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# A comparative study on the hydrography of the coast of Chennai

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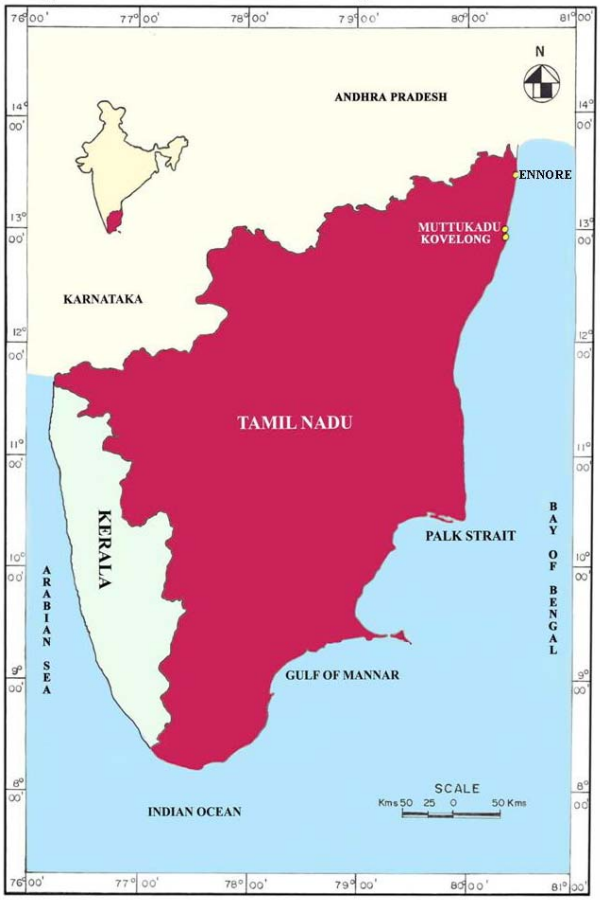
**Abstract:** Surface seawater samples were collected from two different stations along the Coast of Chennai, Station-1, the Ennore Coast where the fly ash effluent from the Ennore Thermal Power Station (ETPS) is directly discharged into the water and Station 2, the Kovelong Coast which is free from such point sources of pollution. Samples were collected between 8.00 a.m. and 9.00 a.m. during low tide from the two sampling Stations for a period of two years i.e. from April 2005 to March 2007. Samples were analyzed for temperature, pH, salinity, different forms of alkalinity (total alkalinity, carbonate alkalinity and total $CO_2$) Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), ammonia nitrogen ($NH_3$-N), nitrite nitrogen ($NO_2$-N) and nitrate nitrogen ($NO_3$-N), and phosphate phosphorous ($PO_4$-P) and N: P ratios. All the parameters studied except salinity and DO were high at Station 1 when compared to Station 2. Further wide fluctuations in the various physico chemical parameters studied were also recorded in samples collected from Station 1.

*Keywords*: Chennai, coastal pollution, water quality.

## Introduction

Studies on the seasonal variation in physicochemical characteristics form an important component of the research on the ecology of coastal waters. Hydrographical studies of the East Coast of India have been carried out time and again (Upadhyay, 1988; Vijaykumaran *et al*., 1996; Govindasamy & Azariah, 1999). The influence of various physico-chemical parameters on coastal water quality was evaluated by factor analysis (Panigrahy *et al*., 1999). Studies on the spatio-temporal distribution of nutrients along the East Coast of India have been carried out (Panda *et al*., 1989; Gowda & Panigrahy, 1995; Satyanarayan Bramha *et al*., 2008; Subrat Naik *et al*., 2008). The seawater quality of coastal waters of Madras was assessed by chemical and biological monitoring (Valsaraj *et al*., 1995). The annual distribution of nutrients, salinity and DO and the seasonal and diurnal variations of hydrobiological features of the Coastal waters Chennai have been studied (Satpathy, 1996; Subramanian & Mahadevan, 1999; Satpathy *et al*., 2007). The present investigation was aimed at comparing the different physico-chemical characteristics of the surface seawater samples of two different stations along the Coast of Chennai, Station-1, the Ennore Coast where the fly ash effluent from the Ennore Thermal Power Station (ETPS) is directly discharged into the water and Station 2, the Kovelong Coast which is free from such point sources of pollution (Fig.1).

**Fig. 1 Seaweed collection sites along the Coast of Chennai**




## Materials and methods

Monthly surface seawater samples were collected in polythene containers from both the sampling stations between 8.00 to 9.00 a.m. during low tide for a period of two years i.e. from April 2005 to March 2007. Samples were brought to the laboratory and the different physico-chemical characteristics were analyzed within few hours. The temperature of surface seawater was recorded using a centigrade thermometer at the time of sampling on the spot. The hydronium ion concentration of surface seawater samples was recorded at room temperature using an Orion pH meter. Methods of analyses followed were as per Strickland and Parsons (1972) for the quantification of Dissolved Oxygen (DO) and

*Table 1. Physico-chemical features of seawater samples collected from station-1 between April 2005 to March 2007.*

| Months | Temp (°C) | pH | Salinity (‰) | Total Alk (mEq) | Carb Alk (mEq) | Total $CO_2$ (mM) | DO (mg/L) | BOD (mg/L) | $NH_3$-N (µM) | $NO_2$-N (µM) | $NO_3$-N (µM) | $PO_4$-P (µM) | N:P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Apr-05 | 28.8 | 7.57 | 30.32 | 2.832 | 2.802 | 2.662 | 2.72 | 2.56 | 115.14 | 5.56 | 27.72 | 18.73 | 7.92 |
| May | 29.0 | 7.66 | 32.81 | 2.783 | 2.753 | 2.698 | 6.24 | 6.08 | 118.32 | 0.29 | 28.63 | 21.14 | 6.96 |
| Jun | 27.5 | 7.87 | 32.86 | 2.306 | 2.256 | 2.143 | 2.40 | 2.24 | 37.14 | 14.03 | 17.40 | 25.27 | 2.71 |
| Jul | 27.0 | 7.96 | 33.15 | 1.609 | 1.589 | 1.423 | 7.84 | 5.44 | 11.79 | 4.47 | 15.58 | 22.69 | 1.40 |
| Aug | 27.5 | 7.96 | 33.50 | 2.191 | 2.171 | 2.063 | 1.92 | 1.12 | 98.90 | 0.058 | 21.36 | 11.01 | 10.93 |
| Sept | 28.5 | 7.57 | 27.46 | 2.595 | 2.565 | 2.540 | 3.04 | 1.76 | 118.62 | 1.65 | 32.19 | 14.23 | 10.71 |
| Oct | 27.0 | 7.63 | 31.65 | 2.815 | 2.785 | 2.757 | 6.72 | 4.16 | 97.57 | 1.97 | 36.55 | 13.50 | 10.08 |
| Nov | 28.5 | 8.37 | 24.80 | 2.342 | 2.262 | 1.923 | 6.56 | 4.16 | 47.03 | 6.38 | 34.55 | 9.80 | 8.98 |
| Dec | 27.0 | 7.57 | 20.55 | 2.276 | 2.266 | 2.334 | 5.60 | 1.92 | 11.78 | 3.06 | 33.55 | 17.10 | 2.83 |
| Jan-06 | 27.0 | 8.30 | 29.54 | 2.043 | 2.018 | 1.711 | 6.88 | 6.72 | 149.25 | 11.11 | 29.50 | 20.23 | 9.39 |
| Feb | 27.0 | 8.45 | 30.56 | 1.869 | 1.739 | 1.391 | 7.20 | 4.80 | 58.60 | 7.80 | 27.86 | 11.60 | 8.13 |
| Mar | 28.0 | 8.59 | 31.30 | 2.205 | 2.045 | 1.636 | 7.20 | 4.96 | 40.29 | 5.50 | 23.56 | 6.27 | 11.06 |
| Apr | 28.5 | 7.85 | 34.23 | 2.293 | 2.232 | 2.098 | 7.36 | 4.80 | 62.96 | 2.37 | 28.06 | 8.86 | 10.54 |
| May | 30.0 | 8.20 | 31.30 | 1.883 | 1.972 | 1.756 | 7.20 | 5.28 | 119.69 | 14.24 | 27.70 | 2.27 | 71.20 |
| Jun | 30.0 | 8.18 | 32.68 | 2.032 | 1.942 | 1.748 | 7.76 | 9.44 | 108.23 | 16.23 | 28.12 | 5.68 | 26.86 |
| Jul | 31.0 | 8.62 | 31.62 | 1.987 | 1.827 | 1.462 | 6.88 | 4.80 | 169.48 | 8.76 | 29.72 | 7.28 | 28.57 |
| Aug | 31.0 | 8.21 | 30.92 | 2.237 | 2.147 | 1.716 | 1.76 | 1.60 | 118.93 | 4.08 | 25.89 | 26.00 | 5.73 |
| Sept | 31.0 | 8.60 | 33.64 | 2.359 | 2.559 | 1.996 | 2.88 | 2.24 | 73.23 | 6.72 | 26.83 | 2.23 | 47.88 |
| Oct | 32.0 | 8.50 | 29.28 | 1.924 | 1.785 | 1.534 | 7.36 | 7.04 | 96.30 | 30.30 | 27.28 | 5.70 | 27.00 |
| Nov | 31.0 | 7.86 | 21.90 | 1.963 | 1.953 | 1.992 | 6.88 | 5.28 | 147.46 | 53.54 | 29.86 | 3.54 | 65.21 |
| Dec | 27.0 | 7.70 | 21.04 | 2.959 | 2.939 | 2.909 | 7.36 | 4.96 | 73.36 | 9.86 | 24.56 | 2.09 | 51.56 |
| Jan-07 | 34.0 | 8.00 | 28.28 | 2.576 | 2.516 | 2.340 | 6.88 | 4.96 | 63.36 | 8.59 | 36.98 | 1.86 | 58.56 |
| Feb | 32.0 | 8.50 | 30.58 | 2.093 | 1.933 | 1.604 | 6.88 | 4.48 | 108.63 | 16.28 | 25.38 | 6.80 | 22.10 |
| Mar | 33.0 | 8.20 | 32.62 | 2.120 | 2.020 | 1.818 | 4.48 | 2.88 | 42.60 | 18.90 | 27.32 | 7.98 | 11.13 |

ammonia – nitrogen, the water samples were fixed on the spot. Throughout the study analytical grade reagents were used.

## Results and discussion

Seasonal variations in various physico-chemical parameters of the surface seawater samples collected from two sampling Stations are given in Tables 1 & 2. Maximum temperature recorded from Stations 1 and 2 was 34 °C and 30°C recorded during Jan 2007 and July 2007, respectively. Variations in temperatures recorded between the two Stations were found to be statistically significant (ANOVA F = 0.829, $P < 0.01$). Temperature of the surface seawater samples of both Stations showed oscillations. Temperature increased during April and May and then gradually decreased up to December. However, the temperature at Station 1 was slightly higher due to the discharge of heated effluents. The variability of temperature recorded in the present study at Station 2 is in accordance with earlier findings along the Chennai Coast (Sivaswamy, 1990). Temperature showed a positive correlation with salinity and nutrients ($NO_2$-N and $NH_3$-N) (Table 3 & 4).

pH of the water samples collected from both Stations remained alkaline. It fluctuated between 7.16 and 8.62 at Station 1 and between 7.78 and 8.90 at Station 2. Variation in pH between the Stations was found significant at $P< 0.01$ level (ANOVA F=12.77). The pH showed a positive correlation with salinity and $NO_3$-N at Station 1 and with $NO_2$-N at Station 2 (Table 3 & 4). Low pH recorded during the monsoon at both Stations might be due to the influx of fresh water and decomposition of organic substances carried by the flood (Upadhyay, 1988; Sai Sastry & Chandramohan, 1990).

Minimum values in salinity were recorded in Dec 2005 and 2006 (18.63 ‰) at Station 1 and during Nov at Station 2 (25.83 ‰). Maximum values were recorded during May 2005 at Station 1 (34.23 ‰) and in May 2006 at Station 2 (38.61 ‰). Salinity showed significant variations between Stations and ANOVA F= 9.845 and $P < 0.01$ and showed a positive correlation with $NO_3$-N and $PO_4$ –

***Table 2. Physico-chemical features of seawater samples collected from station-2 between April 2005 and March 2007.***

| Months | Temp (˚C) | pH | Salinity (‰) | Total Alk (mEq) | Carb Alk (mEq) | Total $CO_2$ (mM)) | DO (mg/L) | BOD (mg/L) | $NH_3$-N (µM) | $NO_2$-N (µM) | $NO_3$-N (µM) | $PO_4$-P (µM) | N:P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Apr-05** | 29.0 | 8.11 | 32.86 | 2.783 | 2.713 | 2.467 | 5.12 | 1.76 | 5.36 | 0.88 | 11.22 | 1.50 | 11.64 |
| **May** | 29.2 | 7.93 | 34.80 | 2.726 | 2.667 | 2.480 | 6.72 | 3.04 | 5.43 | 0.21 | 12.87 | 2.10 | 8.81 |
| **Jun** | 28.6 | 7.78 | 34.43 | 2.083 | 2.023 | 1.881 | 6.72 | 2.40 | 2.64 | 0.42 | 6.08 | 1.55 | 5.90 |
| **Jul** | 28.0 | 7.95 | 34.62 | 2.153 | 2.093 | 1.905 | 6.4 | 4.48 | 1.89 | 0.26 | 3.25 | 0.59 | 9.15 |
| **Aug** | 28.0 | 8.12 | 33.34 | 2.331 | 2.251 | 2.048 | 5.76 | 4.48 | 4.24 | 1.44 | 6.11 | 1.27 | 9.28 |
| **Sept** | 28.0 | 7.86 | 33.98 | 2.111 | 2.061 | 1.978 | 7.36 | 4.00 | 3.89 | 0.21 | 6.56 | 4.95 | 2.15 |
| **Oct** | 29.0 | 7.86 | 34.35 | 2.250 | 2.200 | 2.090 | 5.60 | 4.80 | 4.71 | 0.24 | 17.75 | 1.28 | 17.73 |
| **Nov** | 29.5 | 8.28 | 26.80 | 2.500 | 2.440 | 2.245 | 5.76 | 3.36 | 6.53 | 0.18 | 13.41 | 1.56 | 12.90 |
| **Dec** | 26.5 | 8.11 | 28.34 | 1.705 | 1.635 | 1.505 | 5.60 | 2.40 | 7.39 | 0.50 | 13.54 | 0.77 | 27.83 |
| **Jan-06** | 24.0 | 8.82 | 29.93 | 1.500 | 1.440 | 1.354 | 6.72 | 2.72 | 0.57 | 0.98 | 4.39 | 0.34 | 17.47 |
| **Feb** | 25.0 | 8.63 | 31.03 | 0.721 | 0.881 | 0.652 | 5.60 | 4.32 | 1.87 | 1.63 | 4.73 | 0.78 | 10.55 |
| **Mar** | 28.0 | 8.82 | 33.64 | 1.500 | 1.340 | 1.072 | 6.08 | 4.64 | 2.82 | 0.23 | 5.44 | 0.72 | 11.79 |
| **Apr** | 28.0 | 8.06 | 34.43 | 0.878 | 0.678 | 0.502 | 6.40 | 4.80 | 3.46 | 0.81 | 9.75 | 1.15 | 12.19 |
| **May** | 28.0 | 7.92 | 38.64 | 1.030 | 0.940 | 0.856 | 7.28 | 7.52 | 3.14 | 0.53 | 10.80 | 1.27 | 11.38 |
| **Jun** | 29.0 | 8.90 | 34.82 | 1.249 | 1.189 | 1.118 | 6.40 | 5.92 | 4.63 | 2.98 | 8.69 | 1.98 | 8.23 |
| **Jul** | 30.0 | 8.29 | 32.98 | 0.925 | 0.675 | 0.486 | 3.84 | 0.64 | 5.86 | 1.64 | 4.32 | 1.39 | 8.50 |
| **Aug** | 29.0 | 8.39 | 33.64 | 1.064 | 0.940 | 0.803 | 3.04 | 1.12 | 5.00 | 0.44 | 4.69 | 2.23 | 4.54 |
| **Sept** | 29.0 | 8.40 | 32.86 | 1.030 | 0.890 | 0.748 | 4.00 | 3.20 | 6.54 | 1.68 | 3.29 | 0.68 | 16.93 |
| **Oct** | 28.0 | 8.50 | 28.68 | 0.996 | 0.836 | 0.703 | 5.76 | 2.40 | 5.60 | 2.03 | 3.86 | 1.16 | 9.90 |
| **Nov** | 29.0 | 8.13 | 25.83 | 2.272 | 2.132 | 1.769 | 4.48 | 2.56 | 7.86 | 0.38 | 12.19 | 2.27 | 9.00 |
| **Dec** | 26.0 | 8.18 | 27.39 | 2.178 | 2.118 | 1.864 | 4.64 | 3.20 | 2.71 | 1.18 | 11.42 | 2.09 | 7.32 |
| **Jan -07** | 26.0 | 8.21 | 30.32 | 2.002 | 1.922 | 1.730 | 4.96 | 3.04 | 4.71 | 0.82 | 7.98 | 1.68 | 19.87 |
| **Feb** | 28.0 | 8.20 | 33.68 | 1.950 | 1.870 | 1.665 | 6.72 | 4.32 | 5.60 | 1.92 | 9.69 | 1.97 | 8.74 |
| **Mar** | 27.0 | 8.17 | 34.68 | 1.963 | 1.853 | 1.649 | 4.96 | 1.92 | 6.46 | 1.86 | 14.91 | 1.82 | 12.76 |

P (Table 3 & 4). Salinity was extremely low during November - December due to the monsoon rainfall (SaiSastry & Chandramohan, 1990; Mishra *et al*., 1993).

The total alkalinity oscillated between 1.61 mEq and 2.95 mEq at Station 1 and between 0.72 mEq and 2.78 mEq at Station 2. Significant differences were recorded between the Stations (ANOVA F=1.998, $P < 0.01$). Alkalinity showed a positive correlation with $NH_3$ - N at both Stations (Table 3 & 4).The values of carbonate alkalinity and total $CO_2$ showed a similar trend during the study period in both Stations. Maximum and minimum values of both parameters were recorded during Dec 2006 and July 2005 in Station 1 and in Apr 2005 and July 2006 from Station 2 respectively. Values of total $CO_2$ were high at both Stations in May 2005. Carbonate alkalinity showed a positive correlation with nutrients except $NO_2$-N at Station 1 and $NH_3$-N at Station 2. Total $CO_2$ however recorded a negative correlation with nutrients except for $NO_2$-N at both Stations. The values of total alkalinity and total carbon dioxide in most cases were high at Station 1 which could be attributed to the i) Alkaline nature of fly ash, due to the presence of Ca, Na, Mg and OH. ii) Calcium oxide which forms calcium hydroxide when mixed with water (Hodgson *et al*., 1982) and iii). Oceanic absorption of about 40% carbon dioxide from the burning of fossil fuels (Post *et al*., 1990).

At Station 1 maximum DO of 9.76 mg/L and minimum of 1.76 mg/L were recorded in Jun 2006 and Aug 2006, respectively. Variations in DO recorded between Stations were found to be significant at $P< 0.01$. Dissolved Oxygen showed a positive correlation with temperature and pH at Station 1 and alkalinity at Station 2 (Tables 3 & 4). The values of BOD ranged between 9.44 and 1.12 at Station 1 and between 7.52 and 0.64 at Station 2. Variations in BOD between Stations were found to be significant (ANOVA $F = 0.879$, $P< 0.05$). BOD showed a positive correlation with salinity and DO at both Stations (Tables 3 & 4). Dissolved Oxygen showed negative correlation with salinity at Station 1 as reported earlier (Subramanian & Mahadevan, 1999). In accordance with earlier findings (Upadhyay, 1988; Subramanian & Mahadevan,

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*Table 3. Correlation matrix of different physico chemical features of seawater samples collected from station - 1 between April 2005 and March 2007*

| | Temp (˚C) | pH | Salinity ‰ | Tot Alk (mEq) | Carb Alk (mEq) | Tot CO2 (mM) | DO (mg/L) | BOD (mg/L) | $NH_3$-N (µM) | $NO_2$-N (µM) | $NO_3$-N (µM) | $PO_4$-P (µM) | N:P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Temp (˚C)** | 1.000 | | | | | | | | | | | | |
| **pH** | 0.299 | 1.000 | | | | | | | | | | | |
| **Salinity (‰)** | 0.084 | 0.450* | 1.000 | | | | | | | | | | |
| **Tot Alk (mEq)** | -0.168 | -0.444* | -0.171 | 1.000 | | | | | | | | | |
| **CarbAlk(mEq)** | -0.186 | -0.478* | -0.168 | 0.977* | 1.000 | | | | | | | | |
| **Tot CO2(mM)** | -0.263 | -0.711* | -0.295 | 0.924** | 0.943** | 1.000 | | | | | | | |
| **DO (mg/L)** | 0.025 | 0.148 | -0.164 | -0.299 | -0.344 | -0.262 | 1.000 | | | | | | |
| **BOD (mg/L)** | 0.122 | 0.192 | 0.024 | -0.288 | -0.325 | -0.281 | 0.879** | 1.000 | | | | | |
| **$NH_3$-N (µM)** | 0.225 | -0.019 | -0.003 | 0.036 | 0.030 | 0.005 | -0.012 | 0.221 | 1.000 | | | | |
| **$NO_2$-N (µM)** | 0.443* | -0.115 | -0.428* | -0.387 | -0.380 | -0.268 | 0.260 | 0.350 | 0.275 | 1.000 | | | |
| **$NO_3$-N (µM)** | 0.206 | -0.137 | -0.380 | 0.369 | 0.348 | 0.337 | 0.195 | 0.078 | 0.244 | -0.007 | 1.000 | | |
| **$PO_4$-P (µM)** | -0.449* | -0.257 | 0.210 | 0.057 | 0.039 | 0.080 | -0.425* | -0.302 | -0.097 | 0.381 | -0.296 | 1.000 | |
| **N:P** | 0.481 | -0.017 | -0.332 | -0.031 | 0.054 | 0.043 | 0.272 | 0.266 | 0.317 | 0.524** | 0.210 | -0.759** | 1.000 |

** Significant at 0.01 level * Significant at 0.05 level

1999) high values of DO and BOD were recorded during pre monsoon and monsoon.

Throughout the course of sampling period the levels of all three forms of nitrogen namely, ammonia nitrogen ($NH_3$-N), nitrite nitrogen ($NO_2$-N) and nitrate nitrogen ($NO_3$-N), and phosphate phosphorous ($PO_4$-P) were found to be high at Station 1, when compared to Station 2. The range of $NH_3$-N was found between 11.78µM and 169.48 µM at Station 1 whereas at Station 2 the values oscillated between 0.57µM and 7.68µM. Variations in $NH_3$-N between the Stations were found significant, (ANOVA $F=6.001$, $P < 0.05$). Positive correlations were recorded between $NH_3$-N and total alkalinity and nutrients at both Stations except $NO_3$-N at Station 1 and $NO_2$ -N at Station 2 (Tables 3, 4). The values of $NO_2$ -N fluctuated between 0.06 µM and 53.54 µM at Station 1 and between 0.18 µM and 2.98 µM at Station 2. The variations recorded between the Stations were found to be significant (ANOVA $F= 150.68$ $P < 0.05$). Values of $NO_3$ – N were ranging from 15.58µM and 36.98µM at Station 1 and between 3.25µM and 17.75 µM at Station 2. Significant seasonal variations were recorded between the two sampling Stations $P < 0.01$. Nitrate-nitrogen showed a positive correlation with nutrients except $NH_3$ -N at Station 1 and $NO_2$ -N at Station 2 (Tables 3 & 4). The variations in the level of $PO_4$ – P between the Stations were found to be statistically significant (ANOVA $F = 71.58$, $P < 0.01$). Phosphate phosphorous showed a positive correlation with salinity, alkalinity, DO and $NO_3$-N at both Stations (Tables 3 & 4). $NO_3$-N and $PO_4$-P showed a distinct seasonal variation with high values being recorded during summer and monsoon at Station 2. These observations are in accordance with the findings in Rushikulya Estuary and in Pulicat Lake (Padma & Periakali, 1999), East Coast of India.

Maximum and minimum values of N: P ratios at Station 1 were recorded in May 2006 and Jun 2005, respectively, while, from Station 2, these values were recorded in Dec 2006 and Sept 2005, respectively. At Station 2 high N: P ratios were recorded during monsoon (Nov-Dec) in accordance with earlier findings (Gowda & Panigrahy, 1995). N: P ratios showed wide fluctuations in the samples collected from Station 1

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*Table 4. Correlation matrix of different physico chemical features of seawater samples collected from station - 2 between April 2005 and March 2007*

| | Temp (˚C) | pH | Salinity ‰ | Tot Alk (mEq) | Carb Alk (mEq) | TotCO2 (mM) | DO (mg/L) | BOD (mg/L) | $NH_3$-N (µM) | $NO_2$-N (µM) | $NO_3$-N (µM) | $PO_4$-P (µM) | N:P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp (˚C) | 1.000 | | | | | | | | | | | | |
| pH | -0.264 | 1.000 | | | | | | | | | | | |
| Salinity (‰) | 0.264 | -0.227 | 1.000 | | | | | | | | | | |
| Tot Alk (mEq) | 0.133 | -0.499* | -0.147 | 1.000 | | | | | | | | | |
| CarbAlk(mEq) | 0.072 | -0.483* | -0.149 | 0.994** | 1.000 | | | | | | | | |
| Tot CO2 (mM) | 0.067 | -0.496* | -0.110 | 0.986** | 0.995** | 1.000 | | | | | | | |
| DO (mg/L) | -0.105 | -0.218 | 0.427* | 0.063 | 0.090 | 0.138 | 1.000 | | | | | | |
| BOD (mg/L) | -0.106 | -0.008 | 0.442* | -0.130 | 0.094 | -0.068 | 0.723** | 1.000 | | | | | |
| $NH_3$-N (µM) | 0.507* | -0.160 | -0.337 | 0.189 | 0.141 | 0.120 | -0.437 | -0.383 | 1.000 | | | | |
| $NO_2$-N (µM) | -0.071 | 0.524** | 0.039 | -0.424* | -0.414* | -0.412* | -0.160 | 0.024 | 0.106 | 1.000 | | | |
| $NO_3$-N (µM) | -0.014 | -0.412* | -0.127 | 0.514* | 0.510* | 0.510* | 0.098 | 0.106 | 0.433* | -0.225 | 1.000 | | |
| $PO_4$-P (µM) | 0.426* | -0.336 | 0.088 | 0.283 | 0.277 | 0.293 | 0.094 | -0.044 | 0.199 | -0.109 | 0.178 | 1.000 | |
| N:P | -0.477* | 0.102 | -0.338 | -0.035 | -0.031 | -0.019 | -0.71 | -0.020 | 0.220 | -0.065 | 0.308 | -0.633** | 1.000 |

** Significant at 0.01 level * Significant at 0.05 level

which were more pronounced during the later half of the sampling period. The high levels of inorganic nitrogen and phosphorus observed at Station 1 could be due to the addition of nutrients not only from fly ash (Tripathi *et al*., 2004) but also from the cooling water released into the environment which is known to contain increased levels of nitrates and suspended solids in addition to chlorides (Langford, 1983).

From the present study it is evident that Station 1 which receives the fly ash effluent shows not only elevated levels of nutrients but also wide fluctuations in the various physico-chemical parameters studied.

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