4.0. VARIATION IN PHYSICOCHEMICAL PARAMETERS OF TEMPLE TANKS SEDIMENT SAMPLES

4.1. INTRODUCTION

Sediments are important sinks for various pollutants like pesticides and heavy metals and play a significant role in the remobilization of contaminants in aquatic systems under favorable conditions and in interactions between water and sediments. The direct transfer of chemicals from sediments to organisms is now considered to be a major route of exposure for many species. The release of trace metals from sediments into the water body and consequently to fish will depend on the speciation (i.e. metals may be precipitated, complexed, adsorbed or solubilized) of metals and other factors such as sediment, the physical and chemical characteristics of the aquatic system (Morgan and Stumm, 1991). Sediments in the aquatic ecosystem are analogous to soil in the terrestrial ecosystem as they are the source of substrate nutrients, and micro- and macro flora and -fauna that are the basis of support to living aquatic resources. Sediments are the key catalysts of environmental food cycles and the dynamics of water quality.

The effects of increased sediment loads such as smothering, clogging of gills or loss of visibility (for catching prey) can kill sensitive fauna such as fish or macro-invertebrates. The contaminated sediments can have both direct adverse impacts on bottom fauna, and indirect effects as the toxic substances move up the food chain. Because of the variability of conditions encountered in stream
systems, lake systems, estuaries, and oceans, a variety of tests may be needed to characterize the physical, chemical, and biological systems that may be affected. Sediment stress results from a change in sediment load originating from within the watershed, ultimately compromising the ecological integrity of the aquatic environment (Nietch and Borst, 2001).

Sediments are soil and mineral particles which are washed away from the land by flood waters and represent extensive pollution of surface water. Sediments are the sources of organic and inorganic matter in the streams, fresh water, river, oceans and other water supply systems. It is estimated that organic matter in sediments are usually higher than in soils. Bottom sediments have the capacity to exchange cations with the surrounding water medium. Sediments are deposits of trace elements or metals such as As, Sb, Cu, Ni, Co, Pb, Mn, etc. Soil erosions in natural process give rise to sediment pollution in water.

Sediment is a natural and necessary of pond system. Sediment fertilizes and creates fertile deltas. But human activity accelerates erosion and increase sediment loads in ponds. Sediment fills lakes and ponds; sun light is blocked, so that plant cannot carry out photosynthesis and oxygen level declaims. Pond sediments consist of biological and non-biological matter accumulated, since from formation of the pond. Sediment sequence in pond represents information about the activities within the pond over a period of time since its inception. Pollutants entering into the pond undergo either absorption or adsorption by fine particles present in the pond water, which may in turn settle down in the form of sludge. Considering the above, the present research work aims to explain the pollution level of sediments of major temple tanks in Kanyakumari district.
4.1.1. REVIEW OF LITERATURE

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<td>1999</td>
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<td>2011</td>
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<td>2013</td>
<td>Devi Priyamvada <em>et al.</em></td>
<td>Study on the quality of water and soil from fish pond in and around Bhimavaram, West Godavari district, A.P., India.</td>
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2013 Kavitha and Sugirtha P Kumar
Evaluation and sediment quality assessment of two Perennial ponds in Kanyakumari district, South India.

2013 Pratheesh and Sujatha
A prelude evaluation and sediment quality assessment of ponds in Palakkad district, Kerala.

2013 Smita Astana et al.
Heavy metal analysis in soil samples of heavy traffic zones of Hyderabad, A.P.
4.2. MATERIALS AND METHODS

Sediment core samples were collected from the ten sampling sites using a PVC coring tube (7.5mm diameter and 2.5m length). The collected samples from the ten temple tanks were analyzed to find their pollution level in terms of pH, electrical conductivity, organic carbon, sodium, potassium, phosphorus, iron, copper, zinc, manganese and lead. The study was carried out from January 2009 to December 2010. The samples were analysed by using standard methods.

The monthly variations in physicochemical parameters of sediment samples were analysed and tabulated. Seasonal variations viz., premonsoon, south-west monsoon (SW monsoon) and north-east monsoon (NE monsoon) were also noted and demonstrated in figures. Statistical analysis was carried out to find correlation coefficient between the physicochemical parameters and two-way ANOVA was also explicated in tables.
4.3. RESULTS

4.3.1. pH

The amount and mean monthly variation of pH of the sediment samples were recorded during the study period (Jan. 2009 to Dec. 2010) and the results are presented in Tables 4.1 and 4.2. In 2009, the minimum pH value of 6.0 was observed in April at site 4 and the maximum pH value of 7.9 was determined at sites 1 (April), 6 (August) and 10 (October). The mean monthly pH value was maximum (7.49±0.24) at site 1 and minimum (6.53±0.27) at site 5 (Table 4.1). During 2010, the maximum pH (7.9) value was found at site 8 in January, while minimum pH (6.1) value was recorded at sites 4 (May) and 5 (February). The mean pH value was found to be maximum in site 1 (7.55±0.18) and minimum mean value (6.53±0.24) was possessed by site 5 (Table 4.2).

In 2009, during premonsoon season, the pH determined in temple tanks sediment samples was varied much. Site 1 possessed maximum mean value of 7.68±0.22 and minimum value of 6.48±0.31 was exhibited by site 5. During south-west monsoon season, the pH value of the temple tanks sediment samples varied between 6.48±0.33 (site 5) to 7.55±0.13 (site 9). During north-east monsoon season, the pH had maximum mean value in site 8 (7.60±0.22) and minimum mean value at site 5 (6.65±0.17) (Fig.4.1). During 2010 premonsoon season, the average maximum value of pH was obtained at site 2 (7.60±0.18) and minimum value of 6.53±0.34 was detected at site 5. In south-west monsoon season, the maximum (7.70±0.08) and minimum (6.33±0.22) mean value of pH was observed at site 1 and site 4. In the north-east monsoon season, site 2 and site
possessed maximum (7.58±0.17) and minimum (6.60±0.18) mean pH values (Fig. 4.2).

In the year 2009, pH registered significant positive correlation with phosphorus, sodium, potassium, lead, iron, zinc and manganese and had significant negative correlation with organic carbon and electrical conductivity in the different sampling sites (Tables 4.23 to 4.32). In 2010, pH showed a significant positive correlation with sodium and copper and it correlated negatively with electrical conductivity (Tables 4.33 to 4.42).

The two way ANOVA test conducted for the data on pH as a function of sampling sites and seasons showed that variation between sites was statistically significant in 2009 [F=45.505; P<0.001] and 2010 [F=12.054; P<0.01]. But the variation between seasons were statistically insignificant [F=2.3179; P>0.05] in 2009, whereas statistically significant [F=3.3958; P<0.05] in 2010 (Tables 4.43 and 4.44).

#### 4.3.2. Electrical conductivity (EC)

In the year 2009, the electrical conductivity of the temple tanks sediment samples was maximum (0.99mS/cm) at site 10 in February and minimum (0.15mS/cm) value was detected at site 8 in May. Site 10 exhibited maximum (0.936±0.04mS/cm) mean value of electrical conductivity and minimum value of 0.202±0.03mS/cm was obtained at site 8 (Table 4.3). During the study period 2010, the electrical conductivity was detected as maximum at site 10 (June) with the value of 0.99mS/cm, while the minimum value of 0.13mS/cm was detected at site 4 (June). The maximum mean electrical conductivity was measured at site 10
(0.873±0.09mS/cm) and minimum mean value of 0.254±0.08mS/cm was recorded at site 4 (Table 4.4).

During the premonsoon season of the year 2009, the electrical conductivity of temple tanks sediment samples varied between 0.208±0.034mS/cm (site 8) and 0.955±0.029mS/cm (site 10), whereas in south-west monsoon season, the electrical conductivity value was ranged from 0.198±0.034mS/cm (site 8) to 0.960±0.022mS/cm (site 10). Similarly in north-east monsoon season also, sites 10 and 8 possessed maximum (0.893±0.032mS/cm) and minimum (0.200±0.018mS/cm) values of electrical conductivity, respectively (Fig. 4.3). The electrical conductivity of the sediment samples of the temple tanks varied from 0.265±0.053mS/cm (minimum) to 0.883±0.091mS/cm (maximum) at sites 1 and 10 respectively during the premonsoon season of the year 2010, whereas in south-west monsoon season, the electrical conductivity value ranged from 0.243±0.079mS/cm (site 4) to 0.908±0.116mS/cm (site 10). But during the north-east monsoon season, the electrical conductivity of the sediment samples fluctuated between 0.215±0.021mS/cm (site 4) and 0.878±0.034mS/cm (site 9) (Fig. 4.4).

During the year 2009, electrical conductivity possessed significant positive correlation with organic carbon, phosphorus and manganese and had significant negative correlation with pH, sodium, potassium, lead, copper and iron in different sampling sites (Tables 4.23 to 4.32). In 2010, EC correlated positively with manganese and organic carbon. It had significant negative correlation with pH, sodium, iron, zinc and potassium (Tables 4.33 to 4.42).
Two way analysis of variance of electrical conductivity showed significant spatial variation in 2009 and 2010 \[F=24.401 \text{ and } F=10.325; P<0.01\]. But temporal variation was insignificant \[F=1.7993 \text{ and } F=0.7764; P>0.05\] in the period of study during 2009 and 2010 (Tables 4.43 and 4.44).

4.3.3. Organic carbon (OC)

The amount of organic carbon in the temple tanks sediment sample varied during the year 2009 and the maximum (2.91ppm) organic carbon content was found at site 10 in March and minimum content (0.19ppm) was observed at site 1 in October. When the monthly average organic carbon content was calculated, it was maximum at site 10 with the value of 2.180±0.52ppm, while the minimum value was observed at site 8 with the mean value of 0.456±0.10ppm (Table 4.5). The amount of organic carbon during 2010 fluctuated from 0.13ppm at site 4 (October) to 2.32ppm at site 5 (February). The mean value of organic carbon content was observed as maximum (1.324±0.48ppm) at site 7, while minimum (0.298±0.19ppm) was recorded at site 4 (Table 4.6).

Taking into account, the seasonal variations during the study period of the year 2009, in premonsoon season, maximum value (2.560±0.388ppm) of organic carbon was identified at site 10, while minimum value was observed at site 8 with mean value of 0.463±0.141ppm, whereas in the case of south-west monsoon season, organic carbon content was maximum at site 10 with the mean value of 2.063±0.081ppm and minimum at site 1 (0.388±0.198ppm). In north-east monsoon season, organic carbon content ranged between 0.453±0.114ppm (site 8) and 2.025±0.459ppm (site 5) (Fig. 4.5). During the premonsoon season of the
year 2010, the amount of organic carbon in the sediment samples of the temple tanks varied and it was high at site 7 with the mean value of 1.878±0.296ppm and low at site 4 with the mean value of 0.503±0.193ppm. During the south-west monsoon season, the organic carbon content varied between the temple tanks and the maximum value was observed at site 10 (1.235±0.538ppm) and minimum at site 4 (0.225±0.069ppm). In north-east monsoon season, site 7 and site 4 registered maximum (0.968±0.243ppm) and minimum (0.165±0.026ppm) values of organic carbon (Fig. 4.6).

During the year 2009, organic carbon possessed significant positive correlation with EC, phosphorus, iron and manganese and it correlated negatively with pH, zinc, sodium, and potassium (Tables 4.23 to 4.32). In 2010, organic carbon showed significant positive correlation with electrical conductivity, phosphorus and iron and significant negative correlation with lead and potassium (Tables 4.33 to 4.42).

The two way analysis of variance for the data on organic carbon as a function of sampling sites and seasons showed that variation between sites was statistically significant [F=37.919; P<0.001] in 2009 and [F=4.2264; P<0.05] in 2010 and the seasonal variations also statistically significant in 2009 and 2010 [F=2.9866 and F=7.5602; P<0.05] (Tables 4.43 and 4.44).

4.3.4. Sodium (Na)

The concentration of sodium in the sediment samples of temple tanks varied during the study period 2009 and site 10 had maximum sodium content (69.8ppm) in January and December and minimum sodium content was observed
at site 9 in June (11.0ppm) The average sodium content fluctuated between 15.17±2.83ppm (site 9) and 62.75±10.21ppm (site 10) (Table 4.7). During the year 2010, the recorded amount of sodium in the sediment samples was maximum at site 10 in September as 69.4ppm and minimum was observed as 12.1ppm at site 8 in December. The mean sodium content varied from 17.42±2.75ppm (site 9) to 46.88±8.67ppm (site 10) (Table 4.8).

During the premonsoon season of the year 2009, the content of sodium varied and maximum (65.40±7.43ppm) value was observed at site 10, but minimum value was found at site 8 with the mean amount of 15.88±2.57ppm. During south-west monsoon season, the maximum amount of sodium was identified at site 10 (56.43±15.31ppm) and minimum (14.35±3.11ppm) value was found at site 9. In north-east monsoon season, sites 10 and 9 possessed maximum (66.43±3.46ppm) and minimum (15.23±2.97ppm) concentrations of sodium (Fig. 4.7). During 2010 premonsoon season, maximum content of sodium was recorded at site 10 with the mean value of 46.35±1.45ppm and minimum value of 15.48±2.28ppm was measured at site 9. In south-west monsoon season, the value of sodium was high (46.45±9.73ppm) at site 3 and low (17.25±0.87ppm) at site 9. During the north-east monsoon season, the amount of sodium fluctuated from 17.90±3.98ppm (site 8) to 49.91±13.20ppm (site 10) (Fig. 4.8).

During the year 2009, sodium possessed significant positive correlation with pH, potassium, iron, copper, zinc and manganese and registered significant negative correlation with phosphorus, organic carbon and EC (Tables 4.23 to 4.32). In 2010, sodium showed significant positive correlation with pH,
potassium, zinc, copper, iron and manganese, but it correlated negatively with phosphorus and EC (Tables 4.33 to 4.42).

The results of ANOVA calculations revealed significant spatial variation of sodium in 2009 and 2010 \([F=47.79921.620; \ P<0.001]\) and possessed insignificant seasonal variations in 2009 \([F=0.2739; \ P>0.05]\) but significant seasonal variation in 2010 \([F=4.0603; \ P<0.05]\) (Tables 4.43 and 4.44).

### 4.3.5. Potassium (K)

The content of potassium in the sediment samples of the temple tanks was determined during the study period 2009 and 2010. In 2009, the maximum value of potassium was observed at site 10 as 33.87ppm in August, while the minimum value was identified at site 4 (4.98ppm) in September. The maximum mean value of potassium was found at site 10 with the value of 29.91±4.24ppm and minimum value (11.25±3.23ppm) was found at site 1 (Table 4.9), whereas during the year 2010, the amount of potassium varied between 8.94ppm at site 4 (February) and 45.68ppm at site 6 (May). The average potassium content was calculated and it was maximum (34.70±11.78ppm) at site 6 and minimum (14.30±4.38ppm) at site 1 (Table 4.10).

During premonsoon season of 2009, maximum potassium content was found at site 9 with the mean value of 29.52±1.36ppm, whereas it was minimum (9.44±0.57ppm) at site 1. In south-west monsoon season, site 10 possessed maximum (30.39±4.28ppm) potassium content and minimum (10.57±0.59ppm) value was measured at site 8. In case of north-east monsoon season, the maximum and minimum content of potassium was observed at site 10 and
(32.21±1.02ppm) and site 4 8.24±3.56ppm) respectively (Fig. 4.9). During the study period of the year 2010 premonsoon season, the amount of potassium varied between the temple tanks. The maximum value was detected at site 3 with the mean value of 34.89±3.55ppm, whereas the minimum content (9.56±0.36ppm) was observed at site 1. During the south-west monsoon season, maximum value of potassium was found at site 6 (43.02±3.56ppm), while the minimum content of potassium was registered at site 4 (15.44±5.39ppm). In north-east monsoon season, maximum (38.10±3.86ppm) value of potassium was measured at site 6, but minimum value (16.84±4.57ppm) was found at site 1 (Fig. 4.10).

During the year 2009, potassium possessed significant positive correlation with pH, sodium, iron, copper, lead and manganese and it correlated negatively with organic carbon, electrical conductivity and phosphorus ((Tables 4.23 to 4.32). In 2010, potassium showed significant positive correlation with sodium, lead, zinc, copper, iron and manganese and exhibited a negative correlation with EC and organic carbon (Tables 4.33 to 4.42).

The two way ANOVA result revealed that potassium content exhibited significant spatial variation [F=22.697; P<0.01] in 2009 and [F=5.0818; P<0.05] in 2010, but it showed insignificant seasonal variation in 2009 [F=1.4825; P>0.05], whereas significant seasonal variation in 2010 [F=6.6804; P<0.05] (Tables 4.43 and 4.44).
4.3.6. Phosphorus (P)

The amount of phosphorus in the sediment samples during the study period 2009 fluctuated in the temple tanks and possessed maximum value (0.889ppm) at site 10 in September and minimum (0.106ppm) at site 3 in December. The monthly average phosphorus content varied from 0.133±0.04ppm (site 4) to 0.786±0.10ppm (site 10) (Table 4.11). During 2010, the maximum content of phosphorus was recorded (0.859ppm) at site 10 in March and minimum (0.109ppm) value was observed at site 3 in April. The mean monthly phosphorus content fluctuated from 0.132±0.02ppm (site 4) to 0.678±0.12ppm (site 10) (Table 4.12).

During seasonal changes, in premonsoon season of the year 2009, maximum content of phosphorus was recorded at site 10 with the mean value of 0.785±0.035ppm, whereas minimum value (0.148±0.054ppm) was observed at site 4. During the south-west monsoon season, the maximum and minimum amount of phosphorus (0.810±0.057ppm and 0.133±0.038ppm) was detected at the same sites. In the north-east monsoon season also, the concentration of phosphorus varied very much and possessed maximum value as 0.762±0.179ppm and minimum value as 0.117±0.008ppm at sites 10 and 4 respectively (Fig. 4.11). During the study period of 2010 premonsoon season, the maximum and minimum amount of phosphorus was recorded as 0.808±0.040ppm and 0.123±0.004ppm, respectively. In the south-west monsoon season, the value of phosphorus was found to be maximum as 0.663±0.104ppm, while the minimum content was observed as 0.141±0.030ppm. In the above two seasons maximum and minimum values were recorded at site 10 and site 4, respectively. But in the
north-east monsoon season, the concentration of phosphorus was maximum at site 7 (0.630±0.017ppm) and minimum at site 4 (0.132±0.009ppm) (Fig. 4.12).

During the year 2009, phosphorus possessed a positive correlation with pH, EC and organic carbon but it showed a negative correlation with copper, sodium and potassium (Tables 4.23 to 4.32). In 2010, phosphorus correlated positively with organic carbon and showed significant negative correlation with iron, zinc, sodium, manganese and lead in the different sampling sites (Tables 4.33 to 4.42).

The results of ANOVA on phosphorus concentration showed significant spatial variation \([F=68.433; P<0.0001]\) in 2009 and \([F=21.046; P<0.01]\) in 2010. But it expressed insignificant temporal variations in 2009 and 2010 \([F=1.7711\text{ and } 1.2685; P>0.05]\) (Tables 4.43 to 4.44).

### 4.3.7. Iron (Fe)

In the year 2009, the maximum content of iron was possessed by site 7 as 56.00ppm in February and minimum content of iron was predicted at site 1 in January as 11.64ppm. The average content of iron in the temple tanks sediment samples during the study period 2009 fluctuated very much and possessed maximum value (50.33±3.02ppm) at site 7 and minimum value (17.92±2.73ppm) at site 1(Table 4.13). During 2010, the maximum concentration of iron was found as 51.98ppm (site 7) in May and minimum value of 10.21ppm was possessed by site 1 in June. The maximum (45.85±3.75ppm) and minimum (14.61±3.32ppm) monthly average values of iron content also reported from the same sites (Table 4.14).
In the premonsoon season of the year 2009, the concentration of iron varied and had maximum value as $50.80\pm3.54$ppm and minimum as $17.89\pm4.19$ppm. During south-west monsoon season, the recorded maximum and minimum amounts of iron was $50.58\pm1.27$ppm and $19.14\pm1.89$ppm, respectively. In north-east monsoon season, the content of iron varied from $49.59\pm4.28$ppm to $16.74\pm1.54$ppm. In all the three seasons the maximum value was reported by site 7 and minimum by site 1 (Fig. 4.13). During 2010 premonsoon season, the quantity of iron fluctuated between $44.71\pm3.58$ppm and $14.55\pm3.52$ppm. In south-west monsoon season, the maximum value of iron was found to be maximum as $49.40\pm2.16$ppm and minimum as $12.66\pm1.85$ppm. In north-east monsoon season, the amount of iron varied from $16.61\pm3.77$ppm to $43.44\pm2.80$ppm. In 2010 also, maximum value was recorded at site 7 and the minimum value was observed at site 1 in all the three seasons (Fig. 4.14).

In 2009, iron had significant positive correlation with pH, organic carbon, sodium, potassium, manganese, copper and lead in the different sampling sites and it exhibited a negative correlation with EC (Tables 4.23 to 4.32). During 2010, iron owed a significant positive correlation with organic carbon, sodium, potassium, copper, zinc and manganese and a negative correlation with EC and phosphorus in the different sampling sites (Tables 4.33 to 4.42).

Analysis of variance (ANOVA) of iron showed significant spatial variation in 2009 and 2010 [$F=125.27$ and $52.627$; $P<0.0001$]. Insignificant temporal variation [$F=0.7940$; $P>0.05$] was obtained in 2009, but significant
temporal variation was reported in 2010 \([F=7.6551; \ P<0.05]\) (Tables 4.43 and 4.44).

### 4.3.8. Copper (Cu)

The concentration of copper in the sediment samples possessed so much variation during the study period (January 2009 to December 2010). In 2009, the value of copper varied from 0.015ppm at site 5 (October) to 0.082ppm at site 2 (May) and site 8 (April). The average amount of copper was found to be maximum at site 2 with the mean value of 0.061±0.018ppm, whereas minimum mean value of 0.029±0.011ppm was recorded at site 5 (Table 4.15). In 2010, the maximum value of copper was observed as 0.080ppm at site 8 (April), while minimum value of 0.017ppm was obtained at site 10 in August. The average copper content was high (0.062±0.019ppm) at site 8 and low at sites 7 and 10 with the value of 0.028±0.008ppm (Table 4.16).

In the premonsoon season of the year 2009, site 2 possessed maximum copper content (0.054±0.019ppm) and minimum of 0.026±0.007ppm was observed at site 5. In the south-west monsoon season, site 8 had the maximum copper content (0.072±0.008ppm) and the minimum value (0.030±0.007ppm) was possessed by site 5. During the north-east monsoon season, the content of copper varied from 0.024±0.006ppm (site 7) to 0.062±0.013ppm (site 2) (Fig. 4.15). During the premonsoon season of 2010, site 3 had the maximum copper content of 0.060±0.014ppm; but minimum (0.022±0.003ppm) was reported by site 10. During south-west monsoon season site 8 had the maximum amount of copper as 0.075±0.004ppm and the minimum value of 0.026±0.005ppm was
recorded at site 7. During the north-east monsoon season also, site 8 had the maximum (0.069±0.008ppm) copper content and site 7 possessed a minimum (0.027±0.008ppm) value (Fig. 4.16).

In 2009, copper possessed significant positive correlation with sodium, potassium, iron and zinc; however it expressed a negative correlation with EC and phosphorus in the sampling sites (Tables 4.23 to 4.32). In 2010 copper showed significant positive correlation with pH, sodium, potassium, iron, zinc and manganese in different sampling sites (Tables 4.33 to 4.42).

The result on two way ANOVA calculation revealed that the variation in copper was statistically significant between sites in 2009 and 2010 [F=6.7381 and F=5.7245; P<0.05]. Similarly the variation in copper was statistically significant between seasons [F=6.000; P<0.05] in 2009, whereas insignificant [F=2.3173; P>0.05] in 2010 (Tables 4.43 to 4.44).

4.3.9. Zinc (Zn)

During the study period 2009, the amount of zinc present in the sediment samples varied much. The value of zinc was found to be maximum (1.620ppm) at site 1 in April and minimum value of zinc was determined as 0.428ppm at site 5 in October. The average maximum content of zinc was observed at site 1 (1.229±0.215ppm), whereas the minimum content of zinc was found at site 5 with the mean value of 0.553±0.142ppm (Table 4.17). In 2010, the content of zinc fluctuated in the temple tanks. The maximum amount of zinc was found at site 1 (1.830ppm) in April and minimum amount was determined at site 4
(0.316ppm) in December. The mean value of zinc varied from 0.529±0.102ppm (site 6) to 1.320±0.311ppm (site 1) (Table 4.18).

Taking into consideration, the seasonal changes in 2009, during the premonsoon season, the maximum (1.438±0.180ppm) amount of zinc was detected at site 1 and site 5 expressed minimum (0.497±0.04ppm) value. During the south-west monsoon season, the content of zinc in sediment samples varied in the temple tanks and the maximum amount (1.116±0.166ppm) of zinc was found at site 1 and the minimum (0.640±0.057ppm) was observed at site 4. During north-east monsoon season, the amount of zinc fluctuated from 0.462±0.046 to 1.132±0.146ppm at site 5 and site 1, respectively (Fig. 4.17). During the premonsoon season of 2010, the content of zinc in the sediment samples possessed maximum value (1.492±0.367ppm) at site 1 and minimum value (0.602±0.056ppm) at site 7. In south-west monsoon season, the amount of zinc in the sediment samples fluctuated from 0.573±0.041ppm (site 6) to 1.427±0.221ppm (site 1). During north-east monsoon season, site 1 possessed maximum concentration of zinc (1.040±0.109ppm) and minimum at site 4 with the mean of value 0.376±0.054ppm (Fig. 4.18).

In 2009, zinc possessed significant positive correlation with sodium, pH, copper, manganese and lead; but it correlated negatively with organic carbon in different sampling sites (Tables 4.23 to 4.32). In 2010, zinc showed significant positive correlation with sodium, potassium, copper, iron and manganese and expressed a negative correlation with EC and phosphorus in the sampling sites (Tables 4.33 to 4.42).
The two way ANOVA calculation revealed that the zinc concentration was statistically significant between sites in 2009 \([F=15.392; P<0.01]\) and 2010 \([F=42.698; P<0.001]\). Similarly the variation in zinc was statistically significant between seasons of both the study period 2009 and 2010 \([F=4.4469\) and 25.731; \(P<0.05\)and \(P<0.01]\) (Tables 4.43 to 4.44).

4.3.10. Manganese (Mn)

The amount of manganese in the temple tanks sediment samples during the study period 2009 was fluctuated, it possessed maximum value at site 5 (16.38ppm) in April and minimum value at site 1 (1.12ppm) in November. The average concentration of manganese was high (12.67±2.19ppm) at site 6 and low (1.79±0.51ppm) at site 1 (Table 4.19). In the year 2010, the content of manganese in the temple tanks sediments was recorded maximum (15.23ppm) at site 6 in August and minimum (1.05ppm) value at site 8 in December. The average amount of manganese possessed maximum (11.91±1.88ppm) value at site 6, while minimum value of 1.82±0.43ppm was observed at site 1 (Table 4.20).

Seasonal wise changes in concentration of manganese was also analysed and are presented in Fig. 4.19 and 4.20. During premonsoon season of the year 2009, maximum content of manganese was recorded at site 5 with mean value of 14.08±1.89ppm and minimum concentration (2.03±0.40ppm) was observed at site 1. During the south-west monsoon season, site 6 and site 1 exhibited maximum and minimum amount of manganese as 15.14±1.43ppm and 1.97±0.61ppm, respectively. In north-east monsoon season also, the maximum (10.82±1.31ppm) and minimum (1.37±0.28ppm) concentration of manganese
was found at the same sites (sites 6 and 1) (Fig. 4.19). In 2010 premonsoon season, the recorded quantity of manganese was maximum (10.54±0.63ppm) at site 6 and minimum (1.72±0.17ppm) at site 10. In south-west monsoon season, the maximum and minimum content of manganese was found as 13.71±1.17ppm (site 5) and 2.03±0.12ppm (site 1). During north-east monsoon season, the amount of manganese fluctuated from 1.52±0.52ppm (site 8) to 11.66±2.24ppm (site 6) (Fig. 4.20).

In 2009, manganese possessed significant positive correlation with sodium, pH, EC, organic carbon, potassium, iron, zinc and lead (Tables 4.23 to 4.32). In 2010, zinc showed significant positive correlation with sodium, EC, potassium, iron, copper, zinc and lead and negative correlation with phosphorus in the sampling sites (Tables 4.33 to 4.42).

Two way analysis of variance for the data on average manganese recorded in the experimental sites showed significant variation in the study period 2009 and 2010 [F=47.163 and 27.327; P<0.001]. Similarly between seasons also, the variations were statistically significant in 2009 [F=14.402 and P<0.01] and 2010 [F=4.3991 and P<0.05] (Tables 4.43 and 4.44).

4.3.11. Lead (Pb)

The result on the value of lead in the temple tanks sediment samples during the year 2009 was presented in Table 4.21. The maximum content of lead (0.391ppm) was measured at site 1 in January and minimum concentration (0.113ppm) was observed at site 3 in December. The maximum mean value (0.278±0.052ppm) of lead was found at site 10 and site 3 possessed minimum
mean values as 0.166±0.026ppm (Table 4.21). In 2010, the maximum amount (0.403ppm) of lead was recorded at site 10 in August, while minimum value (0.121ppm) was found at site 3 in October. The average concentration of lead varied between 0.164±0.025ppm (site 3) to 0.270±0.074ppm (site 10) (Table 4.22).

In premonsoon season of the year 2009, the content of lead was recorded as maximum at site 1 with the mean value of 0.309±0.063ppm and minimum value (0.168±0.017ppm) was found at site 4. During the south-west monsoon season, the concentration of lead was detected as high (0.300±0.045ppm) at site 10 and low (0.175±0.032ppm) at site 4. In north-east monsoon season, at site 8 maximum quantity of lead was identified with mean value of 0.250±0.056ppm and minimum value of 0.142±0.020ppm was recorded at site 3 (Fig. 4.21). In 2010 premonsoon season, the maximum content of lead was determined at site 9 (0.229±0.049ppm), and site 3 showed minimum value (0.157±0.026ppm). During south-west monsoon season, the maximum (0.317±0.063ppm) and minimum (0.170±0.027ppm) lead content was reported at site 10 and site 7. In north-east monsoon season, site 10 and site 3 expressed maximum (0.308±0.035ppm) and minimum (0.158±0.034ppm) amount of lead (Fig. 4.22).

In 2009, lead possessed significant positive correlation with pH, potassium, iron, zinc and manganese and it correlated negatively with EC (Tables 4.23 to 4.32). In 2010, it showed significant positive correlation with potassium and manganese, but negative correlation with phosphorus and organic carbon in the sampling sites (Tables 4.33 to 4.42).
Two way analysis of variance for the data on lead as a function of sampling sites and seasons showed that the variation between sites and seasons were statistically significant \(F=10.229\) and \(4.6219; P<0.01\) and \(P<0.05\) in 2009 (Table 4.43). In 2010 also, the two way ANOVA test as a function of sampling sites and seasons showed that the variation between them were statistically significant \(F=5.8243\) and \(5.1666; P<0.05\) (Table 4.44).
4.4. DISCUSSION

Results reported on physicochemical parameters of the temple tanks sediment samples are generally influenced by continuous anthropogenic activities and festival inputs. Seasonal variations of different physicochemical parameters in the temple tanks sediment samples depend on the fresh water inflow and contamination by heavy metals. This contamination was largely dependent upon drainage area, and to a lesser extent upon pond surface area, the predominant source of contamination in these ponds appears to be related to vehicle usage.

4.4.1. pH

pH of the sediment is a measure of its acidity or alkalinity and the toxicity of heavy metals gets enhanced at particular pH. Acidic sediments mobilize metals that can be toxic to aquatic species. Thus pH is having the primary importance in deciding the quality of sediments (Pravin U Singare et al., 2011b). In the present study, throughout the study period the maximum sediment pH (7.9) recorded at sites 1, 6, 8 and 10, while the minimum pH value (6.0) was found at site 4. Variation in pH might be attributed to redox changes in sediment and water column apart from the influence of freshwater (Tukura et al., 2012).

In 2009, pH was maximum in premonsoon season, similarly Satheeshkumar and Anisa Khan (2009) reported maximum pH in summer at selected waterbodies sediment samples in Pondicherry. Minimum pH was recorded during south-west monsoon season, similar to the findings of Sulabha and Prakasam (2006) in sediment sample sof Thirumullavaram temple pond, Kollam, Kerala; Saravanakumar et al. (2008) at arid zone of Kachchh, Gujarat.
and Bagade (2011) at Amblikoppa lake, Karnataka. Erema R Daka and Miebaka Moslen (2013) found higher pH values during the dry season months and lower during the wet season months at Azuabie creek sediments of the Upper Bonny, Niger delta.

pH of the sediment samples possessed negative correlation with organic carbon, similar to the findings of Nnaji et al. (2010) in sediments of river Galma, Nigeria. Joanna Cieślewicz and Maciej Operacz (2010) stated that the relatively low pH value of sediments can be related to the absence of inorganic carbon and the high content of organic matter. pH correlated positively with zinc in this study. But, Fred W Rabe and Stephen B Bauer (1977) reported reverse correlation in their study at lakes of the Coeur d’Alene river valley, Idaho. Similarly, pH and EC established negative correlation, but a reverse correlation was noted with the report of Sulabha and Prakasam (2006) in the sediment samples of Thirumullavaram temple pond of Kollam, Kerala.

4.4.2. Electrical conductivity

Electrical conductivity is a good measure of dissolved solids. Conductivity is a measurement used to determine mineralization and determining amount of chemical reagents or treatment chemicals to be added to water (Pravin U Singare et al., 2011a). In the year 2009, value of electrical conductivity fluctuated between 0.15mS/cm (site 8) to 0.99mS/cm (site 10). But in 2010, maximum of 0.99mS/cm and minimum of 0.13mS/cm were reported at sites 10 and 4, respectively. Sediment electrical conductivity is higher due to nitrate, sulphate and chloride ions in water (Nnaji et al., 2010).
Throughout the study period of 2009, maximum and minimum values of electrical conductivity were accounted for south-west monsoon seasons at sites 10 and 8 respectively. But, in the year 2010, maximum EC was recorded during south-west monsoon season and minimum EC was reported during north-east monsoon season. Bagade (2011) justified this result by his study in the sediment samples of Amblikoppa lake, Karnataka; which states that high value of electrical conductivity in sediment was obtained during south-west monsoon season.

4.4.3. Organic carbon

Organic carbon in sediment is derived from primary production within the aquatic ecosystem and also from terrestrial biota by transport of leached and eroded materials into the temple tank. In addition to this, an increase in organic matter content in sediment may be due to fine nature of sediments and high rate of sedimentation. The distribution of total organic carbon was followed by the distribution of sediment type.

In the present study, the amount of organic carbon was found to be maximum (2.91ppm) at site 10 and the minimum (0.13ppm) was observed at site 4 during entire the study period of 2009 - 2010. High organic matter may be due to longer residence time of water in the temple tank (Nnaji et al., 2010). While considering seasonal changes, premonsoon season in 2009 showed maximum organic carbon content and south-west monsoon season showed minimum content. Even in the year 2010 also, premonsoon season registered a maximum content of organic carbon and north-east monsoon season registered a minimum content of organic carbon. Similar result was suggested by Mohamed Ali and
Amaal M Abdel Satar (2005) at El-Fayoum province, Egypt; Sulabha and Prakasam (2006) at Thirumullavaram temple pond of Kollam, Kerala and Saravanakumar et al. (2008) at arid zone of Kachchh, Gujarat. Maximum value of organic matter in premonsoon season might be attributed to the flourishing of phytoplankton and zooplankton leading to high organic productivity during the season. Low value of organic carbon in monsoon was caused by the decomposition of organic matter in the presence of dissolved oxygen (Mohamed Ali and Amaal M Abdel Satar, 2005). This result was in accordance with the reports of Sulabha and Prakasam (2006) in the sediment samples of Thirumullavaram temple pond of Kollam, Kerala and Erema R Daka and Miebaka Moslen (2013) at Azuabie creek sediments of the Upper Bonny, Niger delta. Increase in organic matter concentrations of the sediment during hot seasons (Abdel-Satar and Elewa, 2001) and the low element concentrations may be attributed to the mobilization of iron from sediment to water (Elewa and Goher, 1999).

High levels of pollutants, mainly organic matter in water cause an increase in BOD, COD, total dissolved solids, total suspended solids and fecal coliform (Kulkarni, 1997). They make water unsuitable for drinking, irrigation or any other use (Hari et al., 1994). The high concentration of organic carbon is associated with oxygen depletion of bottom sediment and excessive bloom of microbes in the sediment. Lower concentration is unfavorable for the growth of benthic organisms that are important food for many species (Idsariya Wudtisin and Claude E Boyd, 2006).
In the present study, organic matter and phosphorus correlated positively with each other, similar to the finding of Sulabha and Prakasam (2008) in Asramam temple pond of Kollam, Kerala. Organic matter showed negative correlation with pH. Similar result was reported by Joanna Cieślewicz and Maciej Operacz (2010) in the sediment samples of selected lakes of the Wel Landscape Park and Nnaji et al. (2010) in river Galma, Nigeria. DO of water and organic carbon content of sediment had negative correlation, this negative correlation was justified by the report of Saravanakumar et al. (2008) in arid zone of Kachchh, Gujarat.

4.4.4. Sodium

Sodium concentration plays an important role in evaluating the surface and ground water quality for irrigation, because sodium causes an increase in the hardness of the soil as well as reduction in permeability (Tijani, 1994). Presence of sodium gives bitter taste to water, besides being dangerous for heart and kidney patients and corrosive to metals (Guru Prasad and Satya Narayana, 2004). Sodium contributes to the increased incidents of high blood pressure and is possibly responsible for health issues like cardiac failure; hence WHO recommended reduced intake of sodium in order to protect human health (Kavitha and Sugirtha P Kumar, 2013).

During the study period 2009 and 2010, site 10 exhibited maximum concentration of sodium (69.8ppm and 69.4ppm). But in the year 2009, site 9 had minimum value of sodium (11.0ppm) and site 8 showed minimum sodium content (12.1ppm) in 2010. High value of sodium is due to high rate of
mineralization in the sediments (Mahananda *et al*., 2010). During the year 2009 and 2010, maximum concentration of sodium was recorded during north-east monsoon season, while minimum values were recorded during south-west monsoon (2009) and premonsoon (2010) seasons. Sodium possessed positive correlation with zinc and manganese. This statement was justified by the report of Sugirtha P Kumar and Patterson Edward (2009) in their study on the sediment samples of Pazhayar river at Manakudy region, Tamil Nadu.

### 4.4.5. Potassium

Potassium is a major nutrient element available in sediment, and it is useful for the production of superior quality crops (Kavitha and Sugirtha P Kumar, 2013). The decrease in potassium content indicates that potassium is used up in the growth of the carp and consumed by young fish (Devi Priamvada *et al*., 2013). In the present study, the amount of potassium possessed maximum value at site 6 (45.68ppm) and minimum value at site 4 (4.98ppm). The concentration of potassium is lower than sodium in all the selected ponds, which was similar to the findings of Kavitha and Sugirtha P Kumar (2013) in the sediment samples of two perennial ponds in Kanyakumari district, Tamil Nadu.

In the study period 2009, maximum and minimum values of potassium were recorded during north-east monsoon seasons at sites 10 and 4, respectively. In 2010, south-west monsoon season and premonsoon season showed maximum and minimum concentrations of potassium respectively. The high values of potassium may be due to the leaching of potassium through rain water from the surrounding fields, which contain potash in the form of fertilizer and it got
deposited at the bottom of the pond. Under low potassium concentration, the growth rate and photosynthesis of algae will be poor and respiration increases in pond ecosystem (Kavitha and Sugirtha P Kumar, 2013).

In the present study, potassium possessed positive correlation with zinc and manganese; this was in accordance with the study of Sugirtha P Kumar and Patterson Edward (2009) in the sediment samples of Pazhayar river at Manakudy region, Tamil Nadu. Potassium correlated negatively with phosphorus in this study, but a positive correlation was reported by Sulabha and Prakasam (2006) in the sediment samples of Thirumullavaram temple pond at Kollam, Kerala.

4.4.6. Phosphorus

Phosphorus pollution caused enormous blooms of the blue-green algae, a form of cyanobacteria, which can produce neurotoxins (affecting nervous system) and heptotoxins (affecting the liver). The same toxin can damage aquatic ecosystem and water quality. The capacity of sediment to retain or release phosphorus is one of the important factors which influence the concentration of inorganic phosphorus in the overlying water (Saravanakumar et al., 2008). Patil et al. (2012) reported that phosphorus stimulates microbial growth. Desorption of phosphate from sediment surface can regulate the availability of phosphorus in sediment under oxic condition (Erema R Daka and Miebaka Moslen, 2013).

During the study period 2009 and 2010, maximum (0.889ppm) and minimum (0.106ppm) concentrations of phosphorus were identified at sites 10 and 3, respectively. Excess amounts of phosphorus and nitrogen cause rapid growth of phytoplankton creating blooms. Blooms decreases the availability of
sunlight, therefore plants cannot photosynthesize, which in turn kills grasses (Pravin U Singare et al., 2011a). High concentration of this occurs in deeper layers due to mineralization and regeneration from the biological material in the sediments especially during anoxic condition (Roberto Bertoni, 2011).

During the study period of 2009, south-west monsoon season had maximum content of phosphorus, while north-east monsoon season showed minimum phosphorus content. But in the year 2010, maximum and minimum values of phosphorus content were found during premonsoon season at sites 10 and 4, respectively. Saravanakumar et al. (2008) found minimum value of phosphorus in summer at arid zone of Kachchh, Gujarat. High values observed may be due to dead organic matter from the top layer and lower values may be related to the removal of top layer sediments (Saravanakumar et al., 2008). Sediment samples show very high concentration of nitrogen and phosphorus leading the pond into hyper eutrophic status (Suneela et al., 2008).

In the present study, phosphorus and organic matter correlated positively as with the finding of Sulabha and Prakasam (2006) at Thirumullavaram temple pond of Kollam, Kerala and Sulabha and Prakasam (2008) at Asramam temple pond of Kollam, Kerala. Phosphorus correlated negatively with potassium in this study. This was in reverse correlation with the report of Sulabha and Prakasam (2006) at Thirumullavaram temple pond of Kollam, Kerala.

### 4.4.7. Iron

Iron plays an important role as an essential element in all systems from invertebrates to humans, but increasing of iron in the environment may result
bioaccumulation in the marine organisms such as bivalves and gastropods (Kesavan et al., 2013). Most ferrous compounds in aquatic environments result from the precipitation of iron in alkaline and oxidizing conditions (Abdulla et al., 1973). The accumulation of ferrous ion and sulfides in sediments can form iron sulfides/polysulfides which give sediments a black color and cause them to exert high, rapid oxygen demand when suspended in the water column (Fred lee, 2007).

During this study period, maximum concentration of iron was reported at site 7 (56.00ppm in 2009 and 51.98ppm in 2010) and minimum amount was recorded at site 1 (11.64ppm in 2009 and 10.21ppm in 2010). The relative lower values of iron may be attributed to its adsorption on the large amount of dissolved organic matter (Mohamed M El Bouraie et al., 2010). While considering seasonal changes, premonsoon season of the year 2009 had maximum iron content and north-east monsoon season registered minimum content. In the year 2010, maximum and minimum contents of iron were observed during south-west monsoon season at different sites (site 7 and site 1).

In the present study, iron showed positive correlation with copper, manganese and lead. Abdo and El-Nasharty (2010) justified this statement by their study at Ismailia canal, Egypt. Iron showed positive correlation with copper; similar to the report of Sugirtha P Kumar and Patterson Edward (2009) at Manakudy region, Tamil Nadu and Mohamed M El Bouraie (2010) at Nile delta in Egypt. Iron and lead correlated positively with each other; this was in
accordance with the report of Joshua Oluwole Olowoyo et al. (2013) at different sites in Pretoria, South Africa.

4.4.8. Copper

Copper is the common element that occurs naturally in the environment and spreads throughout the environment and remains for a long period because it settles when it starts to rain. Copper strongly attaches to organic matter and minerals (Smita Asthana et al., 2013). Copper is used in agriculture in the form of fertilizers, bactericides and fungicides and an algaecides in water purification. The source of copper from the dust and soil samples may be due to corrosion of metallic parts of cars derived from engine wear, thrust burning, brushing and bearing metals (Joshua Oluwole Olowoyo et al., 2013).

In the present study, copper content was high at sites 2 and 10 (0.082ppm) and low at site 5 as 0.015ppm. Copper in excess could induce hemolytic anemia and kidney damage (WHO, 1993 and Kaki Christopher et al., 2011). During 2009 and 2010, maximum concentration of copper was recorded in south-west monsoon season, and minimum values were recorded during north-east monsoon (2009) and premonsoon (2010) seasons. Results of the year 2010 were justified by the findings of Mohamed Ali and Amaal M Abdel Satar (2005) at El - Fayoum province, Egypt. Similar results were reported by Shrivastava and Jain (1998) in the sediment samples of Kerwan dam, Bhopal; Jespin Ida (2012) at Suchindramkulam, Tamil Naduand Pratheesh and Sujatha (2013) at some ponds in Palakkad, Kerala also. Bordoloi et al. (2002b) had reported that metals
deposited in the sediments come out during heavy rainfall and flow into the water system.

Copper and zinc correlated positively with each other; similar finding was reported by Yuebing Sun et al. (2010); Njogu et al. (2011); Eva Singovszka and Magdalena Balintova (2012) at different waterbodies. Copper correlated positively with iron. Abdo and El-Nasharty (2010) reported positive correlation between copper and iron from their study at Ismailia canal, Egypt. Copper showed positive correlation with iron and zinc. This was in accordance with the report of Sugirtha P Kumar and Patterson Edward (2009) at Manakudy region, Tamil Nadu and Mohamed M El Bouraie (2010) at Nile delta in Egypt.

4.4.9. Zinc

Zinc is the essential mineral for humans, plants, animals and micro-organisms. They can accumulate considerable amount of zinc in their system without having any damaging effect. According to Landner (1976), infinitely low levels of heavy metals are regarded as potential pollutants in aquatic ecosystems because of their adsorption in bottom sediments even at a lower concentration, environmental persistence, toxicity at low concentration and their ability to be incorporated into the food chain and concentrate in aquatic organisms. Thus the level of zinc observed in the study can be considered as potential toxicants (Neera Srivastava et al., 2009).

During the study period, zinc value fluctuated from 0.316ppm (site 4) to 1.830 ppm (site 1). The lower concentration value of zinc may be caused by their mobilization from sediment to overlying water due to the low pH values and
microbial activity (Elewa and Goher, 1999 and Abdo, 2004). Throughout the study period 2009 and 2010, maximum concentration of zinc was accounted for during premonsoon season, while minimum concentration was observed during north-east monsoon season. This was opposite to the finding of Mohamed Ali and Amaal M Abdel Satar (2005) at El - Fayoum province, Egypt and Ayse Elmaci et al. (2007) at lake Uluabat, Turkey.

In the present study, zinc and copper correlated positively with each other, similar to the findings of Yuebing Sun et al. (2010); Njogu et al. (2011); Eva Singovszka and Magdalena Balintova (2012) at different water bodies. Zinc possessed positive correlation with lead; this result was justified by Yuebing Sun et al. (2010) at typical regions of Shenyang, China; Njogu et al. (2011) at lake Naivasha basin, Kenya and Joshua Oluwole Olowoyo et al. (2013) at different sites in Pretoria, South Africa. Zinc correlated positively with sodium, potassium, copper and manganese. Sugirtha P Kumar and Patterson Edward (2009) have also found the same pattern of correlation in their study in Pazhayar river at Manakudy region, Tamil Nadu.

4.4.10. Manganese

Manganese is an essential micronutrient and does not occur naturally as a metal in aquatic ecosystems (Ambedkar and Muniyan, 2012). Manganese is not a toxic metal, but occurs in the domestic waste waters, industrial effluents, received by rivers, streams and thereby enters waterbodies (Kavitha and Sugirtha P Kumar, 2013). In the present study, manganese content recorded was maximum as 16.38ppm and minimum as 1.05ppm at sites 5 and 8, respectively. The lower
concentration value of manganese may be caused by their mobilization from sediment to overlying water due to the low pH values and microbial activity (Elewa and Goher, 1999; Abdo, 2004). Throughout the study period of 2009 and 2010, maximum value of manganese was noted during south-west monsoon season, while north-east monsoon season expressed minimum concentration. Enrichment of manganese in the ponds may be attributed to the inflowing water and also due to deposition of atmospheric particulates. Manganese is considered as a mobile element, because it can be exchanged between water and sediments during physicochemical changes (Kavitha and Sugirtha P Kumar, 2013).

In the present study, manganese had positive correlation with iron and lead. Abdo and El-Nasharty (2010) justified this result by their report at Ismailia canal, Egypt. Manganese correlated positively with sodium, potassium and zinc; similar to the findings of Sugirtha P Kumar and Patterson Edward (2009) at Pazhayar river, Manakudy region, Tamil Nadu.

4.4.11. Lead

Lead is naturally present in the environment; the high level of lead in sediments could be attributed to the industrial and agricultural discharge (Mason, 2002). Lead is mainly associated with the Fe-Mn oxide fraction and had high retention in sediment (Fernandez et al., 2000). Lead in the soil sediments results mainly from the dry and wet deposition of atmospheric lead (Smita Asthana et al., 2013). In the present study, the amount of lead was found to be maximum (0.391ppm) at site 1 and the minimum (0.133ppm) was observed at site 3. In the
year 2010, maximum and minimum lead contents were registered at site 10 and site 3 as 0.403ppm and 0.121ppm, respectively.

During the study period 2009, maximum and minimum contents of lead were found during premonsoon and north-east monsoon seasons. Similar finding was reported by Mohamed Ali and Amaal M Abdel Satar (2005) at El-Fayoum province, Egypt. But, in the year 2010, maximum amount of lead was recorded during south-west monsoon season and minimum was reported during premonsoon season. The relative increase of lead concentrations during winter may be related to the decaying of plankton and precipitation of organic matter associated with lead to the sediment (Goher, 1998; Mohamed M El Bouraie et al., 2010). Domestic, industrial effluents and atmospheric deposition may be the major sources of the observed high level lead (Ayse Elmaci et al., 2007). Higher levels of lead often occur in water bodies near high ways and large cities due to high gasoline combustion (Kavitha and Sugirtha P Kumar, 2013).

In the present study, lead showed positive correlation with iron and manganese, similar to the findings of Abdo and El-Nasharty (2010) at Ismailia canal, Egypt. Lead possessed positive correlation with zinc; similar result was reported by Yuebing Sun et al. (2010) at typical regions of Shenyang, China; Njogu et al. (2011) at lake Naivasha basin, Kenya and Joshua Oluwole Olowoyo et al. (2013) at different sites in Pretoria, South Africa. Iron and lead correlated positively; this result was justified by Joshua Oluwole Olowoyo et al. (2013) at different sites in Pretoria, South Africa. Generally high positive correlation between heavy metals shows similar geochemical behavior origin, while low
positive correlation shows that the metal comes from different sources (Njogu et al., 2011).