CHAPTER I

PHYSICO-CHEMICAL ENVIRONMENT
INTRODUCTION

The chemical composition of natural waters is the result of a variety of chemical reactions and physico-chemical processes acting in concert. These reactions include, acid-base reactions, gas solution processes, precipitation and dissolution of solid phases, coordination reactions of metal ions and ligands, redox reactions and adsorption processes at interface (Stumm and Morgan, 1970). An aquatic ecosystem normally responds to variations in temperature, pressure, pH, oxygen concentration, nitrogen, carbon, phosphorus. Biological activity of water can be too high (eutrophication) or too low (oligotrophication). Eutrophication is caused by an excess food or energy source in a water body. A suggested method of controlling the very high rate of eutrophication is the lowering of levels of nitrogen and phosphorus in a lake (Stumm and Morgan, 1970).

The water analyses provide useful data for the biotic environment if multiple sampling is carried out at regular intervals to determine the degree of fluctuations of metal pollution in water.
Considerable amount of work has been done in this regard in the United States and Europe (Anderson and Home, 1975; Dillon, 1979; Goldman, 1960, 1981; Vollenweider, 1976).

Although Indian subcontinent is rich in fresh water ecosystems, most of the work on water quality assessment pertains to fresh water ponds, reservoirs and rivers (Pruthi, 1933; Zafar, 1964; Mishra and Yadav, 1978; Das, 1970; Goel et al. 1980; Soni et al. 1981; Bhargava, 1983, a, b, etc.).

Little information is available on the hydrochemical features of high altitude Himalayan lakes (Das and Jyotsna, 1978). During the last few years a lot of work has been carried out on hydrochemical features of Kashmir lakes (Kant and Kashoo, 1971, 1974; Kaul, 1977; Zutshi and Vass, 1977; 1982; Zutshi et al. 1980, Zutshi and Khan, 1978; 1982 and Subla et al. 1984).

Most of these studies pertain to urban lakes. Very little attention seems to have been paid to the lakes situated in the rural area of Kashmir. Furthermore, detailed chemical analyses of lake waters have been lacking e.g. the trace metal studies have been completely ignored.
In view of the paucity of information a detailed study was undertaken on the hydrochemical features of three rural lakes of Kashmir during 1981-83. The physico-chemical features investigated are:

(i) Physical parameters: Light transparency, temperature and fluctuations in water column depth.

(ii) Chemical parameters: These include both the macro and micro elements.

(a) The major constituents investigated are Na\(^+\), K\(^+\), Ca\(^{2+}\), Mg\(^{2+}\), Cl\(^-\), HCO\(_3\)\(^-\), Fe\(^{3+}\), pH and conductivity, dissolved oxygen.

(b) The minor constituents include PO\(_4\)\(^-\)P, Tot.P, NH\(_4\)-N, NO\(_3\)-N and Si.

MATERIALS AND METHODS

Water samples were collected in water tight one litre polyethylene bottles. Surface samples were collected directly just below 10 cm level and for deep waters Ruttner plexiglass sampler was used. Water temperature, Secchi transparency and fixation of dissolved oxygen was carried out in the field. The samples were carried to the laboratory on the same day and were analysed for various constituents.
methods followed for chemical analyses are after Mackreth (1963), APHA (1970) and Golterman et al. (1978).

(i) Water transparency:

A standard Secchi disc (20 cm dia.) was used for measuring water transparency (Welch, 1948). The depth in meters at which the Secchi disc disappeared was taken as the measure of light penetration. This usually corresponds to 15% of the light Extinction co-efficient -

It was calculated with the help of following formula (Poole and Atkins, 1929).

\[
\frac{1.7}{D} = \text{Extinction co-efficient.,}
\]

where D stands for Secchi disc values.

(ii) Temperature - The temperature of the water was noted with the help of a standard centigrade thermometer graduated to 0.5°C.

(iii) Depth - Water depth of the lake at different sites was obtained by using a graduated nylon rope attached to a heavy lead weight. The lake bottom was sounded with the lead weight.
(iv) Dissolved oxygen - The unmodified Winkler's method was used for the determination of dissolved oxygen of water samples (Mackereth, 1963).

The samples were collected in well stoppered glass bottles (100 ml). 0.5 ml MnCl$_2$ solution and 0.5 ml Winkler reagent were introduced to precipitate Mn(OH)$_2$. The bottles stoppered tightly were transported to laboratory.

In the laboratory 0.5 ml conc. H$_2$SO$_4$ was introduced in each sample in order to dissolve Mn(OH)$_2$ precipitate. 50 ml of this solution was titrated against N/100 Na$_2$S$_2$O$_3$ using starch as indicator. The volume of Na$_2$S$_2$O$_3$ (in ml) used is multiplied by 1.6 to obtain dissolved oxygen concentration (mg L$^{-1}$).

The Winkler reagent was prepared by mixing the two solutions of KOH and KI. 100 g KOH was dissolved in 75 ml distilled water; and the other solution was obtained by dissolving 60 g KI in 100 ml distilled water. The two solutions were mixed and the volume raised to 200 ml.
(v) **pH** - The pH of the unfiltered water samples was noted with the help of an E.C. pH meter connected to stabilized electric mains. The combined glass-calomel electrode was used for this purpose. The pH meter was standardized with known buffer solutions of pH 4 and 9.2.

(vi) **Specific conductivity** - The specific conductivity of unfiltered water samples was recorded using Systronic Direct reading Digital Conductivity meter. The results are expressed as \( \mu \text{mho cm}^{-1} \) at 25°C. The instrument was standardized with N/10 KCl solution. Temperature factors were obtained from the tables provided by Golterman and Clymo,(1978).

(vii) **Silicate (SiO\(_2^2-\))** - Silicate was determined spectrophotometrically (Toshniwal).

The standards were prepared from Na\(_2\)SiO\(_3\). 5H\(_2\)O (A.R.) and were in the range of 0.2 - 6 mg l\(^{-1}\) Si.

To 25 ml of unfiltered sample, 2 ml of Ammonium Molybdate solution was added and extinction measured at 400 nm after 15 minutes.
Ammonium Molybdate solution was prepared by dissolving 10 g of the salt in 90 ml distilled water. This solution was mixed with 100 ml $\text{NH}_2\text{SO}_4$. The standards were also treated in a similar manner as samples and concentration expressed in mg l$^{-1}$.

(viii) Iron ($\text{Fe}^{3+}$) - To 25 ml of unfiltered water sample 0.5 ml 1:1 HCl was added followed by the addition of one drop of Br$_2$- water for oxidising $\text{Fe}^{2+} \rightarrow \text{Fe}^{3+}$. Then 0.5 ml of KSCN 8N solution was added and the extinction measured at 480 nm using Toshniwal colorimeter.

The standards were prepared from FeSO$_4$. $(\text{NH}_4)_2\text{SO}_4 \cdot 1\text{H}_2\text{O}$ (A.R. grade) and were treated in the same way as water sample. The standards were prepared in the range of 0.1-2.0 mg l$^{-1}$.

(ix) Ammonium ($\text{NH}_4^-$-$\text{N}$) - 25 ml of the water sample was treated with 0.5 ml Seignette salt followed by an addition of 1.5 ml Nessler's reagent. These were thoroughly mixed. The extinction was noted at 400 nm after a period of 30 minutes.

The standards in the concentration range of 10 - 500 $\mu$g l$^{-1}$ were prepared from ammonium
sulphate (A.R.). The standards were also treated in the same way as the samples.

Seignette salt (NaKC\textsubscript{4}H\textsubscript{4}O\textsubscript{6}) - Twenty grams of sodium potassium tartarate (G.R. grade) were dissolved in 200 ml of double distilled water and a trace of HgI\textsubscript{2} was added to prevent mould growth.

Nessler's reagent: (according to Winkler) - 10 g H\textsubscript{2}I\textsubscript{2} (G.R.) and 50 g of KBr (G.R.) were mixed in a beaker and dissolved by adding 100 ml of distilled water. In another beaker, 25 g NaOH were dissolved in 50 ml of distilled water. 850 ml of hard water was poured in the two solutions, adding a pinch of CaCO\textsubscript{3} and shaking the contents violently. This was allowed to stand at least for two days till all turbidity and impurities were precipitated. The clear supernatant liquid was siphoned off in a small reagent bottle for use.

(x) Nitrate (NO\textsubscript{3}^- -N) - To one ml of unfiltered sample one drop of concentrated NaCl solution was added followed by an addition of 4 ml of nitrate reagent. The solution was shaken intensively and cooled at once in cold water. The extinction was measured at 410 nm after a period of 70 minutes using spectrophotometer.
Nitrate reagent: The stock solution was prepared by dissolving 2.2 g of diphenylamine in a mixture of 150 ml of conc. H₂SO₄ and 58 ml distilled water.

20 ml of this stock solution and 380 ml distilled water were mixed in a 3 l flask, followed by the addition of one litre conc. H₂SO₄ under cooling conditions. Before use it was ensured that the reagent is clear and without any blue colour.

The standards were prepared from KNO₃ (G.R.) grade) in the concentration range of 40 - 300 μg l⁻¹ and were treated in the same manner as the samples.

(xii) Orthophosphate (PO₄-P) - Orthophosphate was determined colorimetrically using the method of Murphy and Riley (1962).

To 25 ml unfiltered water sample 1 ml of Vogler's reagent was added. The solution was thoroughly mixed and 0.25 ml ascorbic acid (10 %) was added. The extinction was noted after 20 minutes at 740 nm.
The standards were prepared from KH$_2$PO$_4$ (A.R. grade) in the concentration range of 10 - 500 µg l$^{-1}$ and were treated like the samples.

The Vogler's reagent was prepared by dissolving 12.5 g of ammonium molybdate and 10 g aminosulphonic acid in one portion of dil. H$_2$SO$_4$ (144 ml conc. H$_2$SO$_4$ + 700 ml bidistilled water). 0.34 g of Antimony potassium tartrate was dissolved in other portion of dil. H$_2$SO$_4$ and the two solutions were mixed.

(xii) Total Phosphorus (Tot. P)- 25 ml of the unfiltered water sample was evaporated to dryness in a silica dish. To the residue 1 ml of HClO$_4$ (A.R. grade) was added and the dish heated to destroy organic matter. Perchloric acid (HClO$_4$) was evaporated by heating and the dishes were allowed to cool. To the cold dry residue 10 ml of distilled water and 0.5 ml of acid molybdate solution were added and the contents mixed thoroughly. The dish was allowed to stand for 5 minutes, followed by the addition of one drop of 2% SnCl$_2$ solution. The extinction of this solution was noted after 15 minutes at 730 nm. The standards were same as used for orthophosphate.
Acid Molybdate - To 5 g of ammonium molybdate 100 ml distilled water was added followed by an addition of 75 ml conc. H\textsubscript{2}SO\textsubscript{4} under cooling conditions. The volume was made up to 200 ml.

(xiii) Sodium and Potassium (Na,K) - Both the elements were determined with the help of a flame Photometer (Toshniwal). The standards used were NaCl (A.R.) for Na and KCl (A.R.) for K. The concentrations in both the cases were obtained in the range of 2 - 10 mg l\textsuperscript{-1} Na or K.

The instrument was connected to stabilized mains (220 V); the gas generator and air compressor were also simultaneously used. The burner was ignited with the ignitor and air pressure adjusted to 6 kg cm\textsuperscript{2}. The gas pressure was adjusted in such a way so as to obtain blue flame in the slits of gas burner. The digital display was adjusted to zero with distilled water and to 100 with highest concentration (10 ppm). In each case appropriate filter was used and known samples were fed to the photometer and the digital display reading noted.

The water samples were also treated in the same way and the readings were noted in
each case. This procedure was followed for both Na and K.

(xiv) Calcium and Magnesium (Ca, Mg) - Both calcium and magnesium were determined by the complexometric titration of the water samples using the complexone EDTA.

Ca + Mg - To 25 ml water sample, 1 ml buffer solution and a little of Erichrome Black T (indicator) was added. It was heated to 70°C and titrated against EDTA till blue colour appeared. The volume of EDTA used was noted.

Ca - To 25 ml water sample, 5 ml 0.1 N NaOH and a little of solochrome dark blue (SDB) was added and the solution titrated against EDTA till blue colour was obtained.

The difference between the volume of EDTA used for Ca + Mg and the volume used for Ca alone is the volume of EDTA used for complexing Mg. The volume of EDTA was multiplied by a factor of 4 in case of Ca and 2.432 in case of Mg so as to obtain their respective concentrations in mg l⁻¹ (Hackereth, 1963).

EDTA - one gram disodium salt of EDTA was dissolved in 800 ml distilled water to which 5 ml
\textsuperscript{1}N NaOH have been added. The volume was raised to 1L.

Buffer solution – Dissolved 67.5 of NH\textsubscript{4}Cl in 200 ml distilled water and to this was added 570 ml of NH\textsubscript{4}OH. The contents were diluted to 1L.

(xv) Chloride (Cl) – To 100 ml of water sample 1 to 2 drops of \(1\%\) K\textsubscript{2}CrO\textsubscript{4} indicator was added and the solution titrated against AgNO\textsubscript{3}(0.028 M). The concentration of Cl (mg l\textsuperscript{-1}) was obtained by multiplying volume of AgNO\textsubscript{3} by a factor of 10.

(xvi) Total Alkalinity – To 100 ml of unfiltered water sample 1 – 2 drops of phenolphthalein indicator were added. In case of colour change the solution was titrated against N/50 H\textsubscript{2}SO\textsubscript{4}. If no colour developed, a drop of methyl orange was added and the solution was titrated against N/50 H\textsubscript{2}SO\textsubscript{4} till a pink coloration was obtained. The volume of the H\textsubscript{2}SO\textsubscript{4} used was multiplied by a factor of 10 in order to obtain CO\textsubscript{3}\textsuperscript{2-} and HCO\textsubscript{3} values expressed in mg l\textsuperscript{-1} (Saunders et al. 1962).
(xvii) Statistical Analysis - The data obtained for various physico-chemical parameters during the period of 24 months (Nov. 1981 to Oct. 1983), has been statistically analysed and interpreted. The commonly used statistical criteria have been used to select the best fit. In the present analysis, the selection has been based on the coefficient of determination and the level of significance. Judged by these criterion it was observed that simple linear growth model is not the best fit and as such the results from exponential growth model have been retained. The exponential growth model used for analysing the present data is:

\[ Y = ab^x \]

or \[ \log Y = \log a + x \log b. \]

where \( Y \) is a variable and represents the corresponding chemical parameter for which the growth rate has been worked out.

\( x \) stands for the time period (24 months) and is a constant quantity.

The relationships between some parameters viz. dissolved oxygen against pH, temperature against
silicate and depth against extinction co-efficient have been obtained by using the co-efficient of correlation method. The computation of correlation coefficients have been done by using the following formula -

\[ r = \frac{\text{E}_{xy}}{\sqrt{\text{E}_{x^2} \text{E}_{y^2}}} \]

where \( r = \) co-efficient of correlation.

RESULTS

A. Physical Parameters -

(i) Depth (m) - The depth of the three lakes fluctuated only to a slight extent during the course of the present investigation as shown in Tables 1 to 3. In Khanpur lake the water column depth was between 0.40 to 4.5 m with a mean value of 1.95 m. In Trigam and Tilwan the values ranged from 0.75 - 2.50 (\( \bar{x} = 1.45 \text{ m} \)) and 0.20 - 2.2 m (\( \bar{x} = 0.70 \text{ m} \)). Out of the three lakes, Khanpur exhibited maximum water depth of 4.5 m. Different sites did not show any significant variations with regard to the changes in the water column depth.
(ii) Extinction co-efficient - The data on extinction coefficient of the three lakes is presented in Tables 4 to 6. The extinction coefficient varied from 0.48 - 4.25 ($\bar{x} = 1.31$) in Khanpur lake. The water clarity was quite high throughout the year in this lake. However, the seasonal variations were not significant. A negative correlation coefficient ($r = -0.79$) was recorded between the depth and the extinction coefficient, which may be indicative of the fact that the light penetration does not depend upon water depth in this ecosystem.

In Trigam lake the 'K' values ranged from 3.0-17.0 ($\bar{x} = 6.26$). Secchi transparency increased gradually from November through February and thereafter remained almost stable till August and then increased during the subsequent months. The correlation coefficient ($r$) between the depth and the extinction coefficient has been found to be 0.07.

In case of Tilwan lake the Secchi transparency did not fluctuate significantly; the 'K' values ranged from 3.4 - 17.0 ($\bar{x} = 8.66$) and the 'r' value was - 0.48.
(iii) Water temperature (°C) - The surface water temperature of the investigated lakes ranged from a minimum of 4°C recorded during December-January to a maximum of 33°C registered in June-July. The temperature variations within the sites and between the lakes were very small. The average temperature observed was 18°C. The data is presented in Tables 7 to 9.

B. Chemical Parameters.

(i) pH - The pH values recorded for Khanpur lake waters ranged from 7.25 - 8.52 with an average of 7.85. In Trigam waters pH varied from 7.84 to 9.20 (X = 8.57) while in case of Tilwan lake pH increased from December - January with a maximum value of 9.02 recorded in September and minimum of 7.56 registered in December. The mean was 8.23. The changes in pH values recorded during this investigation are given in Tables 10 to 12.

(ii) Dissolved Oxygen (mg l⁻¹) - The data on oxygen concentration in the three lakes is provided in Tables 13 to 15.

No definite spatial and temporal pattern with regard to oxygen concentration was observed. The maximum value of 14,1 mg l⁻¹ and a minimum of
3.2 mg l\(^{-1}\) with an average of 8.0 mg l\(^{-1}\) was obtained for Khanpur lake. A negative correlation coefficient \((r = -0.50)\) has been observed between pH and dissolved oxygen content.

In Trig\(\text{m}\) lake the dissolved oxygen showed a maximum value of 19.28 mg l\(^{-1}\) in January and a minimum value of 3.95 mg l\(^{-1}\) in July with a mean value of 7.97 mg l\(^{-1}\). For surface and bottom waters the respective ranges were: 3.40 to 20.48 \((\bar{x} = 11.07)\) and 0.96 to 17.4 \((\bar{x} = 7.48)\) mg l\(^{-1}\). A positive correlation co-efficient between dissolved oxygen and pH has been obtained \((r = 0.77)\).

The oxygen concentration of Tilwan lake ranged from 4.40 to 21.44 \((\bar{x} = 9.18\) mg l\(^{-1}\)\) with surface and bottom waters registering 5.40-21.44 \((\bar{x} = 9.51\) mg l\(^{-1}\)\) and 4.0-14.84 \((\bar{x} = 7.89\) mg l\(^{-1}\)\) concentrations. A negative correlation coefficient \((r = -0.42)\) has been obtained between dissolved oxygen and pH.

(iii) Specific Conductivity \((\mu\) mho cm\(^{-1}\) at 25\(^\circ\)C\) -

The data on specific conductance of the three lakes is given in Tables 16 to 18.

In Khanpur lake the values ranged from 214-557 \((\bar{x} = 355 \mu\) mhos). For surface and bottom
waters the ranges were: 214-411 (x=325 μmhos) and 226-557 (x = 345 μmhos) respectively.

The average conductivity value for Trigam lake was 1380 μmhos. The maximum value (1980 μmhos) was obtained in January and minimum (960 μmhos) in May and August.

The surface waters (range = 1163-2050; x = 1413 μmhos) exhibited slightly higher conductance values as compared to bottom waters (range = 960-1702; x = 1349 μmhos).

In case of Tilwan lake the conductance ranged from 850 to 1222 (x = 1049 μmhos). For surface and bottom waters the conductivity ranged from 857-1222 (x = 1040 μmhos) and 850-1222 (x = 1046 μmhos). The conductivity values were high for Trigam and Tilwan lakes and low for Khanpur lake.

(iv) Iron (mg l⁻¹) - The data on the iron content of three lakes is provided in Tables 19 to 21. A perusal of the tables indicated that, in Khanpur lake, the values ranged from 0.06-0.60 (x=0.24 mg l⁻¹) during the study period. For surface and bottom waters the values were 0.06-0.60 (x=0.22 mg l⁻¹) and 0.14-1.07 (x = 0.31 mg l⁻¹) respectively. The iron concentration exhibited a growth rate of -1.07 %, significant at 50% level (Table 55).
In Trigam lake iron concentration ranged from 0.44 to 1.96 (\(\bar{x} = 1.13 \text{ mg l}^{-1}\)) during the study period. For surface and bottom waters, the respective ranges were: 0.44 - 1.70 (\(\bar{x} = 0.97\)) and 0.63 - 1.96 (\(\bar{x} = 1.26 \text{ mg l}^{-1}\)). The growth rate of iron was found to be 1.44% significant at 10% level (Table 56).

The iron concentration of Tilwan lake fluctuated from 0.32 - 3.53 (\(\bar{x} = 1.21 \text{ mg l}^{-1}\)). The growth rate being 0.77% which was significant at 80% level (Table 57). For surface and bottom waters the values ranged from 0.32 - 3.50 (\(\bar{x} = 1.20\)) and 0.30 - 3.48 (\(\bar{x} = 1.13 \text{ mg l}^{-1}\)) respectively. The waters of Tilwan showed highest iron content and Khanpur the lowest. The site variations within the lakes were not significant.

(v) Sodium (mg l\(^{-1}\)) - The data on sodium concentration is given in Tables 22 to 24. In Khanpur lake the concentration ranged from 0.70 - 7.5 mg l\(^{-1}\) with an overall mean value of 3.44 mg l\(^{-1}\). A growth rate of 4.59% (significant at 0.1% level) was obtained for sodium (Table 55). The range values for surface and bottom waters were: 0.3 - 6.0 (\(\bar{x} = 3.68 \text{ mg l}^{-1}\)) and 0.7 - 7.5 (\(\bar{x} = 3.22 \text{ mg l}^{-1}\)) respectively.
In Trigam the concentration ranged from 40-343 ($\bar{x} = 150.0 \text{ mg l}^{-1}$). The growth rate observed was 1.69% (significant at 50% level) as shown in Table 56. For surface and bottom waters the respective ranges were: 37-343 ($\bar{x} = 148.6$) and 50-342 ($\bar{x} = 146.3 \text{ mg l}^{-1}$).

In case of Tilwan lake the sodium content exhibited a growth rate of 1.55%, significant at 50% level (Table 57). The concentration ranged from 31.5-325.0 ($\bar{x} = 125.0 \text{ mg l}^{-1}$). Sodium content in surface and bottom waters ranged from 31.5-330 ($\bar{x} = 120.4$) and 40-325 ($\bar{x} = 128.8 \text{ mg l}^{-1}$) respectively. The sodium content was highest in Trigam and lowest in Khanpur lake.

(vi) Potassium (mg l$^{-1}$) - The potassium concentration of the three lakes is presented in Tables 25 to 27. In Khanpur lake the values ranged from 0.57-5.88 ($\bar{x} = 2.90 \text{ mg l}^{-1}$). The growth rate calculated was 3.25%, significant at 1% level (Table 55). For surface and bottom waters the ranges were: 0.60-5.9 ($\bar{x} = 2.78$) and 0.72-5.4 ($\bar{x} = 2.60 \text{ mg l}^{-1}$) respectively.

In Trigam waters the potassium content exhibited a growth rate of 2.28%, significant at 20% level (Table 56). The average value recorded was 160.1 mg l$^{-1}$.
with a range of 54-420 mg l\(^{-1}\). For surface and bottom waters the values ranged from 54-347 (\(\bar{x} = 156.8\)) and 56-420 (\(\bar{x} = 164.6\)) mg l\(^{-1}\) respectively.

For Tilwan lake the potassium content ranged from 3.0 to 465.0 (\(\bar{x} = 85.81\)) mg l\(^{-1}\) with a growth rate of 10.32 %, significant at 5 % level (Table 57). The concentration ranged from 3.0-465.0 (\(\bar{x} = 80.5\)) and 4.2-240.0 (\(\bar{x} = 78.8\)) mg l\(^{-1}\), for surface and bottom waters respectively. The potassium content was highest in Trigam and lowest in Khanpur lake.

(vii) Calcium (mg l\(^{-1}\)) - The calcium concentration of the three ecosystems is depicted in Tables 28 to 30. In Khanpur waters the growth rate was 0.08 %, significant at no levels (Table 55). The concentration ranged from 7.0 - 77.6 (\(\bar{x} = 45.6\)) mg l\(^{-1}\). The values depicted a range of 8-52 (\(\bar{x} = 46.4\)) mg l\(^{-1}\) and 7.0 - 62.0 (\(\bar{x} = 43.2\)) mg l\(^{-1}\) for surface and bottom waters. In Trigam lake the calcium concentration ranged from 18-92 (\(\bar{x} = 51.31\) mg l\(^{-1}\)) showing a growth rate of -1.61 %, significant at 50 % level (Table 56). For surface and bottom waters the ranges were 18.0-90.4 (\(\bar{x} = 49.8\)) mg l\(^{-1}\) and 18.8-92.0 (\(\bar{x} = 52.4\)) mg l\(^{-1}\) respectively.
The calcium content in Tilwan lake showed a growth rate of 3.28 \%, significant at 10 \% level (Table 57). The concentration values ranged from 11.6 to 120.0 (\bar{x} = 74.33) mg l\(^{-1}\). A range value of 12.8 - 103.6 (\bar{x} = 78.8) and 11.6-120.0 (\bar{x} = 67.20) mg l\(^{-1}\) was recorded for surface and bottom waters respectively.

(viii) Magnesium (mg l\(^{-1}\)) - The magnesium concentration in Khanpur had a growth rate of 1.29 \%, significant at 50 \% level (Table 55). The values ranged from 2.43 to 26.14 (\bar{x} = 11.31) mg l\(^{-1}\). For surface and bottom waters the ranges were: 2.43-25.4 (\bar{x} = 10.42) and 2.98-26.14 (\bar{x} = 12.37) mg l\(^{-1}\) respectively. The site variations were not significant.

In Trigam lake magnesium content recorded an average value of 42.63 mg l\(^{-1}\) (range = 14.6-65.4). The growth rate obtained for the present data was 2.30 \%, significant at 0.2\% level (Table 56). For surface and bottom waters a range value of 14.6-62.8 (\bar{x} = 40.6) and 20.4-65.4 (\bar{x} = 43.8) mg l\(^{-1}\) was recorded.

While as, in case of Tilwan lake the magnesium concentration ranged from 1.94-55.57 (\bar{x}=32.01)
mg l\(^{-1}\) with a growth rate of 2.57 % (significant at 20% level) obtained for the present analytical data. For surface and bottom waters the ranges were: 1.94-52.55 (\(\bar{x} = 28.78\)) and 7.3-55.57 (\(\bar{x} = 33.6\)) mg l\(^{-1}\) respectively. The data is presented in Tables 31 to 33.

(ix) Chloride (mg l\(^{-1}\)) - The data for chloride concentration is provided in Tables 34 to 36.

In Khanpur lake the concentration varied from 8.0-96.0 (\(\bar{x} = 26.23\)) mg l\(^{-1}\). For the present data a growth rate of -0.58%, significant at 80% level (Table 55) was registered. The values ranged from 8-88 (\(\bar{x} = 25.94\)) and 8.96 (\(\bar{x} = 26.6\)) mg l\(^{-1}\) for surface and bottom waters respectively.

In Trigam lake a growth rate of 0.82%, significant at 50 % level (Table 56) was recorded. The values ranged from 128 to 418 (\(\bar{x} = 273.0\)) mg l\(^{-1}\). For surface and bottom waters the respective ranges were: 128-412 (\(\bar{x} = 266.0\)) and 132-418 (\(\bar{x} = 257.8\)) mg l\(^{-1}\).

However, in case of Tilwan lake chloride concentration ranged from 32-111 (\(\bar{x} = 71.03\)) mg l\(^{-1}\) with a growth rate of 1.45% (significant at 10% level). Surface and bottom waters depicted a range of 32-104 (\(\bar{x} = 70.1\)) and 32-102 (\(\bar{x} = 70.4\)) mg l\(^{-1}\) respectively.
Among the three ecosystems the Trigam lake showed highest chloride concentration while as Khanpur the least. The site variations as 'standard deviation' within the sites and over the time are also presented in Tables 34-36.

(x) Total alkalinity (mg l\(^{-1}\)) - The analytical data concerning total alkalinity of the three lakes is given in Tables 37 to 39.

In Khanpur lake the alkalinity values ranged from 52-230 (\(\bar{x} = 166.8\) mg l\(^{-1}\)) showing a growth rate of 0.203 % which was significant at 80 % level (Table 55). The ranges for surface and bottom waters were: 80-220 (\(\bar{x} = 174.3\)) and 52-230 (\(\bar{x} = 158.0\)) mg l\(^{-1}\) respectively.

In case of Trigam lake the alkalinity ranged from 307 to 580 with an average value of 445.0 mg l\(^{-1}\). The data exhibited a growth rate of 0.61%, significant 50 % level (Table 56). A range value of 307-580 (\(\bar{x} = 440.2\)) and 300-540 (\(\bar{x} = 444.8\)) mg l\(^{-1}\) was recorded for surface and bottom water samples of Trigam lake.

In case of Tilwan lake a growth rate of 0.16%, significant at no levels (Table 57) was recorded. The overall concentration range was between 82 and
for surface and bottom waters the ranges were: 80 - 280 ($\bar{x} = 168.3$) and 84 - 275 ($\bar{x} = 178.4$) mg l$^{-1}$ respectively.

(xi) Silicate (mg l$^{-1}$) - The data for the silicate concentration is provided in Tables 40-42.

The silicate content in Khanpur lake ranged from 1.11 to 9.0 ($\bar{x} = 4.31$) mg l$^{-1}$. The temporal and spatial variations were not significant. The range values for surface and bottom waters were 1.11 - 9.00 ($\bar{x} = 4.48$) and 1.26 - 8.94 ($\bar{x} = 4.50$) mg l$^{-1}$ respectively. The maximum value was recorded in September and minimum in March (Site I), January (Site II) and December (Site III and IV). A positive correlation coefficient ($r = 0.55$) has been obtained between temperature and silicate content. The 'r' value being significant at 0.5% level.

In Trigam lake the silicate content varied from 1.66 to 8.85 ($\bar{x} = 4.69$) mg l$^{-1}$ with maximum concentration obtained in November and minimum in September. The site variations were not significant. For surface and bottom waters the ranges were: 1.66 - 8.0 ($\bar{x} = 4.30$) and 2.32 - 8.85 ($\bar{x} = 4.20$) mg l$^{-1}$ respectively. A correlation coefficient of 0.22 (significant at 50% level) was recorded.
between temperature and silicate concentration.

The silicate content of Tilwan lake recorded maximum value in December and the minimum in April. The concentration ranged from 3-30.0 (x=10.62 mg l⁻¹). In case of surface and bottom waters following ranges were recorded: 3-30.0 (x=10.54) and 3.63-28.82 (x = 9.54 mg l⁻¹). A correlation coefficient of 0.34 (significant at 50% level) was obtained between temperature and silicate content.

Out of the three ecosystems, Tilwan lake showed highest silicate content and the Khanpur exhibited the lowest concentration.

(xii) Ammonium (μg l⁻¹) - The data for ammonium concentration of the three lakes is given in Tables 43 to 45.

In Khanpur lake the concentration ranged from 72-780 (x = 233 μg l⁻¹) with a growth rate of 1.05%, significant at 50% level (Table 55).

In Trigam lake the values ranged from 232 to 764 μg l⁻¹ with an average value of 440 μg l⁻¹. Based on the present data a growth rate of 1.04 %, (significant at 50 % level) was obtained for the lake. The extent of variations recorded for various sites are given in Table 44.
In case of Tilwan waters the ammonium concentration varied from 240-2280 ($\bar{x} = 755$) $\mu g \text{ l}^{-1}$ showing a growth rate of 1.00 %, significant at 50 % level (Table 57). The concentrations registered at different sites are presented in Table 45. Tilwan lake recorded highest ammonium content and Khanpur the lowest.

(xiii) Nitrate ($\mu g \text{ l}^{-1}$) - Data on nitrate concentration for the three lakes is provided in Tables 46-48.

In Khanpur lake the concentration ranged from 58-1098 ($\bar{x} = 244$) $\mu g \text{ l}^{-1}$ with surface and bottom waters showing following concentrations:

58-1098 ($\bar{x} = 252$) and 73-998 ($\bar{x} = 235$) $\mu g \text{ l}^{-1}$.

A growth rate of 0.78 %, significant at 50% level, has been obtained using the present data.

In Trigum lake the nitrate concentration varied from 51-387 ($\bar{x} = 155$ $\mu g \text{ l}^{-1}$). For surface and bottom waters the ranges were: 51-387 ($\bar{x} = 156$) and 53-320 ($\bar{x} = 148$) $\mu g \text{ l}^{-1}$ respectively. The variations within the sites and over a period of time are provided in Table 47. A growth rate of 4.76%, significant at 0.1% level (Table 56) was obtained for the lake.
In Tilwan lake the nitrate content was between 43.8 to 394.4 (\(\bar{x} = 156\)) \(\mu g\) \(l^{-1}\) during the present investigation. The growth rate being 1.31% (Table 57), significant at 50% level. For surface and bottom waters the respective ranges were 44-394.4 (\(\bar{x} = 152\)) and 51-321 (\(\bar{x} = 150\)) \(\mu g\) \(l^{-1}\) respectively.

The Khanpur waters exhibited high nitrate concentration.

(xiv) Orthophosphate (\(\mu g\) \(l^{-1}\)) - The analytical data obtained for the phosphate concentration is given in Tables 49 to 51.

A perusal of Table 49, indicates that in Khanpur lake the phosphate concentration ranged from 11-391 (\(\bar{x} = 42\)) \(\mu g\) \(l^{-1}\), with surface and bottom waters ranges being 11-391 (\(\bar{x} = 50\)) and 11-310 (\(\bar{x} = 34\)) \(\mu g\) \(l^{-1}\). A growth rate of 0.58% significant at 80% level (Table 55) has been obtained for the present data.

In Trigam lake a growth rate of 1.78%, significant at 10% level (Table 56) was recorded. The concentration ranged from 44-332 (\(\bar{x} = 161\)) \(\mu g\) \(l^{-1}\) with surface and bottom waters having 44-332 (\(\bar{x} = 170\)) and 46-340 (\(\bar{x} = 152\)) \(\mu g\) \(l^{-1}\) of orthophosphate.
In case of Tilwan lake the orthophosphate content varied from 22-231 (\(\bar{x} = 79\)) \(\mu g\) \(l^{-1}\). A growth rate of 1.60 % (significant at 10 % level) has been worked out for the phosphate content. For surface and bottom waters the ranges were: 22-231 (\(\bar{x} = 82\)) and 22-210 (\(\bar{x} = 78\)) \(\mu g\) \(l^{-1}\) respectively.

The Trigam lake recorded high phosphate concentration as compared to other two lakes.

(xv) Total phosphorus (\(\mu g\) \(l^{-1}\)) - The data obtained for the total phosphorus concentration of the three lakes is presented in Tables 52 to 54.

For Khanpur lake the value ranged from 61-440 (\(\bar{x} = 225\)) \(\mu g\) \(l^{-1}\), with a growth rate of 1.50 % (Table 55) which is significant at 5 % level. For surface and bottom waters a range value of 63-440 (\(\bar{x} = 240\)) and 61-368 (\(\bar{x} = 210\)) \(\mu g\) \(l^{-1}\) was obtained.

In Trigam lake the concentration ranged from 187-700 (\(\bar{x} = 417\)) \(ug\) \(l^{-1}\) with a growth rate of 2.12% (Table 56) which is significant at 0.2% level. For surface and bottom waters the ranges were:

132-700 (\(\bar{x} = 384\)) and 187-654 (\(\bar{x} = 442\)) \(\mu g\) \(l^{-1}\) respectively.

In Tilwan lake the total phosphorus showed a growth rate of 6.51% which is significant at 0.1 %
level (Table 57). The values varied from 66-594 ($\bar{x} = 261$) µg l$^{-1}$. For surface and bottom waters the values ranged from 66-594 ($\bar{x} = 235$) and 66 - 580 ($\bar{x} = 284$) µg l$^{-1}$ respectively.

The total phosphorus content was highest in Trigam and lowest in Khanpur lake. The variations as calculated by standard deviation over a period of time and within the sites are depicted in Tables 52-54.

Conclusions -

The lakes under investigation are essentially small sized shallow water bodies with little differences in their respective areas. Rawson, (1955) and Hayes, (1957) attach considerable importance to the mean depth in determining the trophic status of a lake. According to these authors water bodies with low mean depth are usually at a higher trophic level in comparison to lakes with higher maximum and mean depth. This parameters could be viewed in terms of the total water volume and the extent of dilution factor. The drainage pattern has also an important influence on the rate of trophic evolution. Lakes with rapid water renewal (drainage type) are less susceptible to incoming effluents than the closed type which are also designated as non-drainage (Zutshi and Khan 1978). Khanpur lake is a semi-drainage lake with an outflow
channel. While Trigam and Tilwan are closed type basins. The maximum (4.5 m) and mean depth (1.95 m) in case of Khanpur lake is higher as compared to that of Trigam (max. = 2.5 m and mean depth = 1.45 m) and Tilwan lakes (max. 2.20, \( \bar{x} = 0.70 \) m). As a result of this Khanpur lake should be at lower levels of eutrophication in comparison to Trigam and Tilwan lakes and the same situation encountered in the present studies.

Temperature is another important factor which governs vital processes in a fresh water ecosystem. Various chemical reactions taking place in the system are directly or indirectly influenced by thermal cycles. The lake waters remain well mixed throughout the year without depicting either summer or winter stratification. According to Crumrine and Beeton, (1975), for developing summer stratification the depth of the lakes should usually exceed 8 m. In present case the maximum depth does not exceed 4.5 m. However, a temperature gradient was observed between surface and bottom waters during summer when upper layers of water heated up quickly. The water temperature in general ranged from 4-33\(^\circ\)C. Besides temperature wind action also plays an important role in developing stratification in water bodies. The lakes under investigation are not well sheltered.
Water transparency is an important factor that controls the energy relationship at different trophic levels. Transparency is not a constant parameter but shows seasonal and annual variations depending upon fluctuations in seston (Riley, 1939), evaporation and disturbance of bottom silt by winds (Banerjee and Roy Choudhary, 1966), density of plankton population (Zutshi et al., 1980) and the entry of storm water. On the basis of average extinction co-efficient, Khanpur ($\bar{x} = 1.31$) has comparatively less turbid waters than Trigam and Tilwan lakes where the extinction coefficient was high ($\bar{x} = 6.26$ and $8.66$) respectively. A negative 'r' value between depth and extinction coefficient indicated that the light penetration does not depend upon the water column level.

The average pH values of 7.85, 8.57 and 8.23 were obtained for Khanpur, Trigam and Tilwan lakes. On comparing the pH data with other Kashmir lakes (Table 58) it is observed that the values compare favourably without depicting any sudden shifts. The lake waters seem to be well buffered.

The average conductance values of 355, 1380 and 1049 umhos were recorded in Khanpur, Trigam and Tilwan lakes respectively. Berg et al. (1958) related high conductivity to higher levels of water enrichment.
Comparing the present data with other valley lakes it was seen that the conductivity values favourably compare with non-drainage lakes which are polluted as is the case with Trigam and Tilwan. The lower conductance of Khanpur can be compared to semi-drainage/drainage type of lakes such as Dal, Anchar and Waskur (Table 58). Thus the higher conductivity of Trigam and Tilwan lakes reflected high ionic concentration of these water bodies. The extent of variation within the three ecosystems was 4:1.

Dissolved oxygen in water is necessary for the survival and growth of biotic community. The oxygen content recorded an average value of 8.0, 7.97 and 9.18 mg l$^{-1}$ in the three lakes with surface water having higher oxygen content than bottom waters. The waters remained well oxygenated with oxygen as a result of aerial saturation of surface film. The richness of dissolved oxygen could be related to high population of macrophytes and phytoplankton which liberate oxygen on photosynthesis.

Calcium is generally the dominant cation in Kashmir lakes because of predominance of lime rich rocks in their catchment area (Zutshi et al. 1980). An average value of 45.60, 51.31 and 74.33 mg l$^{-1}$ was recorded for Khanpur, Trigam and Tilwan lakes. According to Ohle, (1934) lake
waters having 10 mg l$^{-1}$ of calcium may be designated as 'calcium poor' and those with more than 25 mg l$^{-1}$ as 'calcium rich'. The three rural lakes fall in the latter category like other valley lakes (Table 58).

The magnesium content remained low ($\bar{x} = 11.31$ mg l$^{-1}$) for Khanpur lake like the other valley lakes. The low content may be due to uptake of magnesium by plants in the formation of Chlorophyll (magnesium porphyrin metal complex) and in enzymatic transformations (Wetzel, 1975). The magnesium content was higher ($\bar{x} = 42.63$ and 32.01 mg l$^{-1}$) for Trigam and Tilwan waters respectively.

Zutshi and Khan (1977) recorded a ratio of 4:1 for Ca and Mg in some Kashmir lakes. In the present case Ca, Mg ratio of 4:1, 1.2:1 and 2.3:1 was obtained for Khanpur, Trigam and Tilwan lakes.

The equivalency order of various cations is:

\[ \text{Ca}^{2+} \rightarrow \text{Mg}^{2+} \rightarrow \text{Na}^{2+} \rightarrow \text{K}^{2+} \quad \text{(Khanpur lake)} \]

\[ \text{K}^{+} \rightarrow \text{Na}^{2+} \rightarrow \text{Ca}^{2+} \rightarrow \text{Mg}^{2+} \quad \text{(Trigam lake)} \] and

\[ \text{Na}^{+} \rightarrow \text{K}^{+} \rightarrow \text{Ca}^{2+} \rightarrow \text{Mg}^{2+} \quad \text{for Tilwan lake}. \]

In majority of the valley lakes the sequence is

\[ \text{Ca}^{2+} \rightarrow \text{Mg}^{2+} \rightarrow \text{Na}^{2+} \rightarrow \text{K}^{+} \quad \text{(Table 58)}. \]
The higher concentration of Na and K in Trigam and Tilwan lakes may be due to inputs from agricultural runoff because a large number of fertilizers having high content of Na and K are added to crops in the catchment areas. This may also account for higher growth rate of Na (4.59%) in Khanpur and that of K (10.32%) in Tilwan lakes. Out of three lakes Trigam exhibited highest growth rate (2.30%) of magnesium and Khanpur the lowest (1.29%). This may be due to higher complexation of Mg by porphyrin (in Chlorophyll formation) in Khanpur lake which is vegetation rich system followed by Trigam and Tilwan.

The negative growth of calcium in Trigam (-1.61%) may be due to precipitation of calcium salts at higher pH.

Thresh et al. (1944) attributed high chloride concentration of water to organic pollution of animal origin. According to Lund (1965) the importance of chloride may be over emphasized in using it as an index of salinity. Oumbey and Kee, (1967) observed three fold increase in chloride concentration in lake Erie (USA) 50 years ago and accounted for 70% of the total increase mainly due to industrial effluents, road salting and municipal wastes. An average value of 26.5, 273.0 and 71.0 mg l⁻¹ of chloride was observed in Khanpur, Trigam
and Tilwan lake. The growth rate of chloride is highest in Tilwan (1.45%) and lowest in Khanpur (-0.58%), indicating that with regard to chloride the Tilwan lake is being rapidly enriched. These findings are in agreement with the reported high levels of chloride in non-drainage lake by Khan, (1978).

Total alkalinity is a measure of temporary hardness expressed as CaCO$_3$ mg 1$^{-1}$. Freiser and Fernando, (1966) state when total alkalinity is high the bicarbonate system prevails and pH usually is on the alkaline side. This is true for the lakes under investigation.

Moyle, (1945) classified lake waters as 'soft', 'medium hard', and 'hard' on the basis of total alkalinity concentration. As per this classification waters having alkalinity up to 40 mg 1$^{-1}$ are 'soft', with 40-90 mg 1$^{-1}$ 'medium hard' and above 90 mg 1$^{-1}$ 'hard waters'. On the basis of this classification all the three lakes can be classified as hard water systems. The equivalency order of anions is HCO$_3^-$ > Cl$^-$ for all the three ecosystems like the other valley lakes (Table 58).

Ratios of various solutes provide another source of information about waters. Mean ratios (weight/weight) are given in Table 59 together with the ratios calculated by Clarke, (1924) and the world mean for fresh waters. The
ratio of Cl⁻/HCO₃⁻, Mg²⁺/Ca²⁺ is lower in Khanpur and highest in Trigam and the ratio of \( \frac{Ca^{2+} + Mg^{2+}}{Alkalinity} \) and Mg²⁺/Cl⁻ is highest in Tilwan and lowest in Khanpur. For Ca²⁺/Cl⁻ ratio Khanpur exhibited a highest value and Trigam the least. In Trigam Mg²⁺/Ca²⁺ ratio is about 3.5 and 2 times higher than Khanpur and Tilwan. The differences in ratios between the present lakes and that of the world mean (Table 59) may be related to their catchment activities. As a result of lesser impact of human settlements the Khanpur waters closely approach the world mean for freshwaters.

The silicate concentration is of immense significance as an essential nutrient for diatoms. According to Hutchinson, (1957) the silicate content of freshwater lakes throughout the world vary between 0.7-5 mg l⁻¹. In case of Trigam and Khanpur an average value of 4.31 and 4.69 mg l⁻¹ was recorded and for Tilwan lake a higher silicate content of 10.62 mg l⁻¹ was observed. A positive correlation was obtained between temperature and silicate content.

The iron concentration recorded an average value of 0.24, 1.13 and 1.21 mg l⁻¹ for Khanpur, Trigam and Tilwan lakes. The iron content of Khanpur is comparable to other valley lakes as seen from Table 58. The higher iron concentration in Trigam and Tilwan may be attributed
to the increased effect of domestic wastes and washing activities as most of the detergents used in washing processes contain trace amounts of iron (Angino et al. 1970). A low value of growth rate (0.77 %) was recorded in Tilwan lake and a high value (1.44 %) in Trigam lake for iron.

The high values of nitrate and ammonium may be due to the use of large quantities of nitrogenous fertilizers in catchment areas. Present results favourably compare with the nitrate and ammonium concentrations recorded for other valley lakes like Anchar and Sheiksar (Table 58). Ellis et al. (1946) state that the amount of ammonia and ammonium compounds in unmodified natural waters is very small (0.1 mg l\(^{-1}\)) while quantities more than 1 mg l\(^{-1}\) are indicative of organic pollution. The higher nitrogen content in rural lakes as compared to Dal (an urban lake) may be due to the increased effect of domestic sewage and agricultural runoff in case of rural lakes, as the drainage systems are not well protected in rural areas. Rybaki and Sikorska (1976) observed that 99% of total nitrogen constituted of ammonia in sewage affected zones of the lakes.

The growth rate was highest in Trigam (4.76%) and lowest in Khanpur (0.78%) indicating thereby the high enrichment rate for the former water body.
From Table 58 it is observed that phosphate concentration of the lake waters is quite high and is comparable to the polluted lakes of Kashmir. Sawyer et al. (1945) suggested that 0.3 mg l\(^{-1}\) of phosphate and 0.15 mg l\(^{-1}\) of nitrate are critical levels beyond which algal blooms may appear indicating cultural eutrophication. In case of Trigam lake the mean phosphate content has exceeded this limit while in Tilwan and Khanpur the values are approaching this limit. Hutchinson, (1957) related the increase in phosphorus as a result of sewage contamination. Vollenweider, (1972) regard phosphate as key element in the process of eutrophication.

A comparison of average concentration of chemical parameters with general tolerance limit of chemical water pollutants, as provided by Water Resources Commission Canada (1968) is presented in Table 60. A perusal of the table indicate that some parameters like pH, chloride, alkalinity, iron and phosphorus in Trigam lake and iron, ammonium and phosphate in Tilwan lake lie above the permissible levels, thereby rendering these waters unfit for human use. The waters of Khanpur fall within the permissible levels except for phosphate content which is slightly higher than the permissible levels.
On the basis of physical features and ionic ratios of chemical parameters the Tilwan and Trigam are more enriched than Khanpur lake. From the growth rate data (Tables 55 to 57) it has been observed that except for Sodium (being higher in Khanpur), the rest of the chemical parameters recorded an increased value in Trigam and Tilwan lakes. The differences in the water quality within the three lakes may be attributed to the increased human activities in the catchment areas of Trigam and Tilwan in comparison to lesser human activities in Khanpur lake. In future, with human interferences increasing at the same rate there is every reason to believe that this lake will also deteriorate. Future studies need to be undertaken on nutrient dynamics, flow pattern and monitoring of water quality over an extended period for ecological conservation of these ecosystems.
REFERENCES


Crumrine, J.P. and A.M. Beeton, 1975. Limnology of lakes of the Sylvania recreation area, Ottawa National Forest Special report No. 25. Centre for Great Lake studies, the Univ. of Wisconsin (USA).


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\* \( \bar{x} \) = Mean, \** S.D.\( \pm \) = Standard deviation.
### Table 2: Depth (m) of Trigam Lake (1981-82)

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(1982 - 83)
TABLE 14. Dissolved oxygen concentration (mg l⁻¹) of Trigam lake (1981 - 82).

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- X: X-bar (mean)
- S.D.±: Standard Deviation

Note: The value in parentheses (1982-83) indicates a specific year range.
TABLE - 15 Dissolved oxygen (mg l$^{-1}$) of Tilwan Lake (1981-82).

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(1982 - 83)

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### TABLE 17: Specific conductance at 25°C (μmho cm⁻¹) of Trigam lake (1981-82).

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TABLE 18: Specific conductivity (µ mho cm⁻¹ 25°C) of Tilwan Lake (1981-82).

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(1982-83)
TABLE 19: Iron (mg l\(^{-1}\)) concentration of Khanpur lake (1981-82).

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(1982 - 83)

| I    | 1.35 | .87  | .85  | 1.23 | .96   | .66   | 1.36| .93  | .93  | 1.35 | 1.20  | 1.51 | 1.10, .27                |
| II   | 1.48 | 1.24 | 1.62 | 1.35 | .84   | .81   | 1.25| 1.00 | 1.00 | 1.25 | 1.24  | 1.61 | 1.22, .27               |
| III  | 1.96 | 1.26 | .91  | 1.03 | .98   | .71   | 1.33| .93  | .93  | 1.31 | 1.92  | 1.74 | 1.25                |
| \(\bar{x}\) | 1.60 | 1.12 | 1.13 | 1.20 | .93   | .73   | 1.31| .95  | .95  | 1.30 | 1.45  | 1.62 | .42                |
| S.D.\(\pm\) | .32  | .22  | .43  | .16  | .08   | .08   | .06 | .04  | .04  | .05  | .40   | .12  |             |
|------|------|------|------|------|-------|------|------|------|------|-------|------|------|-------|-------|
| I    | 3.53 | .82  | .51  | .38  | .38   | .63  | .63  | .57  | .57  | 3.79  | .76  | 1.07 | 1.14  | 1.195 |
| II   | 3.53 | .66  | .51  | .32  | .60   | .58  | .79  | .82  | .88  | 3.28  | .63  | .88  | 1.12  | 1.08  |
| III  | 3.16 | 1.58 | .63  | .63  | .51   | .76  | 1.14 | 1.20 | 1.20 | 3.16  | 1.32 | 1.51 | 1.40  | 0.89  |
| x    | 3.41 | 1.02 | .55  | .44  | .50   | .66  | .85  | .86  | .88  | 3.41  | .90  | 1.15 | -     |       |
| S.D. ± | .49  | .07  | .16  | .11  | .09   | .26  | .32  | .32  | .33  | .37   | .37  | 1.32 | -     |       |

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TABLE 20: Calcium (mg l⁻¹) concentration of Khampur Lake (1981-82).
### Table 29: Calcium (mg l\(^{-1}\)) Concentration in Trigam Lake (1981-82)

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(1982-83)

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TABLE 30 - Calcium (mg l\(^{-1}\)) variations in Tilwan lake (1981-82)

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TABLE 31 - Magnesium (mg l\(^{-1}\)) concentration in Khanpur Lake (1981-82 and 1982-83)

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TABLE - 32: Magnesium (ng l⁻¹) concentration of Trigumm Lake (1981-82).

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\[ \bar{x}, S.D. \pm (1982-83) \]

\[ \bar{x}, S.D. \pm (1982-83) \]
TABLE 39 - Total alkalinity (mg l$^{-1}$) values of Tilwan lake (1981-82).

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### TABLE 40: Silicate (mg l⁻¹) concentration in Khanpur lake (1981-82).

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| $\bar{x}$ | 4.03 | 2.17 | 2.69 | 2.41 | 2.26 | 2.41  | 3.05| 3.24 | 5.39 | 6.20 | 3.42  | 6.47|               |
| S.D.$\pm$ | .17  | .37  | 1.27 | .45  | 1.04 | .31   | .34 | 0.40 | 0.30 | .52  | .45   | .75 |               |

### Table 40 (1982 - 83)

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| $\bar{x}$ | 5.29 | 2.36 | 2.25 | 2.65 | 3.34 | 5.14  | 2.23| 3.70 | 4.84 | 6.79 | 0.43  | 7.19|               |
| S.D.$\pm$ | .82  | .29  | .55  | .25  | .39  | 1.06  | .56 | .26  | 1.19 | .70  | .39   | .90 |               |
TABLE 4.1: Silicate (mg l\(^{-1}\)) concentration of Trigon lake (1981-82).

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**TABLE 44. Ammonium (µg l⁻¹) concentration in Trigam lake (1981-82).**

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| II | 980  | 820  | 782  | 522  | 528   | 720 | 410  | 400  | 408  | 1456  | 1080 | 1420 | 793.8, 375.29    |
| III | 805  | 950  | 866  | 520  | 330   | 532 | 398  | 404  | 424  | 1845  | 1320 | 1706 | 846.5, 519.28    |
| $\bar{x}$ | 945.0 | 906.0 | 793.3 | 542.0 | 500.0  | 620.7 | 420.0 | 420.0 | 440.0 | 1500.3 | 1200.0 | 1450.0 |                |
| S.D.$\pm$ | 126.2 | 71.48 | 67.72 | 29.60 | 103.74 | 94.45 | 20.35 | 31.24 | 42.33 | 324.78 | 120.0 | 242.40 |                |
### TABLE 46: Nitrate (μg l⁻¹) concentration in Khanpur lake (1981 - 82)

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TABLE 47 - Nitrate (µg l\(^{-1}\)) content of Trigan lake (1981-82)

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### TABLE 48 - Nitrates (μg l⁻¹) Concentration of Tilwan Lake (1981-82)

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| $\bar{x}$ | 243.33 | 132.66 | 176.33 | 168.0 | 95.0 | 59.67 | 59.67 | 85.33 | 114.67 | 158.0 | 229.0 | 263.0 |
| S.D.$\pm$ | 161.40 | 21.59  | 103.06 | 80.0  | 7.0  | 18.44 | 12.56 | 22.42 | 8.08   | 29.44 | 30.27 | 25.98 |

### (1982-83)

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| $\bar{x}$ | 252.0 | 140.67 | 184.0 | 175.67 | 100.33 | 72.0 | 77.67 | 92.33 | 122.67 | 174.0 | 242.0 | 288.0 |
| S.D.$\pm$ | 152.67 | 20.03  | 103.71 | 103.18 | 5.69   | 8.54 | 4.51  | 6.03  | 21.59 | 100.54 | 102.59 | 22.72 |
TABLE 49: Phosphate (μg l⁻¹) content of Khanpur lake (1981-82)

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(1982-83)

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### TABLE 50: Phosphate (μg l⁻¹) content in Trigaran Lake (1981-82)

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### Additional Information
- Lake Trigaran
- Samples collected over 12 months
- Data analyzed for phosphate content
- Statistical analysis provided (mean, standard deviation)
- Specific concentrations noted for each month
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TABLE - 53 : Total Phosphorus (µg l⁻¹) concentration of Trigum lake (1981-82)
TABLE 54 - Total phosphorus (μg l⁻¹) concentration of Tilwan lake (1981-82).

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### TABLE - 55

Monthly Growth Rate of Chemical Constituents in Khanpur lake (Nov 1981 to October 1983).

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<th>Parameter</th>
<th>Regression equation ( \log y = \log a + x \log b )</th>
<th>( R^2 )</th>
<th>( t ) value</th>
<th>Growth Rate ( (b-1) \times 100 )</th>
<th>Level of significance</th>
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<td>Mg (mg l(^{-1}))</td>
<td>( \log y = 0.9935 + x(5.55 \times 10^{-3}) )</td>
<td>0.0302</td>
<td>0.847</td>
<td>1.287</td>
<td>50%</td>
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<tr>
<td>Ca (mg l(^{-1}))</td>
<td>( \log y = 1.6258 + x(3.48 \times 10^{-4}) )</td>
<td>1.6 \times 10^{-4}</td>
<td>0.060</td>
<td>0.08</td>
<td>No level</td>
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<td>Na (mg l(^{-1}))</td>
<td>( \log y = 0.492 + x(0.0195) )</td>
<td>0.4413</td>
<td>4.262</td>
<td>4.59</td>
<td>0.1%</td>
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<tr>
<td>K (mg l(^{-1}))</td>
<td>( \log y = 0.4221 + x(0.0159) )</td>
<td>0.2684</td>
<td>2.904</td>
<td>3.25</td>
<td>1%</td>
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<tr>
<td>Fe (mg l(^{-1}))</td>
<td>( \log y = -0.6523 + x(4.68 \times 10^{-3}) )</td>
<td>0.0339</td>
<td>0.899</td>
<td>-1.07</td>
<td>50%</td>
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<tr>
<td>Cl (mg l(^{-1}))</td>
<td>( \log y = 1.3796 + x(2.5 \times 10^{-3}) )</td>
<td>0.0077</td>
<td>0.424</td>
<td>-0.58</td>
<td>80%</td>
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<tr>
<td>Alkalinity (mg l(^{-1}))</td>
<td>( \log y = 2.082 + x(8.8 \times 10^{-4}) )</td>
<td>0.0028</td>
<td>0.255</td>
<td>0.203</td>
<td>80%</td>
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<td>NO(_3)-N (( \mu )g l(^{-1}))</td>
<td>( \log y = 2.2616 + x(3.38 \times 10^{-3}) )</td>
<td>0.0180</td>
<td>0.648</td>
<td>0.78</td>
<td>50%</td>
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<td>NH(_4)-N (( \mu )g l(^{-1}))</td>
<td>( \log y = 2.3405 + x(4.53 \times 10^{-3}) )</td>
<td>0.0460</td>
<td>1.051</td>
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<td>PO(_4)-P (( \mu )g l(^{-1}))</td>
<td>( \log y = 1.55 + x(2.52 \times 10^{-3}) )</td>
<td>0.0053</td>
<td>0.351</td>
<td>0.58</td>
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<tr>
<td>Total P (( \mu )g l(^{-1}))</td>
<td>( \log y = 2.3413 + x(6.47 \times 10^{-3}) )</td>
<td>0.1876</td>
<td>2.304</td>
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Degree of freedom = 23
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<th>$R^2$</th>
<th>'t' value</th>
<th>Growth Rate $(b-1) \times 100$</th>
<th>Level of significance(%)</th>
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<td>Mg(mg l$^{-1}$)</td>
<td>$\log y = 1.6166 + x(0.86 \times 10^{-3})$</td>
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<td>Ca(mg l$^{-1}$)</td>
<td>$\log y = 1.6585 - x(7.04 \times 10^{-3})$</td>
<td>0.050</td>
<td>1.102</td>
<td>-1.61</td>
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<tr>
<td>Na(mg l$^{-1}$)</td>
<td>$\log y = 2.0926 + x(0.0073)$</td>
<td>0.0377</td>
<td>0.948</td>
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<td>K (mg l$^{-1}$)</td>
<td>$\log y = 2.1469 + x(0.0098)$</td>
<td>0.0896</td>
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<td>Fe (mg l$^{-1}$)</td>
<td>$\log y = 0.0341 + x(6.19 \times 10^{-3})$</td>
<td>0.1159</td>
<td>1.734</td>
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<td>Cl(mg l$^{-1}$)</td>
<td>$\log y = 2.4255 + x(3.55 \times 10^{-3})$</td>
<td>0.0619</td>
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<td>Alkalinity (mg l$^{-1}$)</td>
<td>$\log y = 2.6379 + x(2.64 \times 10^{-3})$</td>
<td>0.0597</td>
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<td>NO$_3$$^{-}$N (µg l$^{-1}$)</td>
<td>$\log y = 2.1474 + x(0.0202)$</td>
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<td>PO$_4$$^{3-}$P (µg l$^{-1}$)</td>
<td>$\log y = 2.1824 + x(7.67 \times 10^{-3})$</td>
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<td>NH$_4$$^+$N (µg l$^{-1}$)</td>
<td>$\log y = 2.6263 + x(4.5 \times 10^{-3})$</td>
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<td>Tot.$\text{P}$ (µg l$^{-1}$)</td>
<td>$\log y = 2.6084 + x(9.09 \times 10^{-3})$</td>
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Degree of freedom = 23
TABLE 57


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<th>'t' value</th>
<th>Growth Rate (b⁻¹)x100</th>
<th>Level of significance (%)</th>
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<td>Mg (mg l⁻¹)</td>
<td>log y = 1.4476 + x(0.011)</td>
<td>0.093</td>
<td>0.541</td>
<td>2.57</td>
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<td>Ca (mg l⁻¹)</td>
<td>log y = 1.8168 + x(0.0140)</td>
<td>0.151</td>
<td>2.025</td>
<td>3.28</td>
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<td>Na (mg l⁻¹)</td>
<td>log y = 2.0420 + x(6.69x10⁻³)</td>
<td>0.046</td>
<td>1.056</td>
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<td>K (mg l⁻¹)</td>
<td>log y = 1.5308 + x(0.0426)</td>
<td>0.195</td>
<td>2.3626</td>
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<td>Fe (mg l⁻¹)</td>
<td>log y = -0.0065 + x(3.35x10⁻⁴)</td>
<td>0.0084</td>
<td>0.433</td>
<td>0.77</td>
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<td>Cl (mg l⁻¹)</td>
<td>log y = 1.8345 + x(6.26x10⁻³)</td>
<td>0.1183</td>
<td>1.757</td>
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<td>Alkalinity (mg l⁻¹)</td>
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<td>NO₃-N (μg l⁻¹)</td>
<td>log y = 2.1425 + x(5.61x10⁻³)</td>
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<td>NH₄-N (μg l⁻¹)</td>
<td>log y = 2.8199 + x(4.3x10⁻³)</td>
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<tr>
<td>PO₄-P (μg l⁻¹)</td>
<td>log y = 1.8806 + x(6.89x10⁻³)</td>
<td>0.1427</td>
<td>1.958</td>
<td>1.60</td>
<td>10</td>
</tr>
<tr>
<td>Tot. P (μg l⁻¹)</td>
<td>log y = 2.3777 + x(0.0274)</td>
<td>0.992</td>
<td>53.40</td>
<td>6.51</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Degree of freedom = 23.
### TABLE 58

Average Chemical Parameters of some lake waters of Kashmir.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Khanpur</th>
<th>Trigam</th>
<th>Tilwan</th>
<th>Anchar</th>
<th>Dal+</th>
<th>Waskur+</th>
<th>Sheiksar**</th>
<th>Hokarsar++</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth (m)</td>
<td>1.95</td>
<td>1.45</td>
<td>0.70</td>
<td>1.10</td>
<td>-</td>
<td>-</td>
<td>0.83</td>
<td>0.64</td>
</tr>
<tr>
<td>Secchi (E)</td>
<td>1.31</td>
<td>6.26</td>
<td>8.66</td>
<td>8.33</td>
<td>-</td>
<td>-</td>
<td>6.20</td>
<td>10.70</td>
</tr>
<tr>
<td>Conductivity µmhos</td>
<td>355</td>
<td>1380</td>
<td>1049</td>
<td>325</td>
<td>133</td>
<td>294</td>
<td>632</td>
<td>325</td>
</tr>
<tr>
<td>Dissolved oxygen (mg l⁻¹)</td>
<td>8.0</td>
<td>7.97</td>
<td>9.18</td>
<td>7.56</td>
<td>11.15</td>
<td>12.55</td>
<td>8.75</td>
<td>6.93</td>
</tr>
<tr>
<td>Calcium (mg l⁻¹)</td>
<td>45.60</td>
<td>51.31</td>
<td>74.33</td>
<td>38.03</td>
<td>19.45</td>
<td>38.24</td>
<td>47.55</td>
<td>56.17</td>
</tr>
<tr>
<td>Magnesium (mg l⁻¹)</td>
<td>11.31</td>
<td>42.63</td>
<td>32.01</td>
<td>7.95</td>
<td>4.19</td>
<td>14.03</td>
<td>7.20</td>
<td>13.30</td>
</tr>
<tr>
<td>Sodium (mg l⁻¹)</td>
<td>3.44</td>
<td>150.0</td>
<td>125.0</td>
<td>-</td>
<td>3.34</td>
<td>5.55</td>
<td>-</td>
<td>3.50</td>
</tr>
<tr>
<td>Potassium (mg l⁻¹)</td>
<td>2.90</td>
<td>160.1</td>
<td>86.0</td>
<td>-</td>
<td>2.03</td>
<td>2.38</td>
<td>-</td>
<td>2.97</td>
</tr>
<tr>
<td>Chloride (mg l⁻¹)</td>
<td>26.23</td>
<td>273.0</td>
<td>71.03</td>
<td>29.39</td>
<td>19.0</td>
<td>19.75</td>
<td>97.05</td>
<td>26.2</td>
</tr>
<tr>
<td>Alkalinity CaCO₃ (mg l⁻¹)</td>
<td>166.8</td>
<td>445.0</td>
<td>173.11</td>
<td>115.6</td>
<td>72.0</td>
<td>164.5</td>
<td>154.12</td>
<td>162.5</td>
</tr>
<tr>
<td>Silicate (mg l⁻¹)</td>
<td>4.31</td>
<td>4.69</td>
<td>10.62</td>
<td>1.87</td>
<td>2.01</td>
<td>3.71</td>
<td>2.05</td>
<td>0.76</td>
</tr>
<tr>
<td>Iron (mg l⁻¹)</td>
<td>0.24</td>
<td>1.13</td>
<td>1.21</td>
<td>0.28</td>
<td>0.14</td>
<td>0.18</td>
<td>0.43</td>
<td>0.19</td>
</tr>
</tbody>
</table>
Table 58 continued

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Khanpur</th>
<th>Trigan</th>
<th>Tilwan</th>
<th>Anchar*</th>
<th>Dal+</th>
<th>Waskur+</th>
<th>Sheiksr**</th>
<th>Hokarsr++</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate (μg l⁻¹)</td>
<td>24.4</td>
<td>155</td>
<td>156</td>
<td>31.6</td>
<td>48</td>
<td>33</td>
<td>355</td>
<td>26</td>
</tr>
<tr>
<td>Ammonium (μg l⁻¹)</td>
<td>233</td>
<td>440</td>
<td>775</td>
<td>212</td>
<td>98</td>
<td>154</td>
<td>229</td>
<td>43</td>
</tr>
<tr>
<td>Phosphate (μg l⁻¹)</td>
<td>42</td>
<td>161</td>
<td>79</td>
<td>28</td>
<td>22</td>
<td>20</td>
<td>29</td>
<td>20</td>
</tr>
<tr>
<td>Total phosphate (μg l⁻¹)</td>
<td>225</td>
<td>417</td>
<td>261</td>
<td>153</td>
<td>66</td>
<td>71</td>
<td>253</td>
<td>92</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>18.7</td>
<td>18.0</td>
<td>18.7</td>
<td>14.1</td>
<td>17.2</td>
<td>17.3</td>
<td>17.2</td>
<td>14.7</td>
</tr>
<tr>
<td>pH</td>
<td>7.85</td>
<td>8.57</td>
<td>8.23</td>
<td>8.39</td>
<td>8.40</td>
<td>8.40</td>
<td>8.93</td>
<td>7.37</td>
</tr>
</tbody>
</table>


** Keng, Tasneem (Personal communication)

TABLE - 59

Chemical ratios in three rural lakes.

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Khanpur</th>
<th>Trigam</th>
<th>Tilwan</th>
<th>Clarke$^+$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl$^-$/HCO$_3^-$</td>
<td>0.16</td>
<td>0.16</td>
<td>0.41</td>
<td>0.16</td>
</tr>
<tr>
<td>Mg$^{2+}$/Ca$^{2+}$</td>
<td>0.25</td>
<td>0.33</td>
<td>0.43</td>
<td>0.17</td>
</tr>
<tr>
<td>Ca$^{2+}$/Cl$^-$</td>
<td>1.71</td>
<td>0.19</td>
<td>1.05</td>
<td>3.60</td>
</tr>
<tr>
<td>Mg$^{2+}$/Cl$^-$</td>
<td>0.43</td>
<td>0.16</td>
<td>0.45</td>
<td>0.60</td>
</tr>
<tr>
<td>Ca$^{2+}$/Mg$^{2+}$</td>
<td>0.34</td>
<td>0.21</td>
<td>0.61</td>
<td>0.68</td>
</tr>
<tr>
<td>Alkalinity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


TABLE - 60

Mean concentrations of chemical parameters of three lakes.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Khanpur</th>
<th>Trigam</th>
<th>Tilwan</th>
<th>Tolerance limit (mg l$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.85</td>
<td>8.57</td>
<td>8.23</td>
<td>6.50-8.30</td>
</tr>
<tr>
<td>Calcium (mg l$^{-1}$)</td>
<td>45.60</td>
<td>51.31</td>
<td>74.33</td>
<td>200.0</td>
</tr>
<tr>
<td>Chloride (mg l$^{-1}$)</td>
<td>26.23</td>
<td>273.0</td>
<td>71.03</td>
<td>250.0</td>
</tr>
<tr>
<td>Total hardness CaCO$_3$ (mg l$^{-1}$)</td>
<td>166.8</td>
<td>445.0</td>
<td>173.11</td>
<td>180.0</td>
</tr>
<tr>
<td>Iron (mg l$^{-1}$)</td>
<td>0.24</td>
<td>1.13</td>
<td>1.21</td>
<td>0.30</td>
</tr>
<tr>
<td>Ammonium (mg l$^{-1}$)</td>
<td>0.23</td>
<td>0.44</td>
<td>0.78</td>
<td>0.50</td>
</tr>
<tr>
<td>Nitrate (mg l$^{-1}$)</td>
<td>0.24</td>
<td>0.16</td>
<td>0.16</td>
<td>45.0</td>
</tr>
<tr>
<td>Phosphate (mg l$^{-1}$)</td>
<td>0.042</td>
<td>0.160</td>
<td>0.080</td>
<td>0.20</td>
</tr>
<tr>
<td>Total phosphorus (mg l$^{-1}$)</td>
<td>0.225</td>
<td>0.417</td>
<td>0.261</td>
<td>-</td>
</tr>
</tbody>
</table>