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# **Hydrochemistry of Lake Jaisamand, Udaipur district**

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**MASTER OF PHILOSOPHY**

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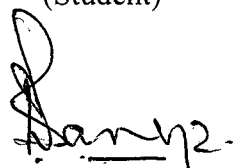
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**CERTIFICATE**

The research work embodied in this dissertation titled " Hydrochemistry of Lake Jaisamand, Udaipur District ", has been carried out in the School of Environmental Sciences, Jawaharlal Nehru University, New Delhi. This work is original and has not been submitted in part or full for any other degree or diploma in this or any other University.

  
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# ***CHAPTER 1: INTRODUCTION***



**INTRODUCTION**

The very existence of life on planet earth is fundamentally braced with the availability of water. Throughout human history, water has always been considered to be an important natural resource for human welfare and economic development. For example the river Nile is regarded as a gift of survival of Egypt civilization likewise the Colombia river is essential for the development of the Tennessee valley in the USA as is the river Volga to the development of western Russia (Than and Biswas, 1996).

Distribution of water in biosphere shows that out of the enormous quantity of water existing on earth surface, only a small proportion is actually usable by human beings. The oceans alone constitute 80% of the hydrosphere and 19% is in the pores of rocks beneath the earth's surface, 1% is in the form of ice, inland surface water (lakes and rivers) accounts for barely .002% (Garrels and Mackenzie, 1971). Estimates put this at 31000-47000 cubic kilometer a year and are important in maintaining terrestrial life. Freshwater however is distributed unevenly over the earth's surface. Most of the earth freshwater is concentrated in the high latitudes - in polar ice sheets and mountain glaciers. In many regions of the world, distribution of water is seasonal, runoff occurs only in rainy season, rest of the year rivers remains dry. In India, water is unevenly distributed as west Rajasthan receives only 100mm rainfall annually, while Cherapunji in Meghalaya gets 11000 mm annually. Rajasthan supports 8% of India's population with only 1% of the country's water resources. The relics of past shows that in Rajasthan there were well-planned systems for conservation of water

resources and drainage. In the middle era lakes, bunds, tankas, talao were built by ruling kings with the following aims:

- Independent, sufficient storage capacity (to cater even for years together) replenishable from rains for drinking purpose.
- Huge water storage in and around to protect the kingship against the raids and attacks.
- Irrigation purposes.
- Recreational purposes and
- Religious purposes.

Increasing population pressure, haphazard urbanization and industrialization has imposed unbearable pressure on the rivers and lakes in the world in general and more specifically in South East Asia, a region of developing countries. Developed countries have far less water pollution problem compared to developing countries due to the availability of advanced technologies resources and community involvement in the water quality management program. Fig (1.1) shows the increasing gap between water supply and population growth. It can also be seen that not all water withdrawn is well used, and thus improving efficiency and reducing loss is needed to make up some short -fall, at least till approximately 2020. Pollution of existing supplies reduces the usable portion of withdrawn water. It would appear that after 2020 a new approach to water management is required. For e.g. Udaipur lakes, to which the city owes its identity are in pitiable condition, due to dumping of domestic and industrial waste, which leads uncontrolled growth of water hyacinth and heavy siltation. 60% of lakes have dried up, which in turn cause lowering of ground water level in that region.

Besides anthropogenic impacts, hydrochemical studies of the lake basin provide basic information on the water chemistry and weathering processes taking place in that region,

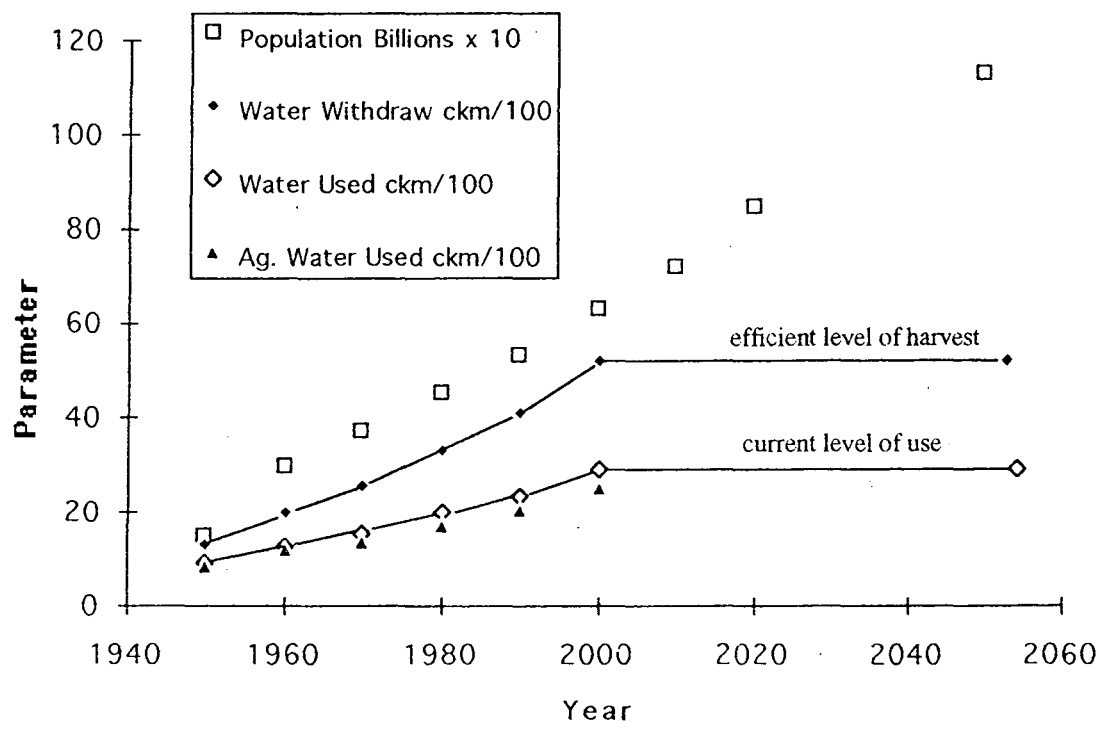


Fig. 1.1: Water use and Population (World Resources Institute 1994-95)

along with impact of other factors on water chemistry viz. geological, climatic, biotic, anthropogenic.

The above discussion indicates the importance of lakes in a state like Rajasthan. Lake Jaisamand situated 54 km S.E. of Udaipur, is one of the oldest man-made lakes in India. The lake Jaisamand was built in 1685 AD by Maharana Jaisingh of Mewar dynasty by the damming river Gomti, which has four tributary rivers. The earlier study conducted on this lake was, "Studies on energy flow and primary productivity of lake Jaisamand in relation to fisheries potential" by Department of Limnology M.L. Sukhadia University, Udaipur in 1984. There has been practically no attempts made to study the hydrogeochemistry, weathering processes, seasonal and vertical variation in physical and chemical parameters and factors controlling ionic composition of water in this important lake basin. Hence in this study, "Hydrochemistry of lake Jaisamand", aspects related to ionic composition of lake water, weathering processes, seasonal and vertical variation in physical and chemical parameters and their controlling factors have been studied and discussed.

## **Objective**

The following are the main objectives of the present study:

- To study the major ion chemistry of lake Jaisamand.
- To study seasonal variation in physical and chemical parameters.
- To study vertical variation in physical and chemical parameters.
- To find out possible sources and mechanism controlling water chemistry.
- To study the impact of regional lithology, climate, vegetation and anthropogenic factors on water chemistry of lake Jaisamand.

### **Scope of the present study:**

Lake Ecosystem is perhaps the most diverse aquatic ecosystem, exhibiting a wide range in its chemical environment, size, shape and the dynamic of water exchange. Chemical composition of any water body in response to geological, climatic, biotic, anthropogenic activities on the regional and local scale depends on hydrological cycle and associated biogeochemical cycle. The present research work will provide the means to identify the complex and interlinked hydrogeochemical processes in the lake Jaisamand. Determination of the physical chemical characteristics of lake Jaisamand will also provide the necessary baseline data against which the damage caused by anthropogenic, agricultural, domestic and industrial activities will be assessed in that particular area. It is particularly important to maintain the lake ecosystem in response to continued degradation of water quality by rising population, industrial, domestic and agricultural activities.

## ***CHAPTER 2: LITERATURE REVIEW***

**LITERATURE REVIEW**

Several workers have been studied world water composition (Livingstone, 1963; Meybeck, 1979,1983). The information on the average composition of global water indicates that the calcium and bicarbonate ions represent the dominant cation and anion respectively. Nearly 50% of the world water is characterized by the composition  $Ca^{++} > Mg^{++} > Na^{+} > K^{+}$  and  $HCO_3^{-} > SO_4^{-} > Cl^{-}$  (Meybeck, 1981). Gibbs (1970) distinguished three major water types on the basis of cation and anions. Calcium and bicarbonate were the dominant ions in the rock dominance group, where rock weathering was the major mechanism controlling solute content and total ion concentrations typically ranged between 50-1000 mg/l. Sodium and chloride were dominant in the other two groups, which were further distinguished by their overall solute content. The rain dominance group, where precipitation provided the major controlling mechanism was characterized by low total ion concentration ( $<50mg\ l^{-1}$ ), whereas the evaporation-crystallization type representing waters in which calcium bicarbonate has precipitated was associated with high levels of mineralization ( $1000mg\ l^{-1}$ ).

Standing inland waters are perhaps the most diverse of aquatic systems, exhibiting a wide range in their chemical environment, size, shape and the dynamics of their water exchange. They range from seasonal ponds to virtual inland seas such as lake Victoria. Lakes are bodies of water usually isolated from each other, a fact, which is used as the basis of their variability from other surficial aquatic systems. Lakes tend to be supplied with dissolved substances largely through their inflowing rivers, and to a lesser extent, from rainwater. The ionic concentration of the lakes is higher than that of the major inflows as ions tend to

accumulate within lakes owing to evaporation, biological turnover and interaction with sediment.

## **2.1. Processes controlling water chemistry of the lakes:**

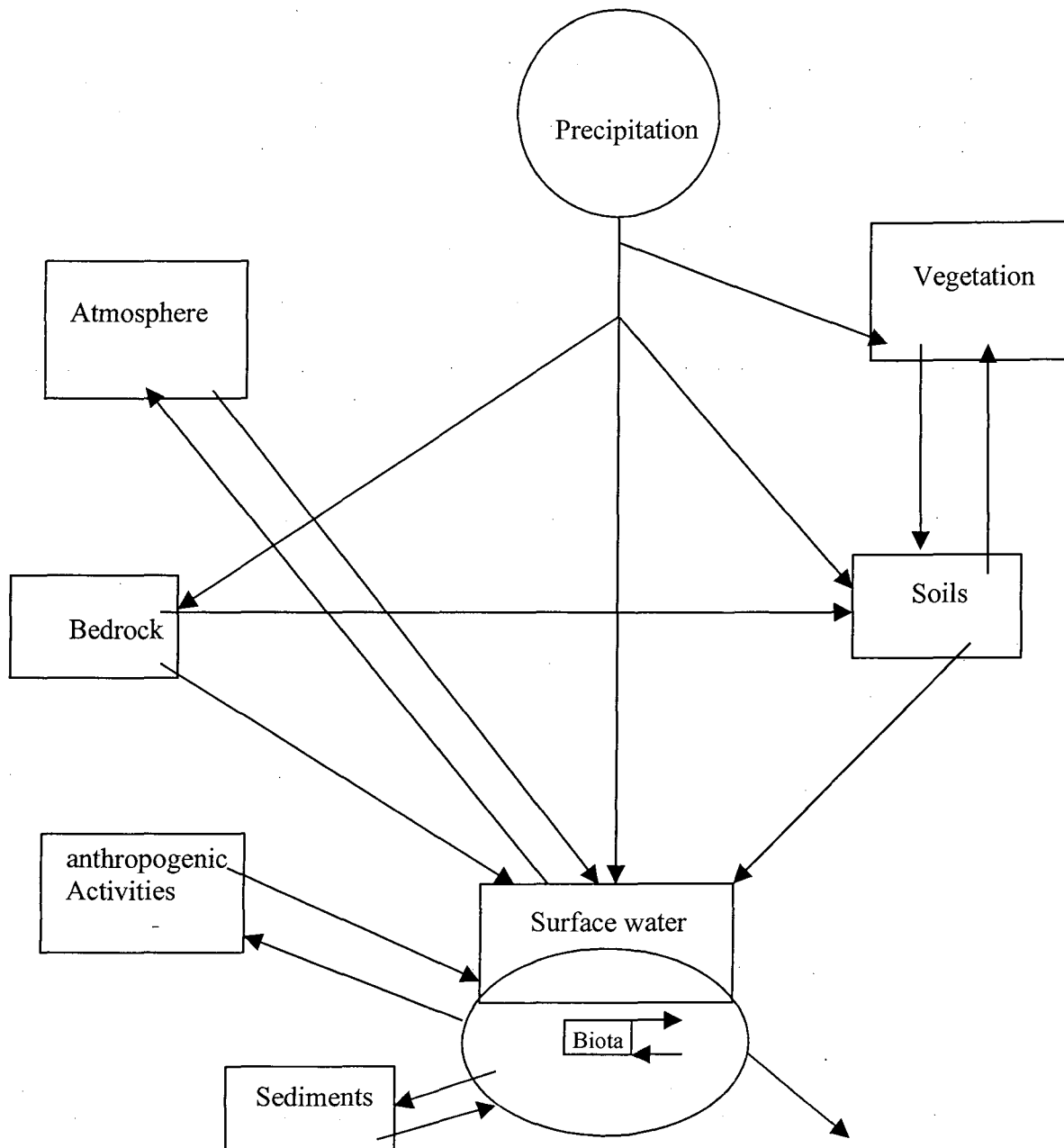
Water chemistry of lake fundamentally depends on; rock weathering processes (Miller, 1961; Drever, 1977, 1982). Other processes such as, climatic, atmospheric, biotic and anthropogenic have secondary impact on composition of water (fig. 2.1).

### **2.1.1 Rock weathering processes:**

The composition of soil and rock and their ion exchange capacities influence both rate of weathering and ion supply to runoff and percolating water. Four general processes of weathering control ion supply, viz. solution, oxidation–reduction, the action of  $H^+$  ions and the formation of complexes (Gorham, 1961; Carroll, 1962).

- The chemical weathering of the rocks is mainly performed by the action of  $H^+$  (which derives from the dissociation of carbonic acid) on minerals in the rock. The importance of carbonic acid in weathering is illustrated by the high proportion of bicarbonate ions in most lake waters. Strong acids ( $H_2SO_4$ ,  $HNO_3$ ) in rainfall originating from air pollution accelerate the rate of weathering (Likens, et al, 1972, 1979). Colloidal acids of humic compounds and acid clays can also supply large amount of  $H^+$  ions for weathering.
- Solution is important, primarily in sedimentary deposits rich in soluble salts. Leaching of marine deposit results in an enrichment of  $Na^+$ ,  $K^+$ ,  $Cl^-$  relative to other ions in recipient lake waters.





**Fig (1.2) Processes controlling water chemistry of lakes.**

- Oxidation-reduction processes primarily affect iron, manganese, sulfur, nitrogen, phosphorus and carbon compounds in lake water.
- Certain soluble organic molecules can chelate or complex ions by bonding, thereby preventing these ions from reacting with others.

### **2.1.2 Climatic processes:**

Climate has a marked effect on the salinity of the lake waters. Saline lakes occur in regions with fluctuating long-term climate, which are often exposed to periods of severe aridity (Great Salt Lake of Utah, Dead Sea, Borax Lake of North California, Chilka and Sambhar Lakes of India). Other significant climatic factors influencing salinity are temperature, wind and rainfall. Temperature influences the rate of rock weathering. Tropical water, for example, which drains strongly weathered soils are usually poor in electrolytes and a large part of the total composition consist of silica (Meybeck, 1984). Wind direction and speed may strongly affect the chemical composition of atmospheric precipitation. Losses of atmospheric salinity are greater in low elevation due to turbulent air masses.

### **2.1.3 Atmospheric processes:**

The atmosphere is a significant source of salinity for many dilute fresh waters and for some saline lakes of arid regions. Rainfall carries much of the atmospheric salt to lake and river waters (Gorham, 1961; Carroll, 1962). Sea spray is the major source of atmospheric  $\text{Na}^+$ ,  $\text{Cl}^-$ ,  $\text{Mg}^{++}$  and  $\text{SO}_4^-$ . The effect of atmospheric transport of ions can be seen in lakes enriched with  $\text{Na}^+$  and  $\text{Cl}^-$  in coastal maritime regions. An additional source of atmospheric salinity is

industrial and domestic air pollution (Likens et al, 1972). For example, in lake Erie, an increase of chlorine content by 70% in last 50 years is recorded by Ownbey and Kee, 1967.

#### **2.1.4 Biotic Processes:**

Biological activity may also exert a strong influence on solute fluctuations in lake through the effect of vegetation die back and leaf fall and the impact of seasonal uptake by plants and animals (Edward, 1973; Laey and Ladle, 1976). At the time of summer stratification due to higher rate of photosynthetic activity, concentration of  $\text{Ca}^{++}$  and  $\text{HCO}_3^-$  in epilimnion depletes, which results in an increase in pH. It has been suggested that uptake by diatoms is the most important factor influencing the silica content of lakes (Edward, 1974; Casey, 1981 et al).

#### **2.1.5 Anthropogenic Processes:**

Increasing population pressure, haphazard urbanization and industrialization has imposed unbearable pressure on rivers and lakes via, increasing consumption of water on the one hand and quality deterioration by dumping of domestic, industrial and agricultural waste on the other hand. Surface runoff from agricultural land contains high concentrations of nutrients, pesticides and other harmful chemicals, which ultimately goes into lakes and rivers. Higher tourism pressure over the lakes deteriorates water quality. Lake Ooty, Dal, Nainital and lakes of Udaipur (Fathasagar, Pichola, and Udaisagar lakes) reflect deteriorating water quality due to anthropogenic activities.

There are three major mechanisms which controls water chemistry viz. rock-dominance, atmospheric-precipitation and evaporation-crystallization processes (Gibbs,

1970, Kilham, 1975; Stallard and Edmond, 1982). Rock dominance lakes are rich in calcium and bicarbonate ions. Atmospheric-precipitation-controlled lakes are characterized by high  $\text{Na}^+$  to  $\text{Ca}^+$  and these fresh water lakes are limited to immediate maritime coastal regions. The third major mechanism that influence salinity of surface water is evaporation-crystallization, with subsequent sedimentation of mineral salts. These lakes are generally located in hot arid regions. Thermodynamic equilibrium conditions determine the maximum amount of mineral that can be dissolved for a given set of environmental condition and the actual magnitude of solute loss depends on the rate of reaction and removal of materials into solution. The relative stability of different minerals can be considered in terms of physical characteristics of the minerals which may imply weakness for penetration by water i.e., grain size, surface area, cleavage hardness, solubility and crystal and atomic structure (Curtis, 1976).

## **2. 2. Distribution of major ions in lake:**

Distribution of major cations and anions in lake are separable into:

**Conservative ions:** Concentration of  $\text{Mg}^{++}$ ,  $\text{Na}^+$ ,  $\text{K}^+$  and  $\text{Cl}^-$  are high but are relatively conservative and under goes minor spatial and temporal fluctuation due to biotic utilization or biotically mediated changes in the environment, i.e., very little is used.

**Dynamic ions:**  $\text{Ca}^{++}$ ,  $\text{CO}_3^{--}$  and  $\text{SO}_4^{--}$  concentrations are lower, but are dynamic i.e., their concentration is strongly influenced by biotic metabolism, and they exhibit more seasonal variability.

### **2.3 Seasonal variation:**

The seasonal variability in salinity of tropical and subtropical lakes has been described by many researchers (Talling, 1957; Bedle, 1966; Ganpat i, 1964,1970; Sreenivasan 1968,1970). Seasonal variation is generally controlled by meteorological, geological, biological and anthropogenic processes. Concentration of solutes in winter increases due to diffusion of solutes from the sediments (Hutchinson, 1975; Likens, 1985; Schindler, 1986) and an influx of soil drainage water during a period of little or no flushing (Hutchinson, 1975; Stoddard, 1987). Biological activities may also exert a strong influence on seasonal solute fluctuations in lake through the effect of vegetation die back and leaf fall along with, seasonal uptake by plants and animals (Edward, 1973; Laey and Ladle, 1976). It has been suggested that uptake by diatoms is the most important factor influencing the silica content of lakes (Edward, 1974; Casey, 1981 et al).

### **2.4 Thermal Stratification:**

Layering of the water due to temperature induced density difference is known as thermal stratification. Lakes are thermally stratified as they experience strong contrasts in seasonal conditions. In summer surface water are warmed and becomes less dense. Water column is divided into three regions due to thermal stratification viz. epilimnion, metalimnion and hypolimnion.. In late summer and fall, circulation starts with gradual cooling of the water column. In winters, when temperature of the water reaches the point of maximum density at 4°C, surface ice can form which results in inverse stratification. As spring progresses, circulation of a stratified lake proceeds by a combination of direct solar radiation's, turbulent

conduction and density currents (Hutchinson, 1941). Many variations are found on stratification of lakes. Stratification depends on regional differences in climate, individual characteristics of the lake morphometry and movement of the water masses. F.A. Forel, who had worked on lake Geneva, Switzerland (1892, 1895 and 1904) classified lakes on the basis of their thermal condition viz. Temperate lake, Tropical lake and Polar lakes. Löffler (1956) and Hutchinson (1957) classified lakes on the basis of circulation patterns. The thermal stratification is always supplemented by the chemical stratification. Vertical distributions of ions depend on temperature gradient, winds, surface runoff, and biotic activity. Decrease in concentration of calcium and inorganic carbon in the epilimnion and metalimnion are directly associated with rapid increase in the rate of photosynthesis by phytoplankton and littoral flora (Wetzel, 1974). Since the concentration of  $Mg^{++}$ ,  $Na^+$ ,  $K^+$  and  $Cl^-$  are relatively conservative, the specific conductance follows the change in  $Ca^{++}$  and  $HCO_3^-$  concentration in nearly a 1:1 relationship ( $r=0.997$ ; Wetzel, 1974).

## **2.5 Water chemistry of some lakes in India:**

Different landmasses of our country, with varying geology, physiography of terrain and agroclimatic conditions and anthropogenic activities provide varying patterns of lake water chemistry. Considerable work has been done on the physico-chemical dynamics of lentic aquatic system viz. Zutshi and Vyas (1973), Kant (1979), Das and Pandey (1978), Sharma and Pant (1979), Pant et al (1985). Most Indian lake have temperature well above 4°C. The thermal stratification is either lacking altogether or evident as a weak thermal gradient which has not been considered true thermocline by Sreenivasan (1965, 1968). For a true thermocline development there should be at least a gradient of 3°C per-meter (Ruttner,

1987). Desai and Singh (1979) reported the well -marked thermocline in Rihand reservoir of Uttar pradesh. Thermal gradients of comparable magnitude have also been reported from Udaipur waters (Sharma, 1980; Rao, 1984; Gupta, 1988, 1991).

Transparency has been considered as a function of suspended organic matter and wind action (Edmondson, 1961; Ganpati, 1962 and Green, 1974), whereas Ruth (1955) and Krishnamurthy and Vishwanathan (1968) considered density of plankton population as well to affect the transparency of water. During monsoon, the water clarity gets reduced mainly due to incoming silt and allochthonous organic matter in the lake (Sharma, 1980; Rao, 1984; Gupta, 1988, 1991). pH of most Indian lakes show alkaline nature. The higher pH value reflects greater photosynthetic activity, which utilizes CO<sub>2</sub> thereby shifting equilibrium towards the alkaline side.

Chemical composition of lake water depends on the weathering processes taking place in the catchment areas. Climatic, biotic, atmospheric and anthropogenic activities also exert considerable impact on chemical composition of water. Dominance of cation and anion in lake Nainital shows carbonate weathering, whereas dominance of cations and anions in lake Pichola and Udaisagar reflects silicate weathering ( Das and Singh, 1994, 1995, 1998).

	Lake Pichola	Lake Nainital
Cation:	$\text{Na}^+ + \text{K}^+ > \text{Ca}^{++} + \text{Mg}^{++}$	$\text{Ca}^{++} + \text{Mg}^{++} > \text{Na}^+ + \text{K}^+$
Aniom:	$\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{--}$	$\text{HCO}_3^- > \text{SO}_4^{--} > \text{Cl}^-$

In most Indian lakes, high concentration of calcium and bicarbonate is observed which suggests that intense chemical weathering is taking place in Indian subcontinent (table 6.4).

## ***CHAPTER 3: AREA OF STUDY***



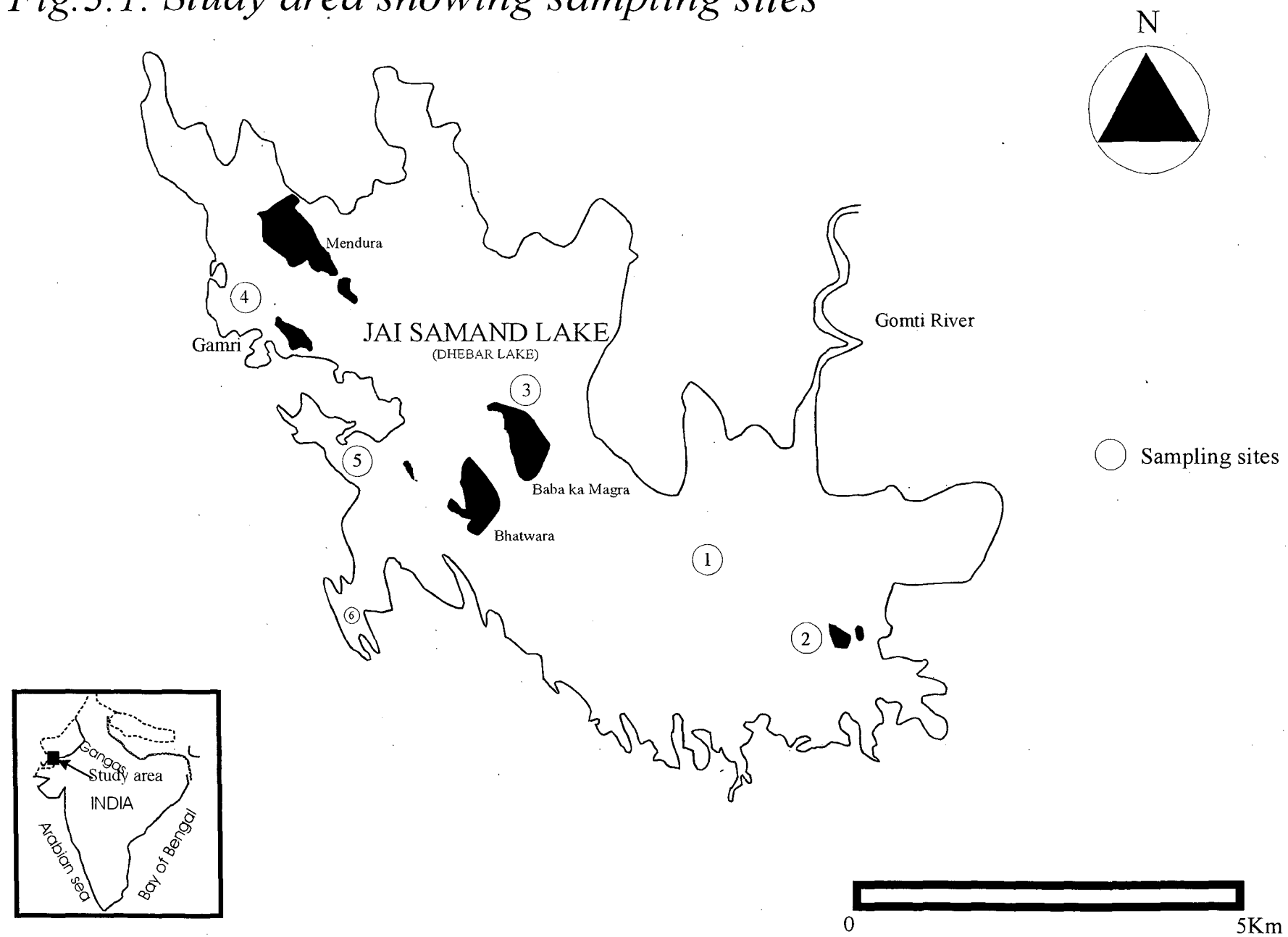
**AREA OF STUDY**

Lake Jaisamand situated 54 km south east of Udaipur at latitude 24 °14' N and longitude 73°53' E (fig. 3.1). It is one of the oldest man made lakes in India. The reservoir Jaisamand was built in 1685 A.D. by Maharana Jaisingh of Mewar dynasty by damming river Gomti which has four other tributary rivers. The lake Jaisamand supports a lucrative fishery perhaps incomparable to any reservoir in India. It has a recreational value as well and is included along with its adjoining game sanctuary in the tourist map of India. This sanctuary was established in 1957 and extends over 52 sq. km of thick forestland.

The shoreline of lake Jaisamand is somewhat irregular having several dendrite processes. The lake is almost surrounded by hills except in the west side where the dam is located. There are eleven islands within the lake that attract several migratory birds in winter. Moreover fishermen community reside in sizable number for whom the marginal cropland area and the fishing in the lake is the source of living.

The lake gets poorly stratified thermally for the major parts of the year. Lake Jaisamand command a total catchment area of about 1127 sq. km, almost all of which extends towards north east. Its source of water is from five rivers, mainly from river Gomati. Lake Jaisamand has a water spread area of about 7160 ha at full reservoir level. The maximum length and breadth of the lake are 13.68 and 8.05 km respectively. The greatest depth point (32 meter) is near the center of the lake and the average depth is 15 meter. Further details of this lake pertaining to morphometric features are indicated in table 3.1.

Fig.3.1. Study area showing sampling sites



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**Table 3. 1: Morphometric features of the lake Jaisamand,Udaipur**

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1.Location:	
Latitude	: 24 <sup>0</sup> 14'N
Longitude	: 73 <sup>0</sup> 57 'E
2. Altitude	: 587 m(MSL)
3.Annual rainfall	: 627.7(mm)
4.Catchment area	: 1127.7sq.Km
5.Area (F.R.L)	: 7160
6.Maximum depth(Zm)	: 32m
7.Mean depth	: 15m
8.Mean depth/Maximum depth	: . 469
9.Maximum Breadth	: 8.05km
10.Maximum Length	: 13.68km
11.Length of shoreline	: 89.4 km
12.Length of dam	: 335m
13.Width of dam	: 31.4m
14.Height of dam	: 40.16m

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### **3.1 Climate:**

Lake Jaisamand area experiences two principal seasons: winter and hot summers. In winter, surface air flows in north-east direction, which is continental in origin and with low humidity and the season known as north-east winter monsoon. During the summer months of June to September, the general flow of winds is from the sea to the land containing much humidity with cold and rain. The direction of wind is south-west and the season is known as south-west monsoon. The lake surrounding area receives an average annual rainfall of 626.7 mm with a maximum precipitation during south-west monsoon i.e. June to September.

### **3.2 Geology of the lake Jaisamand catchment:**

The lake Jaisamand is surrounded by Aravalli hills, which extends from Delhi in the north-east to the Gulf of Cambay in south-west. Precambrian basement of the region is made up of the banded gneissic complex and a sedimentary succession comprising the Aravalli supergroup. Aravalli supergroup is predominantly made up of argillaceous rocks. These rocks exhibit prograde metamorphosed character towards the core of the Aravalli range. Aravalli supergroup is unconformably overlain by Delhi supergroup.

Aravalli succession is intruded by granites and ultrabasic rocks. Two types of granites have been found in this area- 1. Fine grained and 2. Coarse porphyritic type. The age of these intrusive activities has been calculated to be ~1900 million years.

Table 3.2: Lithology of the Aravalli supergroup.

Age in million years	Lithology
2000	Dharwal and Amet granite Slates, Phyllites and thin Quartzite Quartzite, Dolomite and silty Arenite
Upper Aravalli Group	Greywacke-Slate-Phyllite Rhythmites Lithic Arenites, Quartz-arenite Feldspathic Arenite Conglomerates
-----UNCONFORMITY-----	
	Carbonaceous and pelitic Phyllites, Dolomite, Quartzite
Lower Aravalli Group	Stromatolitic phosphorite near the base Chlorite Schist, Amphibolites (meta-lavas and tuffs), Quartz Arenite, local Conglomerates
-----UNCONFORMITY-----	
2500-3500	BGC, Granites of Ahor river and Udaisagar

### **3.3 Soil type:**

The soil around the lake is dark brown in colour and sandy-clay-loam. The water holding capacity of the soil has been observed and it varies from 16.32% to 42.26%. The southern sides of the lake mainly consist of clay mixed with gravel. The eastern side is muddy, where as the northern and western sides are rocky. Desert and brown soils develop in area where the potential evapotranspiration is much greater than the rainfall.

### **3.4 Fauna and Flora:**

The Jaisamand lake is the abode of crocodiles, turtles and a variety of fishes. Various species of terrestrial and water birds can also be seen in this lake. The leopard, hyana, jungle cat, fox and wolf are among the carnivores of the sanctuary while other wildlife includes sambar, chital, langur and chinkara.

The lake Jaisamand area is covered with thick forest. Forest type is tropical thorn forest, plants remain leafless during most parts of the year. During rains, grasses and herbs become abundant. The common plants of this forest are *Acacia nilotica*, *Prosopis spicigera*, *Albizzia*, *Zizyphus*, *Tamirix*, *Euphorbia*, *Calotropis*, *Madhuca*, *Tephrosia*, *Crotalaria*, *Panicum*, *Saccharum* and *Cenchrus*. *Butea monosperma*, *Azadiract indica*, *Ficus bengalensis* (Bergad), *Ficus religiosa* (Peepal) and *Mangifera indica* (Mango) are also common.

### **3.5 Human Interference:**

The human interference in this lake is mainly due to agriculture, fishing and tourism. There is no prominent source of industrial and domestic effluents as the lake is far away from the city.

***CHAPTER 4: MATERIALS AND  
METHODS***

**MATERIALS AND METHODS**

For this present study, systematic sampling was conducted during August 2000 to December 2000 from the lake Jaisamand. Water samples were collected from the different parts of the lake. Six sampling sites were fixed in the lake, the sampling sites are given in the fig. (3.1). These sites were selected on the basis of lake features such as depth, distance from shore, approachability etc. The details of sampling and analytical procedure is discussed below:

**4.1 Sampling methodology:**

Prior to each field work polyethylene bottles of one liter capacity were washed in the laboratory with dilute hydrochloric acid and then rinsed twice with double distilled water. At the sampling sites, all bottles were washed with the lake water before collecting the samples. The water samples were collected for analysis at three depths: surface, middle and bottom layer at each sampling site of the lake. The surface and middle layer depth was determined by euphotic zone criteria (Trivedi and Goel, 1984) and the bottom layer was taken below the euphotic zone of the lake at the selected sampling sites. Surface water samples were collected simply by lowering the bottle in the surface water. For middle and bottom layer sampling, a specially designed sampler was used. By using this sampler the water sample can be collected from any desired depth without mixing the water from different layers. The samples were kept at 4<sup>0</sup>C in cold room throughout the period of chemical analysis.

The physical parameters, pH (resolution 0.01 and accuracy of  $\pm 0.01\%$ ), conductivity (accuracy  $\pm 0.5\%$ ), total dissolved solids (TDS  $\pm 0.5\%$ ) were measured by using water and soil



analysis kit (Model 161 E, SSS Company, India). Temperature were measured, both in atmosphere and of water samples, by using Cole Palmer temperature probe Model Tegam 132 C TRMS Multi meter (USA), equipped with type KT<sup>0</sup>C probe. For transparency measurement, 20-cm diameter Secchi disc was used.

## 4.2: Analytical Methodology

### 4.2.1 Separation of suspended sediments:

Suspended sediments were separated from the water samples in the laboratory by using 0.45  $\mu$  Millipore membrane filters of 47 mm diameter. Vacuum pump was used to for faster filtration.

Weight of the suspended sediment was found out by weighing the filters before filtration and subtracting this weight from the weight of the filter with sediment after the filtration. Before taking the weight of the sediment on the filter paper, it was kept for one week in desiccator to remove moisture from the sediment. Volume of the samples was measured by glass measuring cylinder. Total suspended matter was calculated for one liter water samples from the volume of filtered water and the weight of the sediment.

### 4.2.2 pH:

pH of water samples were measured by Consort microcomputer (P -307) ion meter. Before measuring the pH of water samples, the electrode was immersed for 10 hours in 0.1 N HCl, to make it stable. After rinsing the electrode with distilled water the instrument was calibrated with a buffer solutions of pH 4.0 and 9.2. After that the electrode was immersed in samples and pH of each sample was recorded. The samples were stirred well during measurement to provide homogeneity.



#### **4.2.3 Electrical conductivity:**

Electrical conductivity (EC) was measured by using Pentax EC meter. It provides measurement of EC by a cell consisting of two -platinum electrode to which an alternative potential is applied. The corresponding is proportional to conductivity of the ionic solution in which the cell is applied. For EC measurement, the instrument was calibrated and set for 0.01M KCl standard. The conductivity was measured in  $\mu\text{S cm}^{-1}$  for water samples.

#### **4.2.4 Bicarbonate:**

Bicarbonates were determined by following potentiometric titration method. Standards of  $\text{HCO}_3^-$  were prepared for required concentration from chemical salt  $\text{NaHCO}_3$ . 50 ml of each standard and samples were titrated against 0.006 N HCl. pH 4.5 is taken as the endpoint of the reaction. A graph was plotted for standard concentrations against the volume of HCl consumed. The concentration of the samples was determined from the graph plotted for standards.

#### **4.2.5 Chloride:**

Chloride ion concentration was measured by the mercury (II) thiocyanate method (Florence and Ferrar 1970). The method involves the reaction of chloride with mercury (II) thiocyanate to form chloromercurate (II) complex ion, with the liberation of thiocyanate ions, which then react with iron (III) to give the light red color. 20 ml of each standard and samples were pipetted out into a 25ml volumetric flask. 2 ml of iron (III) nitrate reagent (prepared by dissolving 15.1 gm of  $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$  in 45 ml of 72% perchloric acid and diluted to 100 ml with distilled water) and 2 ml of mercury thiocyanate (saturated solution in ethanol) was added and total volume made to 25 ml with distilled water. After mixing well, solution was poured into the absorbance cell of

the spectrophotometer and reading was taken against a reagent blank at 460 nm after 5 minutes and the chloride concentration was estimated by comparing reading with calibration curve prepared by carrying chloride standard through the entire procedure.

#### **4.2.6 Sulfate:**

Sulphate concentration was measured by turbidimetric method (APHA 1985). The method is based on the principle that  $\text{SO}_4$  is precipitated in an acetic medium with barium chloride ( $\text{BaCl}_2$ ), so as to form barium sulphate crystal of uniform size. Light absorbance of barium sulphate suspension is measured by UV/VIS spectrophotometer at 420 nm and the concentration is determined by comparing the reading with standard curve. 100 ml of standard and samples were measured in a volumetric flask and 20 ml of buffer solution (prepared by dissolving 30 gm of  $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ , 5 gm of sodium acetate, 1 gm potassium nitrate and 0.111 gm of sodium sulphate and 20 ml of acetic acid in 500 ml of distilled water and then the total volume was made-up to 1000 ml) was added and mixed with the help of magnetic stirrer. While stirring a spoonful of  $\text{BaCl}_2$  crystal was added. This was stirred for 60 seconds with constant speed. After the stirring period, solution was poured into the absorbance cell of the photometer and absorbance reading was taken at 420 nm after 5 minutes. Sulphate concentration was determined by comparing reading with calibration curve prepared by carrying sulphate standard through the entire procedure.

#### **4.2.7 Dissolved silica ( $\text{H}_4\text{SiO}_4$ ):**

The dissolved silica was determined by molybdosilicate method (APHA 1985). 20 ml of each standard and samples were pipetted out into a 100 ml volumetric flask and 10 ml of ammonium

molybdate solution (prepared by dissolving 2 gm of ammonium molybdate in 10 ml distilled water and 6 ml of conc. HCl and volume was made to 100 ml) and 15 ml of reducing agent (prepared by mixing 100 ml of metol sulphite solution, 60 ml 10% oxalic acid and 120 ml of 25% H<sub>2</sub>SO<sub>4</sub> and the volume was made upto 300 ml) were added. The samples were stirred well and kept for three hours to complete the reaction. The optical density was measured for standard and water samples at 812nm by using UV/VIS Spectrophotometer.

#### **4.2.8 Phosphate:**

Phosphate was determined by the ascorbic acid method (APHA 1985). Phosphate standard solution of different concentration was prepared from the potassium dihydrogen phosphate (KH<sub>2</sub>PO<sub>4</sub>). 40 ml of each standard and water samples were pipetted out into a 50 ml volumetric flask and 5 ml of molybdate antimony solution and 2 ml of ascorbic acid solution was added and mixed well. The mixture was diluted to 50 ml and absorbance was measured at 640 nm using UV/VIS spectrophotometer. Molybdate solution was prepared by dissolving 4.8 gm of ammonium molybdate and 0.1 gm of sodium antimony tartrate in 400 ml of 4N sulphuric acid and making the total volume to 500 ml with the same acid. Ascorbic acid was prepared by dissolving 2 gm of ascorbic acid in 100 ml water.

#### **4.2.9 Nitrate:**

Concentration of nitrate in water samples was determined by brucine -sulphanilic acid method. The method is based on the reaction of the nitrate ion with brucine sulphate 13 N H<sub>2</sub>SO<sub>4</sub> solution at a temperature of 100<sup>0</sup>C. The colour of resulting complex is measured at 410 nm. 10 ml of standard and samples were pipetted out into a 50 ml tube. 10 ml of 13N H<sub>2</sub>SO<sub>4</sub> solution

was added to each tube with swirling and allowed tubes to come to thermal equilibrium in the cold bath. 0.5 ml brucine-sulphanilic reagent (prepared by dissolving 1 gm brucine sulphate and 0.1 gm sulphanilic acid in 70 ml hot distilled water. 3 ml of HCl was added to this solution and volume made to 100 ml with distl. water.) was added to each tube and mixed thoroughly. The tube rack was then kept in water bath at 100 °c for 25 minutes. After that tubes were removed from the water bath and allowed to reach room temperature and the absorbance was measured at 410 nm against reagent blank.

#### **4.2.10 Ca<sup>+2</sup>, Mg<sup>+2</sup>, Na<sup>+</sup> and K<sup>+</sup> :**

The content of major cations calcium, magnesium, sodium and potassium was determined on GBC 906 atomic absorption spectrophotometer (ASS). Calcium and magnesium concentration was determined in absorbance mode and sodium and potassium in emission mode.

## ***CHAPTER 5: RESULTS***

## RESULTS

Water samples from the lake Jaisamand were collected three times, August 2000, October 2000 and December 2000. Samples were analyzed in the laboratory using standard methods described in the previous chapter. The analyses were directed towards the deciphering of the major ion chemistry, the seasonal and vertical variation in solute concentration and their sources and mechanisms controlling water chemistry. The major ion chemistry of the lake water is presented in table (5.2 to 5.5). The tables also show detailed anion and cation charge balance in milliequivalents. The observed charge balance between cations ( $TZ^-$ ) and anion ( $TZ^+$ ) is within  $\pm 10\%$ , which confirms the reliability of the analytical results.

### **5.1 Colour:**

The lake water was turbid and brownish during monsoon, blue-green during post monsoon and light blue-green in winter. However during summer water retained its blue-green colour in winter months.

### **5.2 Water level:**

Highest water level recorded during present investigation period was 15 meter at the sampling site numbered six, while the lowest was 4 meter with an average depth of 8 meter (table 5.1).

### **5.3 Air temperature:**

The air temperature during the present investigation period fluctuated from a minimum 28°C to a maximum 35°C.

### **5.4 Water temperature:**

Maximum surface water temperature 31°C was recorded in August 2000, where as the minimum of 23°C was recorded in December 2000. The temperature at mid depth ranged between 22°C to 30°C, with the maximum value in August 2000 and minimum in December 2000. At the bottom, the maximum temperature was 29°C in August 2000 and the minimum temperature was 21°C during December 2000 (table 5.2 to 5.5).

### **5.5 Transparency:**

Transparency varied between 120-150 cm in August 2000. In October 2000, it was 100 -175 cm and in December 2000, 120-200 cm transparency was observed. This indicates comparatively clear water status (table 5.1).

### **5.6 pH, EC (Electrical Conductivity) and TDS (Total Dissolved solids):**

In the surface water, average minimum and maximum pH value were 8.77 and 9.23 respectively. In mid-depth water the average minimum pH value was 8.65 and average maximum pH was 9.30. For bottom layer, average minimum pH value was recorded 7.11 and 9.16 as maximum during the period of investigation. The EC is a measurement of the ability of a solution to conduct electric current transferred by ions in solution. Average value of EC was 560  $\mu\text{s}/\text{cm}$ , 562  $\mu\text{s}/\text{cm}$  and 586  $\mu\text{s}/\text{cm}$  in surface, middle and bottom layers respectively.



Table 5.1: Different sampling Sites, depth and transparency.

Locations	Depth (meter)	Transparency (meter)		
		August	October	December
1. Near Gomti river	4	1.25	1.50	2.00
2. Baba Ka Magra	6	1.20	1.25	1.50
3. Near Resort	11.5	1.50	1.75	1.75
4. Gamari	4.5	1.00	1.10	1.20
5. Near Band	7.25	1.00	1.00	1.50
6. Near Band	15	1.25	1.25	1.25

This shows an increase of EC from surface to bottom. Average value of TDS was 520 mg/l, 521 mg/l and 531 mg/l in surface, middle and bottom layers respectively (table 5.5).

### **5.6 Dissolved Silica:**

Average silicate values at three different depths indicated higher content in bottom water (table 5.5). In August 2000, the surface water silica concentration ranged between 10 mg/l to 11.10 mg/l with an average of 10.63 mg/l. For middle depth water concentration of silica ranged between 10.12 mg/l to 11.59 mg/l with an average of 10.79 mg/l. In bottom layer, the range of silica concentration was 10.37 mg/l to 19.51 mg/l with an average of 15.45 mg/l (table 5.2). In October 2000 the surface water silica concentration varied between 16.95 mg/l to 19.88 mg/l with an average of 18.19 mg/l. For middle depth water concentration of silica varied between 17.80 mg/l to 23.05 mg/l with an average of 19.76 mg/l and in bottom layer the range of silica concentration was 18.05 mg/l to 26.95 mg/l with an average of 20.74 mg/l (table 5.3). In month of December 2000, surface water silica concentration was observed from 14.35 mg/l to 20.72 mg/l with an average of 18.20 mg/l. For middle depth water concentration of silica ranged between 16.48 mg/l to 21.96 mg/l with an average of 19.91 mg/l and in bottom layer the range of silica concentration was 18.94 mg/l to 21.96 mg/l with an average of 18.94 (table 5.4).

### **5.7 Cation Chemistry:**

*August 2000:*  $\text{Na}^+$  and  $\text{K}^+$  are the dominant cation in the lake Jaisamand water. On an average  $\text{Na}^+$  and  $\text{K}^+$  constitutes 58% of the total cation in equivalent units and 14 % of the TDS. In surface water  $\text{Na}^+$  concentration ranged between 67.95 mg/l to 79.04 mg/l, with an

average concentration of 71.75 mg/l. In middle layer, concentration of  $\text{Na}^+$  ranged between 72.46 mg/l to 73.62 mg/l, with an average concentration of 73.26 mg/l. In bottom layer  $\text{Na}^+$  concentration ranged between 67.51 mg/l to 71.97 mg/l, with an average concentration of 70.31 mg/l (table 5.2 and 5.5). Average concentration of  $\text{K}^+$  was 35.78 mg/l, 34.20 mg/l and 34.27 mg/l in surface, middle and bottom layers respectively (table 5.2). Calcium and magnesium ions accounts for 9.88 % and 32.68 % of the total cation in surface water and for middle layers their contribution were 9 % and 33.24 %. In bottom layer  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$  were contribute 9.17 % and 33.22 % of the total cations.  $\text{Ca}^{++}$  was the least dominant cation in all three layers and average concentration of  $\text{Ca}^{++}$  in surface, middle and bottom layer was 14.21 mg/l, 13.27 mg/l and 12.87 mg/l respectively (tab.5.5).

*October 2000:* Major cation  $\text{Na}^+$  and  $\text{K}^+$  constitute 21% of the TDS.  $\text{Na}^+$  and  $\text{K}^+$  in surface water showed an average concentration 71.75 mg/l and 27.88 mg/l, respectively. In middle layer average concentration of  $\text{Na}^+$  and  $\text{K}^+$  were 69.72 mg/l, 27.88 mg/l. In bottom it was 70.31 mg/l, 27.92 mg/l respectively (table 5.3).  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$  constitute 8% of the TDS. Concentration of  $\text{Mg}^{++}$  ranged between 27.45 mg/l to 29.23 mg/l in surface water. For middle and bottom layers concentration range were 27.88 mg/l to 29.58 mg/l and 28.58 mg/l to 30.21 mg/l (table.5.3 and 5.5). Average concentration of  $\text{Ca}^{++}$  in surface, middle and bottom layer was 14 mg/l, 11 mg/l and 12 mg/l (table 5.5).

*December 2000:* Among the four-measured cation,  $\text{Na}^+$  is the most dominant cation. Average concentration of  $\text{Na}^+$  in surface, middle and bottom layer was 77 mg/l, 75.72 mg/l and 75 mg/l, respectively (table 5.4). The concentration of  $\text{K}^+$  ranged 39.20 mg/l to 34 mg/l in surface layer. The average concentration of  $\text{K}^+$  in middle and bottom layer was 35 mg/l and

37 mg/l. The average concentration of  $Mg^{++}$  and  $Ca^{++}$  in surface layer was 29.68 mg/l, 14.79 mg/l, and in middle layer concentration of  $Mg^{++}$  and  $Ca^{++}$  was 29.60 mg/l and 16.73 mg/l. For bottom layer  $Mg^{++}$  and  $Ca^{++}$  concentration was 29.73 mg/l and 15.26 mg /l (table 5.4 and 5.5).

### **5.8 Anion Chemistry:**

*August 2000:* The contribution of anions is 70% of the total dissolved solids (TDS). Bicarbonate is the most dominant anion and average contribution was, 61% of the total anion in equivalent units and 51% of the TDS. Average concentration of bicarbonate was 261 mg/l, 264 mg/l and 244 mg/l in surface, middle and bottom layer respectively. On an average chloride was account for 34 % of the total anions. Average concentration of  $Cl^{-}$  was 82.76 mg/l, 81.47 mg/l and 84.10 mg/l in surface, middle and bottom layer respectively. Sulphate on an average was 12.83 mg/l, 11.06 mg/l and 10.69 mg/l in surface middle and bottom layer respectively and accounts for 4% of the total anion in equivalent unit. Concentrations of nitrate in surface, middle and bottom layer were 2.11 mg/l, 2.30 mg/l and 2.30 mg/l respectively. Concentrations of  $PO_4^{-}$  in surface, middle and bottom layers were 90  $\mu$ g/l, 80  $\mu$ g/l and 190  $\mu$ g/l, respectively (table 5.2 and 5.5).

*October 2000:* Anion constitutes 68% of the TDS during this sampling period. The average concentration of bicarbonate in surface, middle and bottom layer were, 265 mg/l, 265 mg/l and 266.26 mg/l respectively, showing increasing trend from surface to bottom.  $NO_3^{-}$  also show increasing trend from surface to bottom, an increase of 0.21 mg/l in bottom observed. Bicarbonate is the dominant anion constituting 62% of total anions. Chlorides come next and accounted for average 35% of total anions. Concentration of  $Cl^{-}$  was observed 80 mg/l, 82

mg/l and 78 mg/l in surface, middle and bottom layer respectively. Concentrations of  $\text{SO}_4^{2-}$  were, 12.63 mg/l, 11.81 mg/l and 10.80 mg/l, in surface, middle and bottom layer respectively.  $\text{NO}_3^-$  and  $\text{PO}_4^{3-}$  had very little contribution to the total anion and accounted for only 1.30% of the total anion (table 5.3 and 5.5).

*December 2000:* The concentration of bicarbonate ranged from 256 mg/l to 276 mg/l in surface water, while in middle and bottom water concentration observed between 251 mg/l to 275 mg/l and 244 mg/l to 287 mg/l.  $\text{Cl}^-$  comes next in anionic abundance with about 34% of the total anions. The measured  $\text{Cl}^-$  concentration varied from 70 mg/l to 87 mg/l in surface, 82 mg/l to 86 mg/l in middle and 78 mg/l to 88 mg/l in bottom layer. The average concentration of  $\text{SO}_4^{2-}$  in this month were, 13 mg/l in surface, 12 mg/l in middle and 11 mg/l in bottom layer. Nitrate and phosphate together accounts for 3.5% of total anions (table 5.4 and 5.5).

Table 5.2: Chemical characteristics of the lake water during August, 2000.

Sites	Temp.	pH	EC	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>+2</sup>	Mg <sup>+2</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>-2</sup>	NO <sub>3</sub> <sup>2-</sup>	PO <sub>4</sub> <sup>-3</sup>	SIO2	TDS	TDS/EC	TZ <sup>+</sup>	TZ <sup>-</sup>
s1	31	8.77	552	70.5	32.4	16.2	29.0	265.5	79.8	12.6	0.6	0.15	10.5	517.1	0.94	7.09	7.01
s2	31	9.19	543	70.6	31.4	14.2	27.2	257.2	79.3	12.9	2.1	0.07	11.0	505.9	0.93	7.05	6.82
s3	30	9.21	547	70.7	30.6	16.5	28.2	258.0	89.6	12.5	2.4	0.07	10.6	519.3	0.95	7.01	7.12
s4	30	9.17	542	67.9	30.2	11.0	27.2	259.4	85.3	13.2	3.2	0.08	11.1	508.6	0.94	7.40	7.06
s5	30	9.16	531	79.0	33.5	15.3	27.7	268.2	79.8	12.9	2.3	0.09	10.0	528.9	1.00	7.09	7.04
s6	30	9.24	536	69.3	31.1	10.3	26.4	259.6	81.3	11.9	2.7	0.08	13.8	506.3	0.94	6.50	6.94
Avg	30.4	9.10	543	71.8	31.6	14.6	27.9	261.6	82.8	12.8	2.1	0.09	10.6	516.0	0.95	7.02	7.00
Max	31	9.21	552	79.0	33.5	16.5	29.0	268.2	89.6	13.2	3.2	0.15	11.1	528.9	1.00	7.40	7.12
Min	30	8.77	531	67.9	30.2	10.3	26.4	257.2	79.3	11.9	0.6	0.07	10.0	505.9	0.93	6.50	6.82
Std	0.52	0.18	8	3.9	1.2	2.7	0.9	4.5	4.1	0.5	0.9	0.03	1.3	9.1	0.02	0.29	0.11
m1	30	8.65	557	66.8	35.7	13.6	28.6	266.3	80.2	11.4	1.9	0.08	10.7	515.4	0.93	6.85	6.98
m2	30	9.18	542	69.7	33.9	17.3	29.1	252.2	78.1	8.3	2.1	0.10	10.4	501.2	0.92	6.29	6.63
m3	30	9.30	544	69.2	31.0	11.4	29.0	256.2	77.3	9.1	2.5	0.08	11.0	496.7	0.91	6.75	6.68
m4	30	9.25	536	70.1	34.0	9.9	26.7	274.4	81.5	10.9	2.3	0.07	11.0	520.9	0.97	5.74	7.12
m5	30	9.30	537	73.6	33.9	11.8	27.1	266.5	89.2	12.9	2.4	0.10	10.1	527.5	0.98	6.88	7.29
m6	29	9.25	541	68.9	30.6	11.4	26.8	268.1	82.5	13.7	2.1	0.08	11.6	515.7	0.95	6.56	7.12
Avg	29.83	9.16	543	69.7	33.2	12.6	27.9	263.9	81.5	11.1	2.2	0.08	10.8	512.9	0.95	6.51	6.97
Max	30	9.30	557	73.6	35.7	17.3	29.1	274.4	89.2	13.7	2.5	0.10	11.6	527.5	0.98	6.88	7.29
Min	29	8.65	536	66.8	30.6	9.9	26.7	252.2	77.3	8.3	1.9	0.07	10.1	496.7	0.91	5.74	6.63
Std	0.41	0.25	8	2.2	2.0	2.6	1.1	8.2	4.3	2.1	0.2	0.01	0.5	11.8	0.03	0.44	0.26
b1	30	8.36	576	71.4	35.7	11.8	28.5	254.4	89.5	11.4	2.2	0.08	12.1	517.0	0.90	6.96	7.04
b2	30	9.12	577	69.1	30.9	9.6	28.4	262.2	80.1	9.8	2.2	0.10	18.9	511.2	0.89	6.61	6.89
b3	29	8.75	578	70.2	31.1	12.5	28.7	272.0	81.7	9.9	2.2	0.08	13.5	521.9	0.90	6.83	7.08
b4	29	9.16	574	72.0	30.5	10.7	26.5	285.5	83.8	10.9	2.4	0.12	10.4	532.6	0.93	6.62	7.43
b5	29	9.16	570	71.6	31.4	10.7	27.5	244.5	90.6	11.9	2.7	0.39	18.3	509.7	0.89	4.45	7.24
b6	27	7.52	590	67.5	31.3	13.6	27.9	244.5	78.9	10.2	2.2	0.39	19.5	496.0	0.84	6.71	6.49
Avg	29	8.68	578	70.3	31.8	11.5	27.9	260.5	84.1	10.7	2.3	0.19	15.4	514.8	0.89	6.36	7.03
Max	30	9.16	590	72.0	35.7	13.6	28.7	285.5	90.6	11.9	2.7	0.39	19.5	532.6	0.93	6.96	7.43
Min	27	7.52	570	67.5	30.5	9.6	26.5	244.5	78.9	9.8	2.2	0.08	10.4	496.0	0.84	4.45	6.49
Std	1.10	0.65	7	1.7	1.9	1.5	0.8	16.2	4.9	0.9	0.2	0.15	3.9	12.4	0.03	0.95	0.32

Table 5.3 : Chemical characteristics of the lake water during October, 2000.

Sites	Temp.	pH	EC	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>+2</sup>	Mg <sup>+2</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>-2</sup>	NO <sub>3</sub> <sup>-2</sup>	PO <sub>4</sub> <sup>-3</sup>	SIO2	TDS	TDS/EC	TZ <sup>+</sup>	TZ <sup>-</sup>
s1	27	9.06	599	74.6	31.9	11.4	28.4	268.8	74.4	11.9	1.7	0.1	18.9	522.0	0.87	7.0	6.8
s2	27	9.23	584	73.8	32.9	10.7	28.7	257.5	79.3	13.5	1.6	0.0	18.0	516.0	0.88	6.9	6.8
s3	27.4	9.09	574	73.5	32.0	12.7	29.2	256.0	87.1	12.9	1.6	0.1	17.8	522.8	0.91	7.0	7.0
s4	27.4	8.94	603	73.5	32.0	15.4	29.2	268.8	85.6	10.9	1.4	0.1	17.5	534.5	0.89	7.2	6.9
s5	28	8.98	598	75.5	32.6	15.1	28.0	271.3	82.8	12.9	1.5	0.1	19.9	539.7	0.90	7.2	7.1
s6	27.6	8.80	612	78.2	32.4	18.4	27.5	267.2	70.4	13.8	1.8	0.0	17.0	526.6	0.86	7.4	7.2
Avg	27.4	9.02	595	74.9	32.3	13.9	28.5	264.9	79.9	12.6	1.6	0.1	18.2	526.9	0.89	7.1	7.0
Max	28	9.23	612	78.2	32.9	18.4	29.2	271.3	87.1	13.8	1.8	0.1	19.9	539.7	0.91	7.4	7.2
Min	27	8.80	574	73.5	31.9	10.7	27.5	256.0	70.4	10.9	1.4	0.0	17.0	516.0	0.86	6.9	6.8
Std	0.50	0.22	19	2.4	0.5	3.9	0.9	7.7	8.4	1.5	0.2	0.0	1.5	11.9	0.03	0.1	0.1
m1	25.4	9.08	590	77.6	38.4	9.9	28.1	267.2	78.9	11.6	1.7	0.0	18.4	531.9	0.90	7.2	6.9
m2	26	9.18	586	74.5	33.4	9.9	27.9	251.0	75.1	11.3	1.8	0.0	17.8	502.8	0.86	6.9	6.5
m3	25.5	9.09	591	72.8	32.7	15.8	29.3	259.1	85.5	10.4	1.5	0.1	18.3	525.5	0.89	7.2	7.0
m4	26	9.07	565	73.1	32.3	9.6	29.6	275.3	82.6	10.9	1.2	0.1	19.0	533.7	0.94	6.9	7.1
m5	28	8.85	588	71.3	32.0	12.1	29.0	267.2	85.5	13.0	1.5	0.1	22.0	533.7	0.91	6.9	7.1
m6	27.6	8.86	603	74.5	32.9	12.1	29.0	270.5	82.7	13.7	2.0	0.0	23.0	540.5	0.90	7.1	7.1
Avg	26.42	9.02	587	74.0	33.6	11.6	28.8	265.0	81.7	11.8	1.6	0.1	19.8	528.0	0.90	7.0	7.0
Max	28	9.18	603	77.6	38.4	15.8	29.6	275.3	85.5	13.7	2.0	0.1	23.0	540.5	0.94	7.2	7.1
Min	25.4	8.85	565	71.3	32.0	9.6	27.9	251.0	75.1	10.4	1.2	0.0	17.8	502.8	0.86	6.9	6.5
Std	1.11	0.13	12	2.1	2.4	2.4	0.7	8.7	4.1	1.3	0.3	0.0	2.2	13.2	0.03	0.1	0.2
b1	25	8.82	580	74.2	34.7	8.5	28.7	255.1	85.9	11.6	1.8	0.0	18.3	518.8	0.89	6.3	6.9
b2	25.4	9.12	577	73.4	35.3	12.5	28.8	264.0	77.0	9.8	1.7	0.1	18.0	520.6	0.90	7.1	6.8
b3	25.5	8.97	584	73.6	35.2	9.9	29.3	271.3	87.9	9.8	2.0	0.1	18.9	538.0	0.92	7.0	7.2
b4	26	9.08	584	73.9	35.4	11.4	26.2	287.4	74.3	10.6	1.9	0.0	18.6	539.8	0.92	6.8	7.4
b5	28	9.08	581	69.7	33.8	12.1	28.8	244.5	54.3	11.4	2.0	0.0	23.7	480.4	0.83	6.9	5.8
b6	24.8	7.76	619	71.2	34.2	16.9	30.2	275.3	86.5	11.5	2.9	0.1	27.0	555.9	0.90	7.3	7.4
Avg	25.78	8.81	588	72.7	34.8	11.9	28.7	266.3	77.7	10.8	2.0	0.1	20.7	525.6	0.89	6.9	6.9
Max	28	9.12	619	74.2	35.4	16.9	30.2	287.4	87.9	11.6	2.9	0.1	27.0	555.9	0.92	7.3	7.4
Min	24.8	7.76	577	69.7	33.8	8.5	26.2	244.5	54.3	9.8	1.7	0.0	18.0	480.4	0.83	6.3	5.8
Std	1.16	0.52	16	1.8	0.6	2.9	1.3	15.2	12.7	0.9	0.4	0.0	3.7	26.0	0.04	0.3	0.6

Table 5.4 : Chemical characteristics of the lake water during December, 2000.

Sites	Temp.	pH	EC	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>+2</sup>	Mg <sup>+2</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>-2</sup>	NO <sub>3</sub> <sup>-2</sup>	PO <sub>4</sub> <sup>-3</sup>	SIO2	TDS	TDS/EC	TZ <sup>+</sup>	TZ <sup>-</sup>
s1	23	9.1	530.0	78.7	36.1	15.4	29.8	259.6	73.2	11.5	1.5	0.21	15.8	521.8	1.0	7.6	6.8
s2	23	9.0	550.0	75.0	39.2	14.7	29.8	278.8	69.0	16.7	1.4	0.11	18.8	543.7	1.0	7.5	7.0
s3	23.4	9.0	516.0	79.2	36.2	15.4	29.7	254.8	63.2	13.1	1.3	0.11	19.9	513.0	1.0	7.4	6.4
s4	23.4	9.0	560.0	75.5	34.0	14.5	29.8	245.2	63.2	12.9	1.5	0.12	19.6	496.2	0.9	7.3	6.2
s5	24	8.9	550.0	75.5	35.0	14.0	29.5	254.8	66.0	15.2	1.4	0.13	20.7	512.1	0.9	7.3	6.5
s6	23.6	9.0	512.0	78.2	35.1	14.7	29.5	259.6	58.7	11.0	1.7	0.12	14.4	503.0	1.0	7.5	6.3
Avg	23.4	9.0	536.3	77.0	35.9	14.8	29.7	258.8	65.6	13.4	1.5	0.13	18.2	515.0	1.0	7.4	6.5
Max	24	9.1	560.0	79.2	39.2	15.4	29.8	278.8	73.2	16.7	1.7	0.21	20.7	543.7	1.0	7.6	7.2
Min	23	8.9	512.0	75.0	34.0	14.0	29.5	245.2	58.7	11.0	1.3	0.11	14.4	496.2	0.9	7.3	6.2
Std	0.38	0.1	19.9	1.9	1.8	0.6	0.2	11.1	5.1	2.2	0.1	0.04	2.5	16.6	0.0	0.1	0.4
m1	21.4	9.1	550.0	75.4	34.7	15.4	29.2	245.2	63.3	11.8	1.5	0.12	16.5	493.1	0.9	7.3	6.2
m2	22	9.1	540.0	75.8	35.3	14.0	29.7	269.0	64.6	13.2	1.5	0.14	19.3	522.6	1.0	7.3	6.7
m3	21.5	9.0	550.0	75.4	35.2	17.6	29.8	254.4	59.6	13.1	1.4	0.11	19.4	506.0	0.9	7.5	6.3
m4	22	9.1	560.0	76.2	35.4	16.5	29.6	259.3	61.9	12.9	1.5	0.10	22.0	515.4	0.9	7.6	6.4
m5	24	9.0	550.0	75.3	33.8	15.1	29.5	269.5	69.5	15.1	1.4	0.15	21.4	530.6	1.0	7.3	6.9
m6	23	9.0	540.0	76.2	34.2	21.7	29.8	288.4	61.8	14.8	1.8	0.12	21.0	549.8	1.0	7.7	6.9
Avg	22.32	9.0	548.3	75.7	34.8	16.7	29.6	264.3	63.4	13.5	1.5	0.13	19.9	519.6	0.9	7.4	6.5
Max	24	9.1	560.0	76.2	35.4	21.7	29.8	288.4	69.5	15.1	1.8	0.15	22.0	549.8	1.0	7.7	7.2
Min	21.4	9.0	540.0	75.3	33.8	14.0	29.2	245.2	59.6	11.8	1.4	0.10	16.5	493.1	0.9	7.3	6.1
Std	1.00	0.1	7.5	0.4	0.6	2.7	0.2	15.0	3.4	1.3	0.1	0.02	2.0	19.7	0.0	0.2	0.4
b1	21	8.9	550.0	76.1	36.8	13.2	29.3	255.0	62.9	12.9	1.6	0.14	14.1	502.0	0.9	7.3	6.4
b2	21.4	8.2	540.0	74.0	36.7	14.3	29.6	264.0	57.9	13.7	1.5	0.12	19.4	511.1	0.9	7.3	6.4
b3	21.5	8.0	550.0	73.9	36.7	22.1	30.1	271.3	58.9	13.7	1.6	0.15	19.9	528.3	1.0	7.7	6.6
b4	22	8.0	540.0	74.1	36.5	18.4	29.0	287.5	64.1	14.6	1.7	0.12	19.9	545.9	1.0	7.5	7.0
b5	23	8.0	530.0	74.4	36.9	15.4	29.9	244.5	56.5	13.3	1.5	0.18	22.0	494.7	0.9	7.4	6.1
b6	20.8	7.1	550.0	74.1	37.1	8.1	30.5	275.3	57.4	13.9	1.7	0.57	18.3	516.9	0.9	7.1	7.0
Avg	21.62	8.0	543.3	74.4	36.8	15.3	29.7	266.3	59.6	13.7	1.6	0.21	18.9	516.5	1.0	7.4	6.6
Max	23.00	8.9	550.0	76.1	37.1	22.1	30.5	287.5	64.1	14.6	1.7	0.57	22.0	545.9	1.0	7.7	7.4
Min	21.62	8.0	543.3	74.4	36.8	15.3	29.7	266.3	59.6	13.7	1.6	0.21	18.9	516.5	1.0	7.1	6.0
Std	0.80	0.5	3.8	0.9	0.2	3.9	0.4	12.2	2.6	0.5	0.1	0.21	1.7	17.0	0.0	0.2	0.5



Table 5.5 : Average chemical composition of lake Jaisamand.

Sites	Temp.	pH	EC	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>+2</sup>	Mg <sup>+2</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>-2</sup>	NO <sub>3</sub> <sup>2-</sup>	PO <sub>4</sub> <sup>-3</sup>	SiO <sub>2</sub>	TDS	TDS/EC	TZ <sup>+</sup>	TZ <sup>-</sup>
s1	27.0	9.0	560.3	74.6	33.5	14.3	29.1	264.6	75.8	12.0	1.1	0.1	15.1	520.2	0.93	7.21	6.82
s2	27.0	9.1	559.0	74.4	34.5	12.7	29.2	264.5	75.9	14.4	1.8	0.1	16.0	523.4	0.94	7.16	6.88
s3	26.9	9.1	545.7	70.7	30.6	16.5	28.2	256.3	80.0	12.8	2.0	0.1	16.1	513.4	0.94	7.01	6.83
s4	26.9	9.0	568.3	70.7	49.4	13.2	28.2	257.8	78.0	13.0	2.3	0.1	14.3	527.1	0.93	7.32	6.81
s5	27.3	9.0	559.7	77.2	33.8	14.0	28.6	264.8	76.2	13.7	1.9	0.1	16.9	527.2	0.94	7.28	6.88
s6	27.1	9.0	553.3	75.2	32.9	14.5	27.8	262.1	70.0	12.4	2.3	0.1	15.0	512.2	0.93	7.12	6.64
m1	25.6	9.0	565.7	73.2	36.3	13.0	28.6	259.6	74.2	11.6	1.8	0.1	15.2	513.6	0.91	7.12	6.69
m2	26.6	9.0	556.0	74.1	36.3	13.9	28.3	261.1	73.4	12.3	2.1	0.1	15.8	517.4	0.93	7.17	6.71
m3	25.7	9.1	561.7	72.5	33.0	15.0	29.4	256.6	74.1	10.9	2.0	0.1	16.2	509.6	0.91	7.16	6.63
m4	26.0	9.1	553.7	73.2	33.9	9.7	28.1	269.7	75.3	11.5	1.8	0.1	17.3	520.6	0.94	6.85	6.89
m5	27.3	9.0	558.3	73.4	33.3	13.0	28.5	267.7	81.4	13.7	2.0	0.1	17.8	530.8	0.95	7.04	7.08
m6	26.5	9.0	561.3	73.2	32.6	15.1	28.6	275.6	75.7	14.1	2.3	0.1	18.5	535.7	0.95	7.12	7.02
b1	25.3	8.7	568.7	73.9	35.7	11.2	26.5	254.8	87.7	12.0	2.0	0.1	14.8	518.7	0.91	7.00	6.87
b2	25.6	8.8	564.7	72.2	34.3	12.1	28.9	263.4	78.5	11.1	2.0	0.1	18.8	521.4	0.92	7.19	7.16
b3	25.3	8.6	570.7	72.6	34.3	14.8	29.3	271.5	84.8	9.8	2.1	0.1	16.2	535.7	0.94	6.88	7.43
b4	25.7	8.7	566.0	73.3	32.9	13.5	26.4	286.8	83.8	12.0	2.1	0.1	16.3	547.3	0.97	7.05	6.42
b5	26.7	8.8	560.3	71.9	34.1	12.7	29.4	244.5	72.4	12.2	2.4	0.2	21.3	501.2	0.89	7.00	7.05
b6	24.2	7.5	586.3	70.9	34.2	12.9	29.1	265.0	82.7	11.9	2.5	0.3	21.6	531.2	0.91	7.00	6.99

EC in micro siemen/cm; Concentrations in mg/l; TDS: total dissolved solids; TZ+ total cations in meq/l; TZ- total cations in meq/l

s represents surface water samples;

m represent middle layer water samples;

b represents bottom layer water samples;

## ***CHAPTER 6: DISCUSSION***

## DISCUSSION

### **6.1 Physical characteristics of the lake water:**

The observed colour of lake water is the result of light being scattered upward from the lake after it has passed through the water to various depths and undergone selective absorption en route. Blue green colour in winter and summer is due to scattering of light from colloidal  $\text{CaCO}_3$ , which is common to hard water lakes. The lake water became turbid and brownish during monsoon due to the entry of allochthonous matter and upwelling of bottom sediments by the in coming turbulent river waters.

The transparency has been considered as a function of suspended organic matter and wind action (Edmonson, 1961; Ganpati, 1962 and Green, 1974). In general, water transparency was high in winter and low during monsoon (table 5.1). In monsoon, the water clarity gets reduced mainly due to in coming silt and allochthonous organic matter in the lake (Sharma, 1980; Rao, 1984; Gupta, 1988, 1991).

### **6.2 Chemical Characteristics of the lake water:**

Lake Jaisamand water is alkaline in nature. pH of the natural waters is governed by the interaction of  $\text{H}^+$  ions, arising from the dissolution of  $\text{H}_2\text{CO}_3$  and from  $\text{OH}^-$  ions, produced during the hydrolysis of bicarbonate. This lake is regulated by the  $\text{CO}_2\text{-HCO}_3^- \text{-CO}_3$ . Electrical conductivity (EC) is a measure of total dissolved solids (TDS) i.e. - it depends upon

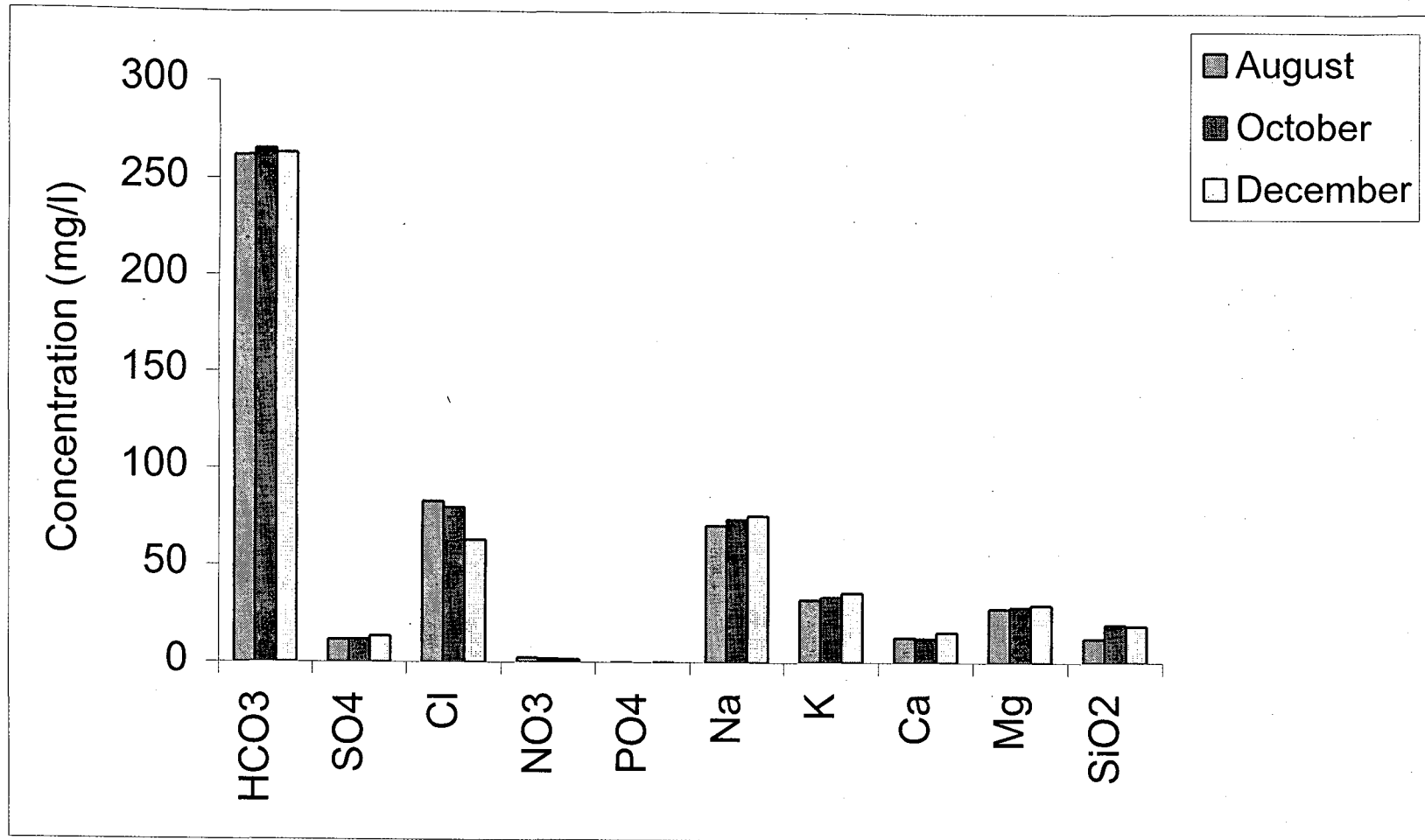


Fig.6.1 Seasonal variation in absolute concentration of various dissolved species in Lake Jaisamand.

the ionic strength of the solution. Increases in the concentration of dissolved solids (TDS ) increases the ionic strength of the solution ( $1/2 \sum Z_i^2 C_i$  = concentration of the  $i^{\text{th}}$  ion in mole/l and  $Z_i$  is the valence of the  $i^{\text{th}}$  ion. This means an increase in dissolved solids (TDS) will cause a proportional increase in electrical conductivity. The ratio of total dissolved solids (TDS) to electrical conductivity (EC) is generally accepted as 0.7 for freshwater (Davis and Deweist 1962). The analyzed TDS values computed against measured EC has shown a close agreement, thus confirming the accuracy of both the chemical analysis and conductivity measurements.

The order of abundance for various cations and anions are  $\text{Na}^+ + \text{K}^+ > \text{Ca}^{+2} + \text{Mg}^{+2}$ , and  $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-} > \text{NO}_3^- > \text{PO}_4^{3-}$ . The dominance of bicarbonate ( $\text{HCO}_3^-$ ) and sodium ( $\text{Na}^+$ ) among the anions and cations in lake Jaisamand suggest that this lake is "  $\text{Na}^+ - \text{HCO}_3^-$  " type of lake. The  $\text{HCO}_3^-$  and  $\text{Cl}^-$  account for 96% of total anions and 67% of TDS. The high chloride content is primarily due to alkaline/saline soils and saline groundwater in the drainage basin, However, contribution from atmospheric dry fallout could also be significant, as the area is rainfall deficient and located a short distance from the sea (Das and Singh, 1995). Lake Jaisamand is considering as mild eutrophic lake. Source of nitrate and phosphate is agriculture and surface runoff from surrounding hills. The high phosphate may be due to its flow through phosphorite deposits persists in the area.

### **6.3 Vertical stratification of the lake Jaisamand:**

The lake Jaisamand showed marked thermal stratification possibly owing to its greater depth. In the present study highest gradient  $4^\circ\text{C}$  is found at a depth of 15 meter (Fig. 6.2). Sreenivasan (1965, 1968) has considered narrow gradient in water temperature as a case of

weak thermal stratification. According to Ruttner (1963), the higher ambient temperature range in this area helps in effective transfer of heat at different strata of water mass. Thus, with narrow thermal gradient even the slight cooling of surface water may initiate the convection currents during cool period (night hours) of the day. Such frequent mixing of water is the probable reason for the comparatively narrow differences in surface and bottom water temperature. Moreover, the gradients in chemical parameters for most part of the year are narrow thus further justifying the lack of complete turnover except for winter, isothermal condition founds in winter this could, therefore, be considered a case of *warm monomictic-cum-meromictic* lake of subtropical regions (Hutchinson, 1957).

The thermal stratification is always supplemented by the chemical stratification. A decrease in pH was observed from surface to bottom (fig. 6.3), because warmer surface water contains less CO<sub>2</sub> as well, photosynthesis utilization might exceed rates of replacement of CO<sub>2</sub>. EC is much higher in bottom at most of sampling stations, an increase of 87 μs/cm was observed in bottom layer (fig. 6.4), HCO<sub>3</sub><sup>-</sup>, Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>-</sup> and PO<sub>4</sub><sup>3-</sup> (fig. 6.6 to 6.10) increase in bottom layer. HCO<sub>3</sub><sup>-</sup> concentration increases in hypolimnion, as the soil zone beneath the lake water body contains elevated CO<sub>2</sub> pressure, which is produced as a result of decay of organic matter and root respiration (Black, 1957). Concentration of nitrate and phosphate also increased in bottom due to release of nutrients from the sediments by bacterial activity and mineralization (Bengston, 1975; Phillip, 1978). Silica concentration increases from surface to bottom, an increase of 18% was observed (fig. 6.11). Utilization of silica by diatoms occurs during photosynthesis causes depletion of silica in surface water. Moreover, in stratified lakes silica concentration increases in bottom water due to biochemical condensation of dissolved silica and sedimentation greatly exceeds inputs to the

sediments from abiogenic sources (Conway et al., 1977). Concentration of  $Mg^+$ ,  $Na^+$ ,  $K^+$  and  $Cl^-$  were high but concentration remains fairly constant in all over lake water due to their conservative nature (Fig. 6.12, 6.14, 6.15 and 6.7).

#### **6.4 Seasonal variation in different geochemical parameters in the lake**

**Jaisamand:** Lake Jaisamand water is alkaline in all three sampling periods. pH is slightly higher in the month of August than October and December (fig. 6.18). Higher pH in August is due to high rate of photosynthesis, which depletes  $CO_2$ . TDS and EC are low in August 2000 and increases in October due to surface runoff with high solute load and again decreases in December 2000, as the sediments gets deposited in bottom of the lake (fig. 6.19 and 6.20). The  $HCO_3^-$  concentration increases in winter season (fig. 6.20) due to higher diffusion of  $CO_2$  from sediments to water and lesser utilization by phytoplankton as the rate of photosynthesis get reduced in winter. An increase in concentration of  $Na^+$ ,  $K^+$ ,  $Mg^{+2}$  and  $Ca^{+2}$  observed in month of December 2000 (fig. 6.27 to 6.30). Concentration of solutes in winter increases due to diffusion of solutes from the sediment (Hutchinson, 1975; Likens, 1985) and an influx of soil drainage water during a period of no flushing (Hutchinson, 1975; Stoddard, 1987).  $NO_3^-$  concentration decreases by 19% in month of December 2000 (fig. 6.23), as low temperature subsequently reduces the rate of litter decomposition in bottom. An increase of 12% in  $PO_4^{--}$  concentration is observed in month of December 2000, which is probably due to lesser uptake by phytoplankton (fig. 6.23). Increase in dissolved silica in month of October 2000 and December 2000 is due to the much biochemical condensation of dissolved silica and sedimentation (fig.6.25).

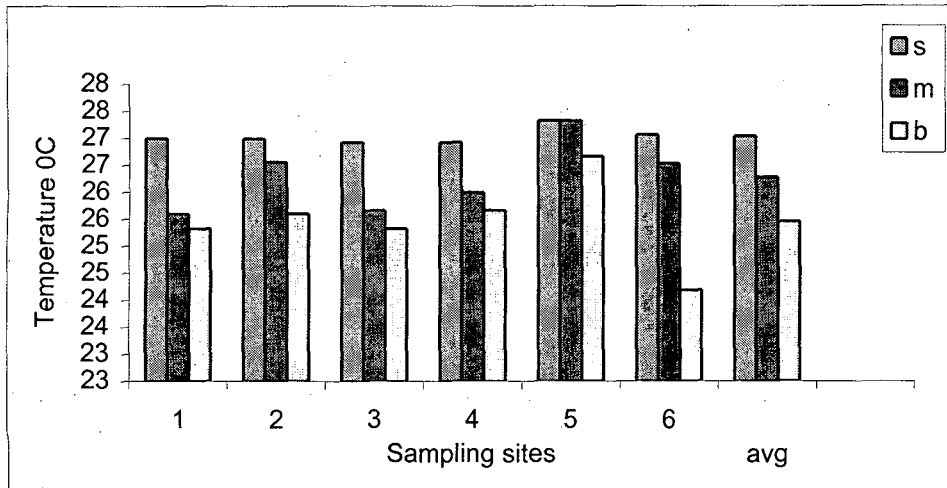


Fig.6.2. Vertical variation in temperature

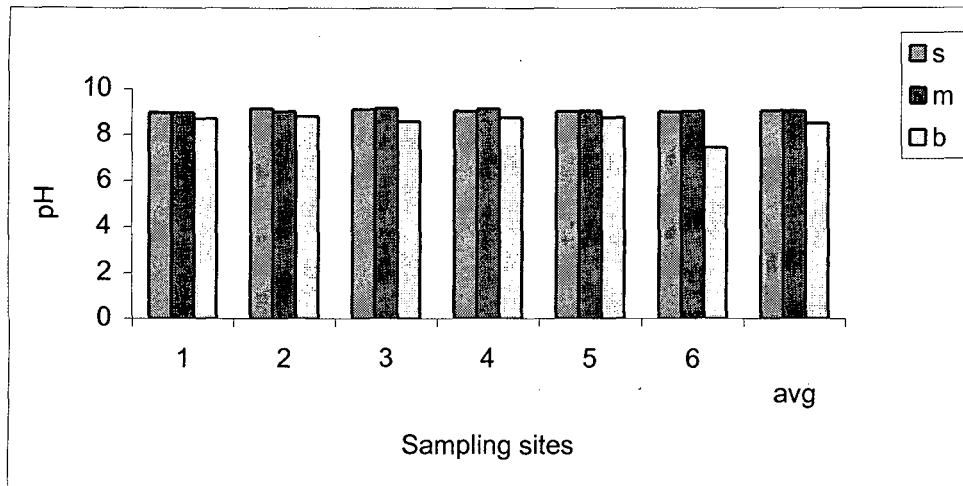


Fig.6.3 Vertical variation in pH

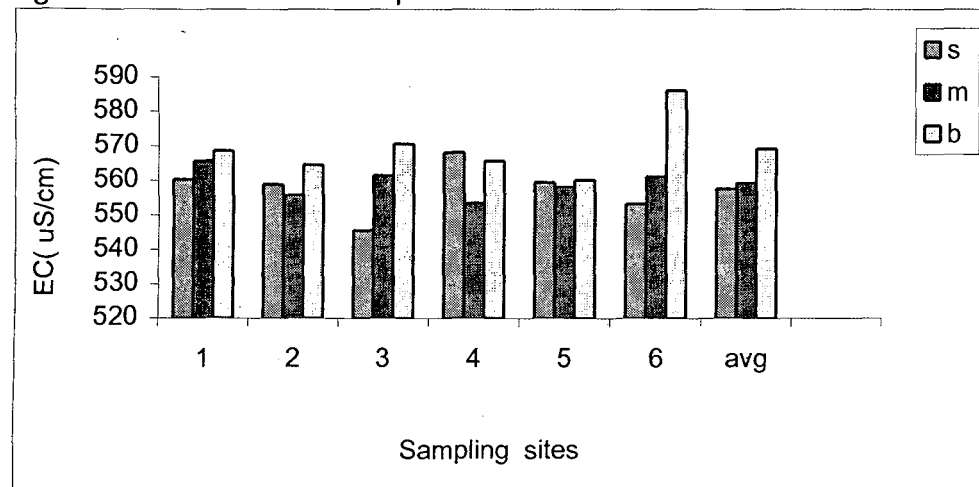


Fig.6.4 Vertical variation in EC

s: surface samples, m: middle layer and b: bottom layer.



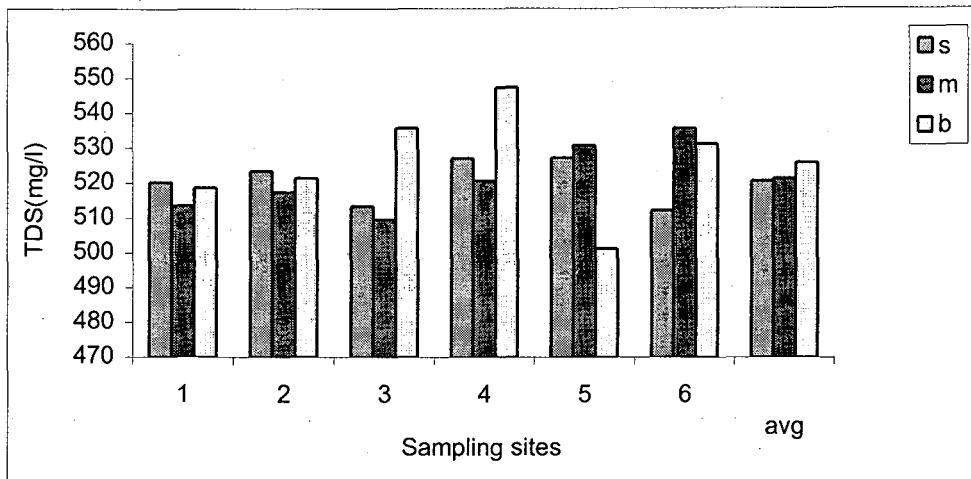


Fig.6.5 Vertical variation in TDS

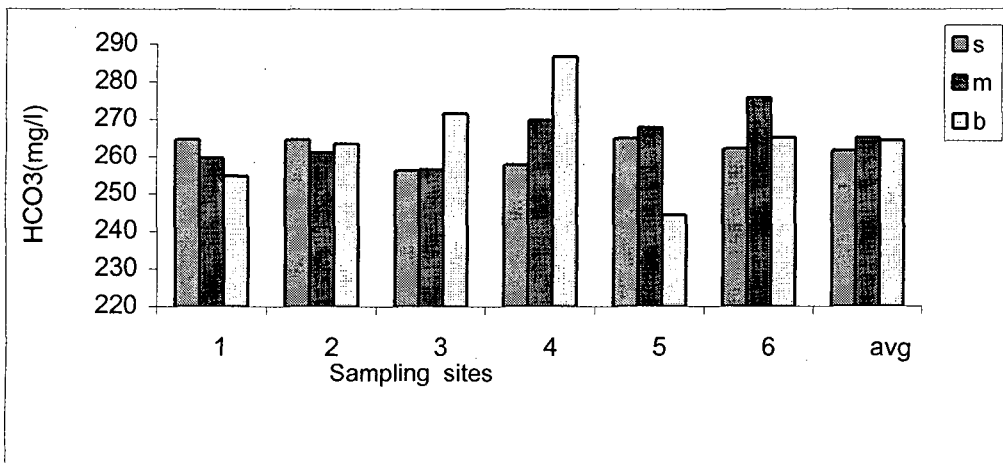


Fig 6.6. Vertical variation in Bicarbonate.

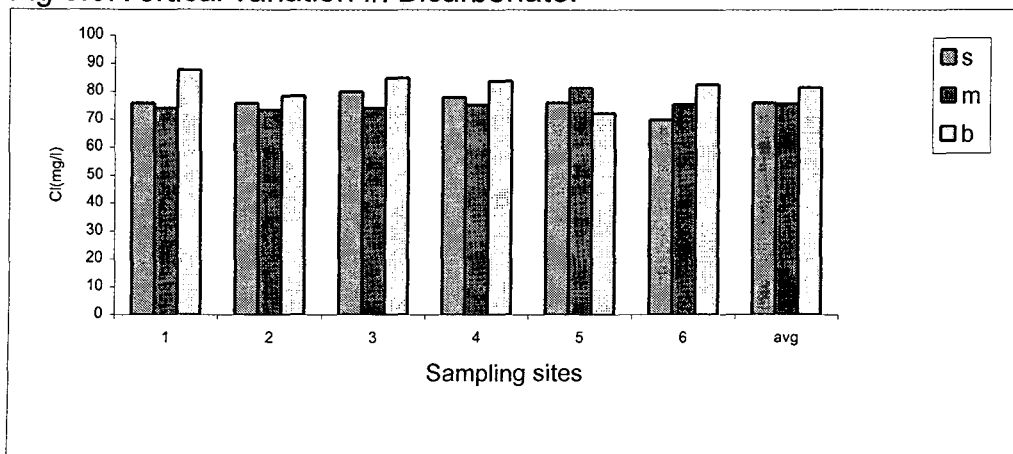


Fig.6.7 Vertical variation in Chloride.

s: surface samples, m: middle layer and b: bottom layer.

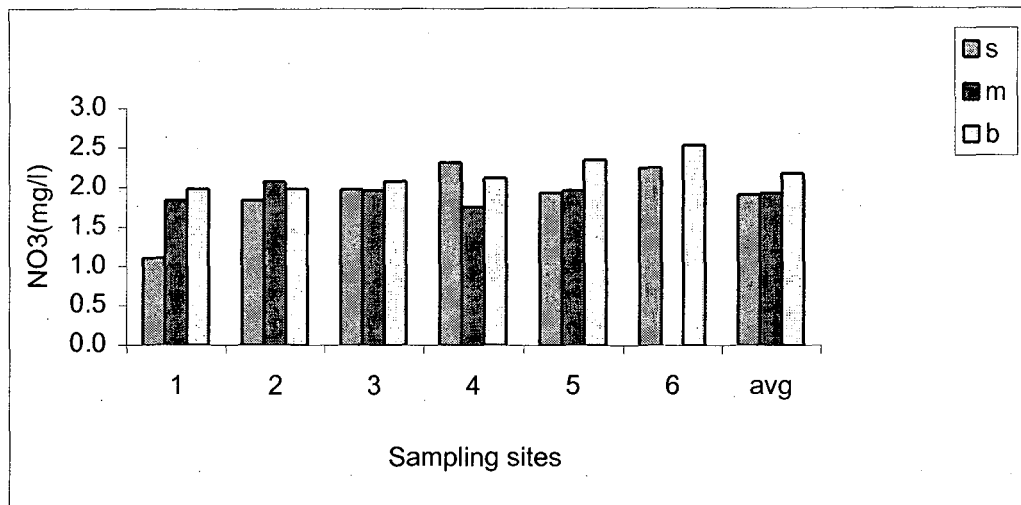


Fig.6.8 Vertical variation in nitrate.

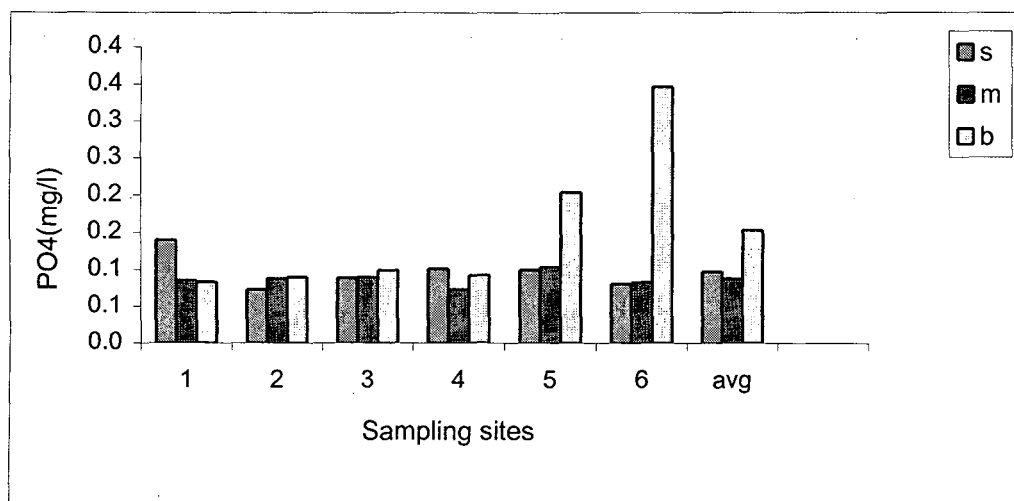


Fig.6.9 Vertical variation in Phosphate.

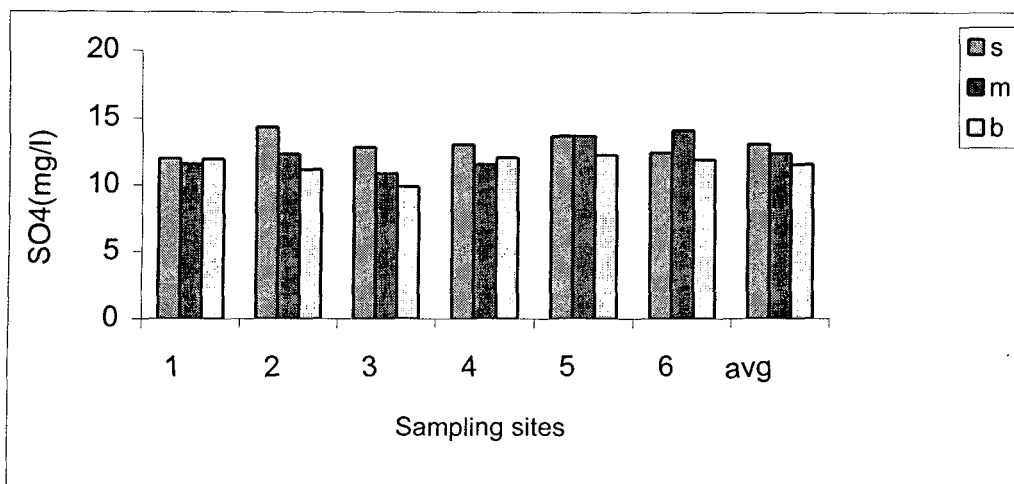


Fig.6.10 Vertical variation in Sulphate.

s: surface samples, m: middle layer and b: bottom layer.

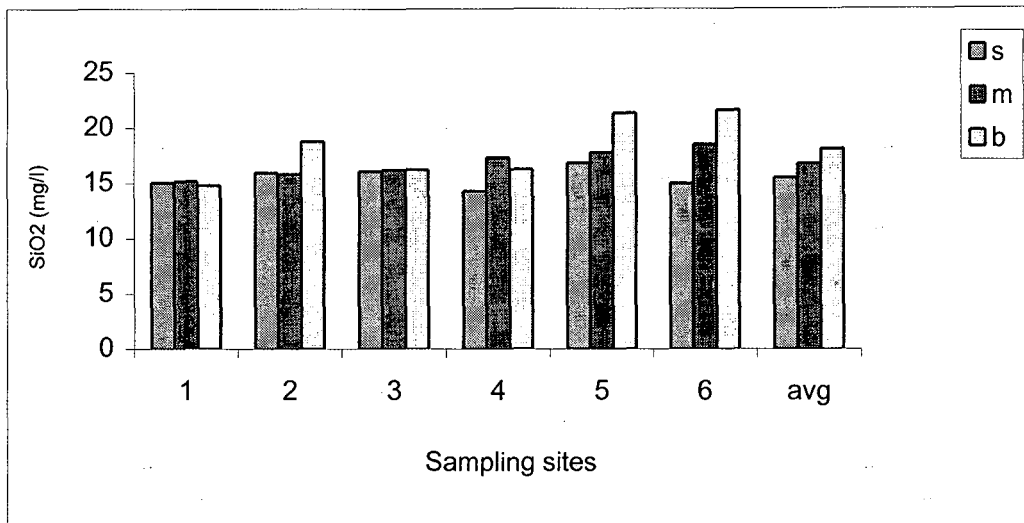


Fig.6.11 Vertical variation in dissolved silica.

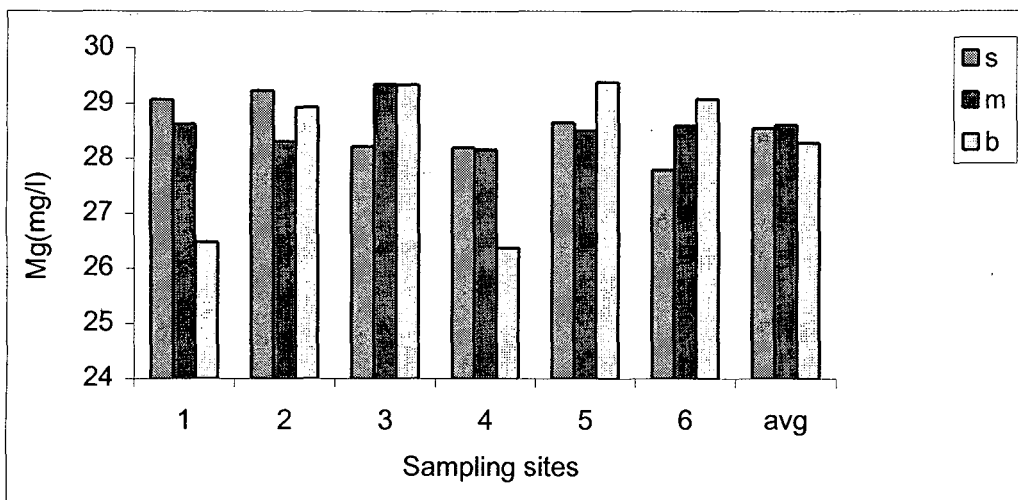


Fig.6.12 Vertical variation in Magnesium.

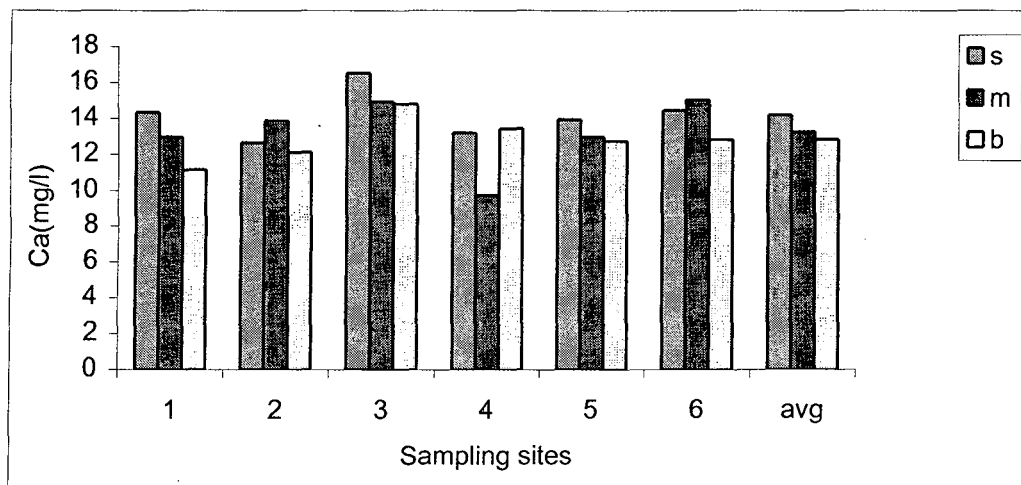


Fig.6.13 Vertical variation in Calcium.

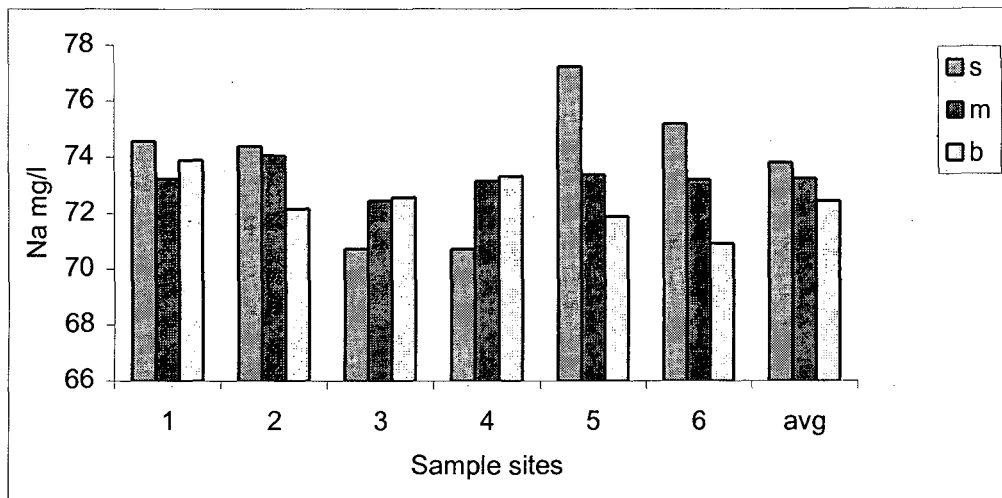


Fig. 6.14 Vertical variation in Sodium

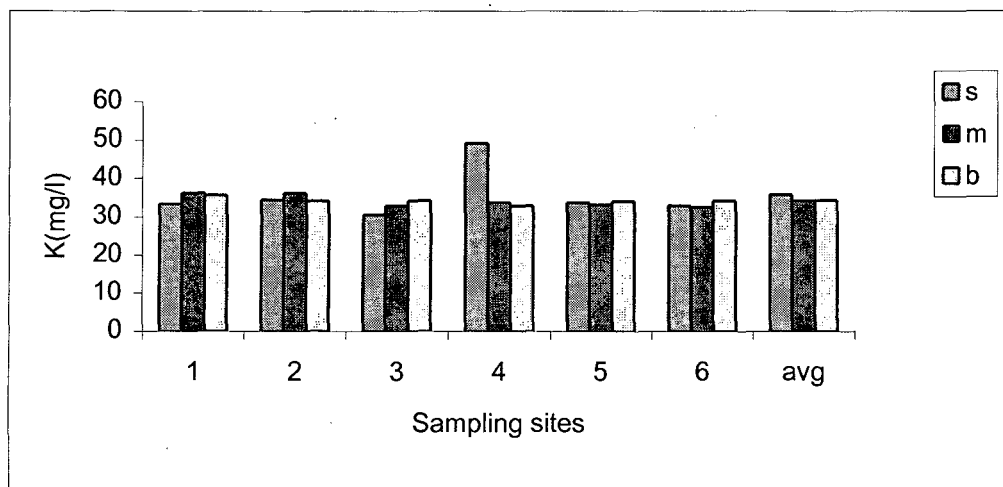


Fig.6.15 Vertical variation in Potassium

s: surface samples, m: middle layer and b: bottom layer.

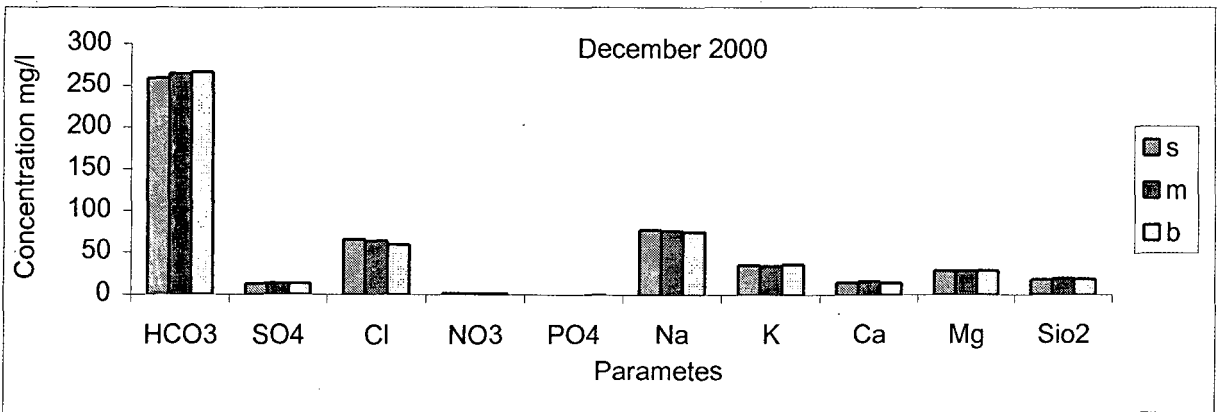
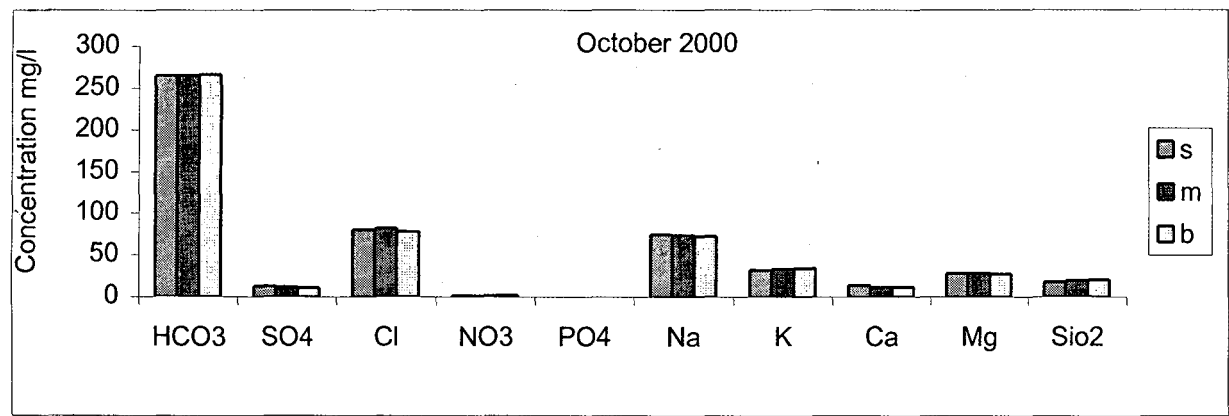
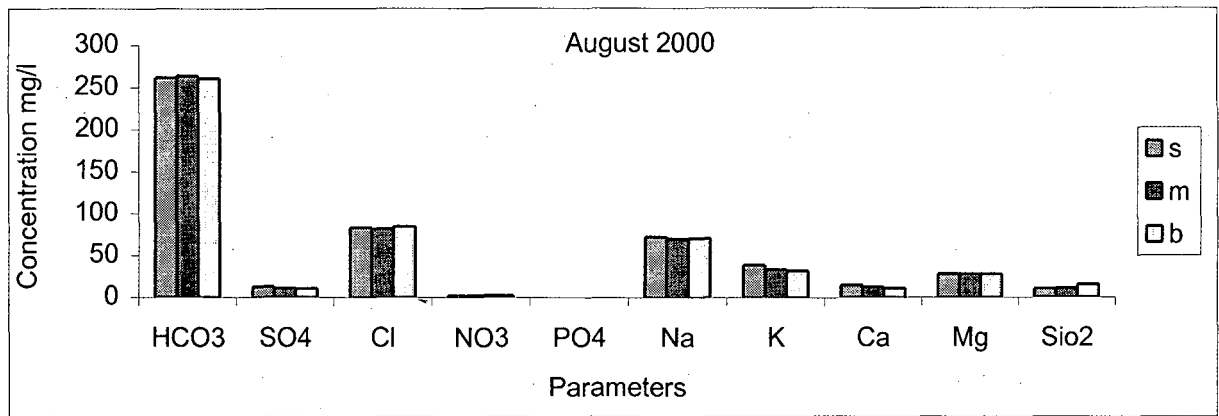


Fig. 6.16. Vertical variation in absolute concentration of various dissolved species in lake Jaisamand. (a) August (b) October and (c) December  
 a; August; o; October, d; December

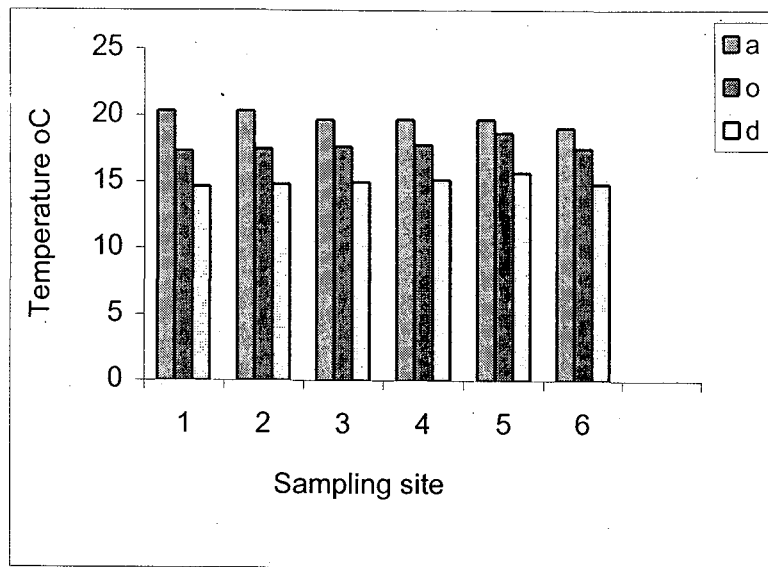


Fig.6.17 Seasonal variation in Temperature.

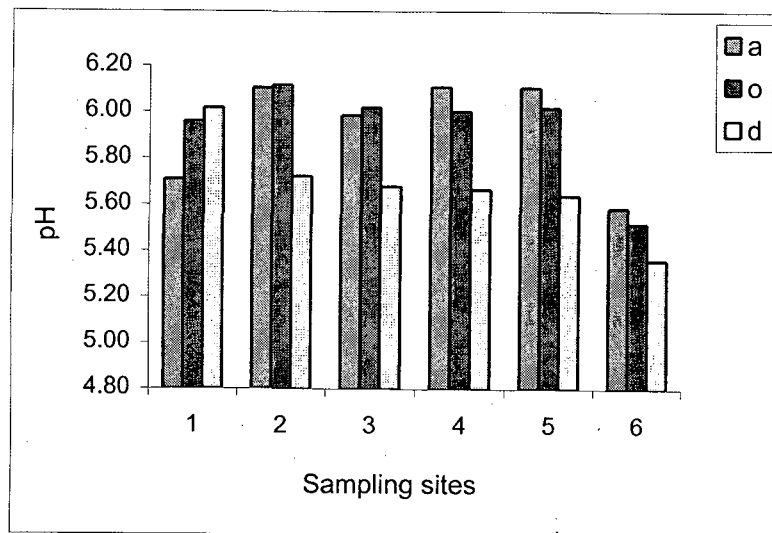


Fig.6.18 Seasonal variation in pH.

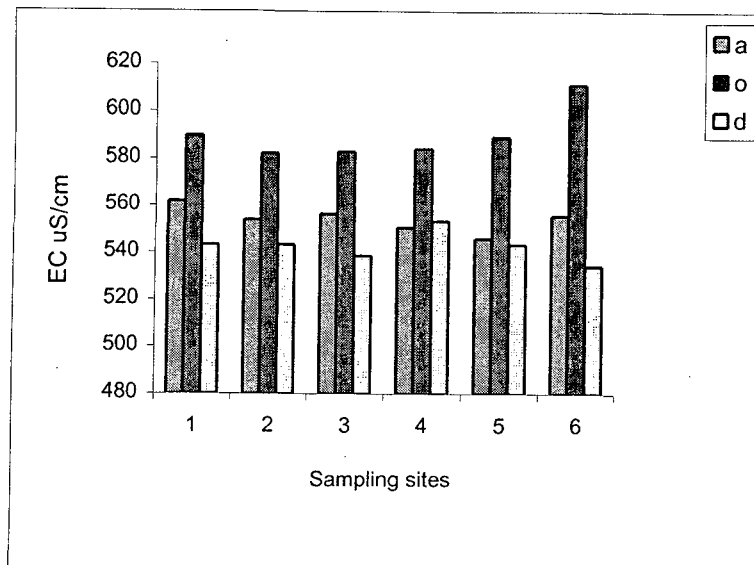


Fig.6.19 Seasonal variation in EC.

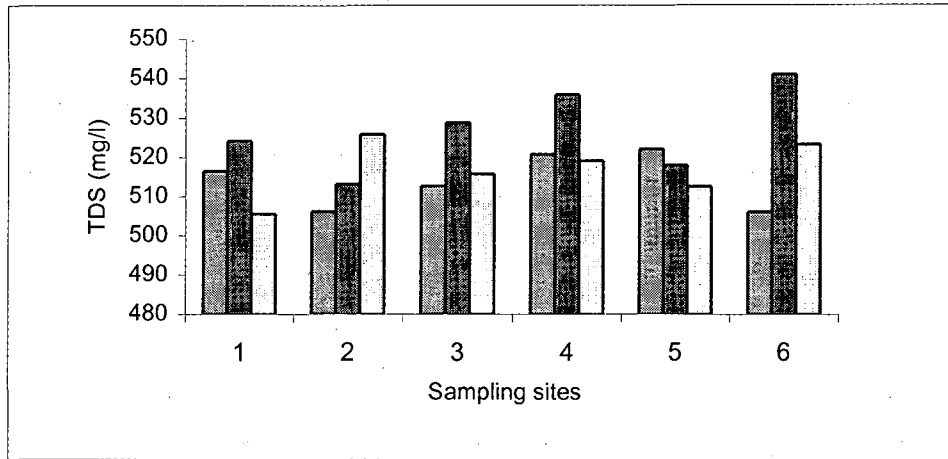


Fig.6.20 Seasonal variation in TDS.

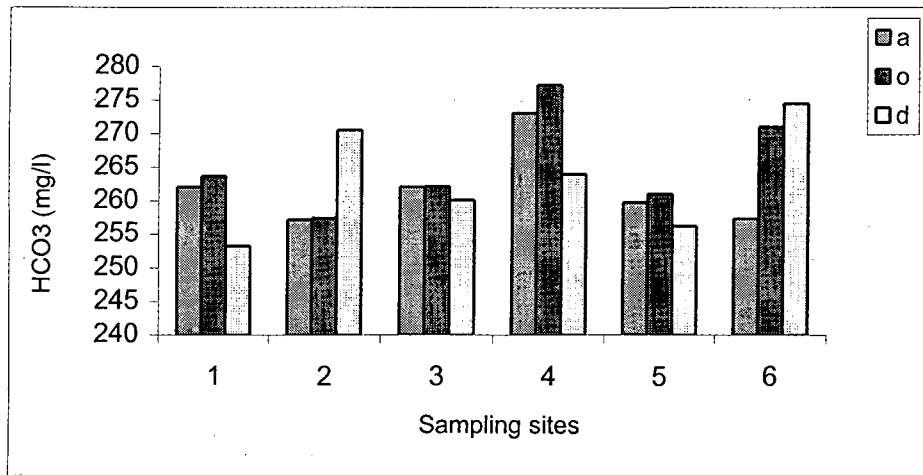


Fig.6.21 Seasonal variation in Bicarbonate.

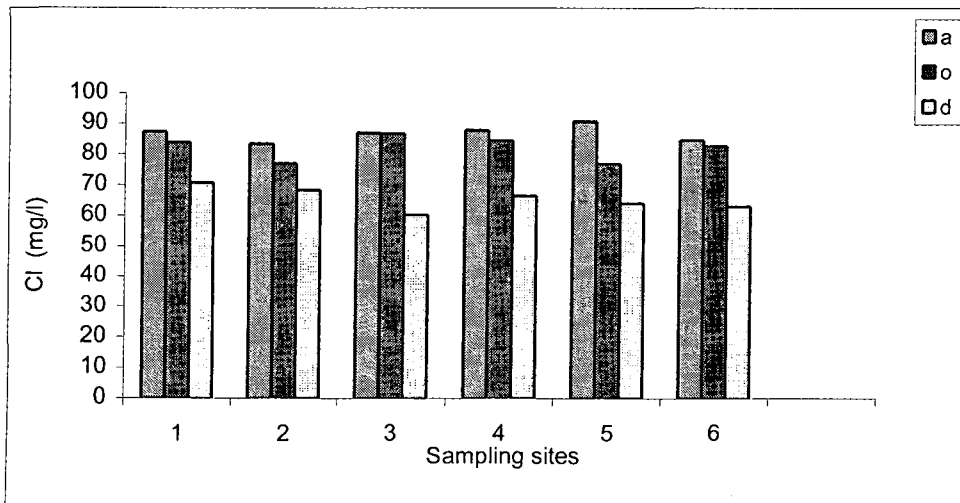


Fig.6.22 Seasonal variation in Chloride.

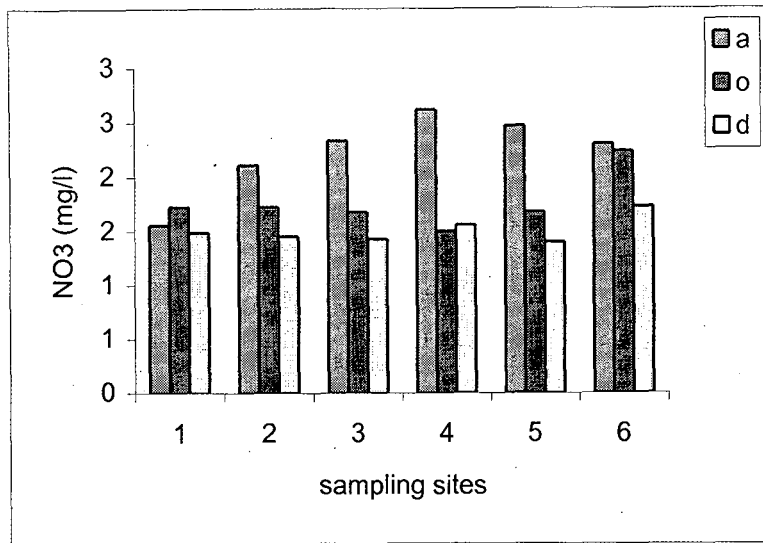


Fig.6.23 Seasonal variation in nitrate.

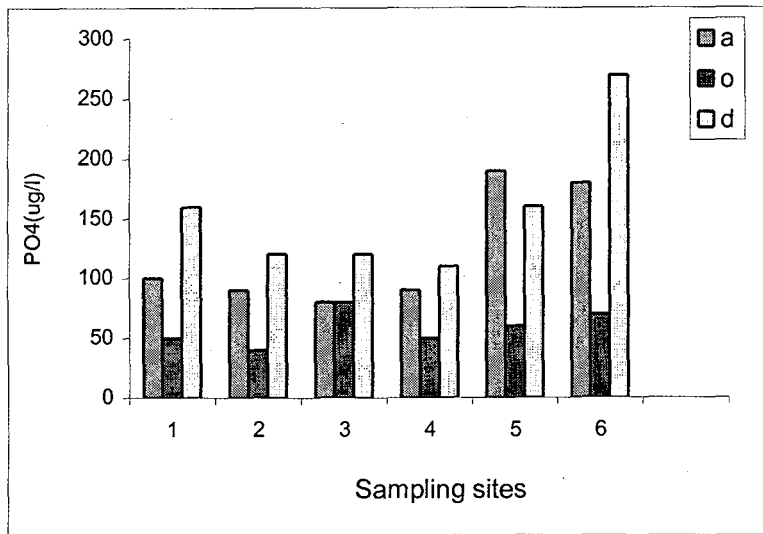


Fig.6.24 Seasonal variation in phosphate.

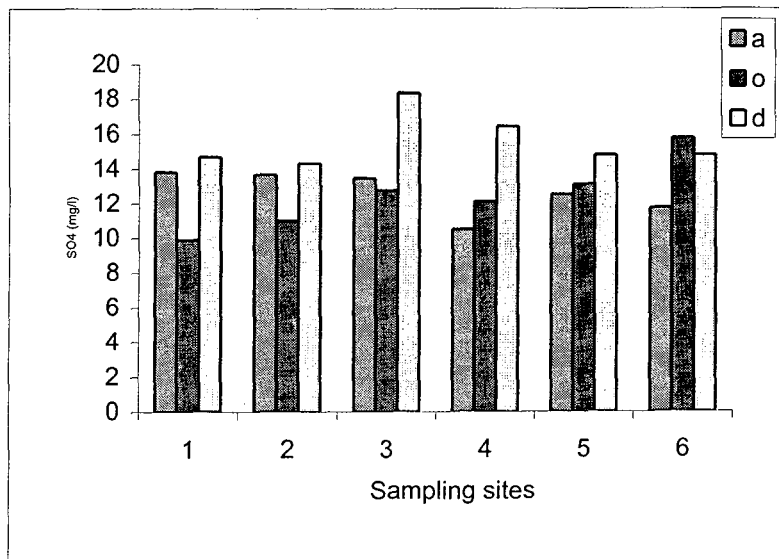


Fig.6.25 Seasonal variation in Sulphate.



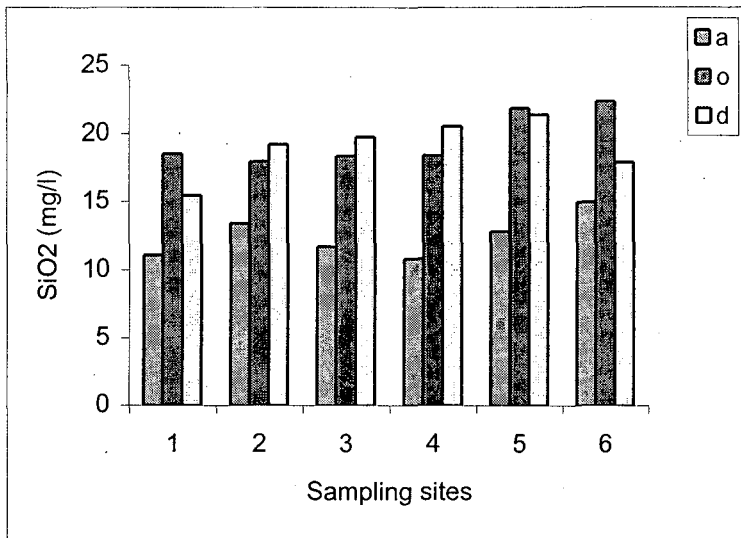


Fig.6.26 Seasonal variation in SiO<sub>2</sub>.

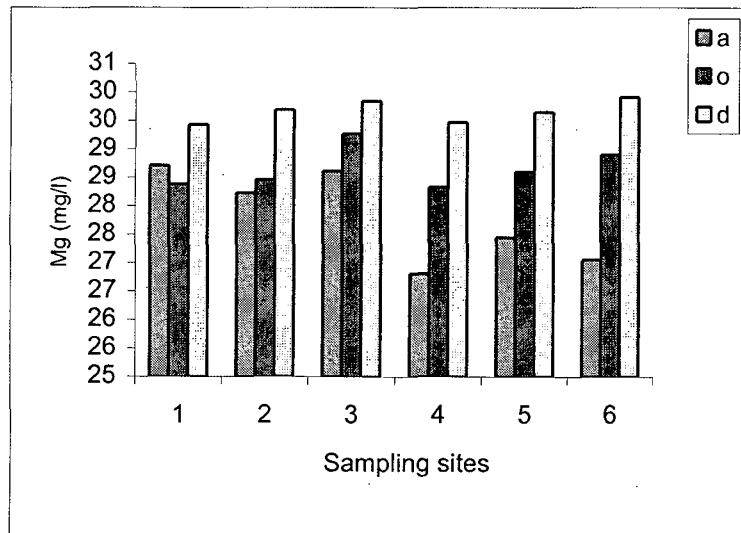


Fig.6.27 Seasonal variation in Magnesium.

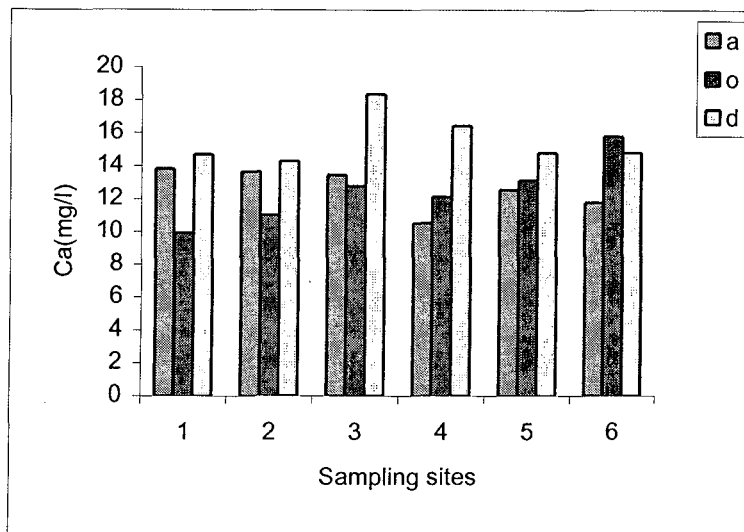


Fig28. Seasonal variation in Calcium.

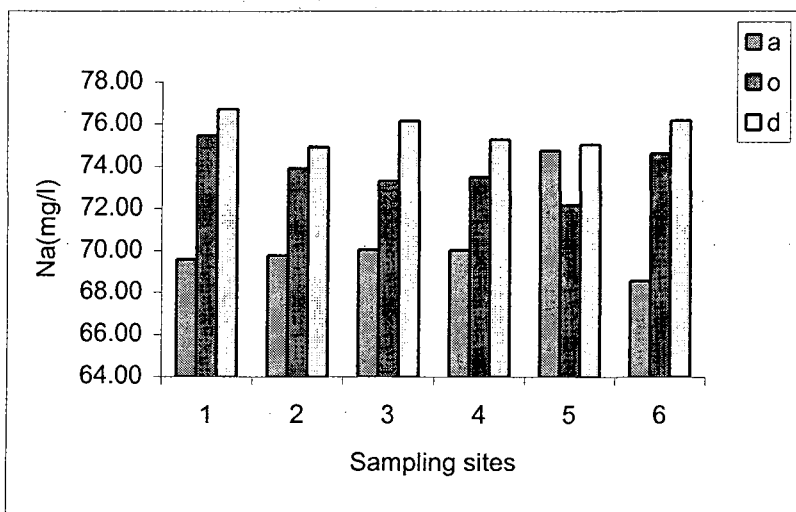


Fig.6.29 Seasonal variation in Sodium.

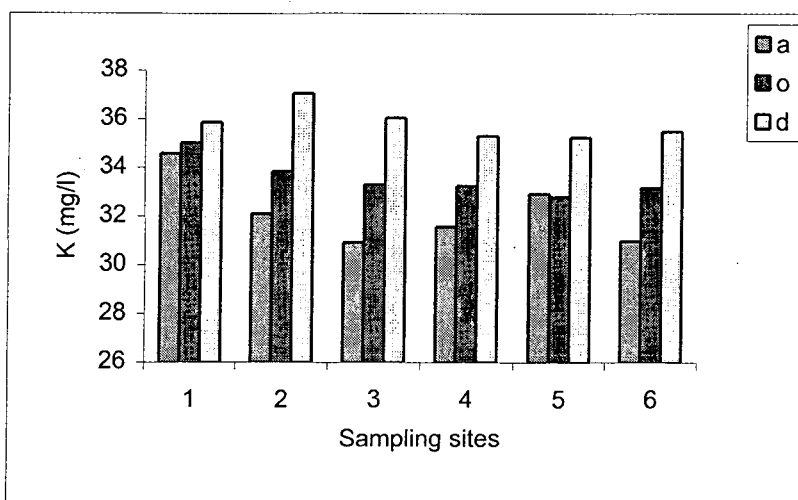


Fig.6.30 Seasonal variation in Potassium.

## 6.5 Average chemical composition and comparison with other Indian and

**World lakes:** Average chemical composition of the lake Jaisamand and the average composition of Indian and the world's major lakes are given in table 6. 1. The table shows that the lake Jaisamand has a high TDS and EC than world average. Nutrient status of lake also suggests its mild eutrophic condition. High bicarbonate concentration exhibit intense rock weathering occurring in lake basin, which is also reflected in lake Pichola Udaisagar and Nainital Lake (Das and Singh, 1994, 1996). Lake Jaisamand attributed to higher dissolved silica concentration, which indicates silicate weathering in the catchment and higher  $\text{Na}^+ + \text{K}^+$  to  $\text{Ca}^{+2} + \text{Mg}^{+2}$  also supports this.

## 6.6 Factors controlling geochemical characteristics of the lake water

The abundance of dissolved major cations and anions in lake water are derived from the weathering of rock forming minerals, along with discharge from agriculture, industry and domestic effluent. Lake Jaisamand is surrounded by a game sanctuary and there is very less anthropogenic activity, so the chemical composition in terms of dissolved ions is mainly due to weathering of various rocks in the catchment area and by surface runoff from surrounding hills. The source of major ions in water can be defined by plotting the samples according to the variation of weight ratios of  $\text{Na}^+ / (\text{Na}^+ + \text{Ca}^{++})$  as a function of the TDS (fig 6.31). Most of the samples lie in the rock weathering dominant area, suggesting that the water chemistry of lake Jaisamand can be explained on the basis of rock weathering in the catchment area.

The chemical weathering of the rocks is mainly performed by the reaction of  $\text{H}^+$  with minerals in the rock. The  $\text{H}^+$  ion in the catchment area is mainly derived from dissolution of

Table 6.1. Average chemical composition of Lake Jaisamand and other major lakes in India and World.

Lake	pH	EC	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>+2</sup>	Mg <sup>+2</sup>	Cl <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	SO <sub>4</sub> <sup>-2</sup>	SiO <sub>2</sub>	PO <sub>4</sub> <sup>-3</sup>	TDS
<b>Jaisamand (Present work)</b>												
surface	9.05	560	74	36	14	29	76	261	13	16	0.1	519
middle	9.05	562	73	34	13	29	76	265	12	17	0.09	519
bottom	8.51	569	73	34	13	29	82	265	11	18	0.15	525
<b>Pichola (Das and Singh,1996)</b>												
surface	9.08	678	73	4	22	21	73	235	35	5	0.103	468
subsurface	8.9	667	76	4	22	20	73	239	27	4	0.107	465
<b>Nanital (Singh,1994)</b>												
surface	8.66	706	13	3.63	33	55	15	350	98	3.44	0.125	571
subsurface	8.2	680	13	3.86	27	63	15	369	103	3.1	0.174	597
<b>Bhimtal (Singh,1994)</b>												
surface	8.9	181	4.38	2	20	6	6.39	91	37	3.82	0.006	171
subsurface	8.75	182	4.62	2	21	6	6.38	92	35	3.74	0.025	171
<b>Naukuchiyatal(Singh,1994)</b>												
surface	9.4	125	4	1	15	5	6.77	74	16	6.34	0.006	128
subsurface	8.54	155	4	1	18	5	6.67	78	16	7.92	0.011	137
<b>Sattal (Singh,1994)</b>												
surface	9.66	119	3	0.72	11	5	7.33	54	19	5.59	0.007	106
subsurface	8.01	116	3	0.83	11	5	7.2	61	13	5.79	0.009	107
<b>Nilnag (Khan and Zutshi,1980)</b>												
surface	ND	230	2.7	0.4	27	5	5	ND	6.5	ND	ND -----	
subsurface		370	4.6	1	39	7.1	7	ND	8.6	6.7	ND -----	
<b>Victoria (Visser and Villeneuve,1975)</b>												
surface	7.8	97	9	4.1	3.9	2.7	3	ND	2.5	6.7	ND -----	
<b>Ontario (Burgis and Morries,1987)</b>												
surface	ND	ND	12.2	1.44	42.9	6.4	26.7	115	27.1	ND	ND -----	

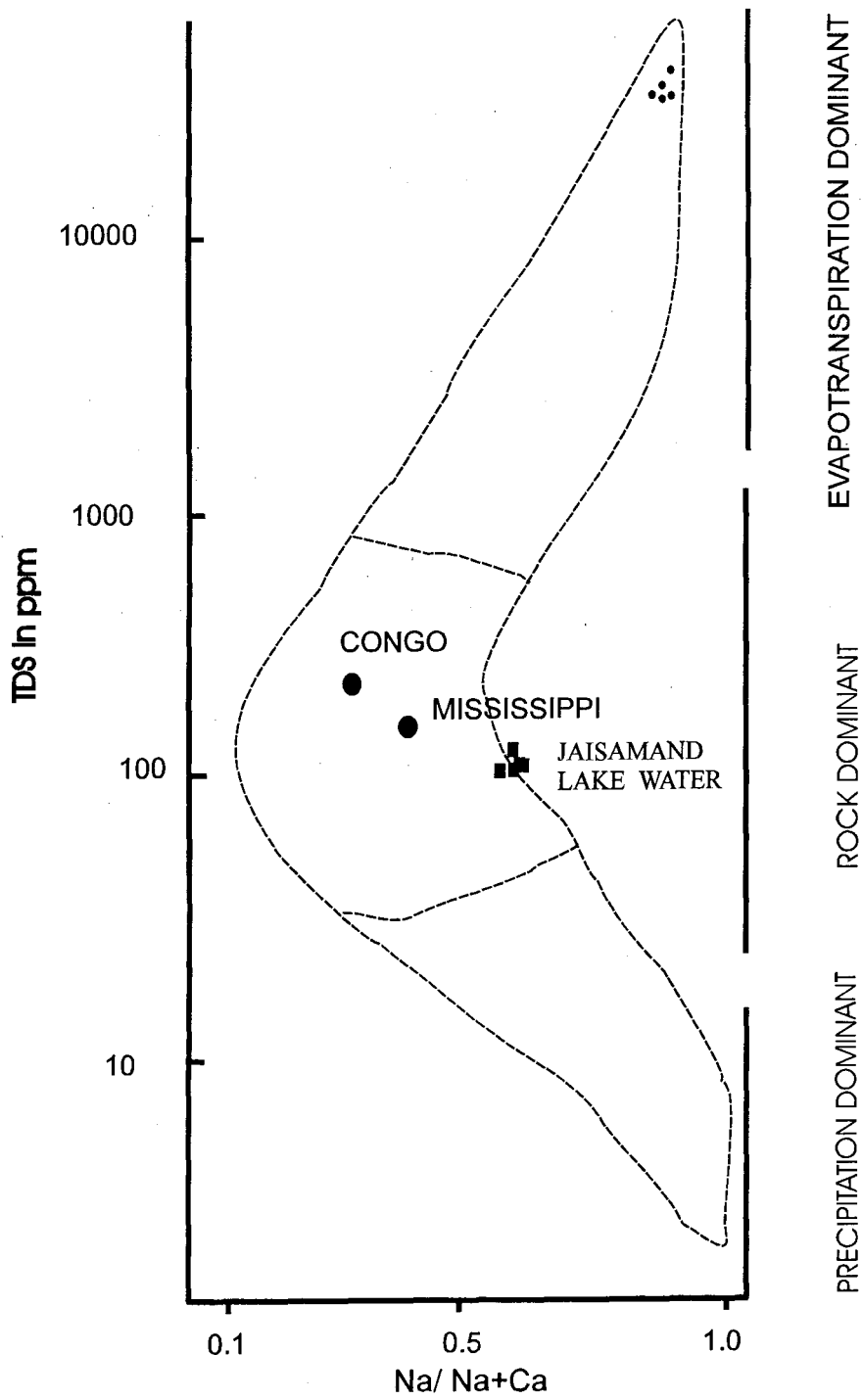
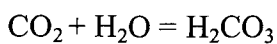


Fig.6.31: Variation of the weight ratio of Na / (Na + Ca) as a function of TDS (after Gibbs 1970)

atmospheric CO<sub>2</sub>, groundwater CO<sub>2</sub> and the oxidation of sulfide minerals (Garrels and Mackenzie, 1971). The major source of CO<sub>2</sub> in the lake is from groundwater. It is also indicated by the higher P<sub>CO<sub>2</sub></sub> pressure in the soil zone beneath the waterbody. The CO<sub>2</sub> in the bottom of lake is produced as a result of organic matter decay and root respiration (Black, 1957), which in turn combines with rainwater to form bicarbonate. The chemistry of dissolved CO<sub>2</sub> can be described by the following reactions:

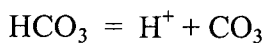


$$K_{\text{CO}_2} = a_{\text{H}_2\text{CO}_3} / p_{\text{CO}_2} \text{ _____ } 1.$$

The weak carbonic acid may again dissociate itself to hydrogen and carbonate ions by the reaction:



$$K_1 = a_{\text{H}^+} \cdot a_{\text{HCO}_3^-} / a_{\text{H}_2\text{CO}_3} \text{ _____ } 2.$$



$$K_2 = a_{\text{H}^+} \cdot a_{\text{CO}_3^{2-}} / a_{\text{HCO}_3^-} \text{ _____ } 3.$$

The equilibrium constants of the above reactions have the following values at 25°C

$$K_{\text{CO}_2} = 10^{-1.47}, K_1 = 10^{-6.35} \text{ and } K_2 = 10^{-10.2} \text{ (Garrel and Christ, 1965)}$$

Combining equation 2 and 3

$$a_{\text{H}^+} + a_{\text{HCO}_3^-} = K_1 K_{\text{CO}_2} * p_{\text{CO}_2}$$

taking logarithm:

$$\log a_{\text{H}^+} + \log a_{\text{HCO}_3^-} = \log(K_1 \cdot K_{\text{CO}_2}) + \log p_{\text{CO}_2}$$

$$\text{or } \text{pH} = \log a_{\text{HCO}_3^-} - \log(K_1 \cdot K_{\text{CO}_2}) - \log p_{\text{CO}_2}$$

$$\log p_{\text{CO}_2} = \log(K_1 \cdot K_{\text{CO}_2}) + \log a_{\text{HCO}_3^-} - \text{pH}$$

$$\text{or } \log p_{\text{CO}_2} = 7.82 + \log m_{\text{HCO}_3^-} - \text{pH} \text{ _____ (4)}$$

Equation 4 can be used to calculate the values of partial pressure of  $\text{CO}_2$  ( $P_{\text{CO}_2}$ ) from pH and bicarbonate content of the lake water.

The result of this calculation for the lake Jaisamand waters have been given in Table 6.2. The table shows that the  $P_{\text{CO}_2}$  values are, -3.6, -3.6 and -3.05 in surface, middle and bottom layer respectively. These values are comparable with the average  $P_{\text{CO}_2}$  values of -3.5 (Wigley, 1973). In contrast to this, the bottom layers value for most of sampling site, especially at site six, high value for  $P_{\text{CO}_2}$  obtained (-2.01 atmosphere). This shows that the lake has a significant fraction of high  $\text{CO}_2$  ground water. This high pressure of  $\text{CO}_2$  in bottom layer get lower as the water comes in the contact with the atmosphere due to degassing of  $\text{CO}_2$ . The plot of  $P_{\text{CO}_2}$  Vs TDS (fig. 6.32) shows that the  $P_{\text{CO}_2}$  remains constant in all over the lake basin, independent of dissolved load.

Plot of  $(\text{Ca}^{++} + \text{Mg}^{++})$  Vs  $(\text{HCO}_3^- + \text{SO}_4^{--})$  for lake Jaisamand water on equivalent unit shows that most of the  $(\text{Ca}^+ + \text{Mg}^+)$  points falls below the 1:1 trend line (fig. 6.33a), reflecting the requirement of cations from weathering of silicate rocks. The plot of  $(\text{Ca}^{++} + \text{Mg}^{++})$  Vs  $\text{HCO}_3^-$ , shows that most points of the  $(\text{Ca}^{++} + \text{Mg}^{++})$  falls below 1:1 trend line (fig. 6.33b) and the ratio is 0.60 to 0.74. This situation requires part of the carbonate alkalinity to be balanced by chemical weathering of silicate minerals. The plot of  $(\text{Ca}^{++} + \text{Mg}^{++})$  Vs  $\text{TZ}^+$  shows that plotted points are also lies far below the equiline with an average equivalent ratio of 0.42 to 0.44 (fig. 6.33c). The relatively high contribution of  $\text{Na}^+ + \text{K}^+$  to the total cations indicates that silicate weathering and/or contributions from alkaline/saline soils and groundwater are the important sources of major ions to the lake waters. This is evident from the lithology surrounding the lake as well as the semiarid conditions prevailing in the area where cycling wetting and drying aids in the formation of alkaline/ saline soil and consequently saline ground water conditions. The high

Table 6.2: Calculated  $PCO_2$  for lake Jaisamand.

site	pH	$HCO_3^-$		$\log pCO_2$	TDS	
		$HCO_3^-$ (mmole/l)	$\log HCO_3^-$			
s1	8.98	264.63	0.004337	-2.36	-3.52	520.20
s2	9.15	264.51	0.004335	-2.37	-3.69	523.45
s3	9.11	256.27	0.004200	-2.37	-3.66	513.39
s4	9.04	257.79	0.004225	-2.37	-3.59	527.15
s5	9.01	264.77	0.004340	-2.37	-3.56	527.17
s6	9.00	262.12	0.004296	-2.37	-3.55	512.18
Avg	9.05	261.68	0.004289	-2.37	-3.59	520.59
m1	8.96	259.58	0.004254	-2.37	-3.50	513.58
m2	9.00	261.13	0.004280	-2.37	-3.55	517.39
m3	9.14	256.55	0.004205	-2.37	-3.69	509.57
m4	9.14	269.68	0.004420	-2.36	-3.68	520.63
m5	9.04	267.72	0.004388	-2.36	-3.58	530.81
m6	9.03	275.64	0.004518	-2.35	-3.56	535.70
Avg	9.05	265.05	0.004344	-2.37	-3.60	521.28
b1	8.71	254.82	0.004177	-2.38	-3.27	518.67
b2	8.80	263.39	0.004317	-2.37	-3.34	521.39
b3	8.58	271.51	0.004450	-2.36	-3.12	535.66
b4	8.75	286.78	0.004700	-2.33	-3.26	547.28
b5	8.75	244.53	0.004008	-2.40	-3.33	501.15
b6	7.46	265.05	0.004344	-2.37	-2.01	531.21
Avg	8.51	264.35	0.004333	-2.37	-3.05	525.89



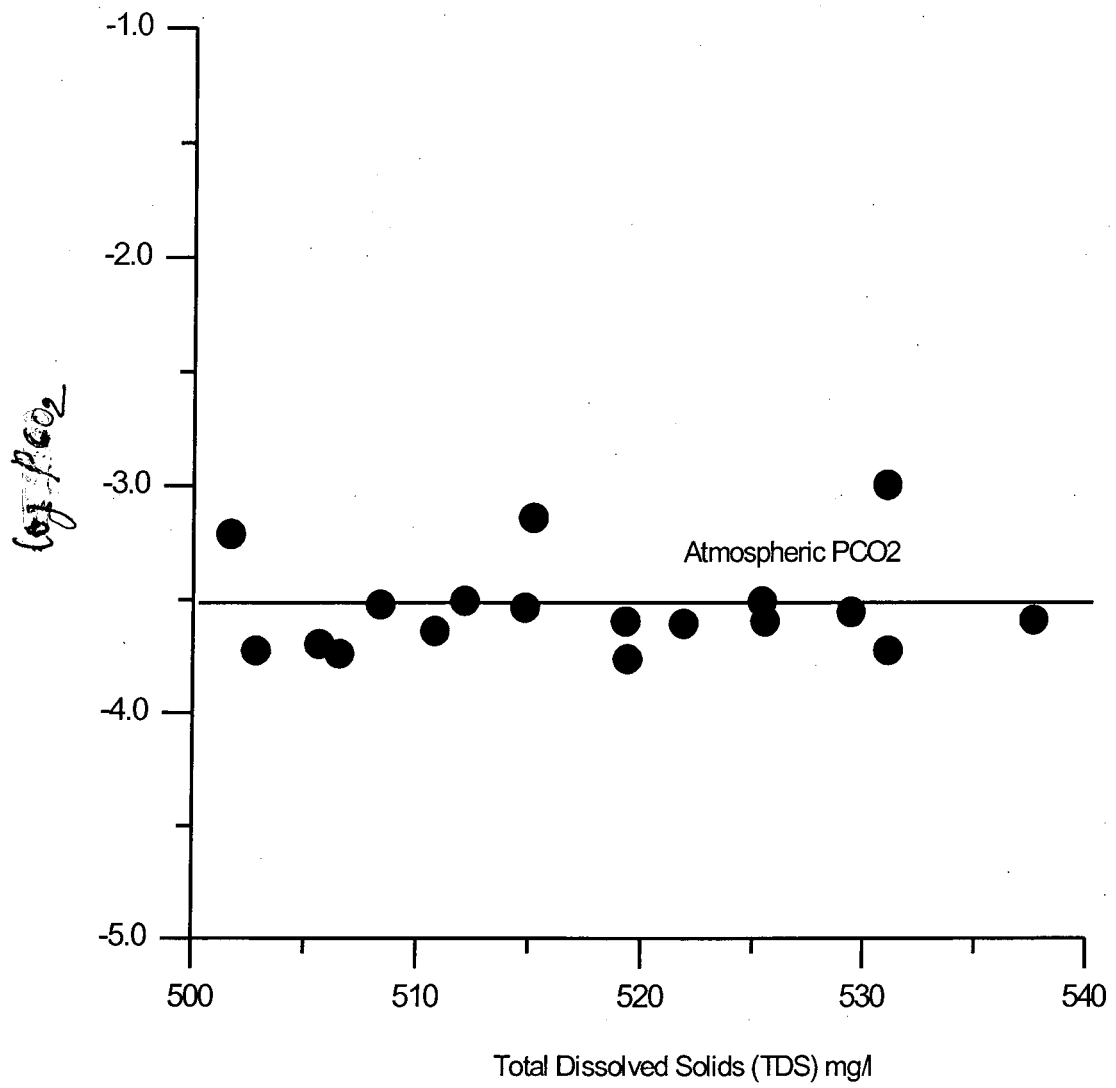


Fig.6.32: Log PCO<sub>2</sub> Vs Total Dissolved Solids (TDS)

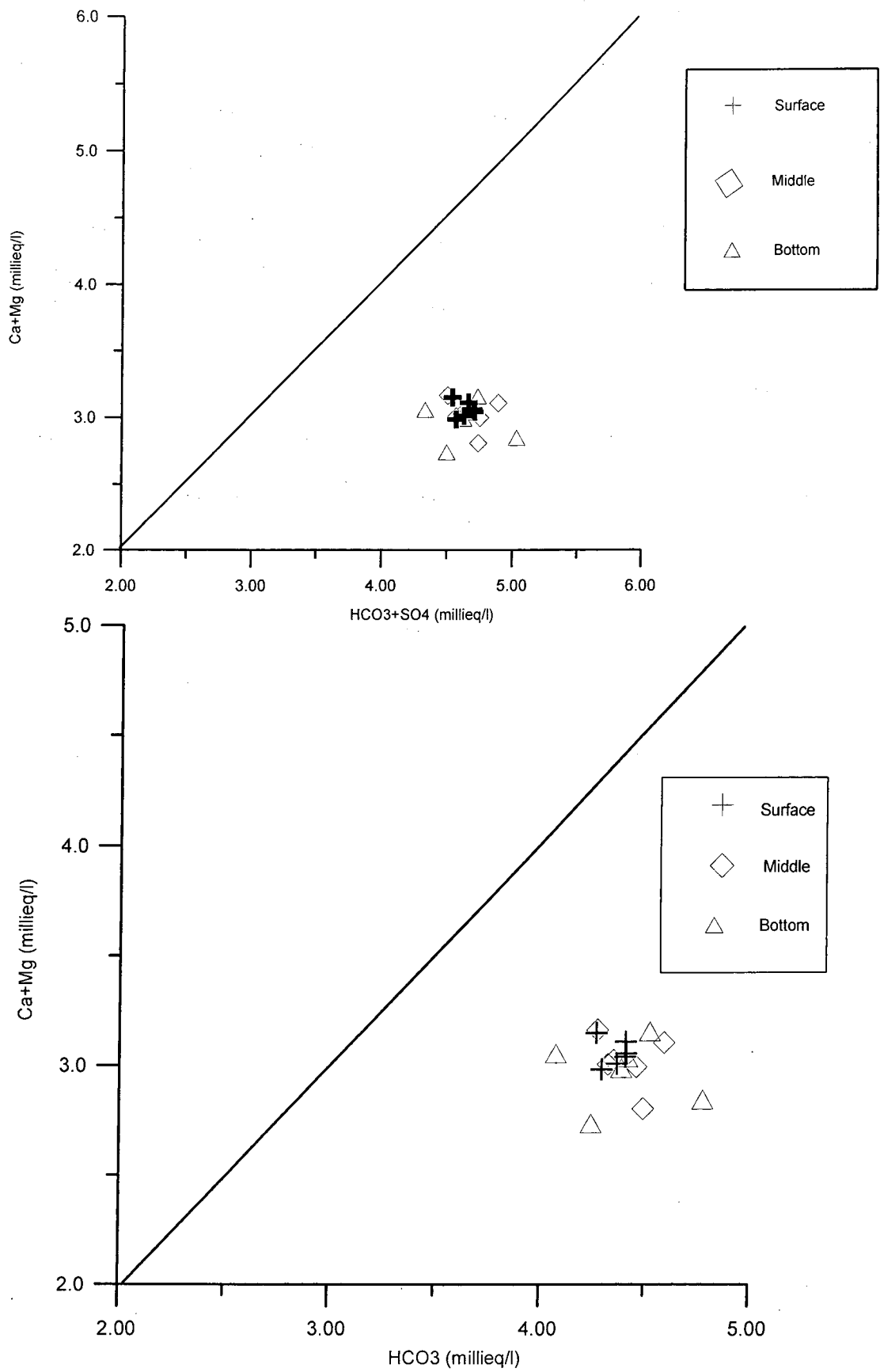


Fig.6.33: Scatter diagram between (a) (Ca + Mg) Vs (HCO<sub>3</sub> + SO<sub>4</sub>) (b) (Ca + Mg) Vs HCO<sub>3</sub>

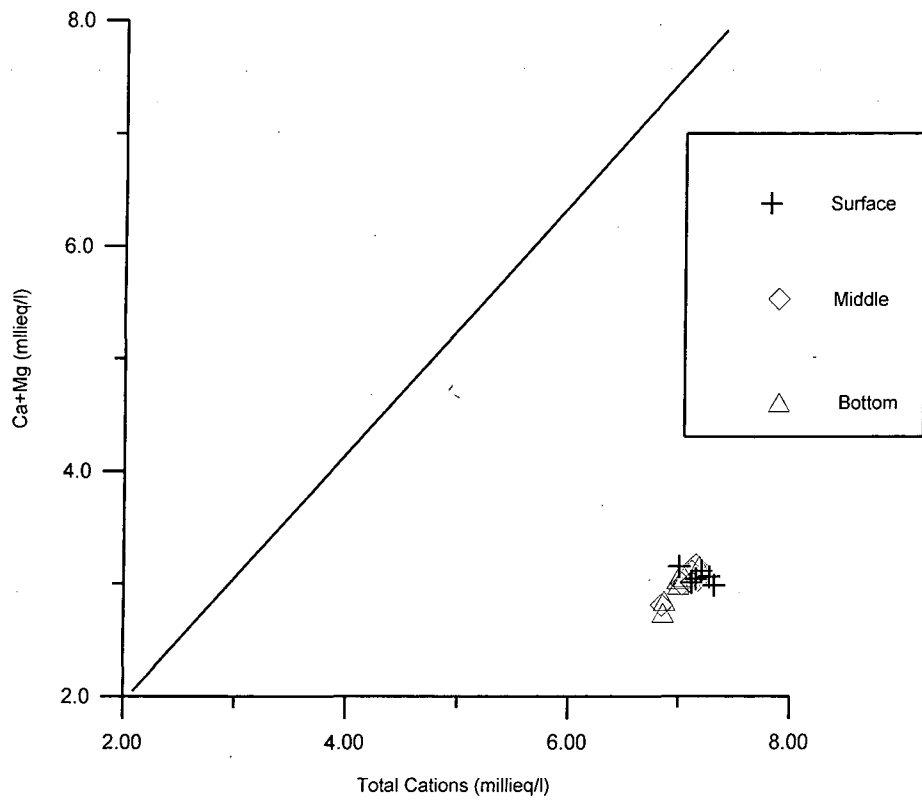


Fig. 6.33(c): Scatter diagram between (Ca + Mg) Vs  $TZ^+$

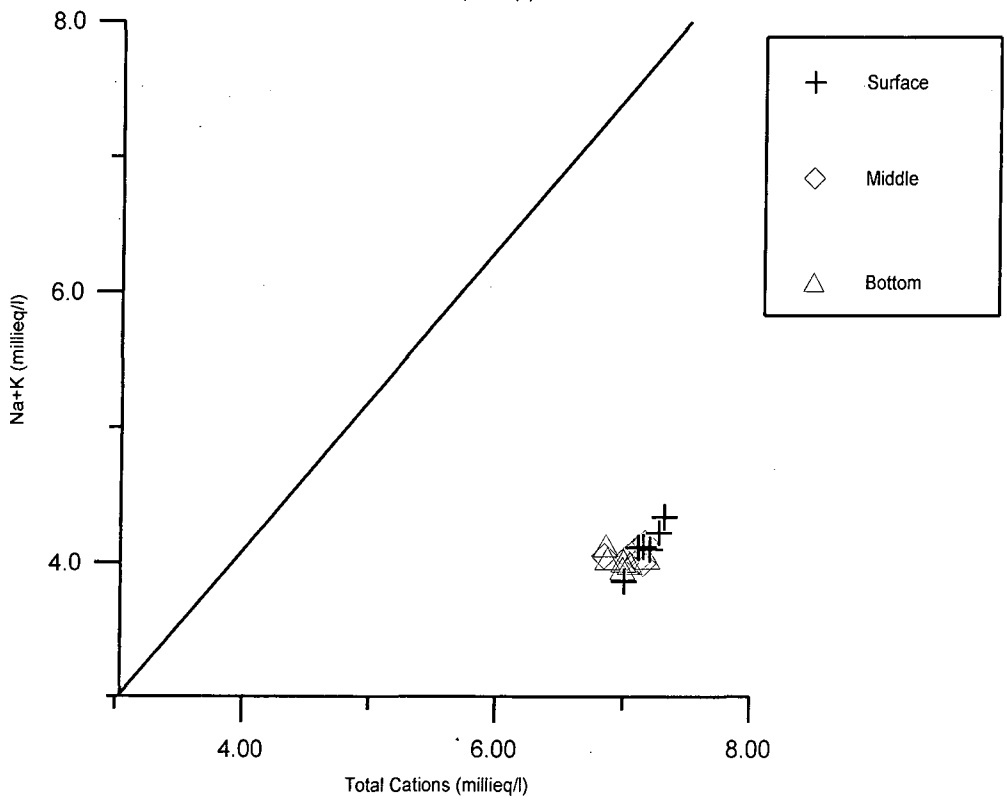
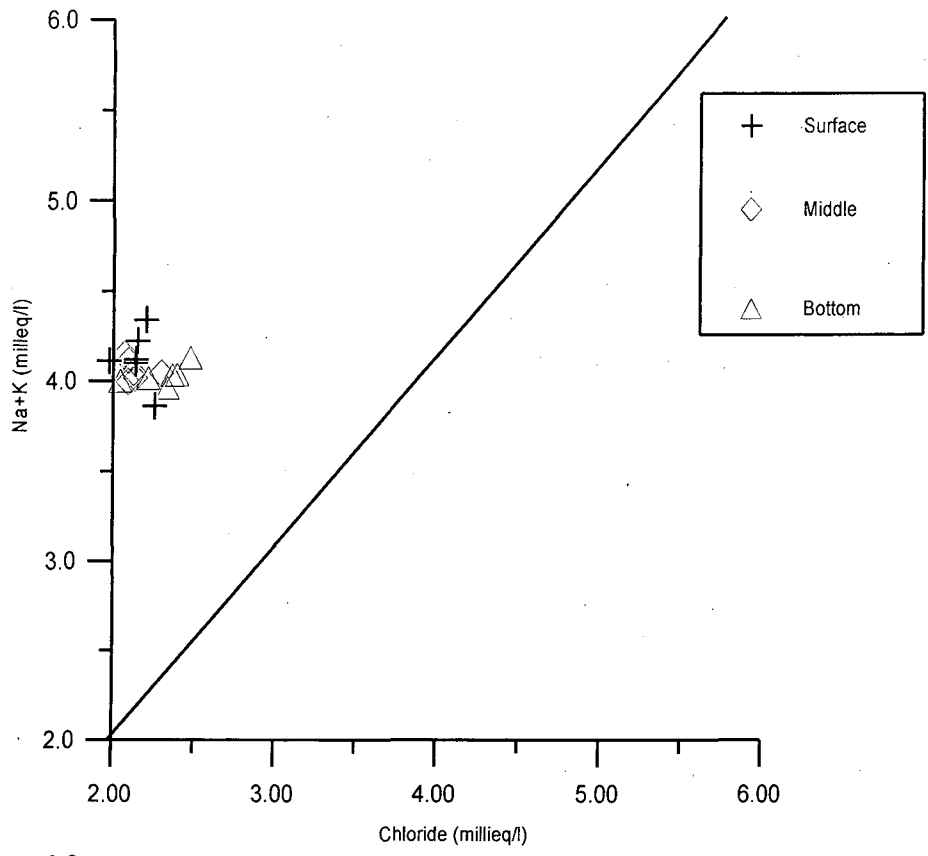


Fig.6.34: a-b Scatter diagram between (a) (Na+K) Vs Chloride and (b) (Na+K) Vs TZ+.

chloride content is primarily due to alkaline/saline soils and saline groundwater in the drainage basin. However, contribution from atmospheric dry fallout could also be significant, as the area is rainfall deficient and located a short distance from the sea (Das and Singh, 1995). The lower  $K^+$  than  $Na^+$  content is due to greater resistance to weathering of the former and is used up in the formation of clay minerals. The sodium concentration in these waters are in excess over chloride and the average  $(Na^+ + K^+): Cl^-$  equivalent ratio is high i.e. 2:1 (Fig. 6.34a). The average value of  $(Na^+ + K^+) / TZ^+$  for the lake Jaisamand ranges (0.55 - 0.60), which indicates the higher degree of chemical weathering of silicate minerals (Fig. 6.34b).

### **6.7 Water mineral equilibrium:**

Mineral stability diagrams offers an opportunity to study equilibrium between silicate minerals and natural water, which can be verified through thermodynamic data. The principle behind such an application is that water derives its composition from the parent rock in the weathering region and the suspended sediments owe their mineralogical composition partly to the parent rock and partly to the chemical reactions of rock and water. Thus by studying the water chemistry, stable mineral assemblages can be theoretically predicted. In the present study an attempt has been made to apply this approach to Lake Jaisamand.

The plot of  $K^+ - Na^+$  Silicate systems (Garrels and Christ, 1965) is shown in fig. (6.35a and 6.35b). The approximate calculation for plotting lake water analysis on the stability diagrams have been given in Table (6.3) for the silicate system. The plot of mineral stability diagram for the silicate system shows the following features:

Table 6.3 : Water composition data used in the stability diagram for silicate system.

S. No	log Na <sup>+</sup> /H <sup>+</sup>	log K <sup>+</sup> /H <sup>+</sup>	log Ca <sup>+</sup> /H <sup>+</sup>	log Mg <sup>+</sup> /H <sup>+</sup>	logH <sub>4</sub> SiO <sub>4</sub>
s1	7.49	5.91	15.91	15.04	-3.60
s2	7.66	6.10	16.20	15.38	-3.58
s3	7.60	6.00	16.23	15.28	-3.57
s4	7.53	6.14	16.00	15.14	-3.62
s5	7.54	5.95	15.96	15.09	-3.55
s6	7.51	5.92	15.95	15.06	-3.60
Avg.	7.56	6.01	16.05	15.17	-3.59
m1	7.46	5.93	15.83	14.99	-3.60
m2	7.51	5.97	15.94	15.07	-3.58
m3	7.64	6.07	16.25	15.36	-3.57
m4	7.64	6.08	16.06	15.34	-3.54
m5	7.54	5.97	15.99	15.15	-3.53
m6	7.53	5.95	16.03	15.13	-3.51
Avg.	7.55	5.99	16.02	15.17	-3.55
b1	7.22	5.67	15.26	14.46	-3.61
b2	7.30	5.74	15.48	14.68	-3.51
b3	7.08	5.52	15.13	14.24	-3.57
b4	7.25	5.68	15.42	14.54	-3.57
b5	7.25	5.69	15.40	14.58	-3.45
b6	5.95	4.40	12.82	12.00	-3.44
Avg	7.01	5.45	14.92	14.09	-3.52

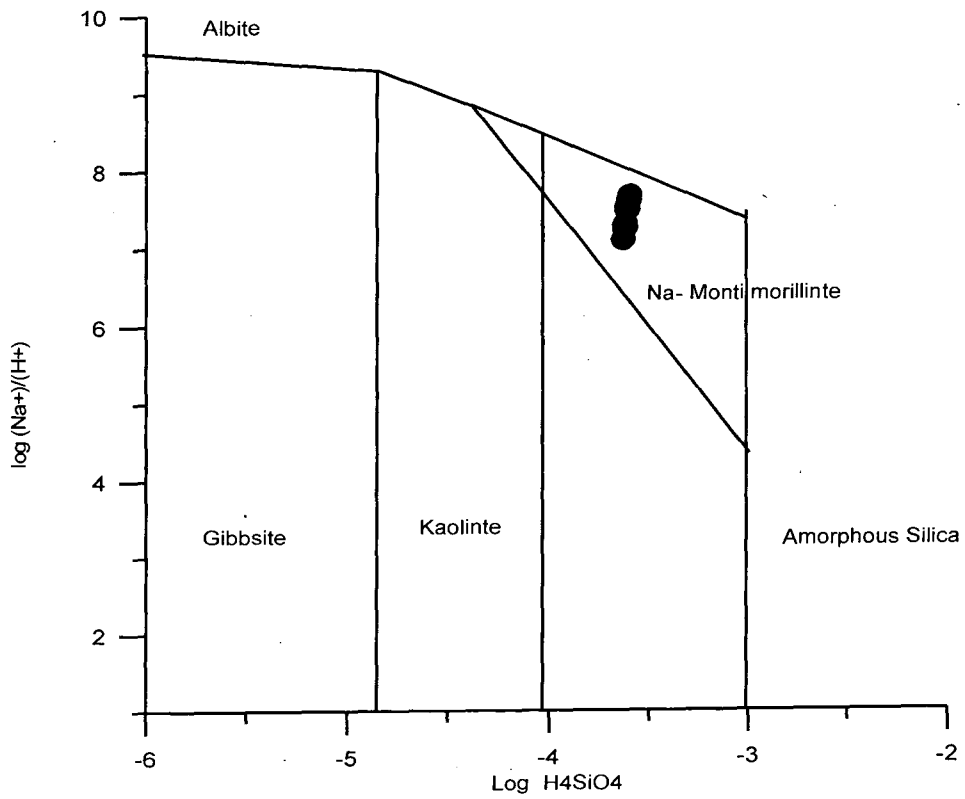
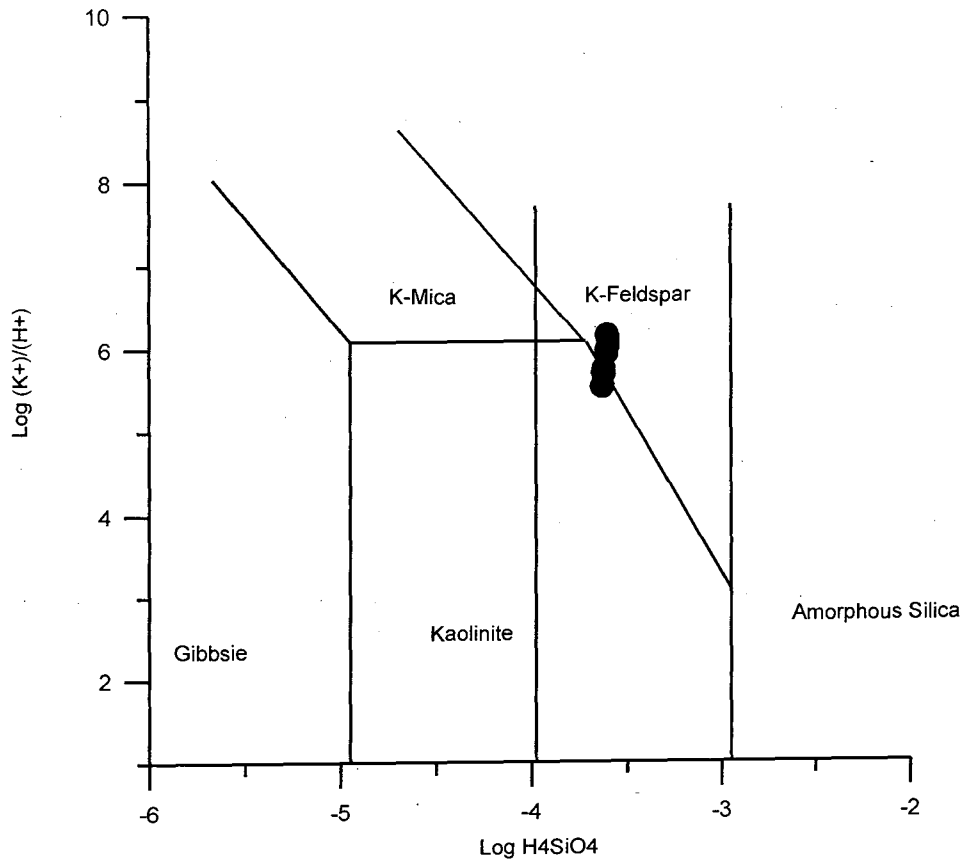


Fig.6.35: a-b Stability diagrams for silicates system

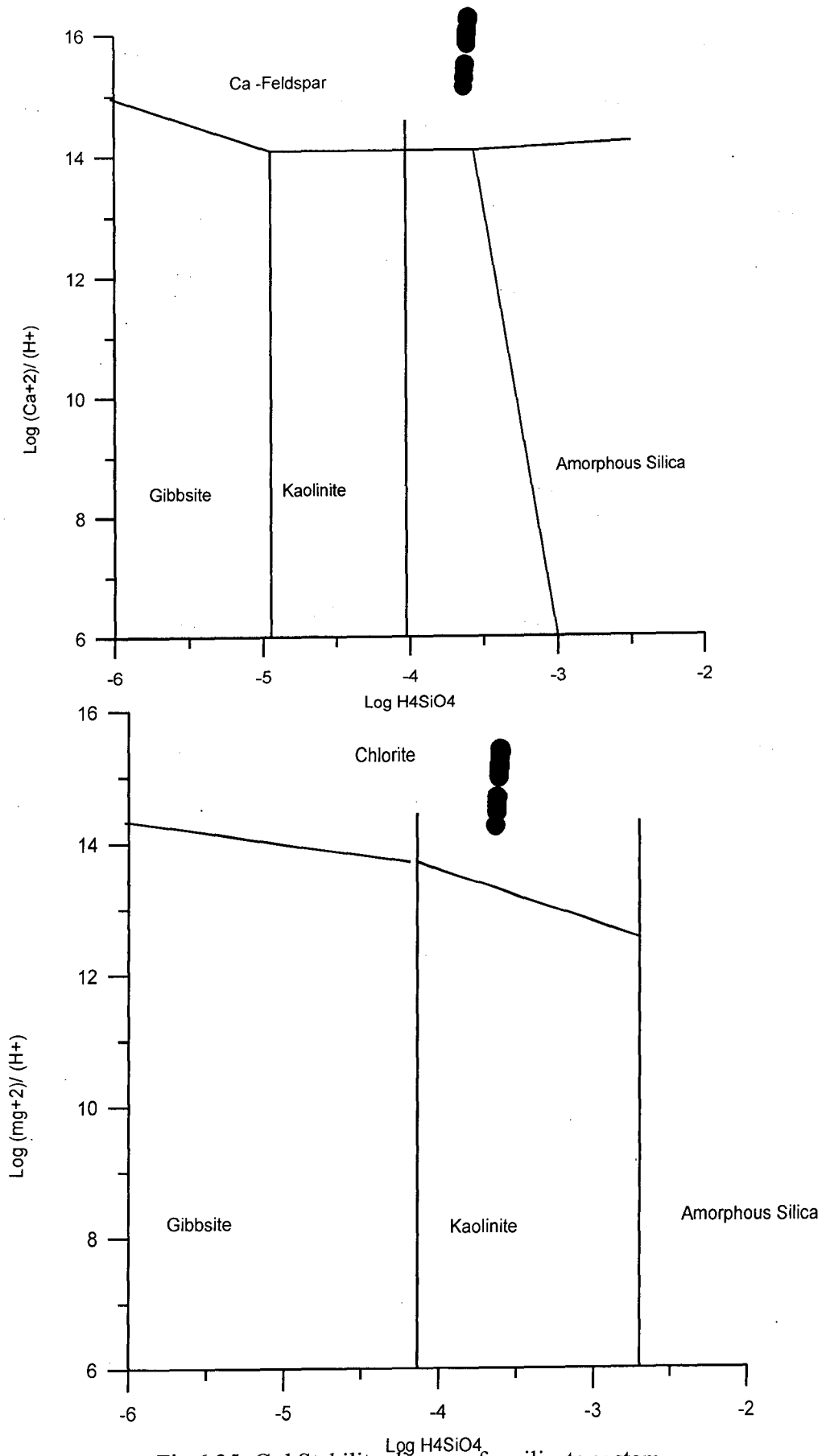


Fig.6.35: C-d Stability diagram for silicate system



- (i) In the stability diagram of K-system, the water composition plots in boundary of kaolinite and K-feldspar (Fig. 6.35a).
- (ii) In the stability diagram of Na -system, the water composition plots in Na-montmorillonite (fig. 6.35b).
- (iii) In the stability diagram of Ca-system, the water composition plots near the Ca-feldspar region (fig. 6.35c).
- (iv) In the Mg- alumina silicate system, all the plotted points fall near the chlorite (fig. 6.35d).

### **6.8 Relative carbonate and silicate weathering:**

In the lake Jaisamand water  $\text{Na}^+$  and  $\text{K}^+$  together accounts for about 21% of TDS and 58% of total cations, while bicarbonate is the dominant ion among anions and constitute 64% of the total anions. The predominance of  $\text{Na}^+$  +  $\text{K}^+$  over  $\text{Mg}^{++}$  +  $\text{Ca}^{++}$  is attributed to the silicate weathering as the catchment area is dominated by phyllite, orthoquartzite, and graywacke lithology. The lower  $\text{K}^+$  than  $\text{Na}^+$  content is also due to greater resistance of weathering of the former and is used up in the formation of clay minerals. The high concentration of bicarbonate indicates that intense chemical weathering processes are taking place in the catchment area. The major source of bicarbonate and calcium are the carbonate rocks containing calcite ( $\text{CaCO}_3$ ) and dolomite  $\{\text{CaMg}(\text{CO}_3)_2\}$ , with a additional supply from the weathering of Ca-silicate minerals.(Ca-plagioclase). Similarly magnesium and bicarbonate can be also be derived by the weathering of dolomites and Mg -silicates (amphiboles, pyroxenes, olivine and biotite). Estimates based on the method of Raymahashay (1986) shows that 33% of the bicarbonate in lake Jaisamand water is derived from weathering of carbonates and the rest 67% is contributed by silicate weathering. Holland (1978), after a

Table 6.4 : Calculated Average value of carbonate and ratio of HCO<sub>3</sub><sup>-</sup>/SiO<sub>2</sub> in the lake Jaisamand.

S. No.	(Ca <sup>2+</sup> )t meq/l	(Mg <sup>2+</sup> )t meq/l	(HCO <sub>3</sub> <sup>-</sup> )t meq/l	(SiO <sub>2</sub> )t mmole/l	.74*Ca <sup>2+</sup> (Ca)t	.4* (Mg)t	(HCO <sub>3</sub> <sup>-</sup> )c	(HCO <sub>3</sub> <sup>-</sup> )si	(HCO <sub>3</sub> <sup>-</sup> )si /SiO <sub>2</sub>	c/si	(HCO <sub>3</sub> <sup>-</sup> )c %	(HCO <sub>3</sub> <sup>-</sup> )si %
s1	0.72	2.39	4.41	0.25	0.53	0.96	1.49	2.92	11.66	0.51	33.72	66.28
s2	0.63	2.41	4.41	0.27	0.47	0.96	1.43	2.98	11.21	0.48	32.46	67.54
s3	0.83	2.32	4.27	0.27	0.61	0.93	1.54	2.73	10.19	0.56	36.06	63.94
s4	0.66	2.32	4.29	0.24	0.49	0.93	1.42	2.88	12.08	0.49	32.98	67.02
s5	0.70	2.36	4.41	0.28	0.52	0.94	1.46	2.95	10.52	0.49	33.07	66.93
s6	0.72	2.29	4.37	0.25	0.53	0.91	1.45	2.92	11.67	0.50	33.16	66.84
Avg ∞	0.71	2.35	4.36	0.26	0.52	0.94	1.46	2.90	11.19	0.51	33.56	66.44
m1	0.65	2.36	4.32	0.25	0.48	0.94	1.42	2.90	11.47	0.49	32.88	67.12
m2	0.69	2.33	4.35	0.26	0.51	0.93	1.44	2.91	11.03	0.50	33.20	66.80
m3	0.75	2.42	4.27	0.27	0.55	0.97	1.52	2.76	10.22	0.55	35.52	64.48
m4	0.49	2.32	4.49	0.29	0.36	0.93	1.29	3.21	11.13	0.40	28.63	71.37
m5	0.65	2.34	4.46	0.30	0.48	0.94	1.42	3.04	10.27	0.47	31.78	68.22
m6	0.75	2.35	4.59	0.31	0.56	0.94	1.50	3.09	10.03	0.48	32.60	67.40
Avg	0.66	2.35	4.42	0.28	0.49	0.94	1.43	2.98	10.66	0.48	32.41	67.59
b1	0.56	2.18	4.25	0.25	0.41	0.87	1.28	2.96	12.00	0.43	30.23	69.77
b2	0.61	2.38	4.39	0.31	0.45	0.95	1.40	2.99	9.56	0.47	31.91	68.09
b3	0.74	2.41	4.52	0.27	0.55	0.97	1.51	3.01	11.15	0.50	33.46	66.54
b4	0.67	2.17	4.78	0.27	0.50	0.87	1.37	3.41	12.59	0.40	28.59	71.41
b5	0.64	2.42	4.07	0.35	0.47	0.97	1.44	2.64	7.44	0.55	35.28	64.72
b6	0.64	2.39	4.42	0.36	0.48	0.96	1.43	2.98	8.31	0.48	32.42	67.58
Avg	0.64	2.33	4.40	0.30	0.48	0.93	1.41	3.00	9.92	0.47	31.91	68.09

comprehensive review of water chemistry and composition of rock concluded that  $74 \pm 10\%$  of  $\text{Ca}^{++}$  and  $40 \pm 20\%$  of  $\text{Mg}^{++}$  in lake water are derived from solution of carbonate minerals and remainder from silicate minerals. Thus the  $(\text{HCO}_3)_c$  and  $(\text{HCO}_3)_{si}$  can be calculated from the following equations (Holland, 1978):

$$(\text{HCO}_3)_c = .74 (\text{Ca})_t + .4(\text{Mg})_t \text{ and}$$

$$(\text{HCO}_3)_{si} = (\text{HCO}_3)_t - (\text{HCO}_3)_c$$

The results of this calculation for the lake Jaisamand have been presented in table (6.4). The ratio of  $(\text{HCO}_3)_c / (\text{HCO}_3)_{si}$  in different parts of the lake can be used as an index of carbonate versus silicate weathering in different parts of the lake. It has been observed that at most of the sampling sites, the ratio of  $(\text{HCO}_3)_c / (\text{HCO}_3)_{si}$  have a value 0.56-0.43, intermediate and low at many sampling sites. Low value indicates weathering of sandstone, granites, and similar silicates, which are the dominant rock type occurring in the catchment area. Therefore it is highly probable that the lake Jaisamand water composition reflects a combined influence of weathering of carbonate and silicate, which occurs in the catchment area of the lake and dominant weathering is silicate weathering.

## ***CHAPTER 7: CONCLUSIONS***

CONCLUSIONS

- The lake water became turbid and brownish during monsoon due to the entry of allochthonous matter and upwelling of bottom sediments by the incoming turbulent river waters. In general water transparency was high in winter and low during monsoon.
- Lake Jaisamand is considered as mild eutrophic lake. Source of nitrate and phosphates are agriculture and surface runoff from surrounding hills. The high phosphate may be due to its flow through Phosphorite deposits persists in the area.
- The order of abundance of various cations and anions in lake water is:  $\text{Na}^+ + \text{K}^+ > \text{Ca}^{++} + \text{Mg}^{++}$ , and  $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{--} > \text{NO}_3^- > \text{PO}_4^{3-}$ . The  $\text{HCO}_3^-$  and  $\text{Cl}^-$  account for 96% of total anions and 67% of TDS.
- The lake Jaisamand showed weakly thermal stratification possibly owing to its greater depth. Frequent mixing of water is the probable reason for the comparatively narrow differences in surface and bottom water temperature in the lake. Moreover, the gradients in chemical parameters for most part of the year are narrow thus further justifying the lack of complete turnover except for winter, therefore; this lake can be considered a case of warm monomictic-cum -meromictic lake.
- $\text{HCO}_3^-$ ,  $\text{Cl}^-$ ,  $\text{NO}_3^-$ ,  $\text{SO}_4^{--}$  and  $\text{PO}_4^{3-}$  increase in bottom layer.  $\text{HCO}_3^-$  concentration increases in hypolimnion, as the soil zone beneath the lake water body contains elevated  $\text{CO}_2$  pressure, which is produced as a result of decay of organic matter and root respiration.
- Jaisamand attributed to higher silica, which shows silicate weathering in the catchment area of the lake and attribute to higher  $\text{Na}^{++} + \text{K}^+$  to  $\text{Ca}^{+2} + \text{Mg}^{+2}$ .

- The plot of  $(Ca^{++}+Mg^{++})$  Vs  $HCO_3^-$ , shows that most points of the  $(Ca^{++}+Mg^{++})$  falls below 1:1 trend and the ratio is 0.60 to 0.74. This situation requires part of the carbonate alkalinity to be balanced by chemical weathering of silicate minerals. The low ratios of the  $(Ca^{++}+Mg^{++})/(Na^{+}+K^{+})$  and  $Ca^{++}/Na^{+}$  suggests weathering of minerals rich in alkalies.
- The ratio of  $(HCO_3^-)_c / (HCO_3^-)_{si}$  in different parts of the lake can be used as an index of carbonate versus silicate weathering in different parts of the lake. It has been observed that at most of the sampling stations, the ratio of  $(HCO_3^-)_c / (HCO_3^-)_{si}$  have a value 0.56-0.43, intermediate and low at many sampling sites. Low value indicates weathering of sandstone, granites, and similar silicates, which are the dominant rock occurring in the catchment area.

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