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Physico-chemical Studies
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Introduction

A lake is a large body of water surrounded by land and inhabited by various aquatic life forms. Lakes are subjected to various natural processes taking place in the environment, such as the hydrological cycle. As a consequence of unprecedented development, human beings are responsible for choking several lakes to death. Storm water runoff and discharge of sewage into the lakes are two common ways that various nutrients enter the aquatic ecosystems resulting in the death of those systems (Sudhira and Kumar, 2000). The washing of large amounts of clothes by dhobis, laundry workers, and the continued entry of domestic sewage in some areas are posing pollution problems (Benjamin et al., 1996). Of all the water quality issues regarding lakes everywhere, eutrophication is of great concern. Eutrophication of a water body signifies the aging of a lake. It is caused by the accumulation of nutrients, sediments, silt and organic matter in the lake from the surrounding watershed.

Physico-chemical and biological characteristics characterize any water body. The physical and chemical properties of fresh water body are characterized by the climatic, geochemical, geomorphological and pollution conditions. The biota in the surface water is governed entirely by various environmental conditions. The primary production of organic matter is in the form of phytoplankton and macrophytes, which are more intense in lakes and reservoirs than in rivers. In contrast to the chemical quality of water bodies, which can be measured by suitable analytical methods, the biological quality is measured by both qualitative and quantitative characterization. The quality of water is vital concern for mankind, since it is directly linked with human welfare. Generally, the functions directly related to their physical, chemical and biological integrity. Water quality evaluation for wetlands leads to information about their misuse by indicating the pollution status. The quality of aquatic life depends on the water quality and a thorough assessment of the water quality is an integral part of wetland evaluation.

Structure and functional attributes of water, which may be categorized as physical, chemical and biological, have to be analysed both qualitatively and
quantitatively in order to have a comprehensive evaluation of the water quality. The addition of pollutants leads to the shift in flora and fauna due to homostatic factors operating in the aquatic systems. The diversity of organisms decreases due to presence of only a few tolerant forms in the polluted conditions. The physical dimensions and chemical properties of the lake interact with climatic and edaphic factors to determine the nature of the lake as an environment and thus its inhabitants. Now a days without the knowledge of water chemistry, biological phenomenon can not be understood fully, because the chemistry of water reveals much about the metabolic changes in the ecosystem and explains interrelationships.

All the physico-chemical parameters of the samples collected from the effluents of Daphrin hospital let into Sagar lake (site A, site B and site C) were conducted by the standard methods of water analysis (Adoni, 1985). The important physico-chemical characters chosen for this study were pH, Temperature, Alkalinity, Chloride, Dissolved oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, Nitrate, Phosphate and free CO$_2$.

The parameters and analytic methods discussed below are the set of measures that were applied to the lake in this study. The objective of choosing this investigative procedure was to develop baseline information in such a short time frame as possible. The lake rating methods and biological analysis allow this objective to be accomplished in an efficient and effective manner.
Materials and Methods

Hydrogen ion concentration

pH is a scale of intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water. If free H⁺ are more than OH⁻ ions, the water will be acidic, or alkaline the other way round. The most chemically pure water is partly dissociated, and a temperature of 22 °C. 10-14 g molecules of water per litre is equally dissociated into H⁺ and OH⁻ ions. The concentration of hydrogen ions thus being 10⁻⁷. Instead of the inconvenient number 10⁻⁷ the pH value is expressed as the negative logarithm of the hydrogen ion concentration. Thus pH 7 indicates neutral water, pH 7 to 14 alkaline, and pH below 7 acidic.

Principle

Activity of hydrogen ions in a solution is measured as the difference in potentials (e.m.f.) of glass electrode with that of a calomel reference electrode over a scale calibrated directly in pH units.

Procedure

- The activity of the hydrogen ions in a solution was measured by the electrometric method.
- The electrodes were dipped into the sample to be studied.
- The reading on the pH meter (Systronics Digital pH meter 335) was noted which showed whether the solution was alkaline, acidic or neutral.

Temperature

Temperature affects the chemical and biological reactions in water. A rise in temperature of water accelerates chemical reactions, reduces solubility of gases, amplifies taste and odour, and elevates metabolic activity of organisms.

Procedure

- The surface water temperature was measured by a mercury thermometer of 0°C to 50 °C range and with 0.2 °C least count.
Surface water taken in a plastic container and its temperature was recorded immediately by dipping the thermometer for about one minute.

The temperature of both air and water, play a crucial role in physiochemical, metabolic and physiological behaviour of any system.

Alkalinity

Alkalinity of water is its capacity to neutralize a strong acid and is characterized by the presence of hydroxyl (OH⁻) ions capable of combining with hydrogen (H⁺) ions. A number of bases viz., carbonates, bicarbonates, hydroxides, phosphates, nitrates, silicates, borates etc. contribute to the alkalinity, however, in natural waters carbonates, bicarbonates, and hydroxides are considered to be the predominant bases. Thus alkalinity may be expressed as total alkalinity or alkalinity due to individual bases.

Principle

Alkalinity is determined by titrating the sample with a standard solution of strong acid. Alkalinity due to hydroxide and carbonate is determined to the first end point (pH 8.3) using phenolphthalein indicator and bicarbonate alkalinity is determined to the second end point (pH 4.5) using methyl orange indicator.

Preparation of reagents

(i) Sulphuric acid titrant (0.02N)

Stock solution of 0.1N H₂SO₄ was prepared by diluting 2.8 mL of conc. sulphuric acid to 1 litre of distilled water. 200 mL of this stock solution was diluted to 1 litre, to obtain 0.02N acid titrant.

(ii) Phenolphthalein indicator

1.25 g phenolphthalein dissolved in 125 mL ethyl alcohol and to it, 125 mL distilled water was added.

(iii) Methyl orange indicator

0.1g methyl orange was dissolved in 200 mL of distilled water.
Procedure

- The Alkalinity was measured by the titration method (Adoni, 1985).
- 50 mL of the sample was taken in 150 mL Erlenmeyer flask and two drops of phenolphthalein indicator was added.
- If pink color appeared then titrated with 0.02N sulphuric acid, till the pink color disappeared.
- Reading was noted and two drops of methyl orange was added to it and titration was continued till color changed from yellow to orange.
- Readings were again noted and calculations were done.

Calculation

\[
\text{Phenolphthalein alkalinity (P) as mg/L CaCO}_3 = \frac{\text{mL of Titrant} \times 1000}{\text{mL of sample}}
\]

\[
\text{Total alkalinity as mg/L CaCO}_3 = \frac{\text{mL of Titrant} \times 1000}{\text{mL of sample}}
\]

Free carbon dioxide

Free carbon dioxide dissolved in water (CO\textsubscript{2} aq) is essentially the only source of carbon that can be assimilated and incorporated into the “Skeleton” of the living matter of all the aquatic autotrophs; once fixed it can further be utilized by the organisms of other categories. In the absence of free CO\textsubscript{2}, plants utilized the bicarbonates. Carbon dioxide dissolved in natural water actively participates in the carbonate system.

\[
\text{CO}_2(g) = \text{CO}_2 \text{ (ag)}
\]
\[
\text{CO}_2 + \text{H}_2\text{O} = \text{H}_2\text{CO}_3
\]
\[
\text{H}_2\text{CO}_3 = \text{HCO}_3^- + \text{H}^+
\]
\[
\text{HCO}_3^- = \text{CO}_3^{2-} + \text{H}^+
\]
\[
\text{CO}_2 + \text{OH}^- = \text{HCO}_3^-
\]
\[
\text{H}_2\text{O} = \text{H}^+ + \text{OH}^-
\]
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Principle

Free CO₂ reacts with sodium carbonate or sodium hydroxide to form sodium-bi-carbonate. Completion of reaction is indicated by the development of pink color, a characteristic of phenolphthalein indicator at the equivalence pH of 8.3.

Preparation of reagent

(i) Standard sodium hydroxide titrant (0.02273 N)

0.909 g sodium hydroxide was dissolved in carbon dioxide free (freshly boiled and cooled) distilled water and volume was made up to 1 L. It was standardized with oxalic acid.

(ii) Phenolphthalein indicator

1.25 g phenolphthalein was dissolved in 125 mL of ethyl alcohol and 125 mL of distilled water. 0.02 N NaOH solution was added drop wise until pink color appears

Procedure

- 50 mL of water sample was taken in 150 mL Erlenmeyer flask and 2 drops of phenolphthalein indicator was added.

- If slight pink color developed then free carbon dioxide was absent in the sample.

- If the sample remains colorless, then titrated with standard sodium hydroxide solution until pink color appeared. End point was noted and calculations were done.

- Results were expressed as free CO₂ mg/L

Calculation

\[
\text{Free CO}_2 \text{ mg/L} = \frac{\text{mL of titrant} \times 1000}{\text{mL of sample}}
\]

Biochemical Oxygen Demand (BOD)

BOD is defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. In other
words, BOD represents quantity of dissolved oxygen in mg/litre required during oxidation of decomposable or biodegradable organic matter by aerobic biochemical action.

**Principle**

The BOD of a water sample is the decrease in oxygen concentration after incubation in the dark at certain temperature for a period of time.

**Procedure**

- 250 mL samples were collected in two separate BOD bottles and one bottle was immediately fixed.
- Dissolved O₂ content was determined by Wrinkler’s method as initial D₁.
- The other bottle was incubated at 20 °C for 3 d and the oxygen content was estimated by Wrinkler’s method as D₂.

**Calculation**

\[
\text{BOD (mg/L)} = \text{D}_1 - \text{D}_2 \\
\text{D}_1 = \text{Initial oxygen (mg/L)} \\
\text{D}_2 = \text{Dissolved oxygen after 3 d incubation (mg/L)}. 
\]

**Chemical Oxygen Demand (COD)**

Chemical oxygen demand (COD) measures the amount of oxygen required for oxidation of organic compounds present in water by means of chemical reaction involving oxidizing substances such as potassium dichromate and potassium permanganate.

**Principle**

The amount of organic matter in water is estimated by their oxidability by chemical oxidants, such as potassium permanganate or potassium dichromate (the constituent carbon and hydrogen are oxidized and not the nitrogen). In the permanganate method the organic matter is first oxidized with a known amount of KMnO₄ and then excess of oxygen is allowed to react with potassium iodide to liberate iodine in amounts
equal to the excess oxygen, which is estimated titrimetrically with sodium thiosulphate solution using starch as an indicator.

**Preparation of reagents**

(i) **KMnO₄ solution (0.1N)**

3.16 g of KMnO₄ and 16 g of NaOH dissolved in little distilled water and made it upto 1 litre.

(ii) **Sodium thiosulphate (0.1M)**

15.81 g of Na₂S₂O₃ dissolved to 1 litre of distilled water.

(iii) **Sulphuric acid (2M)**

900 mL distilled water was added to 100 mL of 18 M sulphuric acid.

(iv) **10% Potassium iodide**

10g KI dissolved in 90 mL of distilled water.

(v) **1% Starch solution**

1 g starch was dissolved in 100 mL lukeworm distilled water and heated slightly.

**Procedure**

- 50 mL of water sample was taken in a 150 mL Erlenmeyer flask.
- 5 mL of KMnO₄ solution was added to it and placed in water bath for 1 h at boiling temperature.
- The samples were then cooled for 10 min, to it was added 5 mL of KI solution and 10 mL H₂SO₄.
- This was titrated against 0.1M sodium thioulphate solution till color changed to pale yellow.
- Then 1 mL of starch solution was added to it, the solution turns blue.
- The titration was continued till blue color disappears.
- The same procedure was done for blank-distilled water.
- Readings were noted and calculation were done.
Calculation

\[
\text{COD in sample (mg/L)} = \frac{8 \times C(A - B)}{S} \times 0.23
\]

- \(C\) = concentration of titrant (mol/L)
- \(A\) = Volume of titrant used for blank (mL)
- \(B\) = Volume of titrant used for sample (mL)
- \(S\) = Volume of water sample (mL)

Chloride

Chloride, in the form of chloride (Cl\(^-\)) ions is one of the major inorganic anions in water and waste water. It is invariably present in small amounts in almost all natural waters and its contents goes up appreciably with increasing salinity.

Principle

Chloride is titrated with soluble silver salt (in weak acid solution) in presence of chromate, yielding relatively insoluble AgCl. The brick red silver chromate is formed at the end point (iodide and bromide, when present get registered as chloride).

Preparation of reagents

(i) **Silver nitrate titrant (0.0141N)**

2.395 g of silver nitrate dissolved in little distilled water and diluted to 1 litre and stored in dark bottle.

(ii) **Potassium chromate indicator**

10 g potassium chromate dissolved in little distilled water and diluted to 200 mL.

Procedure

- The chloride content was determined by titration method. Chloride was titrated with soluble silver salt in presence of chromate to form AgCl showing brick red silver chromate at end point.
- 50 mL of sample was taken in 150 mL Erlenmeyer flask and five drops of potassium chromate was added to it.
Yellow color thus appeared was titrated with standard silver nitrate solution till brick red color appears.

Readings were noted and calculations were done.

**Calculation**

\[
\text{Chloride (mg/L)} = \frac{\text{mL of Titrant} \times N \times 35.46 \times 10^3}{\text{mL of sample}}
\]

where \(N\) - Normality of titrant

**Dissolved Oxygen (DO)**

Oxygen dissolved in water, often referred to as DO, is a very important parameter of water quality and is an index of physical and biological processes going on in water. There are two main sources of dissolved oxygen in water - (i) diffusion from air, and (ii) Photosynthetic activity within water. Diffusion of oxygen from air to water is a physical phenomenon and depends upon solubility of oxygen which, in turn, is influenced by factors like temperature, water movements, and salinity etc. Photosynthetic activity is a biological phenomenon carried out by autotrophs (mainly phytoplankton in water) and depends upon autotroph population, light conditions, and available gases etc.

**Principle**

It is usually determined by Wrinkler's method which is based on the reaction of dissolved oxygen with manganese ions to form a precipitate of manganese dioxide.

\[\text{Mn}^{2+} + \text{O}_2 \rightarrow \text{MnO}_2 \downarrow\]

The manganese dioxide is then treated with iodide ions when iodine is liberated in an amount chemically equivalent to the original dissolved oxygen.

\[\text{MnO}_2 + 2\text{I}^- + 4\text{H}^+ \rightarrow \text{Mn}^{2+} + \text{I}_2 + 2\text{H}_2\text{O}\]

The liberated iodine is determined usually by titrating it with sodium thiosulphate.

\[2\text{S}_2\text{O}_3^{2-} + \text{I}_2 \rightarrow \text{S}_4\text{O}_6^{2-} + 2\text{I}^-\]
Preparation of reagents

(i) **Manganous sulphate solution**

182 g of manganous sulphate (MnSO₄·H₂O) was dissolved in previously boiled distilled water, filtered and diluted to 500 mL.

(ii) **Alkaline iodide azide solution**

350 g KOH and 75 g KI were dissolved separately in distilled water. Both were mixed and made the volume up to 500 mL. 5 g of sodium azide (NaN₃) was dissolved separately in 20 mL of distilled water. This azide solution was added to the alkaline iodide reagent.

(iii) **Standard sodium thiosulphate titrant (0.025 N)**

6.205 g of sodium thiosulphate (AR grade) was dissolved in freshly boiled and cooled distilled water and diluted to 1 L. One pellet of NaOH as a preservative was added.

(iv) **Starch indicator**

1 g starch (soluble) was dissolved in 200 mL of hot distilled water and few drops of toluene were added as a preservative.

(v) **Sulphuric acid (conc.)**

Sp. gr. 1.84 (18 M).

**Procedure**

- 250 mL of water sample was collected without bubbling in 250 mL BOD glass-stoppered bottles.

- 2 mL of manganous sulphate was added followed by 2 mL of alkaline iodide azide reagent, using separate pipettes. A brown precipitate was appeared.

- Then the bottle was stoppered and shaken many times to mix the contents well and the brown precipitate was allowed to settle down.

- This precipitate was dissolved by adding 2 mL of conc. sulphuric acid and the bottle was re-stoppered and mixed by inverting it several times until the precipitate dissolves completely.
50 mL of this aliquot was taken in 150 mL Erlenmeyer flask and titrated with standard sodium thio-sulphate solution (0.025 N) till the color changed to pale straw.

After this 2 mL of starch solution was added and titrated further till the blue color disappeared. The readings were noted and calculations were done.

Results were expressed as DO in mg/L.

**Calculation**

(i) if whole content is used for titration:

\[
\text{DO in mg/L} = \frac{V_1 N \times 8 \times 1000}{V_2 - V_3}
\]

(ii) if a fraction of the content is used for titration:

\[
\text{DO in mg/L} = \frac{V_1 N \times 8 \times 1000}{V_4 (V_2 - V_3 / V_2)}
\]

Where,

\[\text{DO} = \text{dissolved oxygen}\]

\[V_1 = \text{volume of titrant (mL)}\]

\[N = \text{normality of titrant (0.025)}\]

\[V_2 = \text{volume of sampling bottle after placing the stopper (mL)}\]

\[V_3 = \text{volume of manganous sulphate + potassium iodide solutions added (mL)}\]

\[V_4 = \text{volume of fraction of the contents used for titration (mL)}\]

**Nitrate**

Nitrate is the highest oxidized form of nitrogen and in water its most important source is biological oxidation of nitrogenous organic matter of both autochthonous and allochthonous origin. Domestic sewage and agricultural runoff are the chief sources of allochthonous nitrogenous organic matter. Metabolic wastes of aquatic community and dead organisms and to the autochthonous nitrogenous organic matter.
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Nitrate in contact with sulphuric acid produces nitric acid in dry condition (in presences of excess conc. H₂SO₄) brings about nitration of phenol disulphonic acid. This nitrophenolic product gives intense yellow color in alkaline medium, which is measured by spectrophotometer at 410 nm. The reaction must proceed in cold otherwise nitric acid may be lost by volatilization.

Preparation of reagents

(i) Phenoldisulphonic acid

25 g pure white phenol was dissolved in 150 mL of conc. sulphuric acid then 75 mL of conc. sulphuric acid (15% free SO₃) was added cautiously and heated for about 2 h on water bath, then cooled, and solution was kept in a dark place.

(ii) Ammonium hydroxide (32% w/v NH₃)

It is available as lab reagent in the market.

(iii) Standard potassium nitrate solution

0.722 g anhydrous potassium nitrate was dissolved in nitrate free distilled water and volume was made up to 1 L. This stock solution contains 1 mg NO₃ - N, i.e. 4.43 mg NO₃ ions.

Procedure

- 25 mL of water sample was taken in a porcelain dish (50 mL capacity) and evaporated to dryness on a hot water bath.
- After cooling residue was rubbed and 3 mL phenol disulphonic acid reagent was added to the residues and dissolved by rotating the dish.
- After 10 min, 15 mL of distilled water was added and stirred with a glass rod. On cooling, the contents were washed down into 100 mL volumetric flask.
- Ammonia was slowly added with mixing till the solution was alkaline as it was indicated by the development of yellow color due to the presence of nitrate.
- Then another 2 mL of ammonia was added and the volume was made up to 100 mL with distilled water.
The intensity of yellow color was measured in the spectrophotometer at 420 nm against distilled water blank and compared with a calibration curve prepared with KNO₃ (MAC® Digital spectrophotometer Model 310 E).

Results were expressed as NO₃ - N in mg/L.

Preparation of standard curve

A stock solution containing 100 ppm nitrate-nitrogen (NO₃) was prepared by dissolving 0.7215 g of AR grade potassium nitrate (oven dried and cooled) in distilled water and making the volume to 1 L. This was diluted 10 times to give a 10 ppm NO₃ solution. Aliquots (2, 5, 10, 15, 20 and 25 mL) were evaporated on boiling water bath to dryness in small porcelain dishes. When aliquot was cooled, 3 mL of phenoldisulphonic acid was added to develop yellow color, which was read as described above. A blank (without nitrate) was run and correction made by adjusting the spectrophotometer to zero with blank. A calibration curve was drawn between concentration of NO₃ and spectrophotometer reading.

Calculation

\[
\text{mg of NO}_3/\text{L} = \frac{\text{µg of NO}_3 \text{ from standard curve}}{\text{mL of sample}}
\]

Phosphates

Phosphorus occurs in natural and in waste waters almost solely as phosphates. Phosphorous is one of the most important major nutrients required by biota. However, in comparison to other major elements, it is required in smaller amounts. Domestic and industrial effluent and agricultural runoff are major sources of the phosphorous in water, hence its high concentration is indicative of pollution. In water, phosphorous occurs both in inorganic and organic form.

Principle

Orthophosphate (PO₄³⁻ - P) in an acidified ammonium molybdate solution produces blue color when stannous chloride is added. This color is measured by spectrophotometer at 690 nm (MAC® Digital spectrophotometer Model 310 E).
Preparation of reagents

(i) Ammonium molybdate strong acid solution

5 g ammonium molybdate \( [(NH_4)_6MO_7O_{24}.4H_2O] \) was dissolved in 35 mL of distilled water. 62 mL of conc. \( H_2SO_4 \) was added cautiously into 80 mL of distilled water, cool and mix with molybdate solution and dilute to 200 mL.

(ii) Stannous chloride solution

0.5 g fresh stannous chloride (\( SnCl_2.2H_2O \)) was dissolved in 2 mL of conc. hydrochloric acid, diluted to 20 mL with distilled water. Freshly prepared solution was used when required.

(iii) Standard phosphate solution

0.1757 g of potassium dihydrogen phosphate (oven dried at 105 °C) was dissolved in distilled water and diluted to 1 L. 1 mL of this solution contains 40 μg PO₄.

Procedure

- 25 mL sample was taken in 150 mL Erlenmeyer flask (also prepare distilled water blank simultaneously).
- 1 mL ammonium molybdate reagent was added and the flask was shaken vigorously after which 0.12 mL (3 drops) of stannous chloride reagent was added and the flask was shaken again.
- Blue color appeared gradually. The intensity of blue color that developed after 10 min but before 12 to 15 min against a blank was measured at 690 nm and compared with a calibration curve (mg/ L).
- Results were expressed as PO₄ - P in mg/L.
Results and Discussions

Hydrogen ion concentration (pH)

In the present investigation, the pH value varied from 7.4 to 9.0 at site A, 7.0 to 9.0 at site B and 7.1 to 9.1 at site C of Daphrin hospital discharge into Sagar lake. The pH value was highest at site C, except in the month of March, while lowest at site A. Thus, when compared the results, site A was found to be neutral as compared to site C which was alkaline. Fluctuation of pH was observed (Jan - June 2004) at site B during the study period (Table 3; Fig.7).

pH of the water appears to be dependent upon the relative quantities of calcium carbonates and bicarbonates. The logarithm of the reciprocal of concentration of hydrogen ions, is thought to be a very important factor in maintaining the bicarbonate and carbonate system of water bodies. It is also thought to be a very important factor in maintaining the neutral condition of mineralized water due to buffering by chemical substances such as carbondioxide, bicarbonate and carbonate complex. Below pH 5, total carbon dioxide is of qualitative importance, while above pH 9.5, carbonates being to be of biological importance (Reid, 1961).

pH is a valuable parameter which guides not only the status of acid alkali balance of the water but also serves as an important index for the degree, of pollution. The natural water used to have pH 7.0 Due to presence of carbonates, the pH of water may fluctuate over 7.0. The factors like photosynthetic and respiratory activity, exposure to air temperature and disposal of industrial wastes etc. bring about the changes in pH (Saxena, 1987).

Sunkad and Patil (2004) assessed the potability of fort lake water of Belgaum district and observed that the fort lake water exhibits high alkalinity with pH ranging from 8.36 (June) to 10.6 (Feb and March). Increase in environmental temperature increases water solubility of atmospheric carbon-dioxide and the rate of degradation of organic matter leading to further built up of carbon dioxide in water. The CO2 level influences pH of water (Borse and Bhave, 2000). Srivastava et al., (2003) analyzed the physico chemical parameterers of water bodies in Jaipur and found that Jalmahal lake is most polluted due to high pH. Pandey et al., (2003) reported alkaline pH of sub surface water of 18 different sites from Makrana district of Nagaur.
Low pH in summer may be due to high decomposition activities which release weak acid, while high pH may be due to increased concentration of bicarbonate alkalinity. In the present investigation all the three sites of the lake showed the alkaline range. This result is in close agreement with the findings of Ramakrishna (2003) who noticed the pH value of two different ponds. Tiruvannamalai of Tamil Nadu. Garg (1990) also noticed the pH value of surface and ground water of Roorkee city in the range of pH 6.5 to 7.5. The high biota production due to high pH values has been supported by high free carbon dioxide values in Omi water body of Ago-Iwoye, Nigeria (Fafioye et al., 2005). Bhatt and Hedge (1997) observed that the pH of the water appears to depend upon the reactive quantities of calcium carbonates and bicarbonates. The water tends to be more alkaline when it contains large quantities of bicarbonates, carbon dioxide and calcium.

**Temperature**

In the present study the temperature (°C) ranged from 18.0 to 27.1 at site A, 18.0 to 26.1 at side B and 18.1 to 26.0 at site C (Table-3; Fig.8). The maximum temperature (27.1 °C) was recorded in the month of May at site A, while minimum temperature (18.0 °C) in Jan at site A and B.

Temperature is one of the most important factors in aquatic environment. It not only affects the physiology, growth and reproduction, feeding and movements of biotic components but also controls their entire environment, which is of prime significance. The heat budget, sediments, storage of heat and thermal stratification contributes significantly in controlling the metabolic characteristics of lakes in temperate as well as in tropical regions. Temperature of both air and water plays a crucial role in physico-chemical properties of the lake and metabolic and physiologic behaviour of aquatic ecosystems. The water temperature closely follows variations with the ambient air temperature (Ghosh, 1986). Kataria et al., (1996) also reported the temperature of the Kolar reservoir of Bhopal from 22.4 to 33 °C. Ramakrishnan (2003) noticed that the water temperature increases from December (23.10 °C) in pond I Sonatheertham and from January (25.10 °C) in pond II- Pallakkothukulom and attain its peak value during July (29.20 °C) for pond I and 30.10 °C for pond II) in both the ponds at Tiruvannamalai, Tamilnadu. The temperature levels were similar at all
Fig. 7: Variation in pH of the discharge of Daphrin hospital into Sagar lake (Jan-June 2004)

Fig. 8: Variation in temperature of the discharge of Daphrin hospital into Sagar lake (Jan-June 2004)
the sampling sites. Dry period temperature was constantly above those of the wet period, due to lack of sunlight. A decline in temperature due to depth is also noted by several workers (Kannan and Job, 1979; Sarkar, 1982 and Sreenivasan, 1968) in ponds and lakes. Borse and Bhave (2000) studied the water temperature of river Aner near Galangi, Jalgaon and Piloda. In Dhulia it ranged between 17 °C and 29 °C and 17.5 °C to 28.5 °C with maximum in summer and minimum in winter respectively.

Hill et al., (2005) observed Bayou Dorcheat, hill farm, Lake Claiborne, and Ray pond of Louisiana and reported that the temperatures were found to be 24.88 ± 1.40 °C, 20.97 ± 2.50 °C, 27.31 ± 0.62 °C and 28.22±0.92 °C, respectively. Gupta (1987) also noticed fluctuation from 18.0 to 33.3 °C in water temperature of Sagar lake. Temperature therefore, is an important physicochemical parameter, which to some extent regulates many of the beneficial uses of water. Generally, temperature increased between 1.00 - 3.00 pm throughout the experiment, may be assumed as time of insolation (Fafoye et al., 2005) Many workers reported similar findings with regard to temperature of water reservoir (Katario et al., 1996; Sohanid et al., 2001; Bhadram et al., 2004; Raman and Murugesan, 2001).

Alkalinity

In the present observation, the alkalinity (mg/L) varied from 102.5 to 151.7 at site A, 99.0 to 104.0 at site B and 65.0 to 94.9 at site C. The water samples collected from site A showed highly alkalinity as compared to site B and site C. Site C showed the least amount of alkalinity. It was also recorded that the amount of alkalinity was less in March at site A, May at site B and in January at site C. Highest alkalinity (151.7 mg/L) in April was recorded at site A (Table 3 ; Fig 9).

Alkalinity of water refers to the quantity and kind of compounds present, which collectively shift the pH to the alkaline side of neutrality. The property of alkalinity is usually imparted by the presence of bicarbonates, carbonates and hydroxides and less frequently in inland water by borates, silicates and phosphates (Wetzel, 1975). Bicarbonate alkalinity showed a direct relationship with total alkalinity and inverse relationship with carbonate alkalinity (Joshi, 1987). The bicarbonate alkalinity values of Sagar lake water ranged from 42.02 to 108.0 ppm during summer, 42.0 to 78.0 ppm during rainy and 58.0 to 130.0 ppm during winter.
(Yadav, 1986), while Gupta (1987) observed variation of bicarbonate alkalinity from 44.0 ppm in October to 122.0 ppm in December. The carbonate alkalinity was also reported which ranged from 8 ppm in October to 88 ppm in March. Ghosh (1986) found that the bicarbonate alkalinity of Sagar lake ranged from 6.0 mg/L\(^{-1}\) in April to 118.0 mg/L\(^{-1}\) in July. Alkalinity of water refers to the quantity and kind of compounds present in it. The alkalinity shifts the pH to the alkaline side of neutrality. It is usually imparted by the presence of bicarbonates, carbonates, hydroxides, borates, silicates and phosphates (Wetzel, 1975). Water samples of five major drains carrying sewage, sullage and industrial effluents efflux their wastes into the river Pandu during its course through Kanpur were reported to be alkaline in nature (Tiwari, 2004).

In the Alkhananda, the total alkalinity was only due to biocarbonates of which a maximum concentration of 251 mg/l was observed at 12 and 16 h and a minimum of 200.55 mg/L at 4 h. However, in the Nandakini the carbonates were present at 16 h. The total alkalinity was maximum (318 mg/L) at 16 h. and minimum (266 mg/L) at 8 h. There was a positive relationship between total alkalinity and pH value in both the rivers. In Alknanda free CO\(_2\) and alkalinity due to bicarbonate exhibit negative relationship with diurnal water temperature variation. Similar observations were also recorded by Dobriyal et al., (1981).

The alkalinity of the lake water is maintained and does not seem to be affected either by oxygen or by carbon dioxide content (Singh 1960; Verma 1969). The correlation matrix and cluster analysis indicated that water temperature, phenolphthalein, alkalinity and pH have greater similarity (Nagarathna and Hosmoni, 2003). Total alkalinity of two ponds (pond I- Pallakothukulam; pond II- Sonatheertham) of Tamilnadu showed significant positive correlation with pollution indices (Ramakrishnan, 2003). This is probably due to effective buffering capacity of water which avoids large variations. Below pH 5, total CO\(_2\) is of quantitative importance, while pH between 7 to 9 bicarbonates are of great significance, while above pH 9.5 carbonates are of biological importance. Alkalinity may reflect long term changes in water quality. Alkalinity increases in response to photosynthetic activity because plants remove CO\(_2\) from the system, resulting in higher pH values. Therefore, high alkalinities may indicate greater plant productivity and nutrient inputs.
Free CO$_2$

Data recorded in the present investigation (Table 3; Fig.10) showed the free carbon dioxide at three different sites of Sagar lake, where the values (mg/L) varied from 6.9 to 47.3 at site A, 5.6 to 52.4 at site B and 5.7 to 43.2 at site C. The maximum free CO$_2$ (52.4 mg/L) value was recorded in February at site B while minimum (5.6 mg/L) in the month of January at site B, thus indicating the pollution level of lake water.

Free carbon-dioxide generally develops in water bodies when oxygen content is low. High free carbon-dioxide concentration therefore generally indicates greater pollution. It is said that the value should not exceed to 10 mg/L in fresh water bodies. The important source of free CO$_2$ in surface water bodies is mainly due to respiration and decomposition by aquatic organisms. It reacts with water to form calcium bicarbonate and in the absence of free CO$_2$ they get converted to carbonates releasing carbon dioxide (Patel 1991; Kaur et al., 1996). Free carbon dioxide present in atmosphere combines with the rain water to form carbonic acid which dissociates into H$^+$ and HCO$_3^-$ ions thus giving acidic nature to water. The carbonate present in the lake are converted into bicarbonates in the presence of free CO$_2$. The total absence of free CO$_2$ is due to its complete utilization in photosynthetic activity (Sreenivasan 1965; Sahai and Sinha 1969). In natural water reduction of CO$_2$ is carried out by photosynthetic activity, removal by the malforming organisms, agitation of water, evaporation and rise of bubbles from the depths. Carbonates are appreciably low in bottom water when compared to surface water.

Yadav (1986) reported that in Sagar lake, free CO$_2$ rarely appeared in surface water, its presence during September, November and December may be due to death and decay of macrophytes. The absence of free CO$_2$ during the major part of the study can be attributed to its complete utilization in photosynthetic activity. This lake differs in this respect from many other Indian lakes and reservoirs. Ramakrishnan (2003) observed the variation in free CO$_2$ values from the month of July 2000 to January 2001, in two water bodies of Tiruvannamalai district of Tamilnadu. Maximum values (56.70 mg/L for pond I- Pallakkothukulam and 51.20 mg/L for pond II- Sonatheertham) were observed during November 2000 and minimum value (36.20 mg/L) for pond I- Pallakkothukulam noticed during January 2001 whereas minimum value (32.50 mg/L) for pond II observed in July 2000. Sreenivasan (1964) also recorded total absence of free CO$_2$ in surface and bottom water.
Fig. 9: Variation in alkalinity of the discharge of Daphrin hospital into Sagar lake (Jan-June 2004)

Fig. 10: Variation in free CO₂ of the discharge of Daphrin hospital into Sagar lake (Jan-June 2004)
Biochemical oxygen demand (BOD)

In the present investigation (Table 3; Fig.11) the BOD (mg/L) varied from 14.4 to 22.0 at site A, 13.8 to 20.1 at site B and 14.3 to 22.1 at site C. The maximum BOD value (22.1 mg/L) was recorded in the month of February at site C, while the minimum BOD (13.8 mg/L) in the month of March at site B. The lowest value was recorded at site B when compared to site A and C while maximum value was at site C. Higher value of BOD was recorded at all sites during winter months, which may be due to higher microorganisms activity of domestic sewage and continuous discharge of toxic effluent.

The BOD is the amount of oxygen required by microorganisms for stabilizing biologically decomposable organic matter (carbonaceous) in water under aerobic conditions. It is already known that the organic matter present in water can be approximated by determining the amount of oxygen required for its microbial decomposition. This is known as biochemical oxygen demand. Thus any lake, river or water sample rich in organic compounds and having high BOD cannot support fish and other organisms on which the fish feed. The fish become rare at BOD value of 4 to 5 ppm and further decrease in BOD will increase anaerobic bacteria. If an industrial plant or municipal sewage system dumps a large amount of organic matter into a river or lake, the killing of fish is not necessarily a result of the organic matter per se, but it can be as the result of oxygen depletion from the microbial decomposition of the organic materials. If the amount of organic matter in sewage is more the more oxygen will be utilized by bacteria to degrade it. Dumping sewage that contains high BOD increases the concentration of soluble organic compounds in the aquatic body where it is discharged. There is depletion of oxygen by aerobic bacteria in the decomposition of organic matter. The quantity of oxygen utilized by bacteria in degradation of organic substances is called biochemical oxygen demand (BOD). The rate of removal (that is consumption) of oxygen by microorganisms in aerobic degradation of the dissolved or even particulate organic matter in water is also called BOD and it is used as an index of organic pollution in water. More the oxidizable organic matter present in water, more the amount of oxygen is required to degrade it biologically, hence more the BOD. Thus it is concluded that BOD
values are useful in evaluation of the self-purification capacity of a water body and is possible to control pollution.

Higher BOD value was observed in pre-monsoon season, which may due to higher microbial activity and high temperature (Klein, 1957). Higher value of BOD in summer was mainly attributed to the high biological activity and high temperature whereas the lowest BOD in winter indicated low biological activity and low temperature (Rai, 1978). The least BOD values are used to determine the pollution and the efficiency of wastewater treatment (Shaw et al., 1991; Bhattacharya et al., 1997). Sunkad and Patil (2004) assessed the potability of fort lake water of Belgaum district and observed that the fort lake water is inferior and not suitable for drinking purpose, where the BOD ranged from 42.6 – 60.6 mg/L.

Afzal et al., (2000) analyzed the results of the Hudia drain samples of Pakistan vicinity and found that the industrial and sewage inputs from India and Pakistan increases the value of Biological oxygen demand (BOD). The Najafgarh drain is the first and the largest drain, which discharge their untreated urban and industrial waste waters into the Delhi segment of river Yamuna. It alone contributes 1667.84 mld i.e. 60% of the total waste water discharge into the river Yamuna and as such add 81.36 tons of BOD load per day (Sharma et al., 2002). The BOD of Bellandur lake water of Bangalore ranged from 89-99 mg/L which may be due to absorption of pollutants by aquatic flora in lake system (Chandrashekar et al., 2003).

More the oxidizable organic matter present in water, more the amount of oxygen is required to degrade it biologically, hence more the BOD. Thus, it is concluded that BOD values are useful in evaluation of the self purification capacity of a water and its possible to control pollution. Fokmare and Musaddiq (2003) noticed that the high BOD value of Purna river water in Akola district, was due to organic enrichment.

Chemical oxygen demand (COD)

The present studies show that the chemical oxygen demand (mg/L) varied from 25.4 to 47.9 at site A, 28.4 to 50.7 at site B and 18.3 to 49.7 at site C. Higher COD value (50.7 mg/L) in March was recorded at Site B, while lower COD value (18.3 mg/L) at Site C in April at sites of Sagar lake water (Table 3 ; Fig.12).
Chemical oxygen demand can also be defined as the amount of oxygen required by organic matter in a sample of water for its oxidation by a strong chemical oxidant and a solution of potassium dichromate. This value is a poor measure of strength of organic matter as oxygen is also consumed in the oxidation of inorganic matter such as nitrates, sulphates, reduced metal ions and also that some organic materials such as benzene, pyridine and few other cyclic organic compounds, are not oxidized by this test. It is very important parameter in management and design of the treatment plants because of its rapidity in determination. Presence of toxins and other unfavourable conditions do not affect COD values. In COD, organics are oxidised chemically instead of biologically but in a shorter time. Since nearly all organics are oxidised in COD test and only some are decomposed during the BOD test, potassium chromate is generally used as an oxidising agent. The chemistry is as follows. A known amount of this chemical added to a measured amount of sample and is boiled. 

\[ C_6H_5O_2 + Cr_2O_7 = + HD CO_2 + H_2O + Cr^{3+} \]

After boiling with an acid, the excess dichromate is measured by adding a reducing agent, usually ferrous ammonium sulphate. The difference between the chromate originally added and the one remaining, is the chromate used for oxidising the organics. The more chromate used, the more organics in sample, and hence the higher the COD.

Chemical oxygen demand (COD) is the measure of oxygen equivalent to the organic content of the sample that is susceptible to oxygenation by a strong chemical oxidant. The intrinsic limitation of the test lies in its ability to differentiate between the biologically oxidisable materials with inert materials (Shaw et al., 1991; Pandoy et al., 1991). Mishra and Trpathi (2003) analysed the Ganga river water and recorded the COD value 4.4 to 208.5 mg.L\(^{-1}\), which was beyond the permissible limit prescribed by WHO and ISI. Similar findings were also reported by several other workers (Unnisa and Khalilullah 2004; Tayade et al., 2002; Raman and Nurugesan 2001). Large variations in the levels of various measured parameters (COD, BOD, pH, total soluble substances and trace metals) were observed along the Hudiara drain in the Pakistan vicinity. These variations were due to different types of industrial effluents and small village drains (Afzal et al., 2000). COD value was remarkably high in Ganda nala effluent of Kanpur. High values indicate the presence of high concentrations of both biodegradable and non biodegradable pollutants (Tiwari, 2004). Rajurkar et al., (2003) observed the COD value from 1.1 to 78.2 mg.L\(^{-1}\) during pre-monsoon and from 5.0 to 310.0 mg.L\(^{-1}\) during post-monsoon in river Umshyrpi at Shillong.
Fig. 11: Variation in BOD of the discharge of Daphrin hospital into Sagar lake (Jan-June 2004)

Fig. 12: Variation in COD of the discharge of Daphrin hospital into Sagar lake (Jan-June 2004)
Chloride

Present results (Table 3; Fig.13) reevaluated that chloride value (mg/L) varied from 30.7 to 180.9 at site A, 28.0 to 181.6 at site B and 33.7 to 191.7 at site C. Maximum chloride content (191.7 mg/L) was recorded in the month of May at site C, while minimum (28.0 mg/L) in the month of March at site B. During the study period, high value of chloride content was observed from site C in comparison to Site A and Site B which recorded lower values of the chloride. The chloride contents were found increased during summer and thereafter decreased during winter season. Similar observations were reported by Yadav (1986); Gupta (1987). The chloride content ranged from 20.2 to 48.0 ppm with minimum and maximum values during September and May respectively (Adoni 1975).

Chlorides are relatively conservative and undergo minor spatial and temporal variations due to least biotic utilization or biotically mediated changes in environment (Wetzel, 1975). Pollution sources like industries and municipal wastes can greatly modify the natural concentration of chlorides (Ownbey and Kee 1967; Pandoy et al., 1991, Bhattacharya et al., 1997). Presence of maximum chloride concentration 125 ml/L to 285 mg/L in the effluent of Ganda nala drain of Kanpur may be attributed to the fact that this particular drain carries the effluents of DIL, a fertilizer factory manufacturing urea (Tiwari, 2004). Hegde et al., (1985) observed chloride concentrations value ranging from 1.2 to 1.35 mg/L, 2.05 to 2.18 mg/L in Alaknanda and Nandakini respectively against the permissible limit 250 mg/L. Chloride content of lake water shows very conspicuous variation during different study period. The variations between the different sampling stations did not show remarkable difference. The concentration of chlorides upto 150 mg/L is harmless, but even a concentration between 250 mg/L and 500 mg/L produces a salty taste. The presence of chloride in natural water can mainly be attributed to dissolution of salt deposits in the form of ions (Cl⁻) otherwise high concentrations may indicate pollution by sewage, industrial waste, intrusion of sea water or other saline water. It is the major form of inorganic anions in water for aquatic life. High chloride content has a deleterious effect on metallic pipes and structures as well as agricultural plants. Their high concentrations are considered to be the indicator of pollution.
which is either due to organic wastes of animal origin or industrial effluents. Chlorides are usually present in low concentration in natural waters and play metabolically active role in photolysis of water and photophosphorylation reaction in autotrophs. Free chlorine which is commonly used as disinfectant for drinking and waste water, soon get either converted into chloride or combines with organic matter to form toxic compound (Adoni, 1985).

Munwar (1970) suggested that higher levels of chloride in water is an index of pollution of animal origin. Bhattacharya et al., (1997) directly correlated chloride concentration with pollution. The weathering of the soil and rocks, atmospheric precipitation and environmental factors directly influence the salinity (Moss and Moss, 1969). The presence of chloride ions in high quantities in natural water without any specific geological reason indicate the extent of organic pollution especially of animal origin (Joshi, 1987).

**Dissolved oxygen (DO)**

It is reported in the present study that the dissolved oxygen (mg/L) ranged from 1.3 to 2.7 at site A, 3.5 to 5.2 at site B and 4.6 to 6.5 at site C. Comparatively higher DO (6.5 mg/L) was recorded at site C in January while lower DO (1.3 mg/L) in April was recorded at site A. Maximum and minimum value was recorded at site C and A respectively (Table-3; Fig.14). The lower value at site A may be due to the absence of any plant species. Site C had a better growth of *Azolla* and *Eichhornia* and due to their respiration and photosynthetic activity oxygen level would have increased. Atmospheric and hydrostatic pressure affects the solubility of gases in water. The saturation of oxygen is considered in relation to the pressure at the surface of the lake. Salinity also reduces the solubility of oxygen in water. Adequate supply of dissolved oxygen is essential for the physiological processes of the aquatic organisms having aerobic mode of metabolism, thus the dynamics of oxygen distribution, behaviour and physiological growth of aquatic organisms are affected (Ghosh 1986; Joshi 1987; Hutchinson 1957).

It is a well known fact that volume of oxygen dissolved at given time is dependent upon (i) the temperature of water (ii) partial pressure of gas in the
Fig. 13: Variation in chloride of the discharge of Daphrin hospital into Sagar lake (Jan-June 2004)

Fig. 14: Variation in dissolved oxygen of the discharge of Daphrin hospital into Sagar lake (Jan-June 2004)
atmosphere in the contact with water and (iii) the concentration of dissolved salts in water. The solubility of oxygen in water is increased by lowering of temperature and is twice that of nitrogen and about one third that of carbon dioxide (Reid, 1961). Gupta (1987) reported dissolved oxygen concentration (6.8 to 11.4 ppm) during summer season, 5.8 to 20.0 ppm during rainy season and 8.0 to 14.8 ppm during winter season. Similar seasonal behaviour of dissolved oxygen was also reported by several workers (Singhal 1980; Adoni 1975; Prasad et al., 1985; Chourasia 1985). Srivastava et al., (2003) evaluated the physiochemical parameter, of water bodies in and around Jaipur and revealed that Ramgarh lake is least polluted as it has high dissolved oxygen. The Yamuna river in Delhi up stream was of better quality, whereas the Delhi down stream was polluted as indicated by very low DO (Ravindra et al., 2003). Ramakrishanan (2003) observed the minimum value of DO during rainy month and maximum value in February 2001 in two ponds (Pallakkothukulam and Sonatheerham) of Tiruvannamalai district of Tamilnadu.

\[ V_{\text{DO}} \approx 27°C\] 

Dissolved oxygen levels vary considerably diurnally as during the day the algae and macrophytes produce oxygen as a byproduct of photosynthesis. Biologically derived decreases in dissolved oxygen levels can be attributed to respiration of plants and animals and decay of the aerobic bacteria. Chandrashekar et al., (2003) reported the DO content of the Bellandur lake of Bangalore ranged from 3.8-6.3 mg/L. The present results are in close conformity with the findings of the other workers (Prasad et al., 1985; Chourasia 1985; Kataria 1990; Grover et al., 1990; Sohanid et al., 2001; Mehta et al., 2003; Bhadram et al., 2004). Ghosh (1972) have observed a decline in DO (3.8-4.8 mg/L) in the textile, paper and pulp, tannery distillery and rubber effluents in the Hooghly river.

**Nitrate**

Data obtained in the present investigation showed (Table-3; Fig.15) that the nitrate (mg/L) ranged from 0.1 to 11.7 at site A, 0.1 to 11.6 at site B and 0.1 to 12.1 at site C. Higher nitrate content (12.1mg/L) was recorded at site C in June, while lower nitrate content (0.1 mg/L at all the three sites) in January.

Nitrate is a key nutrient factor in the growth of aquatic algae and other organisms. An increase in the levels of nutrients in water bodies can trigger the onset
of algal blooms. Nitrate content is an excellent parameters to judge the organic pollution. It was noticed that this lake usually has a high nitrate content which is further aggravated by sewage waste disposal and household activity near ghats. Kumar et al., (1993) noticed that the nitrate concentration increases with decrease in pH and with increase in hardness in Medchal block of Andhra Pradesh. Plachta et al., (2003) studied the vertical distribution and seasonal changes in the number of bacterioplankton in the water of lake Hancza, particularly in the period of reservoir summer stratification and found variation in the content of nitrate nitrogen from 0.004 mg N-NO₃/ dm³ in 10 m deep water. The concentrations of the main nitrogenous species (NO₃ and NH₄⁺) display a reverse relationship. The fact that this correlation is less prominent and clear during spring (April) might be attributed to the contribution of ammonia deriving from the first metabolic product of plankton after the spring bloom (Scoullos, 1983).

Nitrate are the most oxidized forms of nitrogen and it is the end product of the aerobic decomposition of organic nitrogenous matter. The significant sources of nitrates are chemical fertilizers from cultivated lands, drainage from livestock feeds, as well as domestic and industries (Sondergaard and Jensen 1979). Natural water in their unpolluted state contains only minute quantities of nitrates. The plant growth is stimulated by nitrates, thus causing algal eutrophication. The subsequent death and decay of these plants cause secondary pollution (Hannan and Young 1975). Nitrates are important for biological oxidation of nitrogenous organic matter. Certain nitrogen fixing bacteria and algae have the capacity to fix molecular nitrogen into nitrates. The main source of polluting nitrates is through domestic sewage. Nitrates may find their way into ground water through leaching from soil and also by contamination (Somasekhar et al., 1991). Vollenweider (1968) concluded that in general, nitrate and nitrogen are easily available than ammonium while nitrites are either absent or present (traces) in well aerated water.

Dixit et al., (2005) reported the nitrate content range from (2.02 to 15.22 ppm) from Shahpura lake, Bhopal. The high concentration of nitrates in this lake water was recorded in May 2004, while the minimum in June - July 2003. There is a sharp rise in nitrate content of water from 2003 to 2004 showing the increasing anthropogenic influence on the lake. The raw sewage is the source of nitrates and phosphates in the
water (Aggarwal et al., 2000). Mishra et al., (2003) recorded nitrate (4.24-46.00 mg/L) in Keonjhar district, Orissa. Gupta (1987) recorded (150 to 750 μg/L) of nitrate in summer season, (20 to 140 μg/L) during rainy and (20 to 140 μg/L) during winter season. Low values were recorded in rainy and winter season, which may possibly be due to dilution, while in winter it may be due to its uptake and utilization by macrophytic growth. Ghosh (1986) reported that nitrate content of Sagar lake ranged from traces to 1090.0 μg/L in June, while Yadav (1986) reported that surface water of Sagar lake had a nitrate value of 20 ppm to 1090 ppm. Maximum value was observed during summer while minimum during rainy season. Nutrient salts of two water bodies of Tiruvannamalai district of Tamilnadu attained it maximum value during the rainy months due to inflow of rain water and its minimum value were observed during summer months showing negative correlation with phytoplankton population (Ramakrishnan, 2003).

**Phosphate**

The data of the present study show that the phosphate (mg/L) values ranged from 0.1 to 0.3 at site A, 0.1 to 0.4 at site B and 0.1 to 0.3 from site C. Higher phosphate contents (0.4 mg/L) were seen in January at Site B, while lower phosphate content (0.1 mg/L) in the month of March at all three sites (Table-3 ; Fig.16).

In nature total phosphorous occurs as inorganic, dissolved, organic and particulate phosphorous. The only significant form of inorganic phosphorous is orthophosphate, which is assimilated rapidly by the biota. Natural origin of phosphorous in aquatic system is mainly due to the erosion, the chemical and mechanical weathering of rocks, human excreta, detergents, urbanization, leaching and drainage of fertilizers and other soil nutrients (Barrette 1953). These factors also tend to increase total phosphate concentration. Phosphorus acts as a limiting nutrient in lakes of various types (Schindler et al., 1971). Presence of phosphate in water is due to detergents, used boiler water, fertilizers and biological processes. They are essential for the growth of organisms and its presence limits the primary productivity of the water body (Jayangoudar 1964). Inorganic phosphorous play a dynamic role in aquatic ecosystems and when present in low concentration it forms the most important nutrient but when in excess along with nitrates and potassium, causes algal blooms (Somasekar et al., 1991).
Dixit et al., (2005) reported the phosphate content ranged from 6.05 to 9.21 ppm of the Shahpura lake, Bhopal, where the highest value (9.2 ppm) was recorded in May 2003, and the minimum value (6.05 ppm) in May 2004. For phosphates, the U.S. Environmental Protection Agency (1976) suggested that 0.08 ppm is the critical level for the occurrence of eutrophication in lakes and reservoirs. Forkmare and Musaddiq (2003) observed high values of phosphate in Purna river water which can be attributed to pollution from detergent and domestic waste. Atmospheric inputs may play a role in the observed enrichment of the surface microlayer, additionally to the biological activities that lead to the decrease of the concentration at the subsurface layer of lake Aghios Nikolaos (Greece). Further more Σ N/P values show that the phosphorus seems to be the limiting factor for the development of the phytoplankton; mainly at the surface enough phosphorus was observed during winter in the deeper layers (Mihopoulos et al., 2000). Sindhu (2003) reported the high concentration of phosphate during winter months in Sagar lake. Slightly higher concentrations of the examined forms of phosphorus were reported regularly for demersal layers of water of lake Hancza (Poland) Plachta et al., (2003). Tong et al., (2005) investigated the role of the microbial community in aquatic ecology and nutrient transformations in the development of eutrophication in large shallow freshwater lakes along Yangtze river, the microbial community in the depth related sediment in lake Chaohu and lake Longganhu when compared. Lake Chaohu is one of the most polluted lakes in china. However, the neighboring lake Longganhu, a mesotrophic lake is relatively pristine, where the total phosphorus concentration in water was detected at 0.193 mg/L and 0.05 mg/L. Ghosh (1986) observed that phosphate content ranged from 14.0 μg/L in January to 484.0 μg/L in July, while Gupta (1987) found 21.8 μg/L in January to 483.0 μg/L in July, from Sagar lake. Chourasia (1985) reported high concentration of phosphate during rainy season. High concentrations in summer season may be due to reduced water level and increased mineralization at higher temperatures may result to low phosphate concentration during winter (Joshi, 1987).
Fig. 15: Variation in nitrate of the discharge of Daphrin hospital into Sagar lake (Jan-June 2004)

Fig. 16: Variation in phosphate of the discharge of Daphrin hospital into Sagar lake (Jan-June 2004)
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Site A : Sewage discharge point; B : Sewage mixing point; C : Lake water; S. No. 3 to 10 : mg/L

DO: Dissolved Oxygen
BOD: Biochemical Oxygen Demand
COD: Chemical Oxygen Demand