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WATER QUALITY STUDY OF THE MANSAR LAKE, DISTRICT UDHAMPUR, J & K

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ABSTRACT

Mansar lake has been recently developed as famous tourist place in the Jammu region. Fastly, increasing population around the lake has caused deterioration of its water quality. Therefore, water quality study of the lake has been carried out. The water samples from different locations at the surface and from three zone (viz. epilimnion, metalimnion and hypolimnion) were collected during May 96, October 96 and January 1997. The physico-chemical analyses have been carried out of these collected samples.

pH value of lake water was found to vary from 7.8 to 8.2 with the maximum at the surface and minimum at the bottom in the lake. In different months, temperature varies with depth. It clearly shows that during winter particularly in January and February lake water become mixed and remains stratified during rainy and summer months.

Calcium, Sodium and Magnesium are dominant cation, and bicarbonate is dominant anion. Presence of cations in the lake water observed as Calcium > Sodium > Magnesium > Potassium and anions as Bicarbonate > Chloride > Sulphate > Nitrate > Phosphate. However, the concentration of these cations are well below the prescribed limit for class A drinking water. The concentration of phosphate was observed to be more than 0.03 mg/l, which is the characteristic of eutrophic lake. Trace elements concentration are also below the prescribed limit.

The physico-chemical analyses reveal that lake water is good for drinking and irrigation purposes. The phosphate concentration indicates that lake is in eutrophic stage.

1.0 INTRODUCTION

Lakes are a source of water for a variety of purposes such as irrigation, drinking, pisciculture and recreation etc. In many parts of the country such as in Nainital, lake water is the only dependable source of water on which almost all the activities of the area are based. Further, lake plays a significant role in maintaining the hydrological, ecological and environmental balance of the region. Any change in the lake water both in quality and quantity will certainly hamper the development of the area. Lake water body exposed to wastes seriously affect the aquatic living resources. The pollutants that seriously affect the lake water can be grouped into the following categories (Rao, 1991). (i) Bacterial and Viral contamination associated with discharge of untreated human sewage, which cause outbreak of waterborne diseases; (ii) Decomposable organic material from sewage or industrial wastes which deplete dissolved oxygen of the waters; (iii) Toxic material from industrial area, farmland waste run-off and a variety of chemical manufacturing plants containing pesticides, herbicides and heavy metals, which may either eliminate the biota or cause damage to their reproductive capability; (iv) Fertilizers which stimulate growth of some life forms at the expense of others and (v) Inert material such as sediments, which fill invaluable aquatic areas. Natural decay of dead and living organisms in the lake together with silt causes a natural pollution. It constitutes a small but continuous source of pollution. It creates turbidity, change in colour and odour problems in the water alongwith change in the distribution of biotic components.

Addition of nutrients greatly accelerates the process of eutrophication while pollutants exert a deleterious effect on the aquatic biota. Eutrophication is the process where a lake accumulates essential plant nutrients principally phosphorus and nitrogen. This process occur naturally at varying rates in every lake and along with sedimentation it leads to the infilling and ultimate disappearance of the lake. However, in many developed areas, streams and groundwater carry high levels of these nutrients that originate from fertilizers and treated/untreated sewage effluent. The human induced overfertilization is called cultural eutrophication, and it is a form of pollution because it induces accelerated growth of algae, which die seasonally in the lake. The process of decaying consumes oxygen dissolved in water. Lack of oxygen makes a lake uninhabitable for fish and other aquatic animals. Increased level of phosphorus are usually responsible for cultural eutrophication of lakes.

A large number of natural lakes exist in Jammu and Kashmir state and are of great socio-economic importance. These lakes are suffering from high rate of eutrophication and siltation resulting into the deterioration of water quality and shrinking of the lake volume. Mansar lake has been developed as a tourist spot in the Jammu region. In order to develop tourism, large number of construction activities have taken place in the lake catchment. One of the major causes of change in trophic stage of lake is the discharge of untreated domestic waste along with higher rate of erosion from agricultural land area. In the January 1997 large scale fish mortality was reported. There is contradiction among the workers about the causes of fish mortality. There are two thoughts, one view explains the phenomena due to the mixing of lake water while other view indicates that the increasing amount of pesticides is responsible for it. For proper use and conservation of lake water, study of the water quality is essential.

1.1 Objective of This Study

To monitor the impact of anthropogenic activities in Mansar Lake, the variation of water quality parameters has been studied. The major objectives of the study are as follows:

1. To study the spatial and depthwise variation of physico-chemical parameters in the lake.
2. To evaluate the quality of lake water for drinking and irrigation purposes.

2.0 DESCRIPTION OF THE STUDY AREA

The Manasar Lake is situated about 55 km North East of Jammu City between the longitude 75^0 5' 11.5" to 75^0 5' 12.5" N and latitude 30^0 40' 58.25" to 30^0 40' 59.25" E and at the elevation of 666 metres above mean sea level in the Siwalik Himalaya (Fig 1). It is a popular tourist spot of Jammu region. Lake water is being used for drinking and irrigation purposes. The P.H.E. Department, Jammu, has installed a pumping station for the supply of water for villages surrounding the lake. Western flank of the lake basin is covered by the agricultural fields, and tourist rest house, northern flank Mansar Bazaar, eastern flank Sesnag Temple, Boat Club and at southern flank wild life sanctuary are located. Lake basin is less populated, however increasing impact of local residents and tourists are mainly causing ecological imbalance due to influx of domestic sewage, detergents, religious congregation and deforestation in the lake basin.

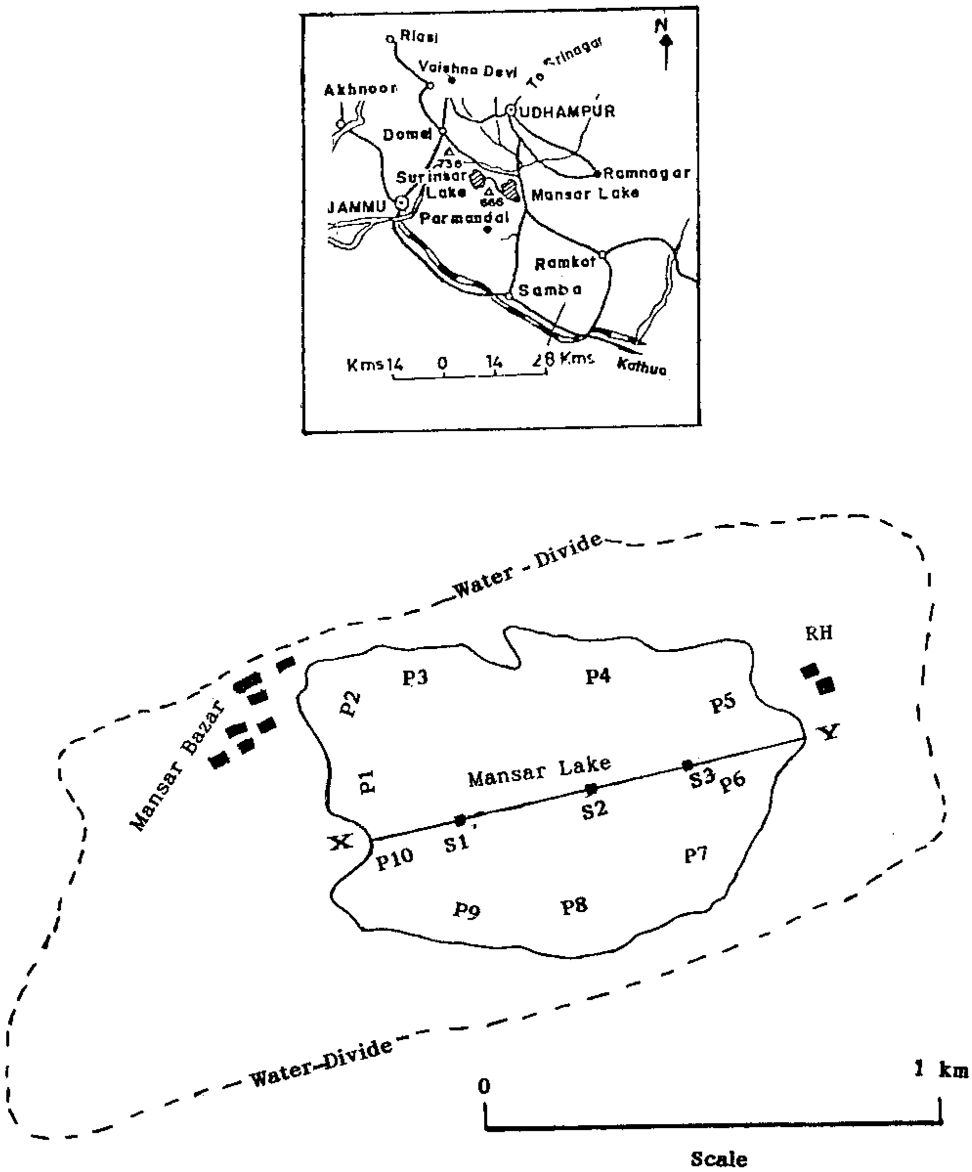

Figure 1: Location map of the Mansar Lake and sampling sites within the lake. P1 to P10 represents surface sampling sites and S1 to S3 represents sampling sites of different depth.

2.1 Geomorphology and Geology of the Study Area

The lake is sub-oval shaped water body surrounded by steep mountain slopes of Lower Siwalik hills. The surface area of the lake is 0.58 km^2 and lake basin covers an area of 1.67 km^2 (measured using digital planimeter from the toposheet No. 43 p/2, 1957-58, Scale 1:50,000). The maximum depth is 40 meter. The maximum length and width of the lake is 1100 metres and 650 metres, respectively. The lake mean width is 527 metres. Geological Survey of India, Jammu, has surveyed the lake surface area in 1997 using Plain Table method. According this survey, lake surface area is 0.53 km^2. There is no inflowing channels into the lake (Fig 1). During the rainy season overflow of the lake falls into the Mansar Wali Khad which joins the river Tawi. Geomorphologically, the area is young and neotectonically active.

Medlicott (1876) first studied the geology of the Siwalik belt in Jammu Region. Among various workers, Wadia (1928), Hazra (1936-38), Bhatt (1961-63) and Karuna Karan and Ranga Rao (1976) have studied in detail the stratigraphy and depositional environment of Siwalik belt of Jammu. A study, carried out by Gupta and Verma (1988) reveals that Mansar Uttarbani section, Jammu district is ideal for detailed future studies and represents as the reference section for the Siwalik Group.

The oldest litho-urit of the Siwalik Group, the Mansar Formation is exposed in Suruin - Mastgarh Anticline in Mansar (Lake Basin) area (Gupta and Verma 1988). It consists of alternating layers of fine grained, hard and compact sandstone, silt stone, mudstone and clay. The sandstone are buff, grey and light greenish gray in colour. The clays are purple, brown, red and yellowish red. The massive sandstone bands stand out as prominent small mounds and ridges, while clay and siltstone generally form depressions. At places the sandstone bands contain lenticles of pseudo conglomerate consisting of pellets and fragments of mudstone, claystone and shale which is bounded with arenaceous matrix. The clay invariably contain interbedded siltstone which at places has been lithified into hard mudstone. The sandstone is frequently transversed by thin calcite veins along the joint planes. Although, the Mansar Formation lies in a different tectonic unit, it appears homotaxial to the lower Siwalik of Ramnagar (Vasishat et al., 1978) and may be Vindobonian in age.

2.2 Flora and Fauna

The reserve forest on the western bank of the catchment covers o.11 km^2 and is mainly represented by *Mangifera indica, Ficus religiosa, Pinus roxburghii* and other subtropical type plants. The lake is heavily infested with macrophytes, weeds, submerged and floating plants in addition to ichthyofauna, amphibia and reptiles. Chlorophyceae, Bacillariphyceae and Cynaophycean are dominated species of phytoplankton. Besides, there is abundance of nectons and plankton invertebrates, diatoms, algae which form ecological link in the food chain of both invertebrate and vertebrate. Besides aquatic fauna, the lake has very intimate association with the wild life of the area. Lake also provides resting place for the migratory birds during their onward journey to south and they interacting with the lake ecosystem directly or indirectly. Fishes in the lake are belonging to three families and five genera. These are *C. gachua* (family-Ophiocephalidae), *Puntius conchonius, Rasbora rasbora, Danio rerio* (all cyprinids) and *Trichogaster fastiatus* (Anabantidae) (Gupta, 1992).

2.3 Origin of the Lake

There are several myths about its origin, but a common geological belief is that the lake owes its origin due to the damming of the river which was flowing along the strike of the Lower Siwalik range. The peaty and sticky soil surrounding almost the entire area of the lake which might had been of greater dimensions in the past support to these observations. Krishnan and Prasad (1970) have reported that the Mansar and Surinsar lakes are ten to fifteen thousand years old.

3.0 RESUME OF PREVIOUS WORK

In the last two decades, Himalayan lakes have drawn attention of many ecologists. Several studies have been carried by various investigators on the limnological and geomorphological aspects of the Jammu and Kashmir lakes. Various workers have made attempt to understand the ecological aspects of the Dal, Woolar, Nagin lakes etc. Among the various workers, Zutshi et al., 1972, 1980; Zutshi and Khan 1978, Zutshi and Vass, 1971, 1977, 1978; Kant and Kachroo, 1974, 1977; Kaul, 1977; Kaul et al., 1980 have studied in detailed the limnological and biological aspects.

Zutshi et al. (1980) have reported that lakes of Jammu and Kashmir are different in their morphology and thermal behavior and vary from sub-tropical monomictic to dimictic type. Zutshi and Khan (1977) have carried out comparative study of the morphometric, physico-chemical and biological parameters of the Mansar and Surinsar Lake. Using radioactive

Carbon Isotope (^{14}C), production rates of Surinsar Lake is much higher than that of the Mansar Lake. On the basis of production rates, Surinsar Lake has been categorised as Eutrophic and Mansar as Mesotrophic (Khan and Zutshi, 1979). Omkar (1994-1995) has carried out the water quality study of the Surinsar Lake. This study suggested that water of the lake is suitable for the drinking and irrigation purposes. Recent studies reveal that the trophic level in the Mansar lake is rapidly advancing during last few years (Zutshi, 1985, 1989; Chandra Mohan, 1992; Gupta, 1992). The trace elements study of the Mansar Lake water has been carried out by the Durani (1993) and Phytoplankton study by Kant and Anand (1976, 1978).

4.0 MATERIALS AND METHODS

4.1 Sampling and Preservation

Sampling is one of the most important and foremost step in collection of representative water samples for water quality studies. Moreover the integrity of the sample must be maintained from the time of collection to the time of analysis. The hydrologist must also be aware of the locations of point and non point sources of pollution such as industrial complexes, sewage outfalls, agricultural wastes etc.

Sampling from lakes is not an easy task because thermal stratification and associated hydrodynamics result into much variation in lake water quality. The physical and chemical parameters of lake water are also affected by a large number of factors like climatological, geochemical and biological processes along with the human activities. In order to overcome this problem, lake may be divided into different zones and series of samples may be taken from each zone.

To monitor the water quality of the lake both surface and depthwise sampling have been carried out. Water samples from 10 locations in the lake were collected during study period at the surface depth along the periphery of the lake (Fig. 1). Along the cross section X - Y at three spots i.e., S1, S2 and S3 (Fig. 1) samples were collected from three different depth to study vertical variation. These three different depths (i.e., 0.25 metre, 15 metre, and 30 metre) are representing epilimnion, metalimnion and hypolimnion zones. In the analysis of the results, samples of different depths are named as surface, middle and bottom. Standard water sampler was used for collecting samples at various depths. Sampling stations were fixed by taking the back bearing of the land mark of the nearby area for monitoring in various months.

4.2 Methods of Analysis and Equipment Used

Physico-chemical analysis was conducted following standard methods as described in National Institute of Hydrology User's Manual (UM-26, Jain and Bhatia, 1987-1988). The physical parameters such as temperature, pH, electrical conductivity and TDS were determined in the field at the time of sample collection using portable thermometer, portable pH meter (Eijkalkamp, The Netherlands) and portable water testing kit (Naina model NPC-361 D).

The total hardness and calcium hardness was determined by EDTA titrimetric method (Table 1) and magnesium hardness was determined by deducting calcium hardness from total hardness. Calcium was calculated by multiplying calcium hardness with 0.401 and Magnesium by multiplying magnesium hardness with 0.243.

Sodium and potassium were determined by flame emission method using Flame Photometer. Chloride concentration was determined by argentometric method in the form of silver chloride. Acidity/ alkalinity was determined by titrimetric method using phenolphthalein and methyl orange indicators. Phosphate, sulphate, nitrate and fluoride concentrations were determined using UV-VIS Spectrometer (Chemito 2000).

Table - 1 Method and Equipment used for analysis of Various Parameters.

S.No	Parameter	Analytical Method	Equipment
1.	pH	Electrometric	Portable Kit and pH meter
2.	Conductivity	Wheatstone bridge	conductivity meter
3.	Temperature	Thermometric	Thermometer installed in Sampler
4.	TDS		Portable kit
5.	Alkalinity	Titrimetric	
6.	Hardness	do	
7.	Calcium	do	
8.	Magnesium	do	
9.	Chloride	Mercuric Nitrate	
10.	Sodium	Flame emission	Flame Photometer
11.	Potassium	Flame emission	do
12.	Phosphate		UV-VIS Spectrophotometer
13.	Nitrate		do
14.	Sulphate	Turbidimetric	Turbidimeter

5.0 RESULTS AND DISCUSSION

The variation of physico-chemical parameters in the vertical profile and horizontal are discussed below.

5.1 Temperature

The vertical temperature profile of a lake is a direct response to the penetration of solar radiation. In thermally stratified lake an upper water oxygenated and circulating layer termed as epilimnion, overlies a lower, cooler and relatively undisturbed region, the hypolimnion. The intervening zone is known as the metalimnion and zone where temperature decreases most rapidly with depth is called a thermocline.

During the study period 1996-1997, temperature of surface water ranged between 14^{0}C (January) to 22^{0}C (May) with the average 25.8^{0}C and 14.2^{0}C in the October and January, respectively (Fig 2). The vertical profile of temperature revealed decrease in temperature with increase in depth except in winter (Fig 2). Chander Mohan (1992) has also studied the depthwise temperature variation in the Mansar Lake. The results clearly indicate that lake have single period of vertical mixing and remains stratified during summer and rainy season months. Similar, phenomenon of stratification and mixing has also been reported by Pant et al. (1981) in the Nainital Lake, Kumaun Himalaya.

5.2 pH

pH value at the surface of lake varies between 7.2 in the January to 8.3 in the May. The average pH value at the surface was observed as 8.19, 8.15 and 7.2 in the May, October and January, respectively. The depthwise analysis indicates that pH is decreasing with depth (Table 2 and Fig 3). The maximum pH values of surface waters obtained during summer month (May) obviously related to the metabolic activities of the autotroph, which utilised carbon-dioxide during active photosynthesis. Rao (1991) has pointed out that low pH value occurred in hypolimnion due to the liberation of acids from the decomposing organic matter under low oxygen conditions resulted into the lower pH value.

5.3 Conductivity

Conductivity values of the surface water occurred between 220 to 270 μ mho/cm. The average conductance of surface water in different months are 265 μ mho/cm, 227 μ mho/cm and 230 μ mho/cm during the May, October and January, respectively. The depthwise study of conductance revealed that it is increasing with the depth (Table 2 and Fig 3). Mineralization of organic matter under reducing condition prevailing in the hypolimnion water was accompanied by their release and as a result water at the bottom showed higher conductance than that at the surface (Mortimer, 1941).

Table 2 Variation of pH and electrical conductance in the vertical profile in the Mansar Lake

Month	Electrical Conductance (μ mho/cm)			pH		
	Surface	Middle	Bottom	Surface	Middle	Bottom
May	256	286	320	8.25	8.05	7.87
October	216	270	313	8.15	7.89	7.70
January	223	260	320	7.31	7.25	7.10

5.4 Total Hardness

Hardness in lake water is due to calcium and magnesium hardness. The average value of hardness in the surface water is 75 mg/l, 67 mg/l and 102 mg/l in month of May, October and January, respectively (Fig 4). There is remarkable difference in hardness from surface to bottom. The maximum 138 mg/l (Bottom) during January and minimum 64 mg/l (surface) during the October was observed (Fig 4). The maximum values of hardness in the January indicates that during the mixing period mineral dissolved at the lake bottom has caused maximum hardness in the lake during the January. Temperature effect may be also a reason for high hardness value. Solution of calcium carbonate as the bicarbonate is promoted in cold waters and solubility of CO_2 is greatly enhanced (Pettijohn, 1984).

5.5 Alkalinity

Alkalinity of the water is mainly due to bicarbonate ions. It is varying in the lake water. Average concentration of the bicarbonate in the lake surface water varied between 78 mg/l to

115 mg/l in October and January, respectively. The alkalinity of water at the surface is lower than the bottom (Fig 4). Alkalinity is showing positive relation with the hardness. The maximum alkalinity has been found in January similar to hardness.

5.6 Variation of Cations

The cations such as calcium, magnesium sodium and potassium were determined in the laboratory. Calcium is the most dominating cation in the lake water. The cations concentration in the lake surface water in descending order is as Calcium > Sodium > Magnesium > Potassium (Fig 5). The concentration of calcium (27.13 mg/l), magnesium (9.01 mg/l) and potassium ions (9.31) were found maximum at the lake surface in January which is mixing period of the lake. Sodium ion was observed maximum in May. The higher concentration of sodium ion during summer month indicates that sodium is reaching into the lake through the leaching of rock with the ground water.

The depth wise variation of cations reveals that the calcium and magnesium ions concentration are maximum in the hypolimnion during May and January while in the October it is maximum in the epilimnion and metalimnion part. The higher concentration during October in the epilimnion zone indicates that during rainy season it reaches into the lake with surface runoff. Variation of sodium and potassium ions concentration with depth is negligible.

5.7 Variation of Anions

The bicarbonate, chloride sulphate nitrate nitrogen and phosphate have been analyzed for different months during study period. The dominance of anions in the lake is in order of Bicarbonate > Chloride > Sulphate > Nitrate > Phosphate. The variation of anions in the lake surface water were found maximum during January (Winter) and minimum in October. In depthwise analysis, marked variation in the concentration of anions have been observed in the epilimnion, metalimnion and hypolimnion (Fig. 6). Bicarbonate, nitrate and phosphate are higher in the hypolimnion and minimum in the metalimnion part. Chloride and sulphate ions concentration were maximum in the metalimnion and minimum in hypolimnion zone.

During mixing period higher concentration of bicarbonate was observed in the lake. It is mainly due to conversion of CO_3 into HCO_3 which takes place in the presence of free Carbon Dioxide (FCO_2). In addition to this, during overturn period the fall in the phytoplankton count and macrophytic growth has been also recorded (Chander Mohan, 1992). The lower concentration of bicarbonate in October also suggest that it is being used by macrophytes in photosynthesis during the luxuriant growth.

The occurrence of different combinations of nitrogen in the lake water depends upon various factors but particularly on the prevailing biological processes (Pant et al., 1981). The highest average concentration of nitrate in the both surface and bottom water was recorded in January (Fig 6). The maximum concentration of nitrate at bottom of the lake revealed that anoxic and reducing conditions at the mud water interface in hypolimnion favors the release of No_3N during overturning of lake.

During study period, phosphorus in surface water varies between 0.04 mg/l (May) to 0.05 mg/l (January). In depth wise analysis, maximum phosphate concentration was recorded in hypolimnion water during May and October i.e. 0.06 mg/l while in January it is maximum in epilimnion, metalimnion and minimum in hypolimnion water. During periods of stratification, surface water became depleted in phosphorus and nitrogen because of incorporation of these elements in tissues of planktonic organisms which sink and accumulate below the metalimnion. The concentration of phosphorus was greater than 0.03 mg/l during study month. A value of 0.01 mg/l or more is considered to be a characteristic feature of an eutrophic or polluted water body (Sawyer, 1947; Vollenweider, 1968). According to Dillon (1975) lakes with total phosphorus concentration of <0.01, 0.01 to 0.02 and >0.02 mg/l are oligotroplic, mesotrophic and eutrophic, respectively. In this view, higher value of phosphate corroborates eutrophic condition of the Mansar Lake. The causes of higher concentration of phosphate in the lake is mainly due to agricultural runoff and urban wastes entering into the lake.

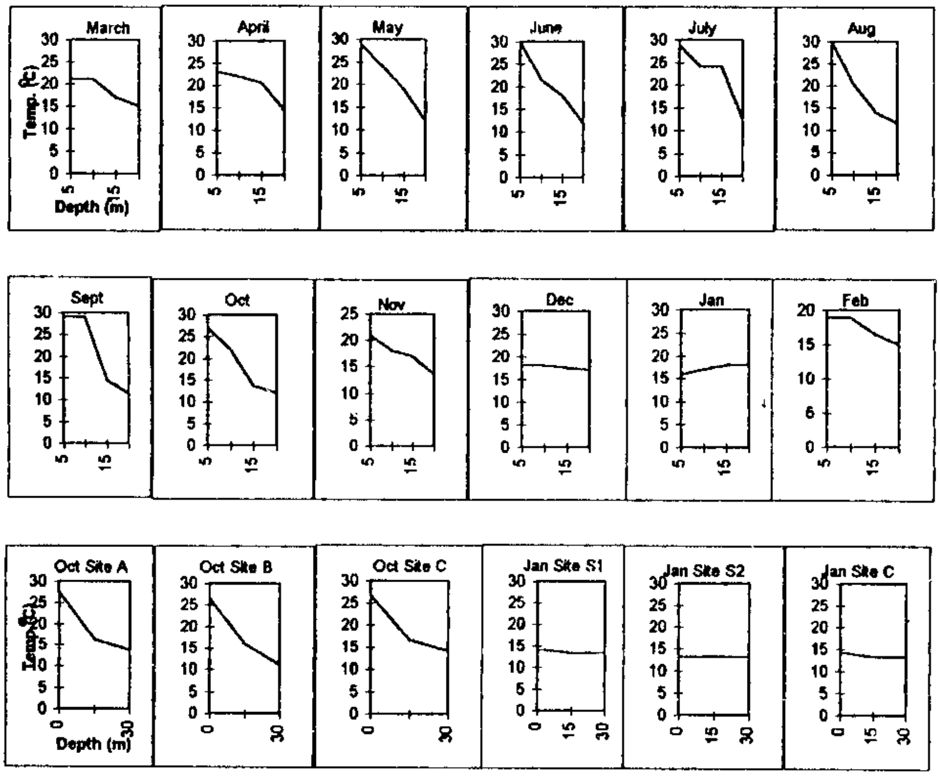

Figure 2: Temperature profiles showing the variation of temperature with the increasing depth in different months.

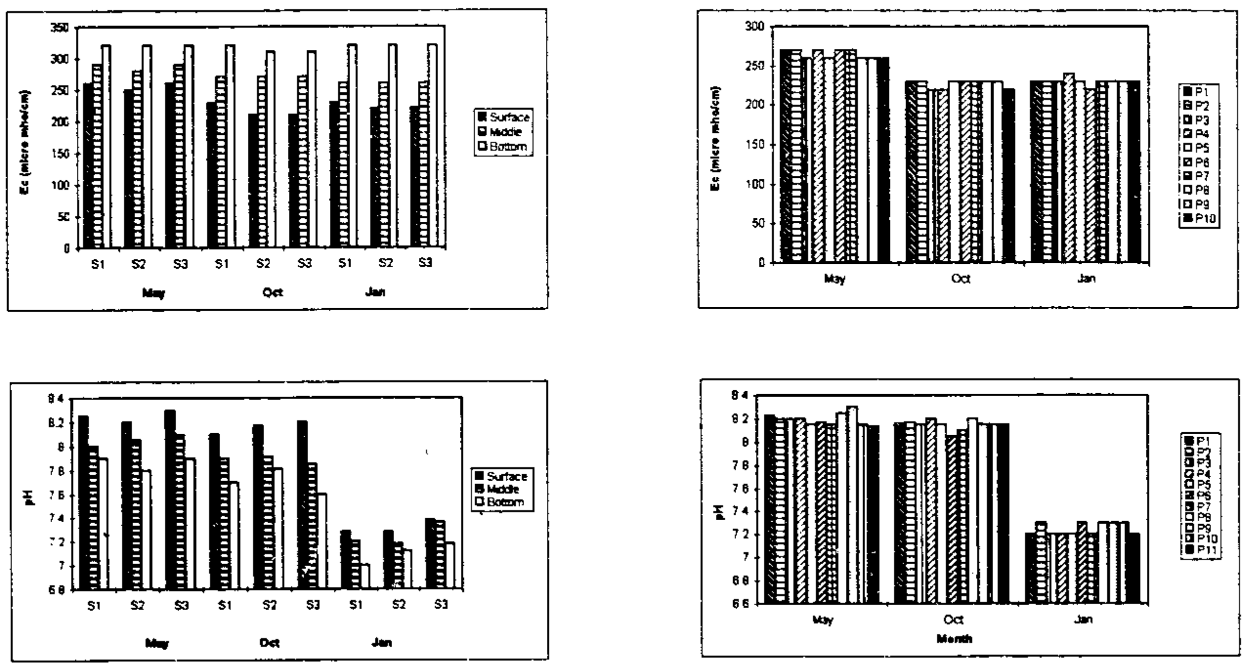

Figure 3: Variation of pH and EC in the lake during study period at the surface and different depth.

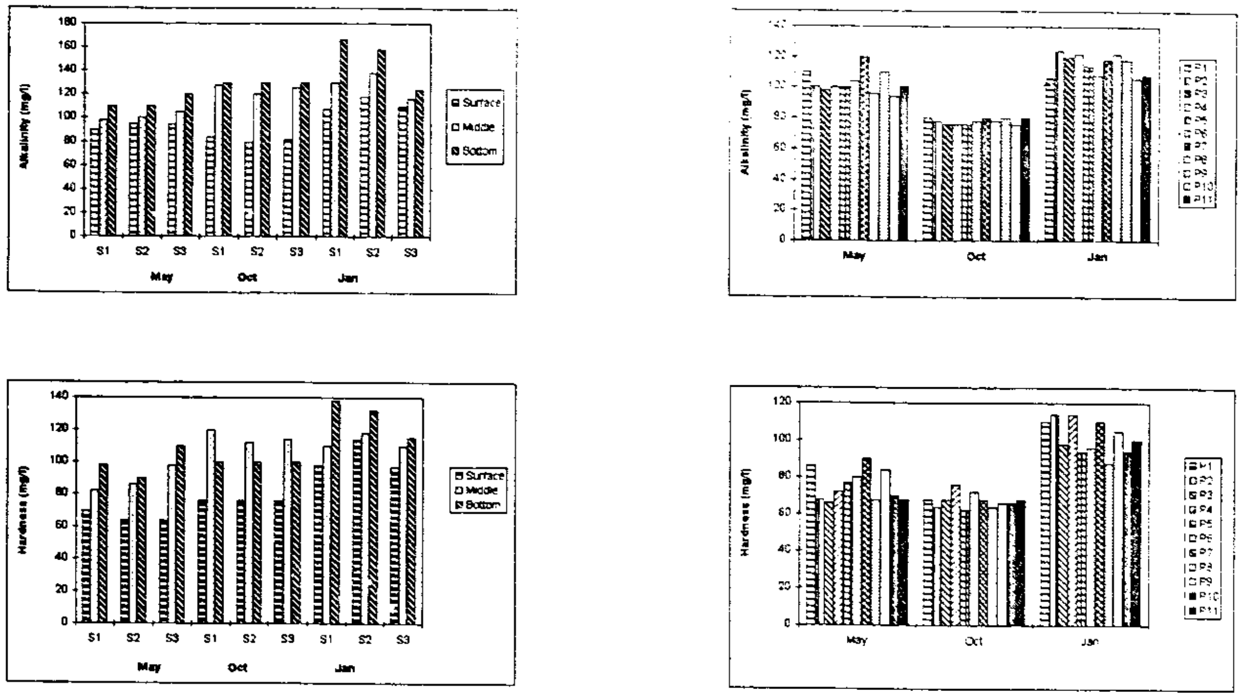

Figure 4: Variation of hardness and alkalinity in the lake during study period at the surface and different depth.

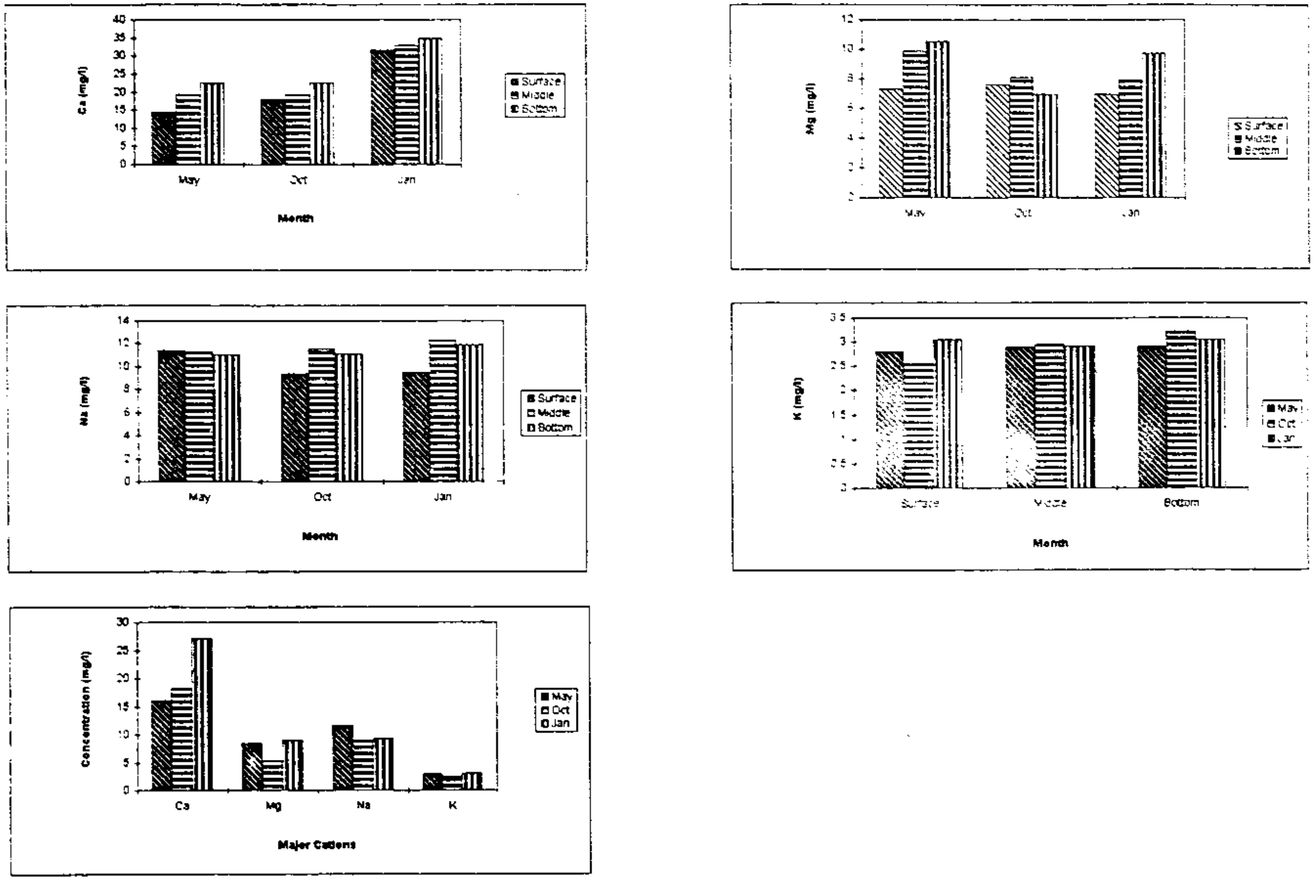

Figure 5: Variation of cations in the lake during study period at the surface and different depth.

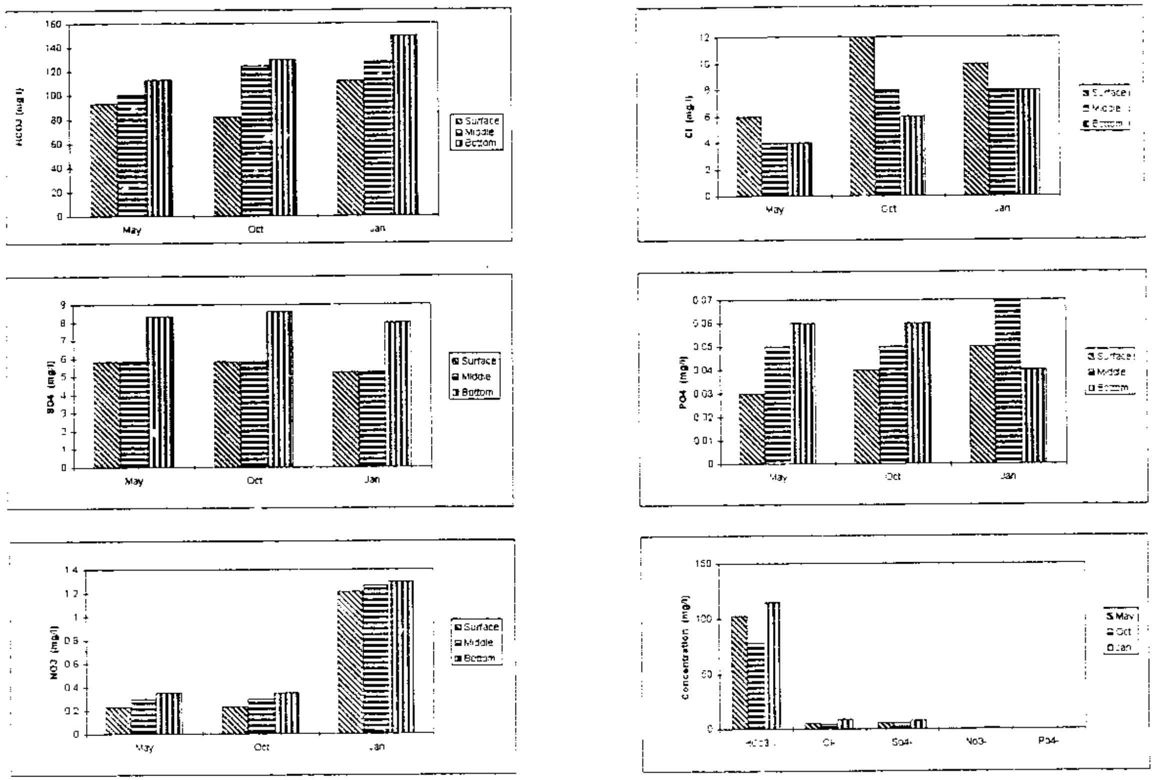

Figure 6: Variation of anions in the lake during study period at the surface and different depth.

5.8 Representation of Chemical Analysis Data and Classification of Lake Water

An attempt has been made to study the water quality variation and geochemical evolution of lake water by using the Piper's diagram. The Piper's diagram consists of two lower triangle field and a central diamond shaped field (Fig 7 & 8) (Piper, 1953). All the three fields have scales reading in 100 parts. The percentage reacting values of the cations and the anions are plotted at the lower left and right triangles, respectively. The respective cation and anion locations for analysis are projected into the diamond shaped area which represents the total ion relationship.

The water quality type can be quickly identified on the basis of the dominant ions in the facies by means of trilinear diagram. On the basis of dominant ions water can be categorised into different hydrochemical facies. The facies are a function of the lithology, solution, dynamics and flow pattern of the aquifer (Back, 1966). Back and Hanshaw (1965) have suggested two main types of facies i.e. cation facies and anion facies. The overall chemical character of water is determined by both cation and anion facies. For the purpose of classification, the central area of the Piper diagram is divided into segments depending upon the dominant ions.

Lake water quality data are plotted in the Piper Diagram. Figure 7 depicts the location of surface samples and figure 8 represents the samples of different depths collected during May, October and January. Their label numbers have been presented in the Table 3 and 4. The cation plots in the diagram reveals that majority of the samples lie in the no dominant, calcium and magnesium type. The anion plot in the diagram reveals that samples fall in bicarbonate type. All these samples fall under the facies Ca, Mg - CO_3, HCO_3 facies. In the depth wise plotting (Fig 8), surface, middle and bottom samples occur at adjacent locations. This slight variation may be due to the lake dynamics process. Surface samples located in two parts; One location is dominated with January samples when lake was homogeneously mixed and at other location May and October samples dominated when the lake remains stratified. It also suggests that lake water at surface is homogeneously mixed. Presence of Ca, Mg - CO_3, HCO_3 facies in the lake water reveals that the water entering into the lake via recharge area acquire their initial chemical characteristics by contact with Lower and Middle Siwalik rocks.

Table 3 Lake Surface Water Samples Identification Plotted in the Piper and Wilcox Diagrams

S.No.	Samples Collected	Label
	May Surface Samples	
1	P1	1
2	P2	2
3	P3	3
4	P4	4
5	P5	5
6	P6	6
7	P7	7
8	P8	8
9	P9	9
10	P10	A
11	P11	B
	October Surface Samples	
12	P1	C
13	P2	D
14	P3	E
15	P4	F
16	P5	G
17	P6	H
18	P7	I
19	P8	J
20	P9	K
21	P10	L
22	P11	M
	January Surface Samples	
23	P1	N
24	P2	P
25	P3	Q
26	P4	R
27	P5	S
28	P6	T
29	P7	U
30	P8	V
31	P9	W
32	P10	X

Table 4 Lake Depthwise Water Samples Identification Plotted in the Piper and Wilcox Diagrams

S.No.	Samples Identification	Label
	May	
	Site S1	
1	Surface	1
2	Middle	2
3	Bottom	3
	Site S2	
4	Surface	4
5	Middle	5
6	Bottom	6
	Site S3	
7	Surface	7
8	Middle	8
9	Bottom	9
	October	
	Site S1	
10	Surface	A
11	Middle	B
12	Bottom	C
	Site S2	
13	Surface	D
14	Middle	E
15	Bottom	F
	Site S3	
16	Surface	G
17	Middle	H
18	Bottom	I
	January	
	Site S1	
19	Surface	I
20	Middle	J
21	Bottom	K
	Site S2	
22	Surface	L
23	Middle	M
24	Bottom	N
	Site S3	
25	Surface	Q
26	Middle	R
27	Bottom	S

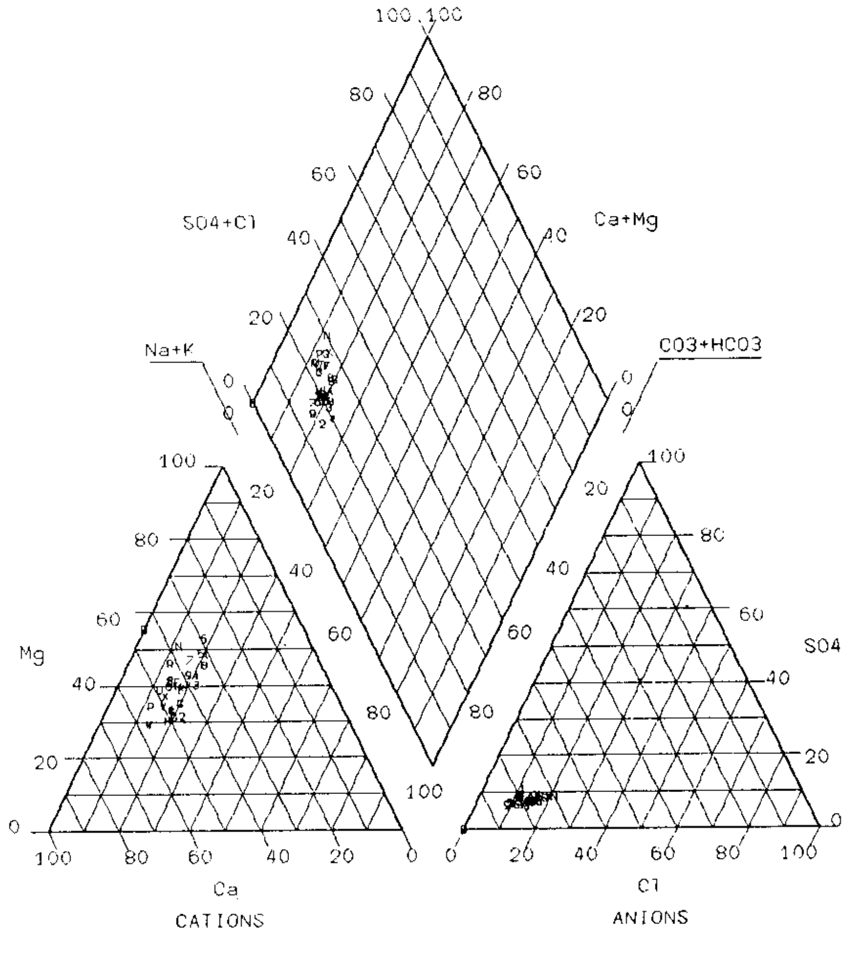

Figure 7: Piper diagram showing the location of the chemical data of the surface samples.

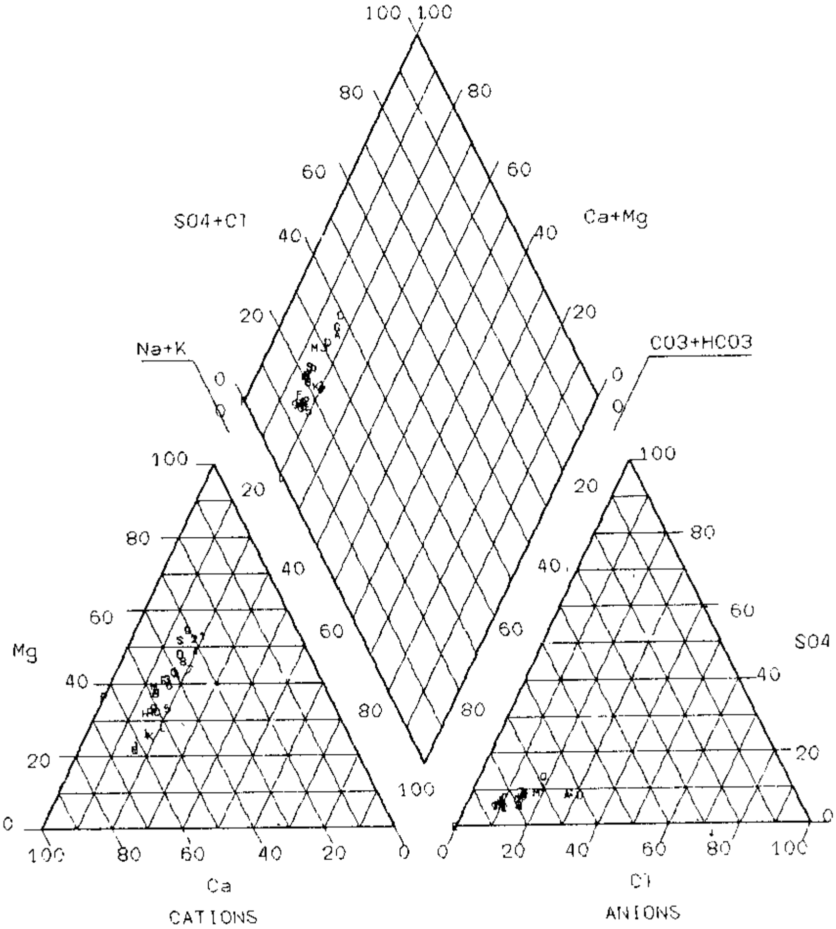

Figure 8: Piper diagram showing the location of the chemical data of the lake water collected from the different depths.

5.9 Water Quality Evaluation For Irrigation

The quality of water is an important factor for productivity and quality of crops. The suitability of an irrigation water depends upon many factors. However, the suitability of a water for irrigation depends mainly upon the mineral constituents of the water on both the plant and the soil. Salt may harm plant growth physically by limiting the uptake of water through modification of osmotic processes, or chemically by metabolic reactions such as caused by toxic constituents. Effects of salts on soils, causing changes in soil structure, permeability, and aeration, indirectly affect plant growth.

The most important constituents of irrigation water are total dissolved solids, sodium percent, sodium absorption ratio, conductivity, boron, chlorides and sulphate. In the present study, total dissolved solids (TDS), conductivity, sodium adsorption ratio (SAR) and bicarbonate concentration have been used to evaluate the suitability of lake water for irrigation purpose.

5.9.1 Salinity

Salinity is usually reported as electrical conductance (EC). The average electrical conductance of lake water is well below 750 micro mhos/cm (Table 2) and total dissolved solids are also within 800 mg/l which are reported for best quality for irrigation purposes. However, specific limits of permissible salt concentrations for irrigation water can not be stated because of the wide variations in salinity tolerance among different plants. On the basis of above study the lake water under present study is good for irrigation purposes.

The results obtained by plotting the USDA classification reveals that the majority of surface water samples of study period fall under C2S1 (Medium salinity Low Sodium) class (Fig 9). The water samples collected from different depth are in the C1S1 (Low Salinity and Low Sodium) and C2S1 (Medium salinity Low Sodium) (Fig 10). Therefore, water of the lake is good for irrigation purposes because both classes (C1S1 and C2S1) have been classified as good water for irrigation.

5.9.2 Sodium Adsorption Ratio.

Sodium concentration is an important criterion in irrigation water classification because sodium reacts with the soil to create sodium hazards by replacing other cations. The extent of this replacement is estimated by the Sodium Adsorption Ratio (SAR). There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil. Lake water for irrigation purposes is classified on the basis of SAR values and all the 59 water samples falls within the excellent class (Table 5). These values are well below the limit of excellent waters for irrigation (i.e., less than 10.0). It implies that lake water is good for irrigation purposes.

Table 5 Classification of water for Irrigation Purposes on the basis of SAR.

SAR	Class of water	No. of the Samples from the Study Area
< 10	Excellent	59
10-18	Good	Nil
18-26	Fair	Nil
>26	Poor	Nil

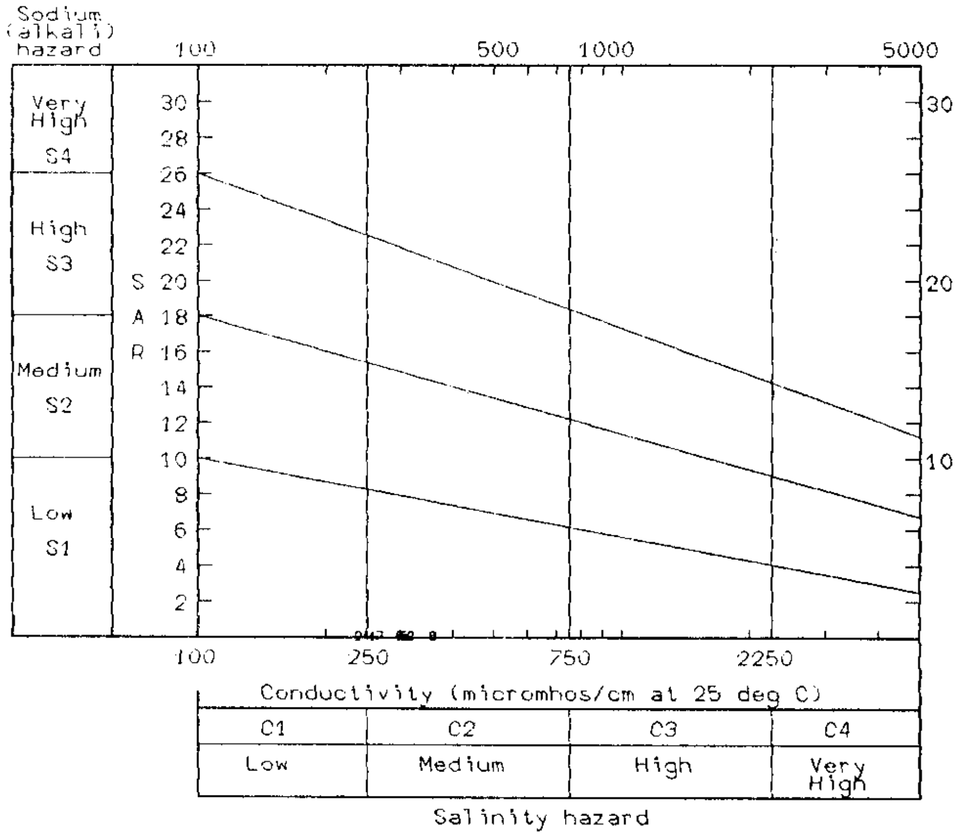

Figure 9: US Salinity diagram showing the location of surface samples.

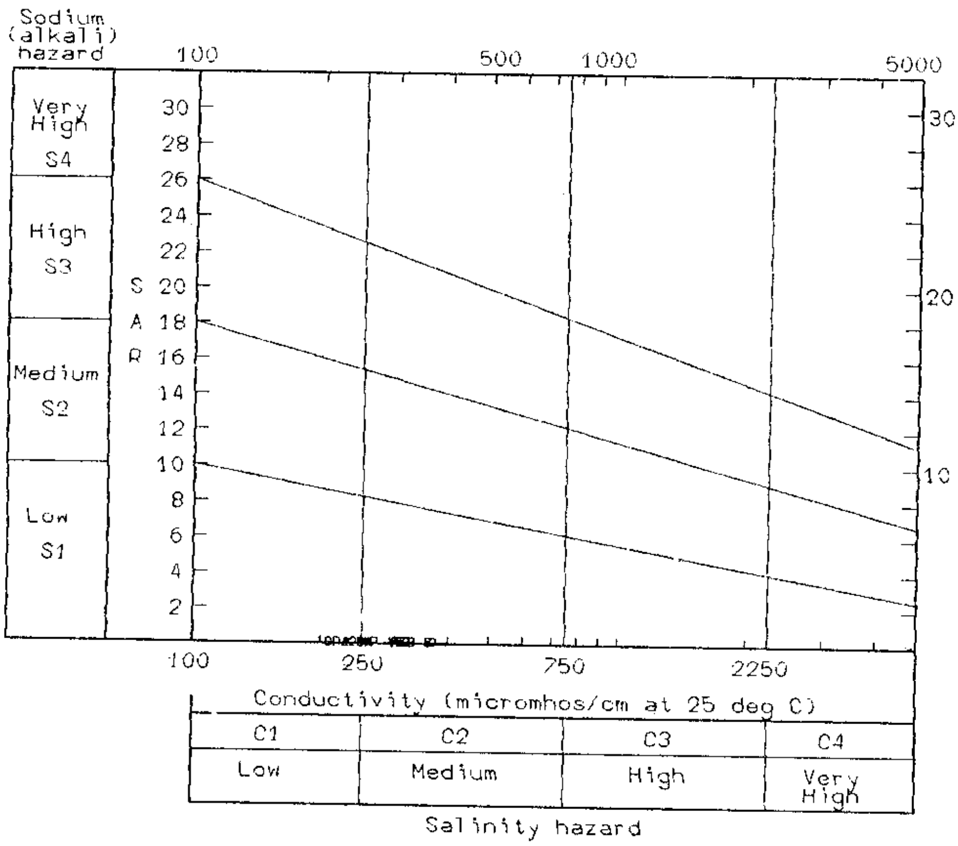

Figure 10: US salinity diagram showing the location of the water samples collected from the different depths.

5.9.3 Bicarbonate Concentration

Bicarbonate concentration of water has been suggested as an additional criterion for determining the quality of irrigation water. If the water contains high concentration of bicarbonate ion, there is a tendency for calcium ions to precipitate as carbonates. As a consequence, the relative proportion of sodium ion increases and gets fixed in the soil by the process of base exchange there by decreasing the soil permeability. The lake water has been classified on the basis of residual sodium carbonate values (Table 6). The Residual Sodium Carbonate (RSC) is as follows:

$$RSC = (CO_3^{-} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$$

The Residual Sodium Carbonate value for all the samples have been computed. The results presented in the table 6 shows that the RSC value of all the samples are below the 1.25 meq/l.

Table 6 Classification of water on the basis of RSC

Category	RSC (meq/l)	No. of the sample from the study area
Safe	< 1.25	59
Marginal	1.25-2.5	Nil
Unsuitable	> 2.5	Nil

Boron is very essential for plants growth in low amount but higher concentration of it becomes toxic for plants. This important parameter for evaluation of water for irrigation purposes shall be taken up in further study.

5.10 Evaluation Of Lake Water For Drinking Purposes

The average value of pH, total hardness, Ca hardness, Mg hardness, sulphate and nitrates observed at different depths have been compared with the class A type of water (Indian standards for Inland surface waters for use as drinking water source without conventional treatment but after disinfection). The results are summerised in the Table 7.

pH value of the lake water during May, October and January at different depth varies between 7.1 to 8.2. It is maximum 8.2 in May and minimum in January. On average TDS value varies between 136 to 209 mg/l. The pH and TDS values are within the tolerance limit. The total hardness, calcium hardness and magnesium hardness is within the prescribed limit (Table 7).

The average chloride values are below the maximum limit as mentioned for class A water. The average sulphate concentration varied from 5 mg/l to 8 mg/l and nitrate occurred between 0.25 mg/l to 1.3 mg/l. The values of sulphate and nitrates are within the range of class A drinking water.

Thus, the present study indicates that water of Mansar Lake can be used for drinking purposes. Although the Do, BOD and other bacteriological studies have been not carried out under this study. But, as per recommendations of Indian standards for Inland surface water under class A, the water should be disinfected before using for drinking purposes.

5.11 Trace Elements

The major rock forming elements viz. O, Si, Al, Fe, Ca, Na, K and Mg occur in natural water in large quantities because rock containing them are much soluble in water. Elements other than these present in minor amount viz, Zn, Mn, Co, Cu, Pb, Hg, Cr and Se etc. are named as trace elements. The high concentration of trace element in water affects adversely the biological activity of human and plants.

Almost all the metals are toxic at higher concentrations and few of them are toxic in low quantity but some are toxic even in traces eg. lead, cadmium, mercury. The presence of such metals in natural water is a subject to serious concern. Natural water which contains higher amount of metals or trace quantity of toxic metals, affect human health to a great extent when it is used for drinking and bathing purposes. The impact of heavy metals in drinking water is generally cumulative, by which the prolonged use of such water is dangerous for health. The trace elements analysis of Mansar lake have been carried out by Durani (1993). The results are summerised in table 8.

The concentration of Chromium, Zinc, Cadmium , Lead, Nickel and Copper in the lake water is found well within the prescribed limits. Lithium concentration is due to dominance of micaceous minerals in the rocks of Lower Siwaliks.

Table - 7 Comparison of Mansar Lake Water with Class-A Inland Water for Drinking Purposes

Parameters	Tolerance Limit of Class A	Average Value of Lake Water at Different Depth								
		Surface			Middle			Bottom		
		May	Oct	Jan	May	Oct	Jan	May	Oct	Jan
pH	6.5 - 8.5	8.2	8.2	7.2	8.2	7.8	7.7	7.3	7.3	7.1
TDS (mg/l)	500 (max)	171	136	153	194	209	169	211	196	183
DO (mg/l)										
Total Hardness (mg/l)	300 (max)	75	67	102	88	115	113	99	100	128
Ca Hardness (mg/l)	200 (max)	40	45	68	48	82	82	56	71	87
Mg Hardness (mg/l)	100 (max)	35	22	34	34	33	31	40	29	41
Sulphate (mg/l)	250 (max)	5.8	5.8	7.5	5.6	5.6	8.0	5.0	5.0	8.0
Nitrates (mg/l)	20 (max)	0.25	0.25	1.30	0.30	0.30	1.26	0.35	0.35	1.30

Table 8 Trace Elements Concentration of the Mansar Lake water in ppm

Variation	Li	Ti	Cr	Mn	Co	Ni	Cu	Zn	Rb	Mo	Ag	Cd	Sb	Ba	Pb	U
Min	0.4	<0.1	0.04	0.03	0.06	0.01	0.01	0.2	0.1	<.1	0.03	<0.01	<0.1	0.4	0.01	<0.5
Max	0.7	<0.1	0.06	0.05	0.08	0.03	0.02	0.3	0.14	<.1	0.03	<0.01	<0.1	0.8	0.02	<0.5

6.0 CONCLUSIONS

The main conclusions of the present study are summarized below.

a) Lake surface area measured from survey of India toposheet (1957-58, Scale 1:50,000) using digital planimeter is 0.59 Km^2. A comparison has been made between the lake surface area measured by the Geological Survey of India in 1997 and the surface area measured by toposheet. It indicates 10% reduction in the surface area of the lake. Thus it points out that the surface area and volume is reducing slowly.

b) The vertical profile of temperature indicates that lake has single period of mixing (during winter) and remains stratified during summer and rainy season months.

c) The pH value of lake water varies between 7.1 to 8.2. It is maximum at epilimnion and minimum in the hypolimnion zone.

d) Hardness of the lake water varies between 67 mg/l to 138 mg/l from epilimnion to hypolimnion. It is due to stratification in lake water. Alkalinity is having positive relation with the hardness.

e) Calcium and Magnesium are the major cations and together account for 76% to 90% of the cations in the surface water and 80-90% in the metalimnion and hypolimnion zone.

f) Among the anions, bicarbonate accounts for 85 to 90% in the surface water and 60 to 85% in the metalimnion and hypolimnion zone.

g) The phosphorous concentration in lake water varies from 0.03 mg/l to 0.07 mg/l. A value of 0.01 mg/l or more in considered to be a characteristic feature of an eutrophic or polluted water body by Sawyer (1947), Vollenweider (1968) and others. It implies that the lake has entered into the eutrophic stage.

h) Trace elements are within the prescribed limit.

i) Various parameters analyzed for evaluation of irrigation water show that lake water is good for irrigation purposes.

j) The physico-chemical parameters of lake water were found within the limits of class A drinking water.

7.0 RECOMMENDATIONS FOR FUTURE WORK

Siltation and addition of the sewage are the two major factors causing the reduction in surface area and volume of the lake and overall deteriorating the lake water quality of Mansar Lake. Large amount of sediments and debris generated during the rainy season from the barren hill slopes and agricultural fields is causing the sedimentation as well as eutrophication in the Mansar Lake. In addition, fertilizers and pesticides from agricultural fields are also reaching into the lake.

Several limnological studies of the Mansar Lake have been carried out by the Bioscience Department, Geology Department and Chemistry Department of Jammu University, Jammu and Kashmir University but no attention has been paid to the hydrological studies. On the basis of the present status of the knowledge about the Mansar lake, It is necessary to carry out the hydrological study comprises the water balance study, identification of recharge zone, leakage zone and hydrodynamics of the lake. The bathymetric survey and computation of sedimentation rate in the lake are important to predict lake life. Hydrodynamics and water quality study is also essential to understand the movement of pollutants into the lake.

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