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WATER QUALITY MONITORING AND EVALUATION OF MANSAR LAKE, DISTRICT UDHAMPUR, J&K.

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ABSTRACT

Water quality monitoring of lakes are essential to detection of various water quality parameters. In order to monitor the lake water conditions, water samples from different depths were collected. The collected samples cover both temporal and spatial variations of lake water. In the present study attempt has been made to monitor water quality characteristics of Mansar lake.

pH value of lake water was found to vary from 7.8 to 8.2 with the maximum near surface and minimum near bottom in the lake. Temperature decreases with depth in July while remains constant from surface to bottom in January. On the basis of temperature in July, Mansar Lake can classified into epilimnion zone (surface to 3 m depth) thermocline (3 to 9 m) and hypolimnion (below 9 m). Temperature variation indicates that mixing of lake takes place in winter and remains stratified in rainy and summer season. Ec, Hardness and alkalinity vary with depth. 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. The concentration of phosphorous is more than 0.03 mg/l, which is the characteristic of eutrophic lake.

1.0 INTRODUCTION

The Jammu and Kashmir state is divided into three regions i.e., Kashmir, Ladakh and Jammu. These three regions are consisting fourteen districts. Among fourteen districts, six each are in Jammu and Kashmir, and two fall under Ladakh. Udhampur is one of the six districts of Jammu regions. Udhampur is a district headquarters. Chenani, Katra, Ramnagar and Reasi are important township in the district Udhampur. The famous holy cave of Mata Vaishnov Devi Ji comes under the Katra township. Kud, Patnitop and Batota are the famous summer hill resorts. Two lakes, namely Mansar and Surinsar are important tourist place of the Jammu region. Other popular lakes are within the Kashmir valley.

A large number of natural lakes exist in Jammu and Kashmir state are of great socio-economic importance. 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 refuse and higher rate of erosion from agricultural land area. These are responsible factor in accelerating eutrophication and causing the deterioration of water quality and shrinking of the lake volume. 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 could be responsible for it.

To evaluate the water quality of the Mansar lake, WHRC, Jammu has started the water quality study of Mansar Lake since 1996. For proper use and conservation of lake water, a long term data comprising all the aspects of water quality is essential.

1.1 Objective of This Study

To monitor the impact of anthropogenic activities in Mansar Lake, monitoring of water quality parameters has been started since 1996-1997. Keeping in view the complex hydrodynamic process of the lake, Regional Coordination Committee in the 7th meeting has been recommended to continue this for the year 1997-1998 with more emphasis on depthwise variation in the lake water quality.

2.0 STUDY AREA

The Mansar Lake is situated about 55 km east of Jammu City between the longitude 75^0 5' 11.5" to 75^0 5' 12.5" E and latitude 32^0 40' 58.25" to 32^0 40' 59.25" N 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 is being used for drinking and irrigation purposes. The P.H.E. Department, Jammu, has installed a pumping station for the supply of water to villages surrounding the lake. Western flank of the lake basin is covered by the agricultural fields and

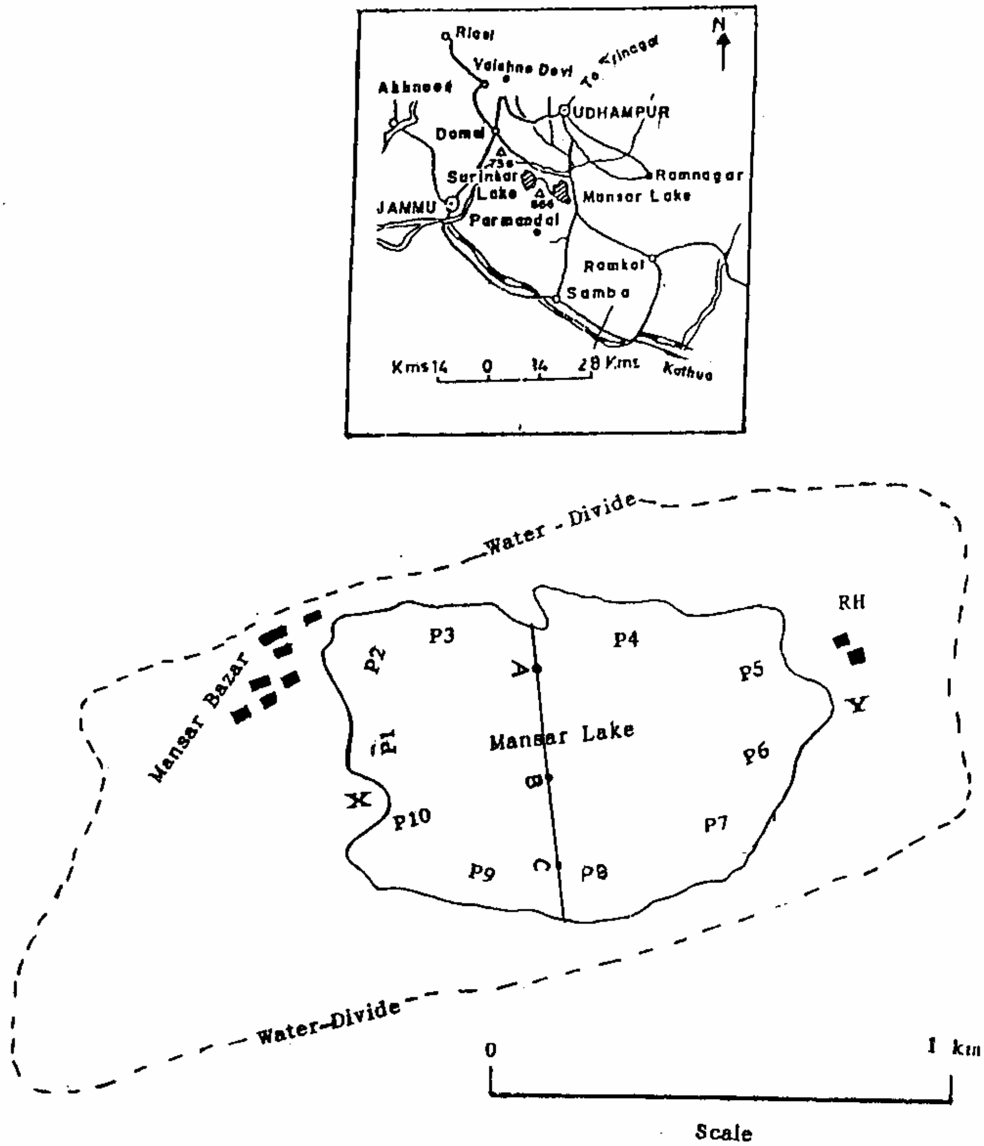

Figure 1: Location map of the Mansar Lake and sampling sites within the lake. P1 to P10 represents surface sampling sites and A, B and C represents sampling sites of different depth.

tourist rest house, northern flank Mansar Bazaar, eastern flank Sesnag Temple, Boat Club and at southern flank wild life sanctuary are located. The lake basin is thinly populated. However increasing impact of local residents and tourists are causing ecological imbalance due to influx of domestic sewage, detergents and deforestation in the lake basin.

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 38.25 meter. The maximum length and width of the lake is 1204 metres .and 645 metres, respectively. The lale mean width is 490 meters and mean depth 20.97 m. Circunference of the lake is 3.4 km. 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.

Medlicott (1876) first studied the geology of the Siwalik belt in Jammu Region. Among various workers, Wadia (1928), Hazra (1938), Bhatt (1963) 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 of Jammu region is ideal for detailed geological studies and represents as the reference section for the Siwalik Group.

The oldest litho-unit 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 grey 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.

2.2 Flora and Fauna

The reserve forest on the western bank of the catchment covers 0.11 km^2 and 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. This 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 (Zutshi, 1985). 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.

Trellis and parallel type drainage pattern around the lake basin are evidence of the structural control on the drainage pattern. Sharp turns straight reaches of streams are controlled by joints, fractures and faults which are developed due to tectonic activities of Himalaya. These geomorphic features indicate that Mansar lake came into existence due to neotectonic movements of the Siwalik Himalaya.

3.0 REVIEW OF LITERATURE

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 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; Chander 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 METHODOLOGY

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 water stored in lakes commonly not uniformly mixed. Thermal stratification and associated changes in water composition are the most frequently observed effects. Single samples from lakes or reservoirs can be assumed to represent only the spot within the water body from which they come. 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. Along the cross section X - Y at three spots i.e., A, B and C (Fig. 1) samples were collected from each three meter depth interval to study vertical variation. 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 (Jain and Bhatia, 1997-1998). Temperature, pH, Electrical Conductivity and TDS were determined in the field at the time of sample collection using portable thermometer, portable pH meter and portable water testing kit.

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 water quality of a lake depends upon various parameters which are influenced by a wide range of natural and man made operations. Temperature, pH, dissolved oxygen, Ec, total hardness, alkalinity, cations and anions variation within the lakes are discussed below:

5.1 Temperature

Temperature variation in lake is most important phenomenon. 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 (Fig. 2).

In July, surface temperature of the lake water was recorded 29^0 C and at 6 meter depth it comes down to 14.6^0 C, and near bottom reaches to 12^0 C (Table 2). In January, temperature in lake water is constant from epilimnion to hypolimnion (Fig. 2).

The temperature difference of 17^0C from surface to bottom during summer and rainy months results into thermal stratification in the lake. For a difference of 10^0 C temperature between two depths in the water columns, the density difference would be 0.0018 (Bhar, 1995-96). This difference in density results into quite stable thermal stratification. Homogeneous temperature conditions in January reveals that mixing of lake water has been started. Pant et al. (1981) pointed out that Nainital lake have sin ie period of vertical mixing and remains stratified from March to November. On the basis of temperature variation, Mansar Lake can classified into epilimnion zone (surface to 3 m depth) thermocline (3 to 9 m) and hypolimnion (9 m to bottom) (Fig. 2).

5.2 pH

pH is important parameter which indicates the acidity and alkalinity condition of lake water. In July pH values varies between 7.96 to 7.6 and in January 8.67 to 6.86 (Table 2). The depthwise analysis indicates that pH is decreasing with depth (Fig 3). 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 Dissolved Oxygen

Dissolved oxygen (DO) in water depends on physical, chemical and biochemical activities in the water body. DO is a important indicator of water pollution. Do values are varying between 2 to 5.8 mg/l in July and 0.6 to 7.1 mg/l in January (Table 2). The maximum values are occuring in the epilimnion and minimum values are found in the hypolimnion. DO decreases below the

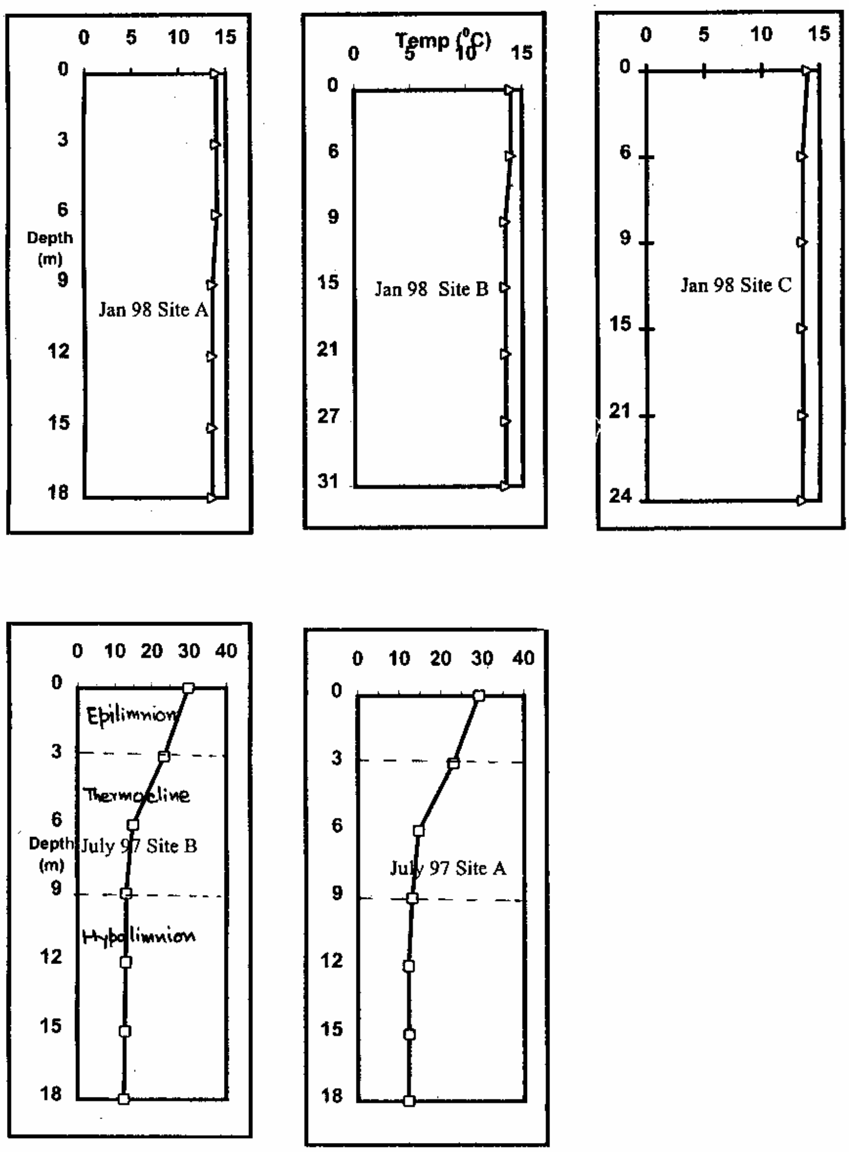

Figure 2: Temperature profiles showing the variation of temperature with the increasing depth in different months.

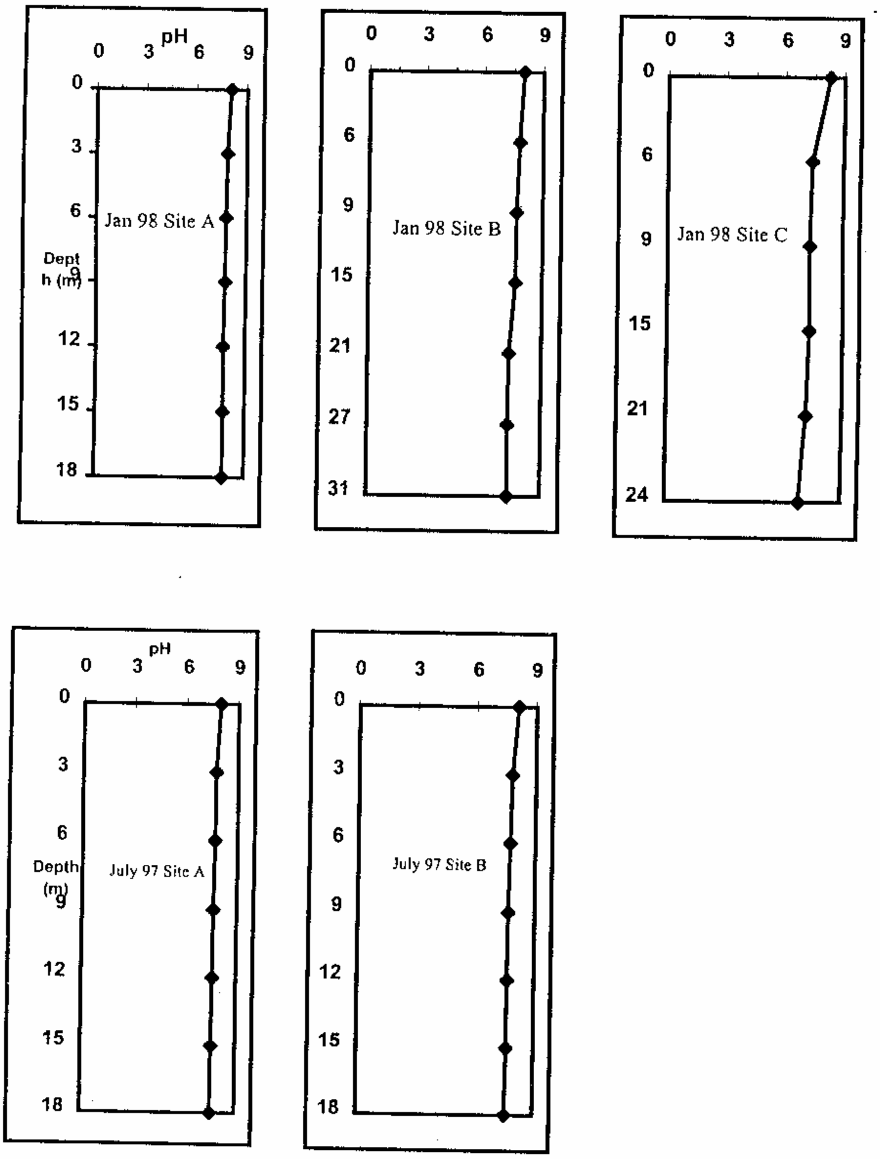

Figure 3: Variation of pH in the lake during study period at different depth.

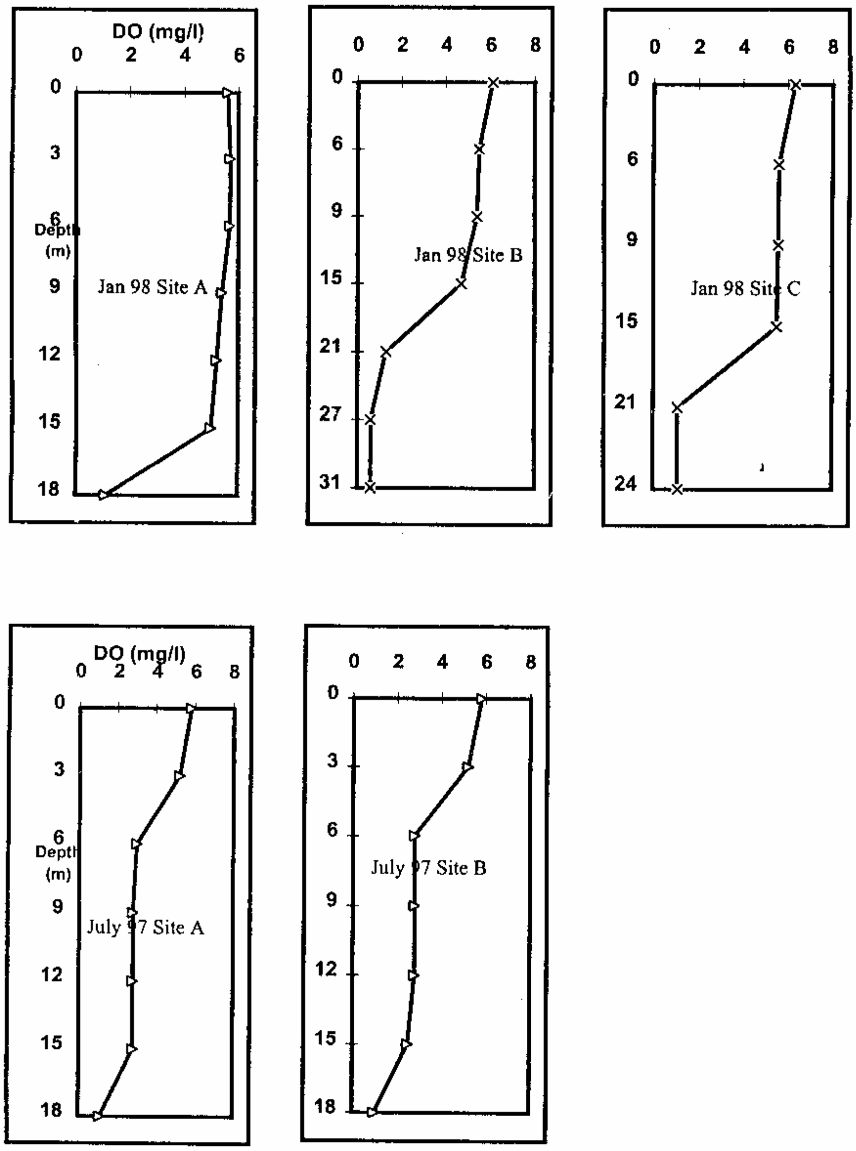

Figure 4: Variation of DO in the lake during study period at different depth.

three meter depth and reached to 2.8 mg/l in the thermocline zone and near the bottom it becomes 1 mg/l. In January DO varies between 4.7 to 6.3 mg/l upto 15 m depth and below the 15 meter depth it reaches o.6 mg/l (Fig. 4). The variation of DO during January indicates that lake is not homogeneously mixed but it indicates process of mixing has been started. Bottom zone in the lake is deficient in the oxygen and showing anoxic conditions.

5.4 Conductivity

Conductivity of the lake water varies between 420 to 520 μ mho/cm (at 25^{0}C) in January and 360 to 450 μ mho/cm (at 25^{0}C) in July (Table 2). The depthwise variation of conductance reveals that it is increasing with the depth at two sites (Site B) but at deepest point, it is again showing the decreasing trend. Mineralization of organic matter under reducing condition prevailing in the hypolimnion water was accompanied by their release and as a result water near the bottom showed higher conductance than that at the surface (Mortimer, 1941).

5.5 Total Hardness

Hardness in lake water is due to calcium and magnesium hardness. Hardness as $CaCO_3$ varies between 72 to 124 mg/l in July, the minimum (72 mg/l) occurs in epilimnion and maximum (124 mg/l) in thermocline zone, while in January, it is varying between 114 to 120 mg/l. The results clearly indicates that during January the variation in hardness is very less due to mixing of the lake water (Fig. 5). On the average higher values of hardness observed 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.

Table 2 Temperature, pH, EC and Dissolved oxygen at different depth in the Lake

DEPTH (M)	JULY - 97				JANUARY - 98				
	Temp (0C)	pH	Ec (μmho/cm)	DO (mg/l)	Depth	Temp (0C)	pH	Ec (μmho/cm)	DO (mg/l)
Site A					Site A				
0	29.2	7.96	360	5.8	0	14	8.05	420	5.6
3	23	7.74	390	5.2	3	14	8.67	430	5.7
6	14.6	7.66	440	2.8	6	14	8.55	420	5.1
9	13	7.64	440	2.8	9	13.5	7.75	430	5
12	12.2	7.63	420	2.9	12	13.5	7.44	490	5.2
15	12.3	7.6	420	2.8	15	13.5	7.7	520	6
18	12.2	7.64	420	2.1	18	13.5	7.85	510	1.1
Site B					Site B				
0	29.8	7.6	360	5.8	0	14	8	420	7.1
3	23.4	7.81	380	5.2	6	14	7.6	440	5.5
6	15	7.62	450	2.8	9	13.5	7.66	420	5.4
9	13	7.66	430	2.8	15	13.5	7.83	490	4.7
12	13	7.64	420	2.8	21	13.5	7.24	530	1.3
15	12.8	7.62	420	2.5	27	13.5	7.03	500	.6
18	12.4	7.63	420	2.0	31	13.5	7.3	470	0.6
					Site C				
					0	14	8.25	400	6.3
					6	13.5	7.4	420	4.6
					9	13.5	7.31	430	4.4
					15	13.5	7.3	420	5.5
					21	13.5	7.15	500	1.1
					24	13.5	6.86	510	1.1

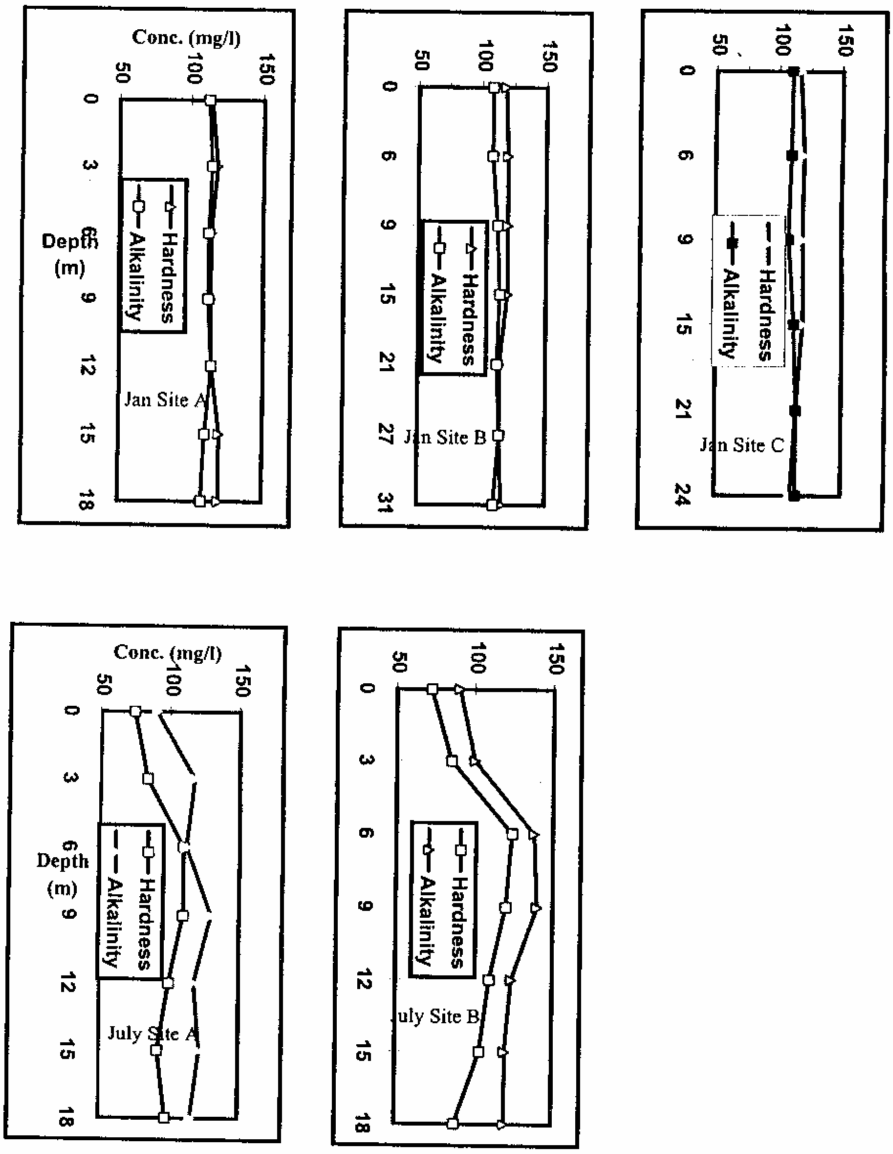

Figure 5: Variation of hardness and alkalinity in the lake during study period at different depth.

5.6 Alkalinity

Alkalinity of the water was mainly due to bicarbonate ions. It is varying in the lake water. In July, bicarbonate concentration is varying between 90 to 140 mg/l with the average 117 mg/l. The minimum values are occuring in the epiliminion zone and maximum concentration in the thermocline area. In January, bicarbonate values are showing very less variation from surface to bottom (Fig. 5). It is having positive relation with the hardness of water.

5.7 Variation of Cations

The cations such as calcium, magnesium sodium and potassium are determined in the laboratory. Calcium is the most dominating cation in the lake water. The cations concentration in the lake water in descending order is as Calcium > Sodium > Magnesium > Potassium. The calcium concentration varies between 21 to 34 mg/l in July and 29 to 34 mg/l in January (Fig. 6). The average concentration of Ca in January at site A,B and C are 31.7, 31.7 and 31.5 mg/l, respectively while in July average value at the sites A and B are 28 and 29 mg/l.

Concentration of the magnesium in July varies between 4 to 9 mg/l and 8 to 10 mg/l in the January. Sodium varies from 9 to 10 mg/l in July and January both months. Potassium ranges between 2.7 to 2.9 mg/l in July and 3.07 to 3.76 mg/l in January (Fig. 7). In January, cations value reveal negligible variation from surface to bottom while in July calcium is higher in the thermocline zone and Mg is showing increasing trend towards lake bottom while Na and K are constant (Fig. 6 and 7). On the average cations concentration are higher in January in comparison to July. Concentration of hardness, alkalinity and cations suggest that mixing of lake water has been started but it is not homogeneously mixed yet.

5.8 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. In depthwise analysis, marked variation in the concentration of anions have been observed in the epilimnion, metalimnion and hypolimnion. Bicarbonate, nitrate and phosphate are higher in the thermocline zone and minimum in the epilimnion zone (Fig. 8 and 9). Chloride and sulphate ions concentration are showing negligible variation from surface to bottom in the lake.

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 concentration of nitrate in the surface water in January (0.76 mg/l) is higher than the July. During study period, phosphorus in lake water varies between 0.03 to 0.06 mg/l in January and 0.03 to 0.12 mg/l in July. Maximum phosphate concentration was recorded in thermocline zone during July 0.12 mg/l while in January it shows negligible variation in the lake from epilimnion to hypolimnion (Fig. 9).

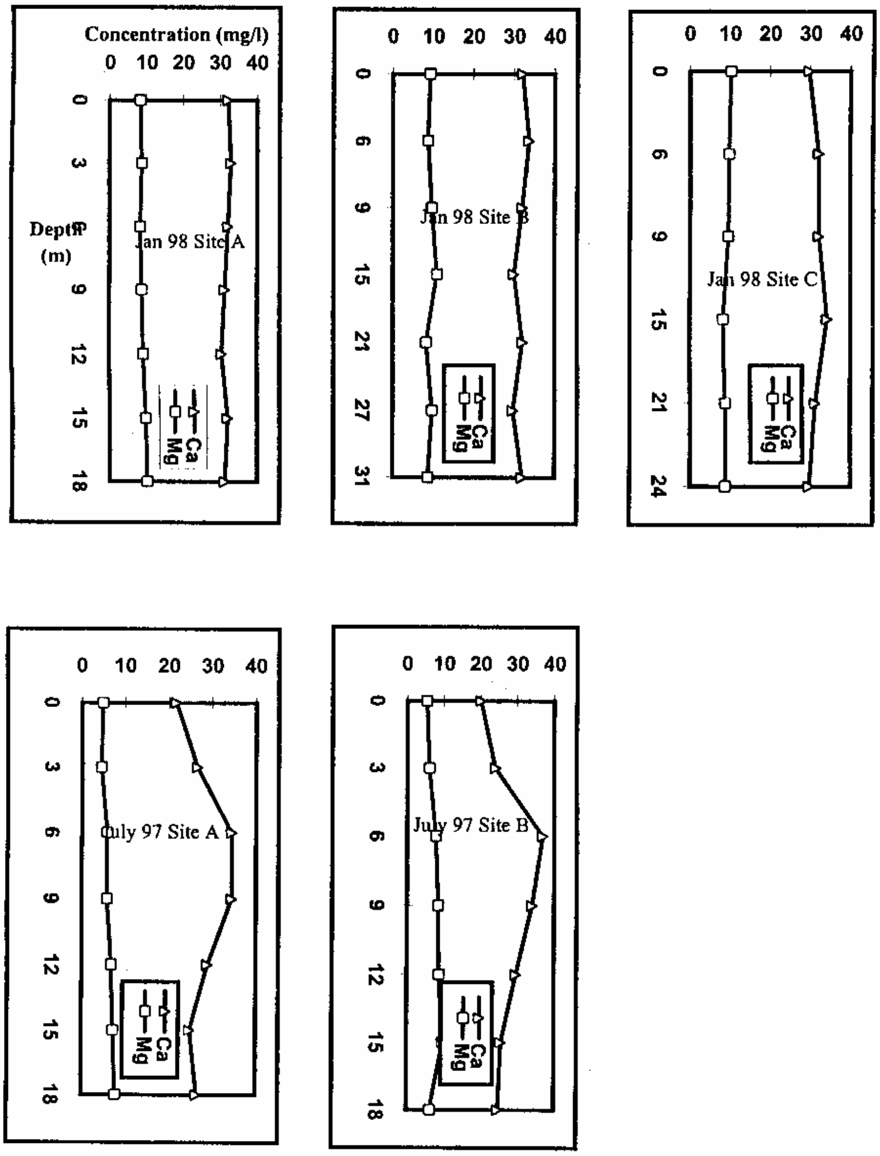

Figure 6: Variation of Ca and Mg in the lake during study period at different depth.

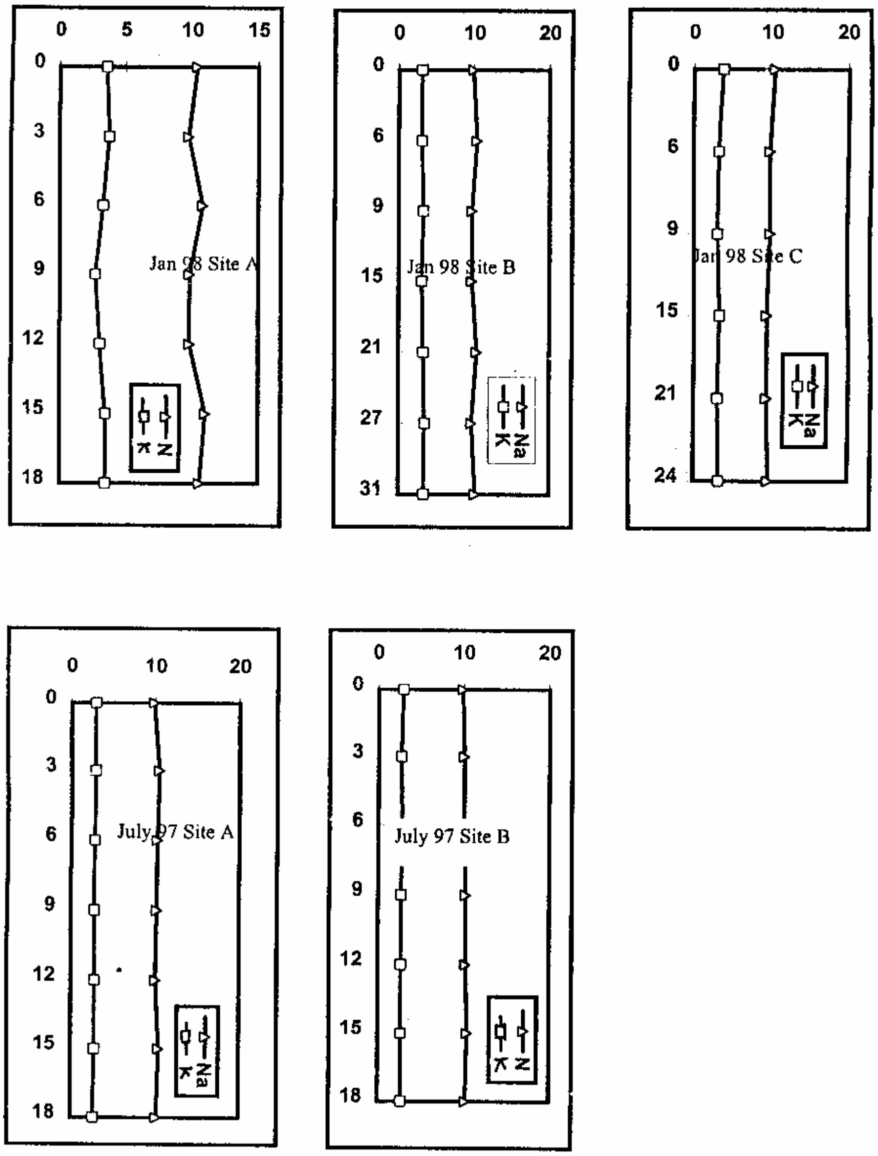

Figure 7: Variation of Na and K in the lake during study period at different depth.

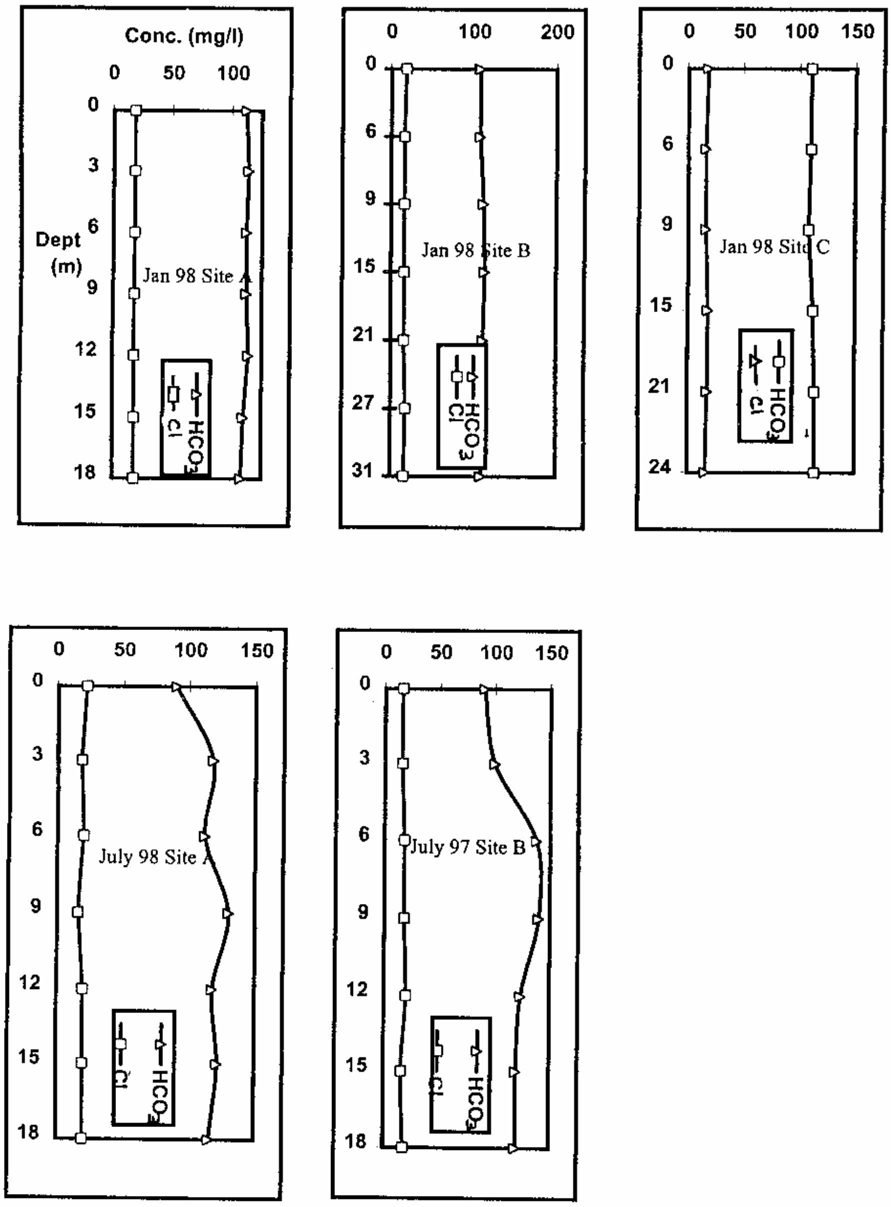

Figure 8: Variation of HCO_3 and Cl in the lake during study period at different depth.

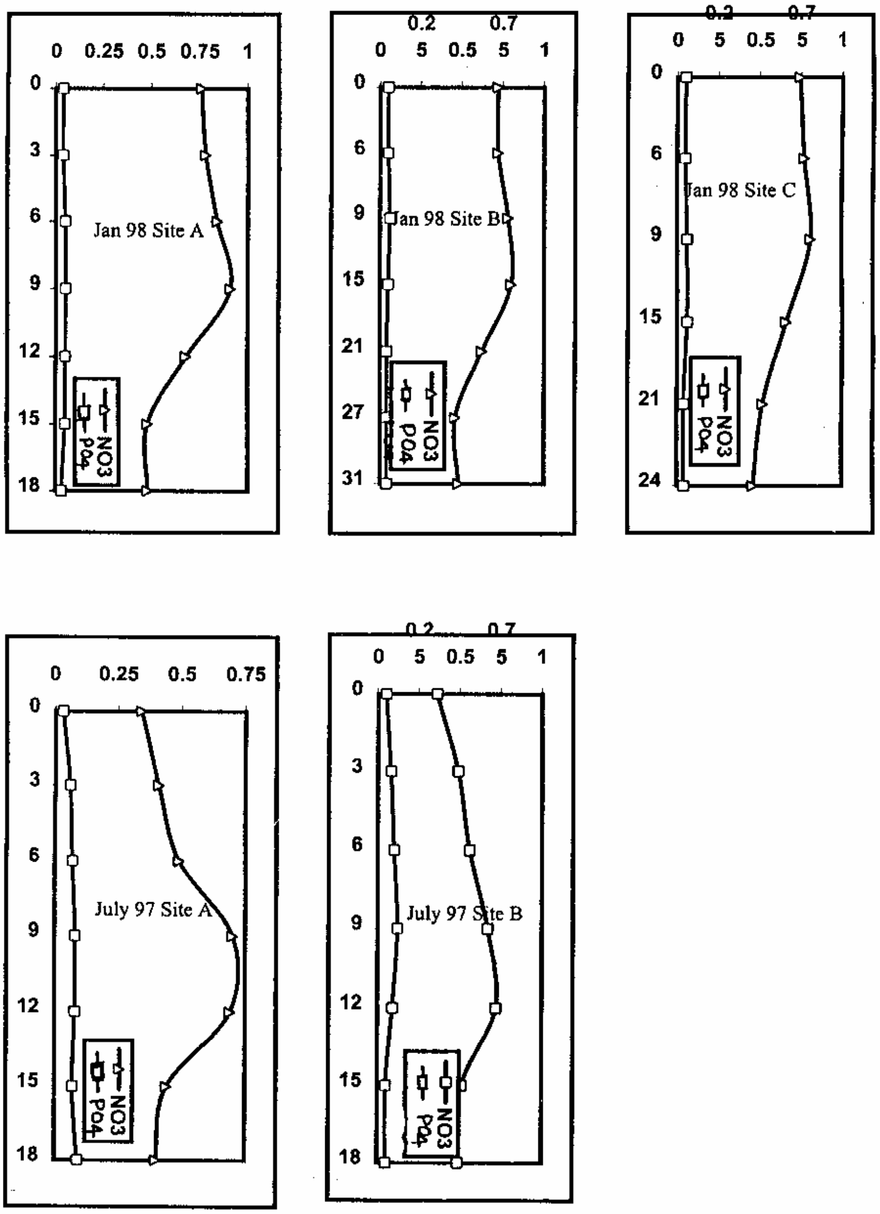

Figure 9: Variation of NO_3 and PO_4 in the lake during study period at different depth.

The concentration of phosphorus is greater than 0.03 mg/l during study months. 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 oligolroplic, 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.

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 lakes 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.

5.9 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. (Piper, 1953). The Piper's diagram consists of two lower triangle field and a central diamond shaped field (Fig. 10). 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.

The water quality data (Table 3) of lake are plotted in the Piper Diagram. Figure 10 depicts the location of samples of different depths collected during July and January. The cation plots in the diagram reveals that majority of the samples lie in the calcium type. The anion plot in the diagram reveals that samples fall in bicarbonate type. All these samples fall under the

Table 3 Water Samples Identification Plotted in the Piper and US Salinity Diagrams and their SAR and RSC value.

S. No.	Sample Site		Label in Pipèr and US Salinity Diagram	SAR Value	RSC Value
1	July Site A	Surface	1	0.50	-0.005
2		3 m	2	0.50	0.25
3		6 m	3	0.43	-0.36
4		9 m	4	0.43	-0.07
5		12 m	5	0.44	-0.06
6		15 m	6	0.47	0.15
7		18 m	7	0.45	-0.05
8	Site B	Surface	8	0.51	0.03
9		3 m	9	0.47	-0.06
10		6 m	A	0.39	-0.21
1		9 m	B	0.41	-0.10
12		12 m	C	0.42	-0.16
13		15 m	D	0.45	-0.11
14		18 m	E	0.48	0.21
15	Jan Site A	Surface	F	0.42	-0.44
16		3 m	G	0.39	-0.49
17		6 m	H	0.44	-0.44
18		9 m	I	0.40	-0.44
19		12 m	J	0.40	-0.41
20		15 m	K	0.44	-0.59
21		18 m	L	0.42	-0.63
22	Site B	Surface	M	0.40	-0.59
23		6 m	N	0.41	-0.63
24		9 m	P	0.39	-0.56
25		15 m	Q	0.39	-0.53
26		21 m	R	0.42	-0.44
27		27 m	S	0.40	-0.41
28		31 m	T	0.41	-0.51
29	Site C	Surface	U	0.42	-0.52
30		6 m	V	0.40	-0.59
31		9 m	W	0.39	-0.61
32		15 m	X	0.38	-0.54
33		21 m	Y	0.38	-0.41
34		24 m	Z	0.40	-0.33
35		Surface	A	0.41	-0.31
36		Surface	B	0.41	-0.27
37		Surface	C	0.39	-0.35
38		Surface	D	0.39	-0.39
39		Surface	E	0.39	-0.40
40		Surface	F	0.39	-0.28
41		Surface	G	0.48	0.002
42		Surface	H	0.43	0.11
43		Surface	I	0.42	0.009
44		Surface	J	0.42	-0.19

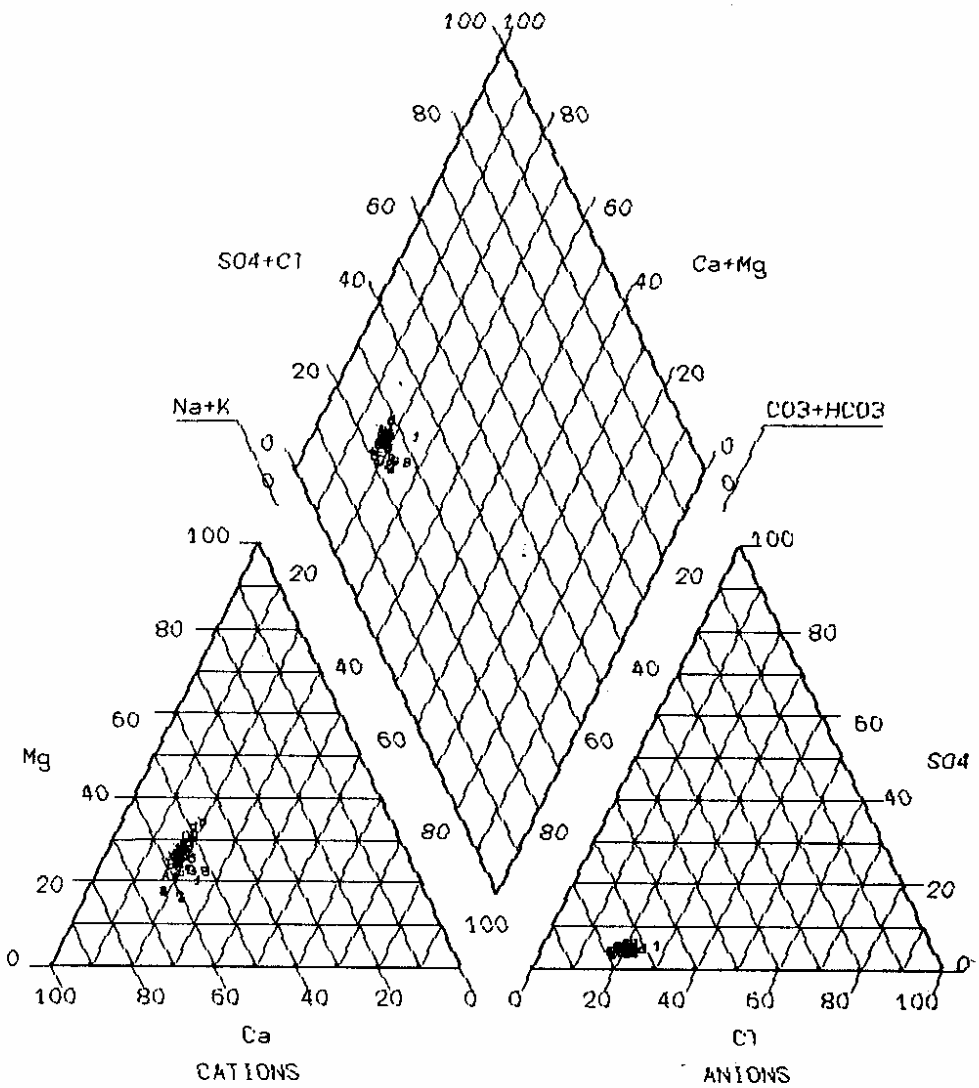

Figure 10: Piper diagram showing chemical facies of the lake water.

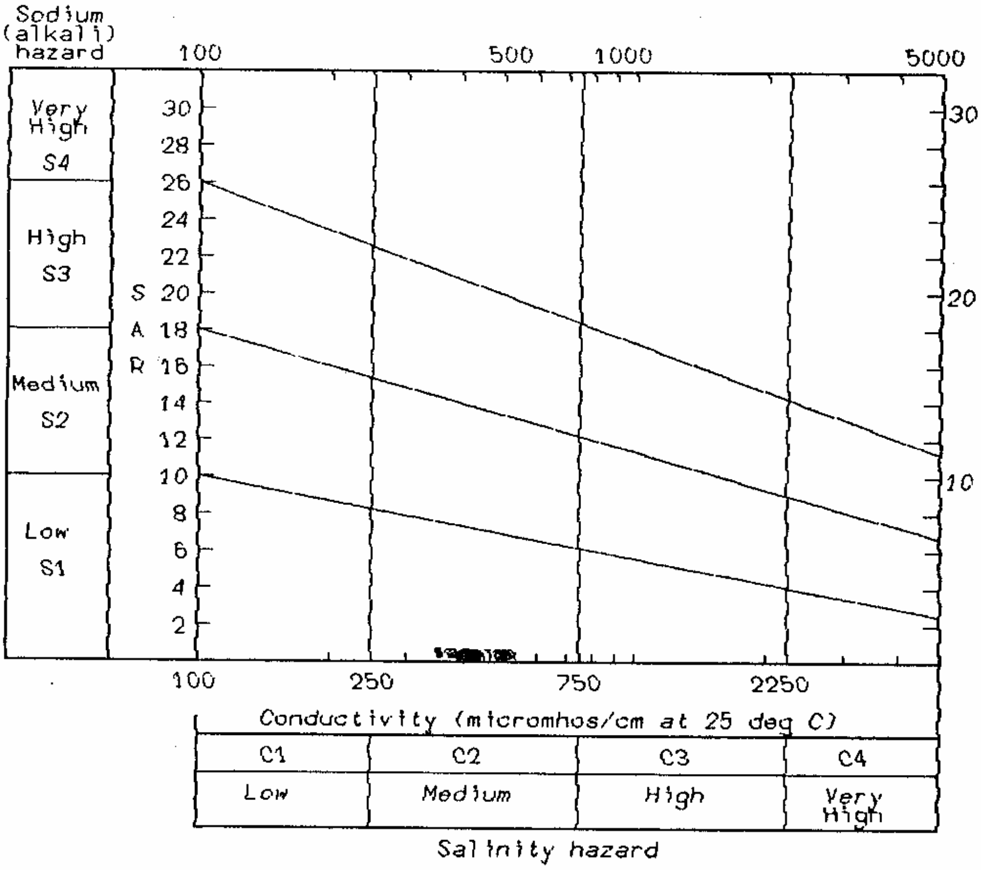

Figure 11: US Salinity diagram showing the suitability of lake water for irrigation.

facies Ca, Mg - CO_3, HCO_3 facies. 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.

5.10 Water Quality Evaluation For Irrigation and Drinking Purposes

5.10.1 Evaluatin for Irrigation Purposes

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.

Salinity is usually reported as electrical conductance (EC). The average electrical conductance of lake water is below 750 micro mhos/cm (Table 2) and total dissolved solids were also within 800 mg/l which are reported for best quality for irrigation purposes. However, specific limits of permissible salt concentrations for irrigation water cannot 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 water samples of study period fall under C2S1 (Medium salinity Low Sodium) class (Fig. 11).

Therefore, water of the lake is good for irrigation purposes.

Sodium Adsorption Ratio 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 water samples falls within the excellent class. These values are well below the limit of excellent waters for irrigation (i.e., less than 10.0) (Table 3). It implies that lake water is good for irrigation purposes.

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 thereby decreasing the soil permeability. The Residual Sodium Carbonate (RSC) is as:

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

The Residual Sodium Carbonate value for all the samples have been computed. The results presented in the table 3 shows that the RSC value of all the samples are below the 1.25 meq/l. These results also suggest lake wateris good for irrigation purposes

5.10.2 Evaluation 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 4.

pH value of the lake water varying from at different depth varies between 7.3 to 8.1. The pH values are within the tolerance limit. The total hardness, calcium hardness and magnesium hardness is within the prescribed limit (Table 4).

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 7 mg/l and nitrate occurred between 0.35 mg/l to 0.78 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 is good for drinking purposes. Although 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.

Table 4 **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 (0 m depth)		Middle (15 m depth)		Bottom (30 m depth)	
		July	Jan	July	Jan	July**	Jan
pH	6.5 - 8.5	7.8	8.1	7.6	7.6	--	7.3
DO (mg/l)	6.0 (min)	5.8	6.3	2.6	5.4	--	0.6
Total Hardness (mg/l)	300 (max)	73	116	98	120	--	128
Ca Hardness (mg/l)	200 (max)	52	78	63	80	--	80
Mg Hardness (mg/l)	100 (max)	21	38	35	40	--	36
Sulphate (mg/l)	250 (max)	6	7	5	6	--	6
Nitrates (mg/l)	20 (max)	0.35	0.74	0.48	0.65	--	0.48

Note: July** Data not recorded.

6.0 CONCLUSIONS

Temperature variation indicates that mixing of lake water takes place in winter and remains stratified in summer and rainy season. Phosphate values in lake water reveals that lake has been entered into eutrophic stage. Anthropogenic activities has accelerated the eutrophication process in the lake. Bottom zone in the lake is deficient in the oxygen and showing anoxic conditions. Physico-chemical parameters of lake water were found within the limits of class A drinking water except dissolved oxygen. DO value is less than 6 mg/l below the 6 m depth in July and below 15 m depth in January. It reveals that water between 3 to 15 m depth is more suitable for drinking purposes. Lake water is good for irrigation purposes.

For the details study of the Mansar Lake a collaborative study with State Pollution Control Board, Jammu has been started since August 1998. This study comprises bathymetric survey, monthly water quality study and sedimentation rate study. The completion of this project will provide more detail picture of lake water quality characteristics.

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