 'Measurements of total carbon dioxide and alkalinity in the North Atlantic Ocean in 1981, in The Changing Carbon Cycle: A Global Analysis, edited by J. R. Trabalka and D. E. Reichle, Springer, New York p. 348 – 370.
- 9) **Dar AC, Das TK, Shokat KM, Cagan RL, 2012**, 'Chemical genetic discovery of targets and anti-targets for cancer polypharmacology', *Nature*, Vol.486(7401), p. 80--84.

- 10) **Das J, Das SN, Sahoo RK, 1997**, ‘Semidiurnal variation of some physicochemical parameters in the Mahanadi estuary, East coast of India’, *Ind. J. Mar. Sci.*, Vol.26, p.323-326.
- 11) **David J. Hydes, Susan E. Hartman, 2012**, ‘Seasonal and inter-annual variability in alkalinity in Liverpool Bay (53.5° N, 3.5° W) and in major river inputs to the North Sea’, *Ocean Dynamics*, Vol.62(2), p. 321-333.
- 12) **Department of Energy (DOE), 1998**, Hand Book of Methods for the Analysis of the Various Parameters of the Carbon Dioxide System in Seawater. (eds. A. G. Dickson and C. Goyet), Ver. 2.
- 13) **Faragallah HM, Askar AI, Okbah MA, Moustafa HM, 2009**, ‘Physico chemical characteristics of the open Mediterranean Sea water far about 60 km from Damietta harbor', Egypt’, *J.Ecol. The Nat.Envliron*, Vol.1(5), p. 106-119.
- 14) **Garg RK, Saksena DN, Rao RJ, 2006**, ‘Assessment of physicochemical water quality of Harsi Reservoir, District Gwalior, Madhya Pradesh’, *J. Ecophys. Occup. Health*, Vol.6, p. 33-40.
- 15) **Gothandaraman N, 1993**, ‘Studies on micro Zooplankton’, Ph.D.Thesis, Annamalai University, India, p. 180.
- 16) **Ghavzan NJ, Gunala VR, Trivedy RK, 2006**, ‘Immunological evaluation of an urban fresh water river with special reference to phytoplankton’, *Pollution research*, Vol.2, p. 259-268.
- 17) **Gnaiger E, Gluth G, Weiser W, 1978**, ‘pH fluctuations in an intertidal beach in Bennuda’, *Limnol. Oceanogr.* Vol.23, p. 851-857.
- 18) **Goyet C, Coatanoan C, Eischeid G, Amaoka T, Okuda K, Healy R, Tsunogai S, 1999**, ‘Spatial variation of total CO<sub>2</sub> and total alkalinity in the northern Indian Ocean: A novel approach for the quantification of anthropogenic CO<sub>2</sub> in seawater’, *Journal of Marine Research*, Vol.57 (1), p. 135–163.

- 19) **Grasshoff K, Ehrhardt M, Kremling K, 1983**, Methods of seawater analysis. (2nd Edn.), Verlag Chemie, Weinheim. 419.
- 20) **Gupta I, Dhage S, Rakesh Kumar, 2009**, ‘Study of variations in water quality of Mumbai coast through multivariate analysis techniques’, *Indian J.Mar.Sci*, Vol.38(2), p.170-177.
- 21) **Hallale SN, Allapure RB, 2012**, ‘Seasonal variation in physic chemical parameters of domestic sewage of Udgir, Maharashtra, India’, *International J pollution Research*, Vol.31(3), p. 401-402.
- 22) **Hetal Parekh, Gadhvi IR, 2015**, ‘Seasonal variation in physico-chemical parameter of seawater at Mithivirdi coast Bhavnagar -West coast of India’, *International Journal of Research in Engineering and Bioscience*, Vol.3( 1), p. 41-47.
- 23) **Honjo S, Weller R, 1997**, ‘Monsoon winds and carbon cycles in the Arabian Sea’, *Oceanus*, Vol.40, p. 24–28.
- 24) **James Balgan Anand D, Mary Jelastin Kala S, Vijaya Kumar P, 2015**, ‘Monthly Variations of Water Quality along South East Coast of India’, *International Journal of Geology, Agriculture and Environmental Sciences*, Vol.3(3), p. 10-15.
- 25) **Jothivel N, Paul VI, 2014**, ‘Comparative physico-chemical profiling of two coastal water bodies from south east coast of India with special reference to their pollution status’, *Int. J. Modn. Res. Revs.* Vol.2( 12), p. 544-553.
- 26) **Kalaiarasi M, Pau P, Lathasumathi C, Stella C, 2012**, ‘Seasonal Variations in the Physico-Chemical Characteristics of the Two Coastal Waters of Palk-Strait in Tamil Nadu, India’, *Global Journal of Environmental Research*, Vol. 6 (2), p. 66-74.
- 27) **Kaliyaperumal, C, 1992**, ‘Studies on the interrelationship between

phytoplankton and zooplankton in the waterways of the Pitchavaram Mangroves (India). Ph.D. Thesis. Annamalai University, India, p. 215.

- 28) **Kannan R, Kannan L, 1996**, 'Physicochemical characteristic of seaweed beds of the Palk bay. South East coast of India', *Indian J. Mar. Sci.*, Vol.25, p. 358-362.
- 29) **Karanth KR, 1987**, Ground water assessment development and management, Tata MaGraw Hill publishing company Ltd, New Delhi, p.725-726.
- 30) **Karuppasamy PK, 1997**, 'Studies on Zooplankton in the Pitchavaram Mangroves and laboratory culture of rotifer *Brachionus plicatilis*', M.Phil. Thesis, Annamalai University, India, P. 85.
- 31) **Kathiravan K, Natesan Usha, Vishnunath R, 2014**, 'Water Quality of Rameswaram Island, Southeast Coast of India – A Statistical Assessment', *International Research Journal of Environment Sciences*, Vol.3(10), p. 12-23.
- 32) **Kim HC, Lee K, 2009**, 'Significant contribution of dissolved organic matter to seawater alkalinity', *Geophys. Res. Lett*, Vol.36, L20603.
- 33) **Kishore K, Joshi B.D, Deepali K, 2005**, 'Physico-chemical characteristics of pond water at Kanpur village in Bareilly district (UP)', *Himalayan Journal of Environmental Zoology*, Vol.19, p. 89-92.
- 34) **Kitack Lee, Lan T Tong, Frank J. Millero, Christopher L. Sabine, Andrew G. Dickson, Catherine Goyet, Geun-Ha Park, Rik Wanninkhof, Richard A. Feely, Robert M. Key, 2006**, 'Global relationships of total alkalinity with salinity and temperature in surface waters of the world's oceans', *Geophysical research letters*, Vol. 33, p. 1-5.
- 35) **Krishnamurthy R, 1990**, 'Hydro biological studies of Wohar reservoir Aurangabad(Maharashtra State) India', *Journal of Environmental Biology*, Vol.11(3), p.335-343.

- 36) **Kumara Vijaya, Narayana J Puttaiach E, 2002**, ‘Phytoplanktonic composition in Jannapura Pond, Near Bhadravathi town (Karnataka)’, *Geobios*, Vol.29(4), p.217-220.
- 37) **Lee C, Jones B, Brink K, Fischer A, 2000**, The upper-ocean response to monsoonal forcing in the Arabian Sea: seasonal and spatial variability, Deep Sea Research Part II’, *Topical Studies in Oceanography*, Vol.47 (7–8), p.1177–1226.
- 38) **Lee K, Tong L, Millero F, Sabine C, Dickson A, Goyet C, Park G, Wanninkhof R, Feely R, Key R, 2006**, ‘Global relationships of total alkalinity with salinity and temperature in surface waters of the world’s oceans’, *Geophysical Research Letters*, Vol .33(19), p.605.
- 39) **Llyina T, Zeebe R, Maier-Reimer E, Heinze C, 2009**, ‘Early detection of ocean acidification effects on marine calcification’, *Global Biogeochemical Cycles*, 23.
- 40) **Madhura Mukadam, Arvind Kulkarni, 2015**, ‘Physico chemical properties of water collected from Bhatye estuary, Ratnagiri’, *J. Harmonized Res. in Applied Sci*, Vol. 3(2), p. 149-151.
- 41) **Mani P, 1989**, ‘Phytoplankton ecology of mangrove ecosystem. Ph.D. Thesis, Annamalai University, India, P. 72.
- 42) **Martin DF, 1970**, Marine Chemistry. Marcel Dekker Inc., New York.
- 43) **Millero FJ, Lee K, Roche M, 1998**, ‘Distribution of alkalinity in the surface waters of the major oceans’, *Marine Chemistry*, Vol. 60, p. 111-130.
- 44) **Misra S, Kundu R, 2005**, ‘Seasonal variations on population dynamics of key intertidal molluscs at two contrasting locations’, *Aqua.Ecol.*, Vol.39, p. 315-324.
- 45) **Mitra A, Patra KC, Panigrahy RC, 1990**, ‘Seasonal variations of some



hydrographical parameters in tidal creek opening into the Bay of Bengal', *Mahasagar-Bull. Natl.Ins.Oceanogr*, Vol.23, p. 55-62.

- 46) **Murugesan AG, Rajakumari C, 2005**, Environmental science and biotechnology, M.J.P. Publication, Chennai, 1-460.
- 47) **Nandan SB, Abdul Azis, 1993**, 'Fish and shell fish fauna of retting and non retting zones of the Kadinamkulam Kayal, Kerala', *J.Indian Fish.Ass*, Vol.23, p. 35-43.
- 48) **Paldor, Anati, 1979**, 'Seasonal variations of temperature and salinity in the Gulf of Elat(Aqaba)', *Deep Sea Research*, Vol.26(6), p. 661-672.
- 49) **Pazhanisamy , 2014**, 'Seasonal variation in physico-chemical properties of Mallipattinam coastal waters, South east coast of TamilNadu, India', *Int. J. Modn. Res. Revs.* Vol.2( 9), p 263-266.
- 50) **Petrov K , Baykara SZ , Ebrasu D, Gulin M , Veziroglu A, 2011**, 'An assessment of electrolytic hydrogen production from H<sub>2</sub>S in Black Sea waters', *International journal of hydrogen energy* Vol.36.
- 51) **Prasad NR, Patil JM., 2008**, 'A study of physico-chemical parameters of Krishna river water particularly in western Maharashtra', *Rasayan J. Chem*, Vol.1(4), p. 943-958.
- 52) **Raghunathan C, Sen Gupta, Wangikar U, Lakhmapurkar J, 2004**, 'A record of live corals along the Saurashtra coast of Gujarat, Arabian Sea', *Curr.Sci*, Vol.87(8), p. 1131-1138.
- 53) **Rajasegar M, Srinivasan M, Ajmal Khan S, 2002**, 'Distribution of sediment nutrients of Vellar esturary in relation to shrimp farming', *Indian Journal of Marine Sciences*, Vol.31(2), p.153-156.
- 54) **Ramalingam Manikannan, Subramanian Asokan, Abdul Hameed Mohamed Samsoor Ali, 2011**, 'Seasonal variations of physico-chemical

properties of the Great Vedaranyam Swamp, Point Calimere Wildlife Sanctuary, South-east coast of India', *African Journal of Environmental Science and Technology*, Vol.5(9), p. 673-681.

- 55) **Ramaraju VS, Sarma VV, Narasimha Rao TV, Vijayakumar, 1987**, 'Variation of physico – chemical characteristics with tide in Visakhapatnam harbour waters, East Coast of India', *Indian J.Mar.Sci*, Vol.16, p. 218-222.
- 56) **Richardson TL, Gibson CE, Heaney SI, 2000**, 'Temperature, growth and seasonal succession of Phytoplankton in Lake Baikal, Siberi', *Freshw Biol*, Vol.44, p.431–440.
- 57) **Romilly Margaret Mendez, 2007**, 'Impact of Trawlers on the microalgae of the aquatic ecosystem', Ph.D.Thesis, Mahatma Gandhi University Kottayam.
- 58) **Salma Kh, Elageed , 2010**, 'Factors controlling the total alkalinity in the Arabian Sea and Red Sea. A thesis submitted in partial fulfillment for the degree of Master of Science in the Universitas Bergesis.
- 59) **Saraswathi R, 1993**, 'Hydrobiology of two estuarine systems (Arasalar and Kaveri) of the southeast coast of India with special reference to plankton', Ph.D. Thesis, Annamalai University. India, p. 267.
- 60) **Saravanakumar A, Rajkumar M, Serebiah JS, Thivakaran GA., 2008**, 'Seasonal variations in physico-chemical characteristics of water, sediment and soil texture in arid zone mangroves of Kachchh- Gujarat', *J. Environ. Biol*, Vol. 29(5), p. 725-732.
- 61) **Satpathy KK, Nair KVK, 1990**, 'Impact of power plant discharge on the physico-chemical characteristics of Kalpakkam coastal waters', *Mahasagar*, Vol.23, p.117–125.
- 62) **Schulz K, Ramos J, Zeebe R, Riebesell U, 2009**, 'CO<sub>2</sub> perturbation experiments: similarities and differences between dissolved inorganic carbon and total alkalinity manipulations', *Biogeosciences*, Vol.6, p.2145–2153.

- 63) **Seenivasan R, 1998**, ‘Spectral reflectance properties of the Vellar estuarine environment, southeast coast of India, M.Phil. Thesis, Annamalai University.
- 64) **Sheathe JO, Kazama F, 2007**, ‘Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji river basin, Japan’, *Environ.Model.Software*, Vol.22(4), p.464-47.
- 65) **Singh NK, Singh B, 1990**, ‘Observation on biochemical and chemical oxygen demands of certain polluted stretch of river Ganga’, *J. Electrochemical Science*, Vol.20, p. 1-7.
- 66) **Soundarapandian P, Permkumar T Dinakaran GK, 2009**, ‘Studies on the Physico-chemical Characteristic and Nutrients in the Uppanar Estuary of Cuddalore, South East Coast of India’, *Current Research Journal of Biological Sciences*, Vol.1(3), p. 102-105.
- 67) **Strickland JDH, Parsons TR, 1972**, In: A practical handbook of seawater analysis. Fish. Res. Bd. Can. Bull. (2nd ed.), Ottawa, p. 419.
- 68) **Subramanian B, Mahadevan A, 1999**, ‘Seasonal and diurnal variation of hydrobiological characters of coastal waters of Chennai, Bay of Bengal’, *Indian J.Mar. Sci*, Vol.28, p. 429-433.
- 69) **Sundaramanickam A, Shivkumar T, Kumaran R, Ammaiappan V, Velappam R, 2008**, ‘A comparative study of Physico-chemical investigation along Parangipettai and Cuddalore Coast’, *J.Environ.Sci.Tech*, Vol.1(1), p.1-10.
- 70) **Thangaraj GS, 1985**, ‘Ecobiology of the marine zone of the Vellar estuary. Ph.D. Thesis, Annamalai University, India, p. 194.
- 71) **Thompson K, 2006**, AWWA Research Foundation, WateReuse Foundation, & Water Quality Association, Characterizing and Managing Salinity Loadings in Reclaimed Water Systems. N.p.: American Water Works Association.

- 72) **Upadhyay K, Mishra P, Gupta AK, 2010**, ‘Studies on the physicochemical status of two ponds at Varanasi and Bhadohi under biotic stress’, *Plant Arch*, Vol.10(2), p. 691-693.
- 73) **Vasantha K, 1989**, ‘Studies on hydrobiology and decomposition of macrophytes in Portonovo marine environment Southeast coast of India. Ph.D. Thesis, Annamalai University, India, p. 252.
- 74) **Zingde MD, Sharma P, Sabnis, 1985**, ‘Physico – chemical investigation in Auranga river estuary(Gujarat)’, *Mahasagar-Bull. Natl.Ins.Oceanogr*, Vol.18, p. 307-321.
- 75) **Zondervan I, Zeebe R, Rost B, Riebesell U, 2001**, ‘Decreasing marine biogenic calcification: A negative feedback on rising atmospheric pCO<sub>2</sub>’, *Global Biogeochemical Cycles*, Vol.15 (2), p.507–516.