DISCUSSION
4. DISCUSSION

4.1. Abiotic factors (fig – 2&3)

Temperature:

Temperature is an important factor in the aquatic ecosystem because no other single factor has so many profound influences, either directly or indirectly (Welch, 1952). It determines the solubility of oxygen and carbon dioxide, and bicarbonate and carbonate equilibrium (NEERI, 1988). According to Welch (1952) in the tropics usually air temperature is more than water temperature. However, in the present study water temperature exceeded air temperature most of the time in Attiveri, Bachanki and Nyasargi reservoirs. Similar observations are those of Ward (1897) and Kumar et al. (1978), according to them some times water temperature exceeds air temperature during rainy and winter seasons.

Lower values of atmospheric and water temperature were recorded in Attiveri reservoir (22.92 ± 4.16°C and 25.67 ± 1.89°C respectively), and higher values in Gangibhavi pond (27.93 ± 3.25°C and 26.57 ± 2.23°C respectively) (Table-10). The variation may attribute to the time of water sampling, as Attiveri reservoir sampling was done in morning 6 am., whereas Gangibhavi pond sampling was done at 9 am., throughout study period.

In all the four reservoirs there was an existence of strong positive correlation between atmospheric temperature and water temperature. However in Battigeri and Gangibhavi tanks this relation was absent (Table 15 to 20). Muragavel and Pandian (2000) also reported the existence of positive correlation between air temperature and water temperature. Other than water temperature, atmospheric temperature was also
positively correlated with Dissolved oxygen in both Nyasargi and Sanavalli reservoir, with conductivity, total dissolved solids in Nyasargi reservoir, Battigeri and Gangibhavi tanks, with salinity, total hardness, calcium, in Battigeri and Gangibhavi tanks, with chlorides, nitrates and bicarbonates in only Battigeri tank.

Whereas the water temperature is positively correlated with atmospheric temperature \((r = 0.632, p< 0.01)\) and salinity \((r = 0.549, p< 0.05)\) in Attiveri reservoir. In Bachanki reservoir it was positively correlated with atmospheric temperature \((r = 0.845, p< 0.01)\) (Table-8) and negatively correlated with biochemical oxygen demand \((r = -0.529, p< 0.05)\). It was positively correlated with atmospheric temperature \((r = 0.788, p< 0.01)\), conductivity \((r = 0.645, p< 0.01)\), total dissolved solids \((r = 0.675, p< 0.01)\) and negatively correlated with chemical oxygen demand \((r = -0.584, p< 0.05)\) in Nyasargi reservoir. In Sanavalli reservoir, it was positively correlated with atmospheric temperature \((r = 0.515, p< 0.05)\), EC \((r = 0.585, p< 0.05)\), TDS \((r = 0.562, p< 0.05)\) and Magnesium \((r = 0.519, p< 0.05)\). In Battigeri tank water temperature has not shown any significant correlation with other variables. In Gangibhavi tank water temperature was positively correlated with Calcium \((r = 0.516, p< 0.05)\), chemical oxygen demand \((r = 0.565, p< 0.05)\), conductivity \((r = 0.696, p< 0.01)\), salinity \((r = 0.646, p< 0.01)\), total dissolved solids \((r = 0.689, p< 0.01)\) and total hardness \((r = 0.517, p< 0.05)\). Existence of positive correlation between water temperature and DO and pH was also reported by Patil and Goder, (1985); Nadoni et al., (2001). However in the present study air temperature was positively correlated with DO in Nyasargi and Sanavalli reservoirs (Table-15 to 20).

In survey, we found that atmospheric temperature did not vary significantly in all the three districts. Water temperature was high in Dharwad district water bodies (Table-11),
followed by Haveri and Uttar Kannada districts water bodies. According to Welch (1952) the response of water temperature to air temperature depends on the size of the water body. The smaller masses of water respond more quickly than bigger sheets having more surface area and mean depth (Munavar, 1970). In the present survey range of water temperature was less in Uttar Kannada district water bodies (24.8 °C to 26.7°C), the variation may attributed to the large area of water bodies (minimum 459 ha). In the water bodies of Dharwad district water temperature range was high (25.4 °C to 29.4°C) which are smaller in size (maximum 466 ha; except Neersagar reservoir) (Table-1). Therefore, it is clear that the water bodies with smaller area responded quickly to the air temperature than that of big reservoirs with more surface area. In the lakes with more surface area the rate of evaporation is more with the result that water gets heated more slowly as compared to the ponds (which have less surface area). In the case of ponds where the rate of evaporation is less with the result that water gets heated faster (Hutchinson, 1957).

Secchi depth Transparency (fig – 4)

Although suspended solids occur naturally in both lotic and lentic waters, human activities can greatly increase their concentration. Several types of materials contribute to suspended solids, including soil particles aquatic organisms (such as phytoplankton and zooplankton) and small fragments of dead plants (Dahlgren et al., 2004).

In the present investigation, the lower values of transparency was observed in Gangibhavi pond (7.14 ± 2.67 cm) and higher values in Attiveri reservoir (52.45 ± 21.01 cm) (Table-10). The higher transparency values in Attiveri reservoir may be due to high water spread area with least anthropogenic disturbances. Incase of Gangibhavi pond, it is a smaller size water body, shallow water with higher anthropogenic disturbances which
caused higher turbidity. The studies of Unni (1985) support this observation because he found that the major reservoir with large quantity of water will have more transparency and the minor reservoirs with less quantity of water will have less transparency.

In the present investigation, seccidi depth transparency of Attiveri reservoir positively correlated with pH ($r = 0.676$, $<< 0.01$) and negatively correlated with inorganic phosphates ($r = -0.642$, $<< 0.01$), calcium content ($r = 0.594$, $<< 0.01$) and total hardness ($r = 0.484$, $<< 0.05$). In Bachanki it was negatively correlated with nitrates ($r = -0.716$, $<< 0.01$) and inorganic phosphates ($r = -0.469$, $<< 0.05$). In Nyasargi reservoir it was positively correlated with conductivity ($r = 0.519$, $<< 0.05$) and total dissolved solids ($r = 0.509$, $<< 0.05$). In Sanavalli reservoir it was positively correlated with chemical oxygen demand ($r = 0.873$, $<< 0.01$) and fluoride ($r = 0.681$, $<< 0.01$), and negatively correlated with total hardness ($r = -0.414$, $<< 0.05$). Water transparency of Battigeri pond was negatively correlated with only ammonical nitrogen ($r = -0.499$, $<< 0.05$), whereas in Gangibhavi pond also it was negatively correlated with ammonical nitrogen ($r = -0.701$, $<< 0.01$), free carbon dioxide ($r = -0.596$, $<< 0.01$), chlorides ($r = -0.529$, $<< 0.05$) and sulphates ($r = -0.518$, $<< 0.05$) (Table-15 to 20).

Muragavel and Pandian (2000) reported the positive correlation of transparency with pH, free CO$_2$, phosphates, DO and nitrates, and he has also reported the existence of negative correlation between transparency and atmospheric temperature, water temperature and pH.

**pH (fig-5)**

pH is an important measures that indicates the chemical conditions existing in natural waters. It represents the negative logarithm of the concentration of free hydrogen ion in a solution. pH governed by the free carbon-di-oxide/ carbonates/ bicarbonates
equilibrium and it also dependents on the phytoplankton growth. In absolutely pure water H+ and OH- ions are present in equal proportions. In natural waters pH may range between 4.4 and 8.5 (NEERI, 1988). Thus the pH of the natural waters is controlled chiefly by the interaction of H+ and OH- ions. The former arises from the dissociation of H2CO3 and the later due to hydrolysis of bicarbonates. The pH of certain global waters is found to be as low as 2 and as high as 12. pH less than 4 is found mostly in volcanic lakes and sphagnum bogs. Very high pH is due to very high concentration of soda in lakes (Wetzel, 1975). Domestic waters have a pH range of 6.5 to 8.5 at values out side this range, water can be corrosive or can cause precipitation of metal salts.

The lowest pH values were recorded in Battigeri tank (Table.10). According to Wetzel (1975), low pH values are found in natural waters rich in dissolved organic matter. It is quite possible that when organic matter is more the aerobic bacterial degradation will also be more which results in the release of carbon dioxide reducing pH depicts that free carbon-di-oxide was comparatively low in the four reservoirs and almost constantly high in the two ponds (Singh, 1987). Similar observations are those of Saha and Pandit (1985).

This is in agreement with the general notion that waters poor in CO2 are more alkaline as compared to those which are rich in it. This can be visualized in the present study by the fact that the Bachanki, Nyasargi and Attiveri reservoirs were with the lowest carbon-di-oxide values were more alkaline and the Battigeri ponds with comparatively higher concentrations of free carbon-di-oxide was less alkaline. However the Gangibhavi pond though it has higher concentration of free carbon-di-oxide was also more alkaline.

Carbon-di-oxide was constantly present in the Battigeri, Gangibhavi ponds and Nyasargi and Sanavalli reservoirs. The absence of free carbon-di-oxide in Attiveri and
Bachanki reservoirs in the month of January 2004 may be due to carbonate systems. This fact is in agreement with Hutchinson (1957) and Goel et al. (1980b) who believe that continuous absence of carbon-di-oxide is possible due to higher pH. Further according to Pearsall (1930) and Gonzalves and Joshi (1946) free carbon-di-oxide is absent when pH is above 8.3. Appearances of carbonates mostly above 8.4, especially in Attiveri and Bachanki reservoir support this view.

The lowest values of pH and dissolved oxygen in Battigeri pond (7.79 ± 0.34) and highest (8.03 ± 0.28) values of these factors found in the Attiveri reservoir is in conformity with the above fact. According to Saran and Adoni (1982) during photosynthesis free carbon-di-oxide and bicarbonates are utilized and there is release of carbonates which increases the quantity of dissolved oxygen and pH. Thus a positive correlation exists between pH and DO. However this relation in our observation was found in only Battigeri pond.

The seasonality of pH was not uniform in all the water bodies. It showed a rising trend from summer to winter through monsoon. In the summer months of 2003 pH values of all water bodies were low. According to Das (1961) the decrease in pH during summer may be due to decrease in the amount of water which ultimately increases the concentration of free carbon-di-oxide released by the respiration of aquatic organisms. Increase in free carbon-di-oxide concentration simultaneously during summer is in agreement with this view.

pH was positively correlated with secchi depth transparency ($r= 0.676, P< 0.01$), fluoride ($r= 0.572, P< 0.05$) and chemical oxygen demand ($r= 0.549, P< 0.05$) in Attiveri reservoir. In Bachanki reservoir, it was positively correlated with fluoride ($r= 0.553, P< 0.05$) and ammonical nitrogen ($r= 0.505, P< 0.05$). In Nyasargi reservoir, it was
positively correlated with free carbon dioxide ($r = 0.658$, $P < 0.01$), ammonical nitrogen ($r = 0.610$, $P < 0.01$), biochemical oxygen demand ($r = 0.570$, $P < 0.05$) and magnesium ($r = 0.562$, $P < 0.05$). In Sanavalli reservoir, it was positively correlated with chemical oxygen demand ($r = 0.700$, $P < 0.01$), orthophosphates ($r = 0.537$, $P < 0.05$) and chlorides ($r = 0.502$, $P < 0.05$). In Battigeri pond, it was positively correlated with magnesium ($r = 0.600$, $P < 0.05$), chemical oxygen demand ($r = 0.500$, $P < 0.05$) and dissolved oxygen ($r = 0.508$, $P < 0.05$), and negatively correlated with nitrates ($r = -0.596$, $P < 0.05$). In Gangibhavi pond, it was positively correlated with sulphates ($r = 0.781$, $P < 0.01$), chlorides ($r = 0.662$, $P < 0.01$), ammonical nitrogen ($r = 0.558$, $P < 0.05$), total hardness ($r = 0.539$, $P < 0.05$), and biochemical oxygen demand ($r = 0.495$, $P < 0.05$) (Table-15 to 20).

Muragavel and Pandian (2000) reported the existence of significant positive correlation of pH with transparency, free carbon-di-oxide, alkalinity and phosphates and nitrates and negative correlation with atmospheric temperature, dissolved oxygen and transparency. Barbieri et al., (1999) also observed the positive correlation of pH with calcium, magnesium, alkalinity and negative correlation with nitrates. Patil and Gouder (1985) noticed the positive correlation of pH with water temperature, dissolved oxygen and conductivity and negative correlation with phosphates.

In survey, the high pH of Hanamapur and Gudgur may be attributed to the presence of algal blooms, which use free carbon-di-oxide for photosynthesis and increase the pH of the water body as suggested by Wurts and Durborow, (1992). The low pH of Devarkoppa, Ganjigatti, Sadankere, Kuradikere, Savanur, Timmapur and Krishnapur may be attributed to dissolved organic matter and it was also observed high free carbon-di-oxide content in Krishnapur and Timmapur tank.

51
Electric Conductivity (fig-6)

Electric Conductivity (E.C.) is the capacity of water to carry the electrical current. It varies with number and types of ions the solution contains. The distilled water has an electric conductivity ranging between 1-5 μmhos. The presence of salts and contaminations increase the electric conductivity of water. Of the six water bodies studied, the lowest values of E.C. were observed in the Nyasargi reservoir (154.0 ± 33.47 μ S cm⁻¹) and higher values in Battigéri pond (Av. 491.8 ± 212.3 μ S cm⁻¹) (Table-10). The lower values of electric conductivity in Nyasargi may be because its depth that holds more quantity of water, whereas Battigéri pond is a smaller size with shallow water had higher values. The studies of Unni (1985) support this observation because he found that the major reservoir with large quantity of water will have low electric conductivity and the minor reservoirs with smaller quantity of water will have high electric conductivity.

Seasonal variation of electrical conductivity showed the highest values during summer in the Battigéri tank. This may be attributed to the fact that there is decrease in the quantity of water that has resulted in accumulation of salts leading to increasing the electric conductivity to reach its highest peak during summer. In all the water bodies the highest values of electric conductivity were observed during summer (fig-6). This is due the high rate of evaporation during summer that might have increased the concentrations of salts. Similar observations were reported by Sreenivasan (1973) and Huddar (1995).

In the present study, electric conductivity was positively correlated with total dissolved solids (r = 0.972, p< 0.01) and salinity (r = 0.572, p< 0.01), and negatively correlated with inorganic phosphates (r = -0.487, p< 0.05) in Attiveri reservoir. In Bachanki reservoir, it was positively correlated with total dissolved solids (r = 0.994, p<
0.01) and salinity (r = 0.890, p< 0.01). It was positively correlated with total dissolved solids (r = 0.988, p< 0.01), water temperature (r= 0.645, p< 0.01), secchi depth transparency (r= 0.519, p< 0.05) and atmospheric temperature (r = 0.596, p< 0.05) in Nyasargi reservoir. It was positively correlated with total dissolved solids (r = 0.992, p< 0.01), water temperature (r= 0.585, p< 0.05), total alkalinity (r= 0.521, p< 0.05), and chlorides (r = 0.470, p< 0.05) in Sanavalli reservoir. In Battigeri tank it was positively correlated with total dissolved solids (r = 0.996, p< 0.01), salinity (r = 0.923, p< 0.01),total hardness (r= 0.950, p< 0.01), chlorides (r = 0.892, p< 0.01), ammonical nitrogen (r = 0.655, p< 0.01), biochemical oxygen demand (r= 0.766, p< 0.01), calcium (r= 0.945, p< 0.01), atmospheric temperature (r = 0.604, p< 0.05), chemical oxygen demand (r= 0.550, p< 0.05) and magnesium (r = 0.610, p< 0.05). In Gangibhavi tank it was positively correlated with total dissolved solids (r = 0.998, p< 0.01), salinity (r = 0.839, p< 0.01), total hardness (r = 0.833, p< 0.01), calcium (r = 0.824, p< 0.01), water temperature (r = 0.696, p< 0.01), atmospheric temperature (r = 0.657, p< 0.01), chemical oxygen demand (r = 0.587, p< 0.05) and chlorides (r = 0.542, p< 0.05) (Table-15 to 20).

Existence of significant correlation between electric conductivity and calcium, magnesium, total alkalinity, and sulphates was also reported by Barbieri et al., (1999) and Rao et al., (1999).

In survey, the Haveri district water bodies are shallower than that of Dharwad and Uttar Kannada district water bodies, which recorded the high conductivity value followed by Dharwad district water bodies comparatively bigger than that of Haveri district water bodies and lowest conductivity was recorded in the Uttar Kannada district water bodies, which are big reservoirs.

The suitability for irrigation water can be determined based on electric conductivity (Elango et al., 1992). Based on the electric conductivity of the water, these tanks have
been categorized into four groups (Table-12). Out of the 41 water bodies surveyed, 26 are excellent, 12 are good and 3 are under the permissible limit. The EC during February 1992 (Table-14) was high compared to the present study. The decrease in conductivity in the present investigation may be attributed to the period of water analysis, because during post monsoon season water bodies contain large quantity of water compared to February month. Due to the rapid evaporation of water in that month might have increased concentration of dissolved solids. Lind and Lind (2002) opined that water quality might be significantly determined by water quantity. While analyzing the Lake Chapala of Mexico they said that the decline in water volume over the past 20 years enhanced water quality problems.

**Total dissolved solids (fig-7)**

Total dissolved solids denote mainly the various kinds of minerals present in the water. However, if some organic substances are also present, as more often in polluted waters, they may also contribute to the dissolved solids. Dissolved solids do not contain any gas and colloidal etc. (Trivedy and Goel, 1984).

In natural waters, dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, sulphates, phosphates, and nitrates of calcium, magnesium, sodium, potassium, iron and manganese etc. In the polluted waters, the concentration of other substances increases depending upon the type of pollution. The determination of dissolved solids does not give a clear picture of kind of pollution. Concentration of dissolved solids is an important parameter in drinking water and other water quality standards. They give a particular taste to the water at higher concentration and also reduce its palatability. However, in case of drinking water the individual concentrations of different substances are more important rather than the total dissolved solids.
Seasonal variation of total dissolved solids showed the highest values during summer in the Battigeri tank (251.09 ± 109 mg/l) (Table-10). This may be attributed to the fact that this water body was dried during April and May 2004 prior to this the decrease in the quantity of water resulted in accumulation of salts increasing the concentration of dissolved solids to reach its highest peak during summer. All most all the water bodies the highest values of dissolved solids were during summer. This is due the high rate of evaporation during summer, which might have increased the concentrations of salts. Also these are the permanent water bodies in which the quality of water decrease during the summer. Similar observations were made by Sreenivasan (1973) and Huddar (1995).

In the present study dissolved solids concentration of Attiveri reservoir were positively correlated with conductivity (r = 0.972, p< 0.01) and salinity (r = 0.521, P< 0.05), and negatively correlated with inorganic phosphates (r = -0.534, P< 0.05). In Bachanki reservoir were positively correlated with conductivity (r = 0.994, p<0.01) and salinity (r = 0.878, p< 0.01). In Nyasargi reservoir TDS were positively correlated with conductivity (r = 0.988, P< 0.01), water temperature (r= 0.675, P< 0.01), atmospheric temperature (r = 0.645, P< 0.01) and secchi depth transparency (r= 0.509, P< 0.05), and negatively correlated with sulphates (r= -0.483, P< 0.05). In Sanavalli reservoir TDS were positively correlated with conductivity (r = 0.992, P< 0.01), water temperature (r= 0.562, P< 0.05), dissolved oxygen (r = 0.520, P< 0.05), biochemical oxygen demand (r= 0.478, P< 0.05), total alkalinity (r= 0.483, P< 0.05) and bicarbonates (r= 0.483, P< 0.05). In Battigeri pond TDS were positively correlated with conductivity (r = 0.996, P< 0.01), salinity (r = 0.943, P< 0.01), total hardness (r = 0.947, P< 0.01), calcium (r = 0.946, P< 0.01), chlorides (r = 0.869, P< 0.01), biochemical oxygen demand (r = 0.740, P< 0.01),
fluoride \((r = 0.707, P < 0.01)\), atmospheric temperature \((r = 0.637, P < 0.01)\), ammonical nitrogen \((r = 0.610, P < 0.05)\), magnesium \((r = 0.557, P < 0.05)\) and chemical oxygen demand \((r = 0.498, P < 0.05)\). In Gangibhavi pond TDS were positively correlated with conductivity \((r = 0.998, P < 0.01)\) (Table-12), total hardness \((r = 0.824, P < 0.01)\), calcium \((r = 0.819, P < 0.01)\), water temperature \((r = 0.689, P < 0.01)\), atmospheric temperature \((r = 0.682, P < 0.01)\), chemical oxygen demand \((r = 0.566, P < 0.05)\) and chlorides \((r = 0.523, P < 0.05)\) (Table-15 to 20).

In all six water bodies total dissolved solids showed very strong positive correlation with conductivity. Rao et al. (1999) also observed the positive correlation of total dissolved solids with electric conductivity, total hardness, calcium, magnesium, alkalinity, chlorides, phosphates and DO and negative correlation with nitrates, and fluoride. Similar observations are those of Al-Hawas (2002) and Nadoni et al., (2001).

In survey, total dissolved solids were recorded high in Haveri district water bodies followed by Dharwad and lower concentration in Uttar Kannada district water bodies. Higher values of TDS in Haveri district water is due to shallow water and increased anthropogenic disturbances.

**Dissolved Oxygen (DO) (fig-8)**

Oxygen is an important factor in limnology. A series of oxygen determinations can reveal more about the nature of the lake than any other chemical factor (Hutchinson, 1957). The occurrence of DO in water is mainly due to the physical process of direct diffusion from the air and the biological process of photosynthesis by aquatic autotrophs. oxygen is the most essential element for the living organisms to keep their metabolic process functional and to meet their energy requirements through respiration. Oxygen is moderately soluble in water and its solubility decreases with increase in temperature. The
solubility of oxygen in pure waters at 0°C is 14.6 mg/l, whereas water usually contains about 8.0 mg/l of dissolved oxygen at room temperature. It is necessary to know the level of DO to assess the quality of raw water (Huddar, 1995).

From the Tables-10, it is clear that the two ponds showed low DO concentration as compared to the four reservoirs. This can be visualized from fig- 8, this may be because of the reservoirs with more surface area have the capacity to take up more oxygen. Similar observations are those of Happey-Wood (1975 cited in Huddar, 1995). This low value of DO in the two ponds may be due to the higher amount of dissolved organic matter as compared to the four reservoirs. Of the four reservoirs, the Attiveri reservoir had comparatively higher (11.79 ± 1.53 mg/l) DO concentration than that of Bachanki reservoir (11.42 ± 1.64 mg/l).

Seasonal variations in DO reveal that in all the four reservoirs oxygen decreased during the monsoon season and was high in summer season, whereas in contradictory in ponds decreased in summer and increased in winter. Oxygen decrease in summer may be due to the increase in temperature during summer which must have increased the catabolic processes utilizing oxygen. Similar observations are these of Gonzalves and Joshi (1946), Rao (1955) and Singh (1960). This summer minimum of DO observed in two ponds may also due to increased decomposition of organic matter during summer, which is in accordance with the studies of Vyas and Kumar (1968) and Sharma et al., (1978). Winter maxima of dissolved oxygen observed in the two ponds may be attributed to the decrease temperature and also that the two ponds being smaller water bodies, responded very quickly to the air temperature and acquired the temperature minima, thus dissolving more photosynthetic oxygen in them. The summer maxima of dissolved oxygen concentration may be due to the higher photosynthetic activity in reservoirs in summer.
Dissolved oxygen content in the present study has not showed any significant correlation in Attiveri reservoir. In Bachanki reservoir it showed negatively correlation with nitrates ($r = -0.504, P< 0.05$). In Nyasargi reservoir, it was positively correlated with calcium ($r= 0.722, P< 0.01$), total hardness ($r = 0.706, P< 0.01$), ammonical nitrogen ($r= 0.677, P< 0.01$), chlorides ($r = 0.575, P< 0.05$), atmospheric temperature ($r = 0.545, P< 0.05$) and inorganic phosphates ($r = 0.518, P< 0.05$). In Sanavalli reservoir, it was positively correlated with biochemical oxygen demand ($r= 0.637, P< 0.01$) (Table-10), ammonical nitrogen ($r= 0.608, P< 0.01$), total dissolved solids ($r= 0.520, P<0.05$) and atmospheric temperature ($r= 0.480, P< 0.05$). In Battigeri pond it was positively correlated with pH ($r= 0.508, P<0.05$) and negatively correlated with nitrates ($r = -0.822, P< 0.01$) and atmospheric temperature ($r = -0.480, P< 0.05$). In Gangibhavi pond it was negatively correlated with nitrates ($r = -0.597, P< 0.05$) (Table-15 to 20).

Murugavel and Pandian (2000) reported the existence of positive correlation between DO and transparency, phosphates and nitrate. They also observed the negative correlation between atmospheric temperature, water temperature, pH, alkalinity, phosphates and nitrates while analyzing the Kodayar reservoir and Pandiyapuram pond. Further they also reported in the Upper Kodayar reservoir the DO has not showed any significant correlation with any of the variables. Patil and Goder (1985) also reported the existence of positive correlation between DO and pH, negative correlation between DO and phosphate. According to Nadoni et al., (2001) dissolved oxygen positively correlates with water temperature, total dissolved solids, hardness, phosphates, sulphates, biochemical oxygen demand, chemical oxygen demand and magnesium. These studies support our findings.

In survey, higher concentration of dissolved oxygen was found in Attiveri, followed by Nyasargi and Bachanki reservoirs of the Uttar Kannada district, which
exhibit low water temperature. Low dissolved oxygen was recorded in Budnal tank (Table-8) of Dharwad district and Krishnapur, Kadkol, and Timmapur tanks of Haveri district where the water temperature was high (Table-11). The high DO in the reservoirs compared to the tanks may be due to slightly lower temperature, more water level, larger surface area and therefore, more dissolution of atmospheric oxygen (Hegde and Huddar, 1995), and lower the concentration of organic inputs. Lower concentration of DO in tanks may be related to less surface area, and also due the presence of high amount of dissolved organic matter as compared to reservoirs. Although Unkal lake has more surface area, was less in dissolved oxygen concentration. It may be due to the deposition of sediments, which reduces lake depth and water storage capacity, and thereby affects the distribution of heat, dissolved oxygen concentrations and other vital water quality parameters (Miranda et al., 2001).

**Free carbon-di-oxide (CO₂) (fig- 9)**

Free carbon-di-oxide is exceedingly soluble in pure water when it dissolved in water it produces a small amounts of carbonic acid (H₂CO₃), which on dissociation forms H⁺ and HCO₃⁻. Therefore the study of the carbon-di-oxide content of water is of great importance in understanding the H⁺ ion concentration of water. Free carbon-di-oxide is of utmost importance to autotrophic primary producers of aquatic ecosystem, since it is the source of carbon for photosynthesis.

The source of free carbon-di-oxide dissolved in water is either direct through dissolution from the atmosphere or produced by the decomposition of organic matter and through the respiration of plants and animals in water. The decrease of free carbon-di-oxide concentration in water is generally due to its photosynthetic utilization, marl forming organisms, evaporation of water etc. Birge and Juday (1911) have classified the
lakes on the basis of quality of bound free carbon-di-oxide as soft water lakes, medium-class lakes and hard water lakes.

Attiveri and Bachanki reservoirs had the lowest value of free carbon-di-oxide (Table-10). Higher values of free carbon-di-oxide were observed in Battigeri and Gangibhavi ponds. The free carbon-di-oxide was present in all the observation with highest value in Battigeri pond. It was absent in the month of January 2004 in Attiveri and Bachanki reservoirs. This may be because of lower concentration of dissolved organic matter in the reservoirs as compared to ponds. Thus the slower rate of decomposition of organic matter might have produced only a small quantity of carbon-di-oxide in the reservoirs. Free carbon-di-oxide is absent if the pH is above 8.3 as found by the early workers Pearsall (1930); Gonzalves and Joshi (1946). In the present study Gangibhavi pond which had the highest pH (8.12 ± 0.34) followed by Attiveri reservoir (8.03 ± 0.28). However, Gangibhavi pond having high pH also had high carbon-di-oxide. High concentration of free carbon-di-oxide was observed in summer months in all the water bodies and low pH in summer except in Gangibhavi pond. According to Das (1961) the decrease in pH during summer may be due to decrease in the amount of water which ultimately increases the concentration of free carbon-di-oxide released by the respiration of aquatic organisms. Increase in free carbon-di-oxide concentration simultaneously during summer is in agreement with this view.

Seasonal variation of free carbon-di-oxide indicates that it was highest during summer in all the water bodies (Table.2 to 7). This may be because during summer the rate of decomposition of organic matter is speeded up resulting in a surplus amount of free carbon-di-oxide, which in turn is responsible for lowering the pH. Similar observations are those of Goel et al., (1980) and Nair et al., (1988).
Free carbon-di-oxide was negatively correlated with carbonates \( (r = -0.520, P < 0.05) \) in Attiveri reservoir. In Bachanki it was negatively correlated with carbonates \( (r = -0.595, P < 0.01) \), fluorides \( (r = -0.552, P < 0.05) \) and chlorides \( (r = -0.497, P < 0.05) \). In Nyasargi reservoir, it was positively correlated with ammonical nitrogen \( (r = 0.812, P < 0.01) \), pH \( (r = 0.651, P < 0.01) \), biochemical oxygen demand \( (r = 0.557, P < 0.05) \), fluoride \( (r = 0.537, P < 0.05) \), sulphates \( (r = 0.526, P < 0.05) \), dissolved oxygen \( (r = 0.495, P < 0.05) \) and chlorides \( (r = 0.492, P < 0.05) \). In Sanavalli reservoir, it was positively correlated with calcium \( (r = 0.753, P < 0.01) \), total hardness \( (r = 0.743, P < 0.01) \), and orthophosphates \( (r = 0.553, P < 0.05) \). In Battigeri pond, it was positively correlated with salinity \( (r = 0.663, P < 0.01) \) and fluoride \( (r = 0.581, P < 0.05) \). In Gangibhavi pond, it was positively correlated with ammonical nitrogen \( (r = 0.717, P < 0.01) \), fluoride \( (r = 0.636, P < 0.01) \), biochemical oxygen demand \( (r = 0.546, P < 0.05) \) and sulphates \( (r = 0.504, P < 0.05) \), and negatively correlated with secchi depth transparency \( (r = -0.596, P < 0.01) \) (Table-15 to 20).

Existence of a significant negative correlation with pH, carbonate and phenolphthalein alkalinity was reported by Huddar (1995). Muragavel and Pandian (2000) also reported that free carbon-di-oxide positively correlates with transparency, pH, alkalinity, phosphates and nitrates, and negatively correlates with atmospheric temperature and water temperature.

**Alkalinity (fig-10)**

Alkalinity of the water is its capacity to neutralize a strong acid and is characterized by the presence of all hydroxyl ions capable of combining with the hydrogen ion. Alkalinity in natural waters is due to free hydroxyl ions and hydrolysis of salts formed by weak acids and strong bases. Most of the alkalinity in natural waters is
formed due to dissolution of carbon-di-oxide in water. It is also produced by the action of water on limestone or chalk (Trivedy and Goel, 1984).

In the present study, the total alkalinity was low in the Sanavalli reservoir (91.67 ± 28.75 mg/l) and high in Gangibhavi pond (176.39 ± 63.48 mg/l) (Table-10). Lower values (91.67 ± 28.75 mg/l) of alkalinity in Sanavalli reservoir may be due to the lower concentration of carbon-di-oxide. As most of the tanks total alkalinity was in the form of bicarbonates alkalinity so its seasonality and correlations were discussed in bicarbonates.

**Carbonates**

In the present study, carbonates were found in equal concentration in Attiveri and Bachanki reservoirs during the January month 2004. Carbonates were absent throughout the study period in Nyasargi reservoir, Sanavalli reservoir, Battigeri pond and Gangibhavi pond. According to Zafar (1966) and Prasad and Singh (1980) when the carbonates are present the water is more alkaline and when it supports large quantities of bicarbonates, carbon dioxide and calcium it is much less alkaline. The water bodies where carbonates were completely absent throughout study period was less alkaline (Table-2 to 7) with high bicarbonates, free carbon-di-oxide and calcium.

Carbonates of Attiveri reservoir was positively correlated with chlorides ($r=0.729$, $P<0.01$) and negatively correlated with atmospheric temperature ($r=-0.475$, $P<0.05$) and free carbon dioxide ($r=-0.520$, $P<0.05$). In Bachanki it was positively correlated with with chlorides ($r=0.745$, $P<0.01$) and negatively correlated with free carbon dioxide ($r=-0.595$, $P<0.01$) (Table-15 & 16).

In survey, carbonates were present only in the Haveri district water bodies namely Heggeri, Kabbur and Akkilalur tanks. This may be due to the complete utilization of free carbon-di-oxide for photosynthetic activity as explained by Faisuddian and Kumari (1990).
**Bicarbonates (fig- 11)**

In the present study, the bicarbonates were in lower concentration in the Sanavalli reservoir (91.67 ± 28.75 mg/l) and higher concentration in Gangibhavi pond (176.39 ± 63.48 mg/l) (Table-10). Lower values of bicarbonates in Sanavalli reservoirs may be attributed to the lower level of free carbon-di-oxide.

Bicarbonates of Attiveri reservoir were positively correlated with total alkalinity ($r= 0.992, P< 0.01$). In Bachanki reservoir, they were positively correlated with total alkalinity ($r= 0.984, P< 0.01$). In Nyasargi reservoir they were positively correlated with fluoride ($r= -0.632, P< 0.01$) and chemical oxygen demand ($r= -0.526, P< 0.05$). In Sanavalli reservoir they were positively correlated with magnessium ($r= 0.668, P< 0.01$), conductivity ($r=0.521, P< 0.05$) and total dissolved solids ($r= 0.483, P< 0.05$). In Battigeri pond they were positively correlated with atmospheric temperature ($r= 0.510, P< 0.05$) and negatively correlated with orthophosphates ($r= -0.542, P< 0.05$). In Gangibhavi pond they have not shown significant correlation with any other variables (Table-15 to 20).

In survey, bicarbonates were high in Uttar Kannada district water bodies compared to the Dharwad and Haveri (Table-11). Presence of high bicarbonates in the Krishnapur tank may be attributed to the presence of high free CO$_2$ content as this tank was with infinite numbers of *Daphnia carinata* species.

**Total Hardness (fig-12)**

The term hardness is frequently used to express the quality of water. It is an important parameter as it indicates the intensity of some dissolved salts especially of calcium and magnesium which are the principal cations imparting hardness to the water.
Hardness of water is due to the presence of certain salts of calcium, magnesium and other heavy metals dissolved in it (Jain and Jain, 1988).

Hardness of water is of two types i) temporary hardness, which is due to the presence of dissolved bicarbonates of calcium, magnesium and other heavy metals and the carbonate iron. Temporary hardness can be removed by boiling. ii) Permanent hardness, which is due to the presence of chlorides, sulphates of calcium, magnesium, iron and other heavy metals. Hard water used for washing purposes does not lather freely with soap. Hard water if used for drinking purposes causes undesirable effects on digestive system (Jain and Jain, 1988).

In the present study, the minimum value of hardness was in the Sanavalli reservoir (35.78 ± 22.51 mg/l) and maximum value in the Battigeri pond (117.75 ± 53.5 mg/l) (Table-10). The maximum values of hardness may be due to the lower volume of water in Battigeri pond. According Bohra and Kumar (2004) in summer, presence of lower water level the concentration of calcium, hardness and total alkalinity will increase.

Seasonal variations showed that hardness increased during monsoon in all the water bodies except the Battigeri pond indicates that the hardness in these water bodies is of allochthonous origin. In Battigeri pond maximum during in March (summer) may be due to low water level as the pond was about to dry. In all these the increase in hardness was coupled with the increase in the calcium concentration which suggests that calcium is one of the important factors contributing to the hardness.

This can be further substantiated by the correlation matrix in which calcium and hardness showed a significant positive correlation in all the six water bodies.
In Attiveri reservoir hardness was positively correlated with calcium \( (r= 0.961, P<0.01) \) and salinity \( (r= 0.534, P<0.05) \) and negatively correlated with secchi depth transparency \( (r= -0.484, P<0.05) \). In Bachanki reservoir it was positively correlated with calcium \( (r= 0.947, P<0.01) \), inorganic phosphorus \( (r= 0.639, P<0.01) \). In Nyasargi reservoir, it was positively correlated with calcium \( (r= 0.977, P<0.01) \), dissolved oxygen content \( (r= 0.706, P<0.01) \) and ammonical nitrogen \( (r= 0.594, P<0.05) \). In Sanavalli reservoir, it was positively correlated with calcium \( (r= 0.975, P<0.01) \), free carbon dioxide \( (r= 0.743, P<0.01) \), chlorides \( (r= 0.532, P<0.05) \), inorganic phosphorus \( (r= 0.538, P<0.05) \) and nitrates \( (r= 0.519, P<0.05) \). In Battigeri tank, it was positively correlated with calcium \( (r= 0.994, P<0.01) \), conductivity \( (r= 0.950, P<0.01) \), total dissolved solids \( (r= 0.947, P<0.01) \), chlorides \( (r= 0.903, P<0.01) \), salinity \( (r= 0.897, P<0.01) \), biochemical oxygen demand \( (r= 0.825, P<0.01) \), fluoride \( (r= 0.777, P<0.01) \), atmospheric temperature \( (r= 0.669, P<0.01) \), ammonical nitrogen \( (r= 0.651, P<0.01) \), and magnesium \( (r= 0.548, P<0.05) \). In Gangibhavi tank it was positively correlated with calcium \( (r= 0.994, P<0.01) \), conductivity \( (r= 0.833, P<0.01) \) total dissolved solids \( (r= 0.824, P<0.01) \), chlorides \( (r= 0.634, P<0.01) \), pH \( (r= 0.539, P<0.05) \), atmospheric temperature \( (r= 0.526, P<0.05) \) and water temperature \( (r= 0.517, P<0.05) \) (Table-15 to 20).

Nadoni et al., (2001) observed the positive correlation of hardness with dissolved oxygen and sulphates and negative correlation with water temperature, chlorides, BOD, COD. Rao et al., (1999) also noticed the positive correlation of total hardness with calcium, electric conuctivity, total dissolved solids, magnesium, alkalinity, chlorides, phosphates and dissolved oxygen, and negative correlation with nitrate and fluoride content. These studies support our findings.
The suitability of water for domestic use can be classified based on hardness (Hegde and Kale, 1995). The classification of water bodies based on the hardness is given in Table 13. Out of 41 tanks surveyed, 11 tanks have soft water, 22 tanks were moderately soft, 7 tanks were slightly hard and only one tank (Krishnapur) had moderately hard (156 mg/l) water. In 1992 the hardness was high compared to the present study (Uttangi, 2001) (Table-14). The lower concentration of hardness in the present study attribute to post monsoon period, where water level remains high compared to February month 1992. Slight increase in hardness of Kelgeri tank in post monsoon indicates that low water level in tank now, because of the conversion of its catchment area in to new housing colonies might have caused this problem.

**Calcium (fig-13)**

Calcium is one of the major cations. It plays an important role in numerous ways in the growth and population dynamics of fresh water flora and fauna. It is considered as a basic inorganic element of algae and is regarded as a nutrient for various metabolic processes (Ruttner, 1953). It is needed as a micronutrient. Calcium is essential for maintenance of the structural and functional integrity of cell membranes in ion absorption (Wetzel, 1975).

The present study showed the lowest values of calcium in the Sanavalli (11.34 ± 7.57 mg/l) and the highest values in the Battigeri pond (42.42 ± 19.99 mg/l). The average values of (Table-10) indicates that the highest concentration of calcium was in the Battigeri tank which also showed the highest values of bicarbonates, carbon-di-oxide and the lowest values of pH. This may be explained as follows when calcium reacts with carbonate which is insoluble as such low values of calcium are observed (Wetzel, 2003). When calcium occurs in the form of calcium bicarbonate it is soluble. In such cases the
higher values of calcium are observed. The availability of calcium mainly depends on pH, carbon-di-oxide, carbonate and bicarbonate.

At lower pH, in less alkaline waters, calcium combines with bicarbonates to form calcium-bi-carbonate which is soluble, hence the higher values of calcium of four major cations it is more reactive and can exhibit marked seasonal and spatial variations (Wetzel, 2003).

Seasonal variations of calcium revealed that maximum values in were during monsoon in all water bodies except Battigeri pond may be due to allochthonous supply. In Battigeri pond maximum during in March (summer) may be attribute to low water level as the pond was about to dry. Faster rate of decomposition during summer may also contributed for the same. And the minimum in monsoon season may be attributed to the dilution. In four reservoirs the highest calcium content was observed in Attiveri reservoir (22.14 ± 5.02), and it was at its peak in May 2004 (summer) may be due to lower water level as observed by Saran and Adoni, 1984.

In Attiveri reservoir calcium was positively correlated with total hardness (r = 0.961 < 0.01), orthophosphates (r = 0.483 < 0.05) and salinity (r = 0.517 < 0.05), and negatively correlated with transparency (r = - 0.594 < 0.05). In Bachanki reservoir it was positively correlated with total hardness (r = 0.947, < 0.01), and orthophosphates (r = 0.662, < 0.01). In Nyasargi reservoir it was positively correlated with total hardness (r = 0.977 P< 0.01), dissolved oxygen (r = 0.722, P<0.01), ammonical nitrogen (r = 0.546, =< 0.05) and orthophosphates (r = 0.492, P<0.05). In Sanavalli reservoir it was positively correlated with total hardness (r = 0.975 P< 0.01), free carbon dioxide (r = 0.753, P< 0.01), orthophosphates (r = 0.580 P<0.05) and chlorides (r = 0.487 P< 0.05). In Battigeri pond it was positively correlated with total hardness (r = 0.994, P< 0.01), total dissolved
solids (r = 0.946, P< 0.01), conductivity (r = 0.945, P< 0.01), chlorides (r = 0.874, P< 0.01), biochemical oxygen demand (r = 0.805, P< 0.01), atmospheric temperature (r = 0.702, P< 0.01) and ammonical nitrogen (r = 0.628, P< 0.01). In Gangibhavi pond it was positively correlated with total hardness (r = 0.994, P< 0.01), conductivity (r =0.820, P< 0.01), total dissolved solids (r = 0.819, P< 0.01), chlorides (r = 0.631, P< 0.01), salinity (r = 0.602, P< 0.05), atmospheric temperature (r = 0.544, P< 0.05), biochemical oxygen demand (r = 0.530, P< 0.05), water temperature (r = 0.516, P< 0.05) and pH (r = 0.516, P< 0.05) (Table-15 to 20).

Barbieri et al., (1999) reported that calcium shows significant positive correlation with pH, electric conductivity, magnesium, total alkalinity and sulphates. Rao et al., (1999) also noticed the positive correlation of calcium with total hardness, electric conductivity, total dissolved solids, magnesium, alkalinity, chlorides, phosphates and dissolved oxygen, and negative correlation with nitrate and fluoride content. These studies support our findings.

In survey, calcium was observed high in Krishnapur pond (59.2 mg/l) of Haveri district followed by Unkal lake (52.8 mg/l) in Dharwad district, and lowest was found in Sanavalli and Nyasargi reservoirs of Uttar Kannada district (Table-8 & 9). Higher concentration of calcium in Krishnapur pond and Unkal lake is allochthonous supply and lower concentration in Sanavalli and Nyasargi reservoir may be due to dilution.

**Magnesium (fig-14)**

It is the major cations, it is relatively conservative in its chemical reactivity. It is required universally by chlorophyllous plants as the component of chlorophyll molecule. Therefore it is an essential constituent of all the primary producers. It helps in transphosphorylation in algae. Magnesium is present in freshwaters in more quantity than its requirement in metabolism of the organism (Wetzel, 2003).
The concentration of magnesium was less than calcium. Among the six water bodies the concentration of magnesium in the reservoirs was low as compared to the ponds (fig-14). This is because the smaller water bodies have the higher concentrations of this element. The lowest values (Table-10) of magnesium were in Sanavalli reservoir (1.55 ± 0.69 mg/l) and the highest were in the Battigeri pond (3.16 ± 1.34 mg/l).

The seasonal variations of magnesium showed the highest value during winter in Attiveri and Nyasargi reservoirs. Similar observations have been made by Panda and Dash (1993). In the Bachanki and Sanavalli reservoirs and Gangibhavi pond the highest value was during the monsoon may be due to allochthonous supply. Highest value in March in Battigeri pond may be due to low water level as the pond was about to dry.

In Attiveri reservoir magnesium was positively correlated with chlorides ($r = 0.531, p< 0.05$). In Bachanki reservoir it was positively correlated with chlorides ($r = 0.634, p < 0.01$). In Nyasargi reservoir it was positively correlated with pH ($r = 0.562, P< 0.01$) and negatively correlated with nitrates ($r = -0.564, P<0.05$). In Sanavalli reservoir it was positively correlated with total alkalinity ($r = 0.668, P< 0.01$) and water temperature ($r = 0.519, P< 0.05$). In Battigeri pond it was positively correlated with chemical oxygen demand ($r = 0.788, P< 0.01$), fluoride ($r = 0.787, P< 0.01$), chlorides ($r = 0.691, P< 0.01$), ammonical nitrogen ($r = 0.685, P< 0.01$),biochemical oxygen demand ($r = 0.654, P< 0.01$), conductivity ($r = 0.610, P< 0.05$), salinity ($r = 0.559, P< 0.05$), total dissolved solids ($r = 0.557, P< 0.01$) and total hardness ($r = 0.548, P< 0.05$). In Gangibhavi pond it positively correlated with chemical oxygen demand ($r = 0.687, P< 0.01$) and fluoride ($r = 0.558, P< 0.05$) (Table-15 to 20).

Barbieri et al., (1999) reported that magnesium shows significant positive correlation with pH, electric conductivity, calcium, total alkalinity and sulphates. Rao et
al., (1999) also noticed the positive correlation of magnesium with total hardness, calcium, electric conductivity, total dissolved solids, alkalinity, chlorides, phosphates and dissolved oxygen, and negative correlation with nitrate and fluoride content. These studies support our findings.

**Chlorides (fig-15)**

Chloride, one of the anions, plays a metabolically active role in the photophosphorylation reactions in autotrophs. It is usually not dominant and is in very low concentrations in uncontaminated waters (Hutchinson, 1957) and in the open lake systems. The lakes near the shore line receive significant inputs of chlorides by atmospheric transport from the seas. In fresh waters the manifold increase in chlorides may be largely due to industrial sources municipal waste waters, irrigation drainage etc. (Wetzel, 1975). Chlorides impart a salty taste to water. High chloride content exerts deleterious effects on metallic pipes as well as on agricultural plants. Higher levels of chlorides in water have a laxative effect in some people. Hence a limit is fixed at 250 mg/l at which level water is not salty (Prasad and Iyer, 1983).

In the present study, lower values of chlorides were observed in Nyasargi reservoir (33.08 ± 14.50 mg/l) and higher values in Battigeri pond (121.21± 79.7 mg/l) (Table-10). The presence of higher values of chlorides in the Battigeri pond is because of its smaller size with less quantity of water as compared to the reservoir. The studies of Unni (1985), according to whom minor reservoirs have higher concentration of chlorides as compared to major reservoirs, support the above mentioned observations. However in Attiveri reservoir chlorides were found high compared to Gangibhavi pond (Table-10). The variation may attribute to the inflow from the agricultural catchment area. Further, in the ponds, chlorides increased when water level was reduced and the values declined
after rains due to dilution, whereas reservoirs the highest concentration of chlorides in January 2004 may attribute to the anthropogenic pollution because these reservoirs situated near the villages, whereas the ponds which are studied are quite away from the villages. When the water level comes down in reservoirs, village people start to enter inside the reservoir for washing their cattle, cloths and bathing. It may also due to the pollution by organic matter of animal origin (Singh, 1960). Increase in chlorides concentration due to evaporation and reduction in the amount of water is also reported by Gonzalves and Joshi (1946), Sreenivasan (1973), Patil and Gouder (1985) and Singh (1990). Higher concentration of chlorides is an indication of rapid decomposition (Sahai and Sinha, 1969).

In Attiveri reservoir chlorides were positively correlated with carbonates \((r = 0.729, P< 0.01)\), ammonical nitrogen \((r = 0.592, P< 0.01)\), chemical oxygen demand \((r = 0.556, P< 0.05)\) and magnesium \((r = 0.531, P< 0.05)\) and negatively correlated with atmospheric temperature \((r = -0.510, P< 0.05)\). In Bachanki reservoir it was positively correlated with carbonates \((r = 0.745, P< 0.01)\), fluorides \((r = 0.667, P< 0.01)\), magnesium \((r = 0.634, P< 0.01)\), ammonical nitrogen \((r = 0.653, P< 0.01)\) and chemical oxygen demand \((r = 0.584, P< 0.05)\) and negatively correlated with free carbon dioxide \((r = -0.497, P< 0.05)\). In Nyasargi reservoir it was positively correlated with ammonical nitrogen \((r = 0.711, P< 0.01)\), dissolved oxygen \((r = 0.575, P< 0.05)\) and free carbon dioxide \((r = 0.498, P< 0.05)\). In Sanavalli reservoir it was positively correlated with ammonical nitrogen \((r = 0.699, P< 0.01)\), total hardness \((r = 0.544, P< 0.05)\), biochemical oxygen demand \((r = 0.544, P< 0.05)\), pH \((r = 0.502, P< 0.05)\), calcium \((r = 0.487, P< 0.05)\) and conductivity \((r = 0.470, P< 0.05)\). In Battigeri pond it was positively correlated with total hardness \((r = 0.908, P< 0.01)\), biochemical oxygen demand \((r = 0.899, P<
conductivity ($r = 0.892, P< 0.01$), calcium ($r = 0.874, P< 0.01$), total dissolved solids ($r = 0.869, P< 0.01$), fluoride ($r = 0.839, P< 0.01$), ammonical nitrogen ($r = 0.775, P< 0.01$), salinity ($r = 0.774, P< 0.01$), magnesium ($r = 0.691, P< 0.01$) and chemical oxygen demand ($r = 0.661, P< 0.01$). In Gangibhavi pond it was positively correlated with sulphates ($r = 0.667, P< 0.01$), pH ($r = 0.662, P< 0.01$), total hardness ($r = 0.634, P< 0.01$), calcium ($r = 0.631, P< 0.01$), ammonical nitrogen ($r = 0.556, P< 0.05$), conductivity ($r = 0.542, P< 0.05$), and total dissolved solids ($r = 0.523, P< 0.05$), and negatively correlated with secchi depth transparency ($r = -0.529, P< 0.05$) (Table-15 to 20).

Rao et al., (1999) also noticed the positive correlation of chlorides with dissolved oxygen, electric conuctivity, total dissolved solids, total hardness, calcium, magnesium, sulphates, alkalinity, chlorides, phosphates and dissolved oxygen, and negative correlation with phosphates, nitrate and fluoride content. Nadoni et al., (2001) also reported the existence of significant positive between chlorides and COD, and negative correlation of chlorides with free carbon-di-oxide, bicarbonates, total dissolved solids and BOD. These studies support our findings.

In survey, chlorides were recorded high in Unkal lake (Table-8) followed by Galgi tank of Dharwad district and Hanamapur tank of Haveri district, whereas low concentration were found in reservoirs of Uttar kannada districts (Table-11). During 1989-1991, Unkal lake had 79.05 mg/l (Table-14) of chlorides in monsoon season (Huddar, 1995). Increase in the concentration of chlorides in Unkal lake (208.74 mg/l) almost three times indicate pollution load in the lake due to increased anthropogenic disturbances like bathing, washing, cattle bathing, etc. This is accordance with the studies of Unni (1985), according to whom chloride content is largely dependent on
domestic pollution; hence the reservoirs situated in urban areas show chloride content to be several times higher than in rural areas. In Galgi tank the high concentration may be due to irrigation drainage as the tank is surrounded by paddy fields, which allows direct entry of water into the tank. In Hanamapur tank it may be due to the high anthropogenic activities and domestic sewage entering the tank. In 2002, Naregal tank had around 45 mg/l of chlorides and it was almost same in 2004 (44.02 mg/l) suggesting that there is less anthropogenic disturbance. The ecological significance of chloride lies in its potential to regulate the salinity of water and exert consequent osmotic stress on biotic community (Chandrasekhar and Jafer, 1998). Salinity was high in Unkal lake, Galgi tank and Krishnapur tank. High salinity in these tanks may be due to anthropogenic activities. According to Williams (2001) with decreased inflows, hydrological balances became disturbed and lake volumes decreased; consequently, since the mass of salt in each lake remains more or less constant, concentration of salt (salinities) increased. As sediment deposition in Unkal lake has reduced the lake depth and water storage capacity, this may be also a cause for the increase in salinity in Unkal lake. Salinity was nil in Budnal and Devarkoppa tanks which may be due to low anthropogenic activities in the water bodies, since these water bodies are quite away from the villages.

**Orthophosphates (fig-16)**

Phosphates occur as orthophosphates, condensed phosphates and naturally found phosphates. Their presence in water is due to detergents, from used boiler waters, fertilizers and due to biological processes. They occur as detritus in the bodies of aquatic organisms. Inorganic phosphorus plays a dynamic role in aquatic ecosystems and it is one of the most important nutrients when present in low concentration, but in excess along with nitrates and potassium, cause algal blooms (Ramachandra et al., 2002). It is
one of the most extensively studied elements in limnology. The amount of phosphorus in the hydrosphere is very small but it is of prime importance in the field of ecology due to its major role in the plankton metabolism (Wetzel, 2003). Phosphorus is important as a nutrient and also as a major component of the cell. It is required by the living organisms to carry out various vital activities like synthesis of nucleic acid and energy release in the form of ATP etc. (Rai and Kumar, 1976).

Phosphorus in water body may be of autochthonous origin by the decomposition of materials and from the sediments or it may be allochthonous origin through the influents to the water body. In the recent years the amount of influent phosphorus to the water body is increasing due to its varied uses. It may be through modern agricultural practices, industrial effluents, detergents and domestic wastes. On the contrary waters running through the sedimentary rock deposits and the lakes rich in organic matter tend to contain higher phosphorus content (Wetzel, 2003). A large portion of total phosphorus content is in the form of organic phosphorus. Of the total organic phosphorus about 70% or more is with the particulate organic material and the remaining as dissolved and colloidal organic phosphorus. Reduction of phosphate input to a productive lake may reduce the productivity of the lake.

Algae take up more phosphorus than the required amount when they are growing in phosphate rich medium (Rai and Kumar, 1976). They absorb and store phosphorus in their bodies, in greater quantities than their actual requirements. They use this when phosphorus in the medium is less or has been completely utilized (Zafar and Seenayya, 1980). From this it may be said that, when there is lack of phosphorus in the lake it doesn’t mean it is non productive. Of the six water bodies studied, the reservoirs had lower concentration of phosphate as compared to the ponds (Table-10). The lowest
concentration was in the Attiveri reservoir (0.82 ± 1.08 mg/l) and highest in the Battigeri pond (2.39 ± 2.38 mg/l). The higher concentration of phosphates in ponds indicates that its concentration depends on the size of the water body and ultimate on the quantity of water in them. In the present study the four reservoirs with more quantity of water in them had lower concentration of phosphate as compared to the ponds.

This further supported by the fact that in these water bodies during summer when the quantity of water decreased the concentration of phosphates increased. Similar observation is also by Unni (1985), who found low amounts of phosphates in the major reservoirs and the greatest quantity in the minor reservoirs. According to Larsen and Malueg (1976) higher values of phosphorus are associated with anoxic conditions. In the present study also the ponds with higher values of phosphates and lower values of dissolved oxygen content might have gone through anoxic conditions.

The study of Ganapati (1940), Sreenivasan (1964), and Jayanagoudar (1964) phosphate was not detected. According to these authors when oxygen is present (aerobic) phosphate is precipitated in the presence of iron as insoluble ferric phosphate. According to Munavar (1970) this conversion depends on aerobic or anaerobic conditions. During aerobic condition ferric phosphate is formed that is insoluble and during anaerobic condition iron is reduced from ferric to ferrous state which is soluble.

Another reason for higher concentration of phosphates in the ponds than the reservoirs may be attributed to the higher amount of organic matter. According to Seenayya and Zafar (1979) and Saha and Pandit (1985) there is release of phosphates in the ponds may be due to the dense phytoplankton, which after their death and decay release large amount of phosphates in to water. The phosphate rich nature of the pond water may also be due to the animals visiting the ponds which through their excreta, add
to the phosphate concentration. Similar high levels of phosphates of animal origin were reported by Donaldson and Whitton (1977) in the freshwater pools of Aldabra Islands in the South-west Indian Ocean. Another reason for the higher levels of phosphates in the ponds may be higher rate of community metabolism during which more nutrients are released.

It is also because the pond shallower, particularly in the littoral, phosphorus circulation time becomes shorter which is responsible for higher phosphorus levels. Similar observations are those of Howard Williams (1977).

The seasonal fluctuation in the concentration of phosphates showed the similar trend in all the six water bodies. The values were highest during monsoon months, which indicate that the increased phosphates concentration in these water bodies is due to allochthonous origin.

Phosphorus content of Attiveri reservoir positively correlated with ammonical nitrogen (r = 0.587, P<0.05), sulphates (r = 0.585, P<0.05), calcium (r = 0.483, P<0.05), and negatively correlated with secchi depth transparency (r = -0.642, P<0.05), total dissolved solids (r = -0.534, P<0.05) and conductivity (r = -0.487, P<0.05). In Bachanki reservoir it was positively correlated with calcium (r = 0.662, P<0.01), ammonical nitrogen (r = 0.545, P<0.01), nitrates (r = 0.506, P<0.05) and total hardness (r = 0.639, P<0.01) and sulphates (r = 0.524, P<0.05) and negatively correlated with secchi depth transparency (r = -0.469, P<0.05). In Nyasargi reservoir it was positively correlated with sulphates (r = 0.749, P<0.01), nitrates (r = 0.627, P<0.01), ammonical nitrogen (r = 0.579, P<0.05), dissolved oxygen (r = 0.518, P<0.05) and calcium (r = 0.492, P<0.05). In Sanavalli reservoir it was positively correlated with calcium (r = 0.580, P<0.05), free carbon dioxide (r = 0.553, P<0.05), total hardness (r = 0.538, P<0.05) and pH (r = 0.537,
P<0.05). In Battigeri pond it was positively correlated with sulphates (r= 0.699, P<0.01) and negatively correlated with bicarbonates (r= -0.542, P<0.05). In Gangibhavi pond it was positively correlated with sulphates (r= 0.632, P<0.01), ammonical nitrogen (r= 0.472, P<0.05) and negatively correlated with atmospheric temperature (r= -0.546, P<0.05) (Table-15 to 20).

Existence of strong positive correlation between phosphate and rain fall, transparency of water, pH, free carbon-di-oxide, nitrate, dissolved oxygen and alkalinity, and negative correlation with atmosphere temperature, water temperature, pH and alkalinity was observed by Muragavel and Pandian (2000) and these observations in support of observations. Rao et al., (1999) also reported that phosphates were positively correlated with alkalinity and fluoride content, and negatively correlated with conductivity, TDS, hardness, calcium, magnesium and chlorides. These studies support our findings.

In survey, orthophosphates content was high in Hanamapur (Table-9), Heggere, Ganjigatti and Devarkoppa, Chebbi and Varavinagalavi tanks. High concentration of phosphorus in Hanamapur tank may be due to the municipal sewage whereas in Heggere, Devarkoppa, Ganjighatti, Chebbi and Varavinaglavi tanks it may be due to the run off from the agricultural catchment areas.

Sulphates (fig-17)

It is a naturally occurring anion in all kinds of natural waters. In arid and searid regions, it is found in particularly higher concentrations due to the accumulation of soluble salts in soils and shallow aquifers. Biological oxidation of reduced sulphur species to sulphate also increases its concentration. Rain water has quite high concentrations of sulphate particularly in the areas with high atmospheric pollution.
Discharge of industrial waste and domestic sewage in waters tends to increase its concentration. Most of the salts of sulphate are soluble in water and as such it is not precipitated. However, it may undergo transformations to sulphur and hydrogen sulphide depending upon the redox potential of the water (Trivedy and Goel, 1984).

In the present study, lower values of sulphates were recorded in Attiveri reservoir (9.59 ± 9.28 mg/l) and higher in Gangibhavi tank (19.39 ± 10.45 mg/l) (Table-10). Higher values of sulphates in Gangibhavi pond is due to run off from the catchment area and the cloth washing, cattle washing and bathing.

Sulphates of Attiveri reservoir were positively correlated with orthophosphates ($r= 0.521$, $P<0.05$). In Bachanki reservoir they were positively correlated with orthophosphates ($r= 0.524$, $P<0.05$). In Nyasargi reservoir they were positively correlated with orthophosphates ($r= 0.749$, $P<0.01$), ammonical nitrogen ($r= 0.615$, $P<0.01$), nitrates ($r= 0.593$, $P<0.05$) and free carbon dioxide ($r= 0.526$, $P<0.05$) and negatively correlated with total dissolved solids ($r= -0.483$, $P<0.05$). In Sanavalli reservoirs they were positively correlated with orthophosphates ($r= 0.476$, $P<0.05$) and negatively correlated with biochemical oxygen demand ($r= -0.488$, $P<0.05$). In Battigeri pond they were positively correlated with orthophosphates ($r= 0.699$, $P<0.01$). In Gangibhavi pond they were positively correlated with pH ($r= 0.781$, $P<0.01$), chlorides ($r= 0.667$, $P<0.01$), ammonical nitrogen (0.639, $P<0.01$), inorganic phosphorus ($r= 0.632$, $P<0.01$) and free carbon dioxide ($r= 0.504$, $P<0.05$) and negatively correlated with secchi depth transparency ($r= -0.518$, $P<0.05$) (Table-15 to 20).

Rao et al., (1999) reported the existence of positive correlation of sulphates values with electric conductivity, TDS, hardness, calcium, magnesium, chlorides, nitrate, and negative correlation with alkalinity, fluoride, dissolved and oxygen. Nadoni et al.,
(2001) also observed the positive correlation between sulphates and hardness, and negative correlation with water temperature, chlorides, BOD and COD. These studies are in support of our observations.

In survey, sulphates were found high in Bupanalli, Medleri, Hosalli, Naregal, Akkialur tanks of Haveri district, and Kalghatgi tank of Dharwad district, which may be due to the run off from the catchment areas.

**Nitrogen Complex (fig-18 & 19)**

Extensive studies have been made on nitrogen components of water bodies to understand their relationship with other factors and among themselves. Nitrogen may be present in the lake waters in different forms like i) molecular nitrogen in solution, ii) Organic nitrogen, iii) free ammonia iv) nitrite and v) nitrate.

The last three are inter convertible. Ammonia is a major nitrogenous and product of bacterial decomposition of organic matter and is an important excretory product of invertebrate animals (Jain and Jain, 1988). Nitrate represents the highest oxidizable form of nitrogen. It may be produced by the biological oxidation of organic nitrogenous matter present in sewage and other water or it may be produced indigenously by certain cyanophyceae members by the process of nitrogen fixation. Phytoplankton may use ammonical nitrogen or nitrate nitrogen or both (Huddar, 1995).

According to Ganapati (1966) tropical waters particularly unpolluted are deficient in nitrates. This may be because of slow process of nitrification due to absence of proper organisms (Zafar, 1964). In the present study reservoirs had low concentrations of nitrate as compared to the ponds (Table-7). The lower values in the reservoirs may be attributed to the bigger size of the water body and more of oxygen in them, which hinders the nitrification process by the microorganisms. Observations of Unni (1985) support the above observation.
The lowest values of nitrates were in the Nyasargi reservoir (0.56 ± 0.45 mg/l) and highest values were recorded in Battigeri pond (1.72 ± 1.48 mg/l) (Table-10). The lowest values of ammonical nitrogen were in the Bachanki reservoir and the highest values were recorded in the Battigeri pond. The lower values of nitrates in the Nyasargi reservoir are suggestive of its unpolluted nature. The presence of minute amount of nitrate in unpolluted lakes may be due to reduction of nitrate by phytoplankton as observed by Jain and Jain (1988).

Nitrate showed a definite seasonal pattern in the reservoirs. In four reservoirs during the summer it was in lower concentration, it increased during monsoon and decreased during winter. This maximum concentration of nitrate observed during monsoon is in accordance with the studies of Pearsall (1930), Gonzalves and Joshi (1946), Rao (1955), Singh (1960), Munavar (1970), Seenayya and Zafar (1979) and Saha and Pandit (1985), according to whom the main source of nitrate in tropical waters is found to be the rain fall and surface runoff. Increase in nitrate–nitrogen during rains may be due to its allochthonous origin due to increased oxygen whereas during summer its decrease may attributed to the decrease oxygen, which causes the denitrification process to be faster. Similar observations are those of Goel et al., (1980).

According to Wetzel (2003), the unpolluted surface waters have small quantities of ammonia and its compounds, whereas anaerobic waters of eutrophic nature have very high values of ammonia nitrogen. They contained less dissolved oxygen and were subjected to biotic disturbances.

Nitrates of Attiveri reservoir were negatively correlated with chemical oxygen demand (r= -0.842, P<0.01), fluoride (r= -0.716, P<0.01), ammonical nitrogen (r= -0.542, P<0.05) and biochemical oxygen demand (r= -0.529, P<0.05). In Bachanki
reservoir it was positively correlated with inorganic phosphorus ($r = 0.506, P<0.05$) and negatively correlated with secchi depth transparency ($r = -0.716, P<0.01$) and dissolved oxygen ($r = -0.504, P<0.05$). In Nyasargi reservoir positively correlated with inorganic phosphates ($r = 0.627, P<0.01$), sulphates ($r = 0.593, P<0.05$), and negatively correlated with magnesium ($r = -0.564, P<0.05$). In Sanavalli reservoir they were positively correlated with total hardness ($r = 0.519, P<0.05$), and negatively correlated with transparency ($r = -0.578, P<0.05$). In Battigeri pond they were positively correlated with atmospheric temperature ($r = 0.696, P<0.01$), and negatively correlated with dissolved oxygen ($r = -0.822, P<0.01$), and pH ($r = -0.596, P<0.05$). In Gangibhavi pond they were negatively correlated with dissolved oxygen ($r = -0.597, P<0.05$) (Table-15 to 20).

Amonical nitrogen in Attiveri reservoir was positively correlated with chemical oxygen demand ($r = 0.842, P<0.01$), fluoride ($r = 0.770, P<0.01$), chlorides ($r = 0.592, P<0.01$) and inorganic phosphorus ($r = 0.587, P<0.05$) and negatively correlated with nitrates ($r = -0.542, P<0.05$). In Bachanki reservoir it was positively correlated with chemical oxygen demand ($r = 0.861, P<0.01$), chlorides ($r = 0.653, P<0.01$), fluoride ($r = 0.588, P<0.05$), inorganic phosphorus ($r = 0.545, P<0.05$) and pH ($r = 0.505, P<0.05$). In Nyasargi reservoir it was positively correlated with free carbon dioxide ($r = 0.812, P<0.01$), chlorides ($r = 0.711, P<0.01$), dissolved oxygen ($r = 0.677, P<0.01$), sulphates ($r = 0.615, P<0.01$), pH ($r = 0.610, P<0.01$), total hardness ($r = 0.594, P<0.05$), inorganic phosphates ($r = 0.579, P<0.05$) biochemical oxygen demand ($r = 0.576, P<0.05$) and calcium ($r = 0.546, P<0.05$). In Sanavalli reservoir it was positively correlated with fluorides ($r = 0.702, P<0.01$), chlorides ($r = 0.699, P<0.01$), biochemical oxygen demand ($r = 0.636, P<0.01$), dissolved oxygen ($r = 0.608, P<0.01$) and pH ($r = 0.470, P<0.05$). In Battigeri pond it was positively correlated with biochemical oxygen demand ($r = 0.834,
P< 0.01), chlorides (r= 0.775, P< 0.01), magnesium (r= 0.685, P< 0.01), conductivity (r= 0.655, P< 0.01), total hardness (r= 0.651, P< 0.01), calcium (r= 0.628, P< 0.01), chemical oxygen demand (r= 0.627, P< 0.01), total dissolved solids (r= 0.610, P< 0.05), salinity (r= 0.589, P< 0.05) and fluoride (r= 0.562, P< 0.05), and negatively correlated with Secchi depth transparency (r= -0.499, P< 0.05). In Gangibhavi pond it was positively correlated with biochemical oxygen demand (r= 0.837, P< 0.01), free carbon dioxide (r= 0.717, P< 0.01), sulphates (r= 0.639, P< 0.01), fluoride (r= 0.577, P< 0.05), pH (r= 0.558, P< 0.05) and orthophosphates (r= 0.472, P< 0.05), and negatively correlated with (r= -0.701, P< 0.01) (Table-15 to 20).

Existence of direct relation between nitrates and hardness, calcium and sulphates and inverse nitrates with electric conductivity, TDS, alkalinity, phosphates and dissolved oxygen was reported by Rao et al., (1999). Similar observation is those of Nadoni et al., (2001). These studies support our findings.

In the present study, the ammonical nitrogen fraction dominated the nitrate in all the six water bodies. This is because higher temperature in the tropical region helps in the decomposition of nitrogenous organic matter at a faster rate. Similar observations are those of Seenayya and Jafar (1979) water having low pH and anoxic conditions. This observation holds good for the two ponds as they had comparatively lower pH and dissolved oxygen than the lakes but had very high values of ammonical nitrogen.

Nitrates were high in Unkal lake and Galgi of Dharwad district, Kabbur, Hosalli and Hanamapur of Haveri district and Nyasargi reservoir of Uttar Kannada district. Ammonical nitrogen was also found high in Unkal lake followed by Sadankeri, Khalghatgi, and Neersagar lake of Dharwad district, Kabbur, Heggeri tank, Hosalli, Galgi tanks of Haveri district. The high nitrate concentrations (and ammonical nitrogen)
in these water bodies are due to the sewage and agricultural run off. During the years 1989-1991 (Table-14) Unkal lake had 0.09 mg/l nitrates in monsoon season and in winter it was 0.07 mg/l (Huddar, 1995). Increase in nitrates to an extent of 0.338 mg/l may be attributed to increased anthropogenic activities.

**Fluoride (fig-20)**

Chloride and fluoride are chemicals commonly found in soil rocks. Although chloride and fluoride belong to the same chemical group (the halogens), their behaviour in the environment differs. Chloride is very mobile in ground water, while fluoride is rendered immobile in the presence of aluminium and iron oxides (MPCA report, 1999).

Igneous rocks are common sources of fluoride. Fluoride is used in industrial processes as a strong acid. It is also a common chemical in phosphorus fertilizers. Fluoride is added many municipal water systems to prevent tooth decay. Coke, glass, ceramic, electronics, pesticides, steel and aluminium processing and electroplating industries are other sources of fluorides. Lower fluoride content was recorded in Sanavalli reservoir (0.72 ± 0.15 mg/l) and higher concentration in Attiveri reservoir (1.42 ± 0.38 mg/l) (Table-10). The higher concentration of fluoride may attribute to the indiscriminate use of fertilizers in the agricultural catchment area.

Fluoride content of Attiveri reservoir was positively correlated with with biochemical oxygen demand ($r=0.672, P<0.01$), chemical oxygen demand ($r=0.913, P<0.01$), ammonical nitrogen ($r=0.770, P<0.01$), pH ($r=0.572, P<0.05$), and negative correlated with nitrates ($r=-0.716, P<0.01$). In Bachanki reservoir it was positively correlated with with chlorides ($r=0.667, P<0.01$), chemical oxygen demand ($r=0.637, P<0.01$), ammonical nitrogen ($r=0.588, P<0.05$), pH ($r=0.553, P<0.05$), and negatively correlated with free carbon dioxide ($r=-0.552, P<0.05$). In Nyasargi reservoir
it was positively correlated with chemical oxygen demand ($r=0.873, P<0.01$), pH ($r=0.629, P<0.01$) and biochemical oxygen demand ($r=0.568, P<0.05$), and negatively correlated with total alkalinity ($r=-0.632, P<0.01$). In Sanavalli reservoir it was positively correlated with chemical oxygen demand ($r=0.744, P<0.01$), ammonical nitrogen ($r=0.702, P<0.01$), secchi transparency ($r=0.681, P<0.01$), pH ($r=0.552, P<0.05$) and biochemical oxygen demand ($r=0.578, P<0.05$). In Battigeri pond it was positively correlated with chlorides ($r=0.839, P<0.01$), magnesium ($r=0.787, P<0.01$), biochemical oxygen demand ($r=0.784, P<0.01$), total hardness ($r=0.777, P<0.01$), conductivity ($r=0.734, P<0.01$), calcium ($r=0.733, P<0.01$), total dissolved solids ($r=0.707, P<0.01$), salinity ($r=0.672, P<0.01$), free carbon dioxide ($r=0.581, P<0.05$), chemical oxygen demand ($r=0.562, P<0.05$), and ammonical nitrogen ($r=0.562, P<0.05$). In Gangibhavi pond it was positively correlated with chemical oxygen demand ($r=0.793, P<0.01$), biochemical oxygen demand ($r=0.702, P<0.01$), free carbon dioxide ($r=0.636, P<0.01$), ammonical nitrogen ($r=0.577, P<0.05$) and magnesium ($r=0.558, P<0.05$) (Table-15 to 20).

The existence of positive correlation of fluoride with alkalinity and and negative correlation with conductivity, TDS, hardness, calcium, magnesium and chlorides, reported by Rao et al., (1999). His observations support our findings.

In survey, except Hanamapur (1.57mg/l) the fluoride content was within the permissible limit (Table 8 & 9). Though the Hanamapur tank having 129.60 ha area due the low rainfall in successive years in these area water levels was very low, which may be the reason for higher concentration of fluoride content, domestic sewage (Groth, 1975) might have also contributed to this.
Biochemical Oxygen Demand (BOD) (fig-21)

BOD is the amount of oxygen utilized by microorganisms in stabilizing the organic matter. On the average basis, the demand for oxygen is proportional to the amount of organic waste to be degraded aerobically. Hence, BOD approximates the amount of oxidizable organic matter present in the solution, and the BOD value can be used as measure of waste strength. It is highly important to know the amount of organic matter present in the water body (Trivedy and Goel, 1984).

In the present investigation lower values of BOD were recorded in the Nyasargi reservoir (2.01 ± 0.84 mg/l) and higher in Gangibhavi pond (2.70 ± 0.69 mg/l). The higher values of Gangibhavi pond may be due to the lower water level in the pond.

BOD of Attiveri reservoir positively correlated with fluoride (r= 0.672, P< 0.01), and negatively correlated with nitrates (r= -0.529, P< 0.05). In Bachanki reservoir it was positively correlated with COD (r= 0.492, P< 0.05), and negatively correlated with atmospheric temperature (r= -0.494, P< 0.05) and water temperature (r= -0.529, P< 0.05). In Nyasargi reservoir it was positively correlated with ammonical nitrogen (r= 0.576, P< 0.05), pH (r= 0.570, P< 0.05), fluoride (r= 0.568, P< 0.05), free carbon dioxide (r= 0.557, P< 0.05) and chemical oxygen demand (r= 0.553, P< 0.05). In Sanavalli reservoir it was positively correlated with ammonical nitrogen (r= 0.656, P< 0.01), dissolved oxygen (r= 0.637, P< 0.01), fluoride (r= 0.578, P< 0.05), chlorides (r= 0.544, P< 0.05) and total dissolved solids (r= 0.478, P< 0.05), and negatively correlated sulphates (r= -0.488, P< 0.05). In Battigeri pond it was positively correlated with chlorides (r= 0.899, P< 0.01), ammonical nitrogen (r= 0.834, P< 0.01), total hardness (r= 0.825, P< 0.01), calcium (r= 0.805, P< 0.01), fluoride (r= 0.784, P< 0.01), conductivity (r= 0.766, P< 0.01), total dissolved solids (r= 0.740, P< 0.01), salinity (r= 0.698, P<
0.01) and magnesium (r= 0.654, P< 0.01). In Gangibhavi pond it was positively correlated with ammonical nitrogen (r= 0.837, P< 0.01), fluoride (r= 0.702, P< 0.01), chemical oxygen demand (r= 0.679, P< 0.01), free carbon dioxide (r= 0.546, P< 0.05), total hardness (r= 0.542, P< 0.05), calcium (r= 0.530, P< 0.05) and pH (r= 0.495, P< 0.05) (Table-15 to 20).

Rao et al., (1999) reported the existence of positive correlation of BOD values with COD, sulphates and fluoride, and negative correlation with conductivity, alkalinity and chlorides. Nadoni et al., (2001) also observed the positive correlation between BOD and COD and DO and negative correlation with water temperature, sulphates, and hardness. These studies support our observations.

In survey, the biochemical oxygen demand was high in Haveri district tanks, followed by Dharwad and Uttar Kannada districts. High BOD was recorded in Krishnapur (3.60 mg/l), Kadkol (3.36mg/l), Timmapur (3.28mg/l) and Heggeri (3.28mg/l) tanks of Haveri district, Unkal (3.03mg/l), Sadankeri (2.93mg/l) and Galgi (2.93mg/l) tanks of Dharwad, and in Sanavalli (2.33mg/l) reservoir of Uttar Kannada suggesting the presence of high organic load as some of these tanks receive domestic sewage or otherwise have high anthropogenic activities viz cattle wading, cattle washing etc.

Chemical Oxygen Demand (COD) (fig-22)

Chemical oxygen demand is the oxygen required by the organic substances in water to oxidize them by strong chemical oxidant. The determination of COD values are of great importance where BOD values cannot be determined accurately due to the presence of toxins and other such unfavorable conditions for growth of microorganisms (Trivedy and Goel, 1984).
In the present investigation lower values of COD were recorded in the Bachanki reservoir (75.34 ± 17.92 mg/l) and higher in Battigeri pond (187.5 ± 62.14 mg/l) (Table-10). The higher values of Battigeri pond may be due to the lower water level in the pond and increased anthropogenic activities like washing cloth, vehicles etc.

COD of Attiveri reservoir was positively correlated with fluoride (r= 0.913, P< 0.01), ammonical nitrogen (r= 0.842, P< 0.01), chlorides (r= 0.556, P< 0.05) and pH (r= 0.549, P< 0.05), BOD (r= 0.508, P< 0.05), and negatively correlated with nitrates (r = -0.842, P< 0.01). In Bachanki reservoir it was positively correlated with ammonical nitrogen (r= 0.861, P< 0.01), fluoride (r= 0.637, P< 0.01), chlorides (r= 0.584, P< 0.05) and BOD (r= 0.492, P< 0.05). In Nyasargi reservoir it was positively correlated with fluoride (r= 0.873, P< 0.01), BOD (r= 0.553, P< 0.05) and free carbon dioxide (r= 0.492, P< 0.05) and pH (r= 0.576, P< 0.05), and negatively correlated with water temperature (r= -0.584, P< 0.05) and bicarbonates (r= -0.526, P< 0.05). In Sanavalli reservoir it was positively correlated with secchi depth transparency (r= 0.873, P< 0.01), fluoride (r= 0.744, P< 0.01) and pH (r= 0.700, P< 0.01). In Battigeri pond it was positively correlated with with fluoride (r= 0.885, P< 0.01), magnesium (r= 0.858, P< 0.01), ammonical nitrogen (r= 0.661, P< 0.01), pH (r= 0.702, P< 0.01), chlorides (r= 0.685, P< 0.01), salinity (r= 0.533, P< 0.05) and conductivity (r= 0.536, P< 0.05). In Gangibhavi pond it was positively correlated with fluoride (r= 0.793, P< 0.01), magnesium (r= 0.687, P< 0.01), BOD (r= 0.679, P< 0.01), conductivity (r= 0.587, P< 0.05), total dissolved solids (r= 0.566, P< 0.05), water temperature (r= 0.565, P< 0.05) and salinity (r= 0.591, P< 0.05) (Table-15 to 20).

Rao et al., (1999) reported the existence of positive correlation of COD values with BOD, sulphates and fluoride. Nadoni et al., (2001) also observed the positive
correlation between COD and BOD, DO and sulphates and negative correlation with water temperature, bicarbonates and Hardness. These studies support our findings.

In survey, the chemical oxygen demand was high in Timmapur (224 mg/l), Hanamapur tank (196 mg/l) and Kadkol (192 mg/l) tank of Haveri district, Galgi tank (158 mg/l) and Unkal (120 mg/l) lake of Dharwad district, indicating the existence of high amount of organic as well as oxidizable inorganic compounds in the water bodies, which attribute to the sewage contamination and increased anthropogenic activities like washing of cloths, vehicles etc.

**Salinity (fig-23)**

Anthropogenic salinization is distinct from the natural or primary salinisation which is responsible for the development of natural salt lakes. Primary salinisation involves the accumulation in closed basins of salts from rain water and leached from terrestrial sources at rates unaffected by human activities (Williams, 2001).

A high salinity content was observed in Battigeri tank (0.25 ± 0.12) followed by Gangibhavi pond (0.19 ± 0.001), in all other remaining tanks were less than 0.14 (Table-10). In Nyasargi and sanavalli reservoirs it remained constant throughout the study period. The high salinity content in Battigeri and Gangibhavi ponds may be due to the rapid evaporation of the pond.

Salinity of Attiveri reservoir was positively correlated with conductivity ($r=0.572$, $P<0.05$), water temperature ($r=0.549$, $P<0.05$), total hardness ($r=0.534$, $P<0.05$), total dissolved solids ($r=0.521$, $P<0.05$) and calcium ($r=0.517$, $P<0.05$). In Bachanki reservoir it was positively correlated with conductivity ($r=0.890$, $P<0.01$) and total dissolved solids ($r=0.878$, $P<0.01$). Salinity of Nyasargi and Sanavalli reservoirs
hasn't showed any correlation because salinity in these reservoirs remained constant. In Battigeri pond salinity was positively correlated with total dissolved solids ($r = 0.943, P < 0.01$), conductivity ($r = 0.923, P < 0.01$), calcium ($r = 0.901, P < 0.01$), total hardness ($r = 0.897, P < 0.01$), chlorides ($r = 0.774, P < 0.01$), biochemical oxygen demand ($r = 0.698, P < 0.01$), fluoride ($r = 0.672, P < 0.01$), free carbon dioxide ($r = 0.663, P < 0.01$), magnesium ($r = 0.559, P < 0.05$) and ammonical nitrogen ($r = 0.589, P < 0.05$). In Gangibhavi pond it was positively correlated with total dissolved solids ($r = 0.840, P < 0.01$), conductivity ($r = 0.839, P < 0.01$), water temperature ($r = 0.646, P < 0.01$), atmospheric temperature ($r = 0.622, P < 0.05$), total hardness ($r = 0.609, P < 0.05$) and chlorides ($r = 0.602, P < 0.05$) (Table-15 to 20).

In survey, salinity values were recorded high in Haveri district (Table-11) water bodies followed by Dharwad and lower concentration in Uttar Kannada district water bodies. Higher values of salinity in Haveri district water is due to the smaller water bodies lower water volume and increased anthropogenic disturbances as explained by Williams (2001).
4.2. Biotic factors

4.2.1. Species composition, abundance, diversity and evenness

A total of seventy one species were identified in the present investigation (Table-21). Of the seventy one species recorded, 38 of them belonging to rotifera, 22 to cladocera, 7 to copepoda and 4 species to ostracoda. Of these, 5 species are new to this region (one cladoceran and four rotifers). Highest species were recorded in the samples of Battigeri pond (47 species) and lower number was in the Attiveri reservoir (29 species). The Bachanki reservoir (36 species), Nyasargi reservoir (33 species), Sanavalli reservoir (42 species) and Gangibhavi pond (39 species) represented an intermediate situation between these two extremes (fig-24).

High species richness in Battigeri pond may be attributed to small water body highly stained shallow water with blue-green algal blooms. Rerecorded species include a considerable number of rotifers (55%) particularly species indicative of eutrophy, such as Brachionus spp., Fillinia longiseta and Pompholyx sulcata (Gannon and Stemberger, 1978; Pejler, 1983). However, in Attiveri reservoir such algal bloom and stained water absent with high transparency and large quantity of water with clear pelagic zone, so species richness was low.

I. Rotifers

Rotifera also called as Rotatoria or wheel animalcules, are a group of small, usually microscopic, pseudocoelomate animals, which have been variously regarded as a separate phylum. The rotifers have attracted much attention from microscopists because of their wide spread distribution in waters of all kinds, the great abundance in which they frequently occur (Edmondson, 1959).
In the present study, rotifera was the richest group with 38 species, which accounts
53 % of total zooplankton group. Taxonomic dominance of rotifers was reported in
several water bodies (Nogueira, 2001; Cavalli et al., 2001; Sampaio et al., 2002; Neves
et al., 2003). This pattern is common in tropical and subtropical freshwaters, whether in
lakes, ponds, reservoirs, rivers, or streams (Neves et al., 2003). This may be due to their
special characteristic i.e., less specialized feeding, high fecundity and frequent
parthenogenetic reproduction, constellation of life traits that make them opportunist and
typical r-strategist, favoured in unstable and eutrophic environments (Rocha et al., 1995).
This may be also due to a wide spectrum of food particles exploited by this group, which
displays the ability to consume bacteria, algae and detritus of different sizes, thus
allowing quite distinct diets for the many species simultaneously present in water body
there are 500 species of rotifers in Indian waters, although only 330 species belonging to
63 genera and 25 families have so far been authenticated. In the present study, 38 species
of rotifers belonging to 13 families were recorded. Of the thirteen families, Brachionidae
was most common representative with 17 species (3 genera), followed by Philodinidae 3
species (3 genera) Lecanidae 3 species (2 genera), Testudinellidae 2 species (2 genera).
Asplanchnidae, Mytilinidae, Fillinidae and Euchlanidae were represented by 2 species
each (1 genera each). Families Notommatidae, Colurellidae, Trichoceridae,
Trocosphaeridae and Flosculariidae were represented by one species each. The rotifers,
*Keratella quadrata*, *Euchlanis triquetra*, *Brachionus bennini* and *Pompholyx sulcata* are
new records from this region. The above species have been reported to occur in
Brahmaputra river basin and Delhi segments of river Yamuna (Sharma, 1983; Sharma
and Sharma, 2001; Arora and Mehra, 2003a).
During the eighteen month study, lower numbers of rotifers were recorded in the samples of Attiveri reservoir (10 species) and higher numbers of species were recorded in the Battigeri pond (26 species). According to Sharma and Sharma (2001) lack of definite pelagic habitats, the shallow nature and growth of aquatic macrophytes is favoured by the rotifers. Presence of large quantity of water with clear pelagic zone in Attiveri reservoir might have limited the rotifera group to only ten species.

Higher rotiferans densities were recorded in the Battigeri pond (69470 Org/L) and lower densities in Attiveri reservoir (6480 Org/L) during the whole study period. In general high densities of rotifers reflect the availability of a wide range of natural sestonic food particles, which rotifers may consume (Gulati, 1990). The highest rotiferan densities were also observed in Battigeri pond (< 20,000 org/L) in March 2004 (fig- 47). This variation may be due to the water level, because during March 2004 pond was becoming dry. In the same month species richness was also found high (19 species). Various investigators reported that the rapid increase in rotifers numbers may be attributed to their intrinsic high fecundity supported by favorable food and environmental conditions (Gulati, 1999; Arora and Mehra 2003 a), thus the presence of favorable physical-chemical (e.g. temperature, nutrients and pH) as also relative abundance of diatoms followed by green algae and blue green algae were possible responsible for promoting the growth of rotifers (Arora and Mehra 2003 a).

Though the species richness was high in Battigeri pond but highest rotiferan diversity was observed in the Gangibhavi pond (Table-35). The variation may attribute to the dominance of *B. angularis*, *B. caudatus*, *B. calyciflorus*, *K. tropica*, *K. cochlearis* and *B. urceolaris* species in Battigeri pond in month of March. High uniformity among the rotiferan population was found in Bachanki and Nyasargi reservoirs (Table-31 & 32).
Brachionus falcatus was at high densities in Attiveri and Bachanki reservoirs (Table- 22 & 23). Fillinia longiseta was abundant in Nyasargi reservoir. In Sanavalli reservoir, Battigeri and Gangibhavi ponds it was K. tropica which was the major contributor to the rotiferan density.

Sampaio et al., (2002) rotifera populations do not exhibit regular seasonal patterns of fluctuation in tropical lakes. But their abundance was observed high during summer months in all the water bodies. Similar observations were also made by Sharma (2005) and Nogueira (2001).

In Attiveri reservoir rotiferan populations were positively correlated with water temperature (r=0.537), cladoceran density (r=0.661), copepodal density (r=0.738) and ostracodan density (r=0.587) (Table-36). In Bachanki reservoir rotiferan populations were positively correlated with atmospheric temperature (r=0.651), water temperature (r=0.517), cladoceran density (r=0.525), copepodal density (r=0.759) and Ostracodan density (r=0.630). In Nyasargi rotiferans populations were positively correlated only with the cladoceran density (r=0.572). In Sanavalli reservoir, it was positively correlated with atmospheric temperature (r=0.563), water temperature(r=0.533), electric conductivity (r=0.513), total dissolved solids (r=0.531), cladoceran density (r=0.819), copepodal density (r=0.890) and Ostracodan density (r=0.687). In Battigeri pond it was positively correlated with atmospheric temperature (r=0.567), E.C. (r=0.817), TDS (r=0.828), calcium(r=0.807), total hardness(r=0.820) chlorides(r=0.712), ammonial nitrogen (r=0.673), cladoceran density (r=0.673), copepodal density (r=0.861) and Ostracodan density (r=0.758). In Gangibhavi pond rotiferan populations were positively correlated with water transparency (r=0.576) and with ostracoan density (r=0.826) (Table-36).
Sharma (2005) also reported that, the rotiferan population density shows significant direct correlations with water temperature, conductivity, dissolved oxygen and alkalinity while analyzing the rotifer communities of flood plain lakes of the Brahmaputra river basin of lower Assam (Northeast India). Similar observations were also made by Patil and Gouder (1985). Minkoff et al., (1983) opined that, the temperature also plays a very important role in hatching of rotifer resting eggs. Existence of direct relation between nitrate-nitrogen and rotifer density was reported by Arora and Mehra (2003 a).

In survey, during the post monsoon season Keratella tropica was the most frequent rotifer, which occurred in 14 water bodies out of 41 tanks, followed by B. falcatus (11 water bodies) and F. longiseta (10 water bodies). Keratella quadrata, E. dialata, B. bennini, E. triquetra, M. acanthophora, P. sulacata, R. tardus, L. rhomobiodes and T. similis were rare and occurred in only one tank (Table-28). The families Brachionidae and Lecanidae were represented by large number of species, which is considered typical, and most frequent in tropical environment (Dumont, 1983). Of the seven genera of Brachionidae five genera i.e., Brachionus, Keratella, Platyias, Anuraeopsis, and Notholca are found in India and they form a significant fraction of Rotifer (Sharma, 1987). Of the 38 species of rotifers, 17 species belong to Brachionidae and 3 species to Lecanidae. Brachionus was the prominent genus represented by 12 species i.e., Brachionus angularis, B. caudatus, B. plicatilis, B. calyciflorus, B. diversicornis, B. quadridentatus, B. falcatus, B. bidentata, B. forficula, B. urceolaris, B. bennini and B. rubens. Genus Brachionus is one of the most ancient genus of monogonont rotifers and represented by 46 species in India (Sharma, 1983). Rotiferan species richness was found high in pre monsoon (summer) compared to the post monsoon season. Similar observations were those of Sharma (2005) and Arora and Mehra (2003 a).
II. Cladocerans

Popularly called as 'water flea' the cladocerans prefer to live in clear waters. As a group they constitute a major item of food for fish. Thus they hold key position in food chain and energy transformation (Uttangi, 2001). About 600 species of fresh water Cladocerans have been reported (Korovchinsky, 1996) to occur throughout the world and in India 110 species have been recorded (Patil and Goudar, 1989). Patil and Goudar, (1982 b, 1989) reported 40 species of Cladocerans from Dharwad region. Uttangi (2001) reported 8 species of Cladocerans from 54 tanks of Haveri district. In the present study 22 Cladoceran species are recorded and the species *Moina oryzae* is new from this area. Hudec (1987) reported occurrence of this species from Tamil Nadu (South India). Chydoridae was the most frequently represented family with 5 genera and 10 species, followed by Moinidae (5 species). Families Daphnidae, Macrothricidae and Sididae were represented by two species each, whereas Bosminidae was represented by only one species. Sontos-Wisniewski (2002) reported that among the organisms inhabiting the littoral region the members of the family Chydoridae, belonging to the cladocera group are present by a major part of the species present. Similar observation was also made by Serafim *et al.*, (2003).

During the eighteen month study period, lower numbers of cladocers were recorded in the samples of Gangibhavi pond (9 species) and higher numbers of species were recorded in the Sanavalli reservoir (12 species). The higher cladoceran species in Sanavalli reservoir is due to the presence of extensive banks of macrophytes, and other plants as observed by Pinto Coelho *et al.*, 2005; Sharma and Sharma, 2001; Serafim *et al.*, 2003; Santos-Wisniewski, 2002, the macrophytes and plants allow a greater heterogeneity of the environment which results in the availability of more niches (Garcia
et al., 2003). Lack of such macrophytes banks in Gangibhavi pond might be the reason for lowest number of cladocerans species.

Though the species richness low in Gangibhavi pond but was recorded high cladocer densities (52600 Org/L). The lower densities were recorded in Nyasargi reservoir (9600 Org/L) during the whole study period. The highest cladoceran densities were also observed in Gangibhavi pond (< 12280 Org/L) in April 2004 (fig-36). This variation may be due to rapid increase in the *D. exicum* species. Similar observation was also noticed by the Rob Hart (2001). As this species grows rapidly in high nutrient conditions (Jana and Pal, 1984), because presence of lower water level in summer. Remains of dead and decaying vegetation as well as burnt and half burnt dead bodies, which results in to the increase of organic matter and growth of bacteria population which increase the zooplankton population (Bohra and Kumar, 2004).

Though the cladoceran species richness was high in Sanavalli reservoir but cladoceran diversity was recorded high in Bachanki reservoir. This is because all the recorded species were not present simultaneously in Sanavalli reservoir. High uniformity of the cladoceran species was observed in the Nyasargi reservoir in the month of February 2004 (Table-32).

The seasonal succession of the cladocera is quite variable, both among species and within the species living in different lake conditions. Some species are perennial and over winter in low population densities as adults (parthenogenetic females) rather than as resting eggs. These species may exhibit one, two more irregular maxima. Some perennial species exhibit maxima in surface layers only during colder period and aestival species that have a distinct diapause in a resting egg stage commonly develop population maxima in the summer (Wetzel, 2003). In the present investigation cladoceran densities
shows two peaks one in August to December (winter) and another one in March to May (summer) in all the water bodies. Similar observations were also reported by Bohra and Kumar (2004) according to whom maximum density of zooplankton in summer may attribute to increased total alkalinity, total hardness and the presence of high population of bacteria.

In the present study, it was observed that *C. cornuta* and *B. deitersi* were the major contributor to the cladocer density in Attiveri and Bachanki reservoirs, in Nyasargi it was *C. cornuta* and *A. pulchella*, whereas in Sanavalli reservoir *B. deitersi*, followed by *C. cornuta* & *C. sphericus*, in Battigeri pond it was *D. excisum* and *C. cornuta* and in Gangibhavi it was *D. excisum* which alone contributed 64% of the cladoceran densities (fig-31 to 36).

In Attiveri and Bachanki reservoirs cladoceran populations were positively correlated with rotifer densities (*r* = 0.661) (Table-36). In Nyasargi it was positively correlated with electric conductivity (*r* = 0.542) and dissolved oxygen (*r* = 0.581) and rotifer densities (*r* = 0.572). In Sanavalli reservoir it was positively correlated with atmospheric temperature (*r* = 0.546), copepod densities (*r* = 0.858), rotifer densities (*r* = 0.819) and ostracod densities (*r* = 0.485). Whereas in Battigeri pond, cladocer populations were positively correlated with electric conductivity (*r* = 0.759), total dissolved solids (*r* = 0.572), calcium (*r* = 0.679), total hardness, rotifer densities (*r* = 0.673) and ostracodan densities (*r* = 0.643). In Gangibhavi pond cladocer densities was positively correlated with atmospheric temperature (*r* = 0.552), total dissolved solids (*r* = 0.483), total hardness (*r* = 0.503) and copepod densities(*r* = 0.861) (Table-36).

Rossa *et al.,* (2001) reported that the highest densities of *C. cornuta* were directly related to water transparency and electric conductivity, and electric conductivity also
influenced the abundance of *B. deitersi*. Though in present study it was not calculated individual species relation with the physico-chemical variables, but over all density which was in most of the tank due to these two species. Rojas *et al.*, (2001) also observed that the temperature and electric conductivity plays an important role in hatching of the *Moina micrura* eggs. Direct relation of zooplankton densities with alkalinity, salinity, water temperature and dissolved oxygen was observed by Alam and Kabir (2000). According Frutos (1996, cited in Rossa *et al.*, 2001) it is difficult to evaluate the factors responsible for the variation of zooplankton in the environments which are subject or not to periodic flooding, in view of the fact that changes in population structure are defined not only by the dynamics of processes internal to the environments, but also by the additional and superposition of changes in the surrounding environments.

In survey, during post monsoon season *D. excisum* was the most frequent species among cladocera group, which occurred in 21 water bodies out of 41, followed by *M. brachiata* (20 water bodies), *C. cornuta* (17 water bodies), *M. micrura* (15 water bodies) and *B. deitersi* (10 water bodies). *Moina oryzae, M.rectirostris, A. cambouei and C. barroisi barroisi* were very rare and they occurred in only one water body (Table-28).

Cladoceran species was also found high in pre monsoon season compared to post monsoon season. This variation may attribute to the high turbid water, as the survey was carried out in the September month, in South India rainy season will start in June and end in September. Inflow brings much of silt to these water bodies from the catchments area, so we found very low water transparency during post monsoon season (Table-8 & 9). Uttangi (2001) opined that cladocerans prefer to live in clear waters. According to Pollard *et al.*, (1998) increased turbidity has been shown to a variety of influences on
biota affecting characteristics such as ecological condition, resource availability and species interactions. For example, in the absence of turbidity laboratory experiments illustrate asymmetrical exploitative competition between rotifers and Daphnia, leading to Daphnia dominance of zooplankton communities. However inorganic turbidity inhibits the competitive abilities of Daphnia and this lead to a decline of cladoceran abundance causing a competitive release of rotifer populations. Similar observations are those of Kirk and Gilbert (1990).

In Akkialur tank was largely colonized by submerged and emerging macrophytes, which almost completely occupy its surface area. Chydoridae and macrothricidae members of cladocerans favour this kind of environment (Serafim et al., 2003; Garcia et al., 2003; Santos-Wisniewski, 2002). Hence we found higher species diversity in this tank in March.

III. Copepods

Freshwater copepods, though small in the number of species, constitute one of the major zooplanktonic communities occurring in all types water bodies and ranging from free living to parasitic forms. They serve as food of several fishes and play a major role in ecological pyramids, trophic levels, food chains and energy transformations in the freshwater ecosystems. Some copepods are the vectors of fishes, tapeworm and nematodes (Patil and Gouder, 1989). Though the extensive literatures exist on zooplankton, especially on rotifers cladocers (Michael, 1980) the information on about the freshwater copepods of India is rather limited (Patil and Gouder, 1982c). Approximately 1200 marine and freshwater species of calanoids, 1000 cyclopoids and 1200 harpacticoids have been recorded so far in worldwide. About 120 species of freshwater free-living copepods are known from India (Uttangi, 2001). Patil and Gouder
(1982c, 1989) reported 7 species of copepods in Dharwad district. In the present study same species have been found belonging to 3 genera of calanoids (3 species) and 3 genera of cyclopoids (4 species).

Though the copepods were in 3rd position in the taxonomic richness in the present study, but it was numerically dominant group. Numerical dominance of copepoda was also reported by Sampaio and Lopez (2000) in Brazil water bodies.

During the eighteen months study period, six species were recorded in four water bodies whereas in Attiveri and Bachanki only five species were recorded. High copepodal densities were recorded in Gangibhavi pond (95990 Org/L) and lower densities in Attiveri reservoir (53720 Org/L) throughout study period. The highest densities (20930 Org/L) were recorded in Gangibhavi pond in the month of March 2004. This variation may again due to the lower water level and high nutrient content in summer.

In copepodal densities nauplii were contributed 53% (Gangibhavi pond) to 64% (Sanavalli reservoir). The numerical predominance of the young forms, especially nauplii, is the most common pattern (Patil and Goudar, 1985; Sampaio et al., 2002; Neves et al., 2003). The high densities of the immature forms are generally a result of the continuous reproduction of these organisms, in tropical regions, with superimposition of various cohorts (Edmondson, 1959). A factor which can determine the proportion of young to adult forms is predation intensity and the balance between predation by invertebrates and vertebrates (Neves et al., 2003). The existence of young form is of grate importance for zooplankton community structure, with regard to population dynamics.

Among adult copepods, cyclopoids were most abundant and they accounted 29% of the total copepod densities in Attiveri reservoir. Tropocyclops prasinus was the most
abundant Cyclops, among calanoid copepod *N. strigilipes* was more abundant. In Bachanki reservoir, cyclopoides were dominant and accounted 29% of the total copepod densities. *Paracyclops fimbriatus* was most abundant and *N. strigilipes* and *H. viduus* were equally dominant calanoids. In Nyasargi and Sanavalli reservoirs, cyclopoida were the dominant group of copepods than that of calanoid, which accounted 22% and 20% of the copepod densities respectively. *Mesocyclops leuckarti* was the abundant cyclop, and *N. strigilipes* was most abundant among calanoids. In Battigeri also Cyclops were dominated over the calanoids and accounted 23% of copepod densities. *Mesocyclops leuckarti* and *P. fimbriatus* were equally dominated among Cyclops and *N. strigilipes* was the most abundant calanoid, whereas in Gangibhavi pond calanoids (24%) were comparatively high than that of Cyclops (23%). *Neodiaptomus strigilipes* was the most abundant calanoid and *M. leuckarti* was most abundant among Cyclops (fig-37 to 42).

In Attiveri reservoir copepod densities positively correlated with atmospheric temperature (*r*=0.625), water temperature (*r*=0.633), rotifer densities (*r*=0.661) and ostracod densities (*r*=0.556) (Table-36). In Bachanki reservoir, copepod densities positively correlated with pH (*r*=0.508), dissolved oxygen (*r*=0.624) and rotifer densities (*r*=0.759), whereas in Nyasargi reservoir it was only showed positive correlation total hardness (*r*=0.706). In Sanavalli reservoir it was positively correlated with atmospheric (*r*=0.725), total dissolved solids (*r*=0.498), cladocer densities (*r*=0.858), rotifer densities (*r*=0.890) and ostracod densities (*r*=0.769). In Battigeri also copepod densities positively correlated with electric conductivity (*r*=0.585) and total dissolved solids (*r*=0.575), calcium (*r*=0.566), total hardness (*r*=0.588) chlorides (*r*=0.533), nitrates (*r*=0.652), rotifer densities (*r*=0.861) and ostracod densities (*r*=0.646). In Gangibhavi pond copepod densities showed positive correlation atmosphere temperature (*r*=0.581), cladocer densities (*r*=0.861) and ostracod densities (Table-36).
Similar observation those of Rietzler, et al., (2002); Joseph Kene (2003); Yang-Chin Lan et al., (2004). Existence of significant positive correlation of copepod densities with water temperature, total dissolved solids, phosphorus and negative correlation with dissolved oxygen, alkalinity, electric conductivity and suspended solids were reported by Casanova and Henry (2004). Patil and Gouder (1985) also reported that copepod densities negatively correlated with dissolved oxygen, phosphates and water temperature. However in our observation we have not recorded any significant negative correlation.

In survey, during post monsoon season among calonoids N. strigilipes was comparatively high in its occurrence (34 water bodies out of 41) than that of H. viduus (31 water bodies out of 41), R. indicus was rare and occurred in only 6 water bodies. Among Cyclops, T. prasinus was the most frequent, which occurred in 34 water bodies out of 41 analysed, followed by P. fimbriatus (24 water bodies out of 41) and M. leuckarti (22 water bodies out of 41), M. hyalinus was rare and occurred only one water body (Table-28). During premonsoon survey also these species were more frequent among the copepods. No particular seasonality was observed regarding pre and post monsoon survey (Table-28).

IV. Ostracods

Ostracods are small crustaceans having the bivalve carapace enclosing the laterally compressed entire body. They inhabit all kinds of freshwater and marine environs. The freshwater ostracods occur in lakes, tanks, pools, swamps, streams and even polluted waters. Majority of them are free living and a few are commensals on the gills of Cray fishes and in the intestine of fishes and amphibians. There no parasitic forms (Patil and Gouder, 1989). About 1700 species of ostracodes of which about 550 species inhabit freshwaters, have been recorded from various parts of the world.
Approximately, 110 species are known from the inland water bodies of the Indian subcontinent (Patil and Gouder, 1989). Only 5 species occur in Dharwad area. In the present study, only four species were recorded.

Except the Attiveri reservoir all other water bodies were recorded the four species. Lower ostracod densities (2830 Org/L) were also recorded in the Attiveri reservoir, and high densities (12930 Org/L) were noticed in the Gangibhavi pond. Highest densities of ostracod were also recorded in Gangibhavi pond in the month of September 2003.

Among ostracoda, the most abundant species was *H. fossucula* which contributed 48% (Sanavalli reservoir) to 66% (Battigeri pond) to the ostracod densities. *Stenocypris* sp. was the rare ostracod contributed 1% (Sanavalli reservoir and Battigeri pond) to 7% (Bachanki reservoir) (fig-49 to 54).

In Attiveri reservoir ostracod densities was positively correlated with water temperature (*r=*0.527), copepod densities (*r=*0.556) and rotifer densities (*r=*0.587) (Table-36). In Bachankki reservoir it was positively correlated with only rotifer densities (*r=*0.630). In Nyasargi reservoir ostracod densities positively correlated with ammonical nitrogen (*r=*0.610) and negatively correlated with pH (*r=*-.608). In Sanavalli reservoir ostracod densities was showed positive correlation with copepod densities (*r=*0.796) and rotifer densities (*r=*0.687). In Battigeri it was positively correlated with atmospheric temperature (*r=*0.630), electric conductivity (*r=*0.704), total dissolved solids (*r=*0.738), calcium (*r=*0.634), total hardness (*r=*0.629), chlorides (*r=*0.570), nitrates (*r=*0.630), cladocer densities (*r=*0.643), copepod densities (*r=*0.646) and rotifer densities (*r=*0.758). In Gangibhavi pond it showed only positive correlation with copepod densities (*r=*0.469) and rotifer densities (*r=*0.826) (Table-36).
In survey during post monsoon season, *H. fossucula* was the most frequent ostracodan, which occurred in 24 water bodies out of 41 analysed, followed by *I. gibba* (18 water bodies out of 41) and *Darwinula sp.* (10 water bodies out of 41). *Stenocypris sp.* was rare and recorded only in 2 water bodies. No particular seasonality was observed for ostracods during pre and post monsoon survey.

4.2.2. Trophic status

The empirical relationships between aquatic communities and lake trophic status have been studies extensively. Consistent models relating phytoplankton biomass to nutrients or water transparency have been developed for both temperature and trophic lakes (Pinto Coelho, 2005). Zooplankton have been used as indicator of lake trophy (Gannon and Stemberger, 1979; Boucherle and Zullig, 1983; Pejler, 1983; Sladecek, 1983; Blancher, 1984; Webber *et al.*, 2005; Pinto Coelho, 2005). Since most zooplankton species are found in a wide variety of lake types, the indicator value of individual species is somewhat limited to extreme oligotrophic to eutrophic conditions. However, the presence or absence of algal blooms and macrophytes growths is usually more prominent evidence of these extreme trophic states than that provided by the relatively inconspicuous zooplankters. Nevertheless, in some instances, certain zooplankton species, especially rotifers, have apparent indicators value for these lake types. Most lakes do not exhibit attributes of extreme oligotrophy or eutrophy. Indicator organisms would be more useful for these w Rotifers respond more quickly to environmental changes than crustacean plankton and appear to be more sensitive indicators of change in water quality (Gannon and Stemberger, 1977; Sladecek, 1983). Because the genus *Brachionus* is connected with the eutrophic waters (except *B. sericus* which is typically acidophilic and *B. plicatilis* from brackish waters) and the genus *Trichocerca* is nearly purely oligotrophic, we can establish a *Brachionus: Trichocerca* quaotient (*Q* _{B/T}) (Sladecek, 1983). This quotient can be established for individual water bodies of standing or slowly-flowing character or even for individual samples, if representatives of at least one of these genera are present.
Based on the quotient $Q_{\text{B/T}}$ values (Table-37) it was observed that in the month of June all the six water bodies were in the oligotrophic condition. In Nyasargi reservoir oligotrophic condition remains until the September, whereas in Gangibhavi pond it was restricted to the only June month. This variation may attribute to the high water level in the water bodies during monsoon season; increased water level diluted the concentrations of nutrients as observed by the Bohra and Kumar, (2004); Hedge and Huddar, (1995).

Hypereutrophic condition was noticed in March to May (summer months) in all water bodies, in Bachanki reservoir it starts from February whereas in Battigeri pond it was started from September itself, and in Gangibhavi it was in July. The Battigeri pond was in hypereutrophic condition through out our study period except from June to August. The Gangibhavi pond was in hypereutrophic condition through out our study period except only June month. This may be due to the smaller water body with lower water level. Because presence of lower water level in summer, remains of dead and decaying vegetation as well as burnt and half burnt dead bodies, which results in to the increase of organic matter and growth of bacteria population which increase the zooplankton population as explained by Bohra and Kumar (2004).

In survey during post monsoon season (September to November), only five (14.63%) water bodies were in Hyper eutrophic state out of 41 water bodies analysed, whereas in pre monsoon survey (February) though it was only six water bodies but out of 13 water bodies means 46.15 % of water bodies were in hypereutrophic state (Table-38 & 39). variation may be due to Again the water lower level, increased anthropogenic activity. Lind and Lind (2002) opined that water quality might be significantly determined by water quantity. While analyzing the Lake Chapala of Mexico they said that the decline in water volume over the past 20 years enhanced water quality problems.