CASE STUDY

CS (AR) 157

WATER QUALITY STUDIES OF SURINSAR LAKE IN JAMMU REGION

आपो हिष्ठा मयोभुवः

WESTERN HIMALAYAN REGIONAL CENTRE
NATIONAL INSTITUTE OF HYDROLOGY
JAMMU - 180 003 (INDIA)

1994-95

PREFACE

Lakes are forms of inland waters which play an important role in the economy of nature and man. Lakes are also important source of fresh water at high altitude areas of the Himalayan Region. They contain over 95% of the earth's fresh liquid surface water. Lakes in general represents additional storage capacity of hydrologic systems. Natural or artificial changes in storages either in quality or quantity of water alter not only the stream flow regime but also the water balance in the region. This alteration of flow regime and quality of lake water may also cause side effects of ecological imbalances in the region.

The various lakes in the J&K are fast shrinking due to siltation, manifestation of weeds and various encrochments by the local people. Rapid growth of human activities in the catchment areas of these lakes are mainly responsible for deterioration of its water quality . In order to keep lakes in healthy condition and to prevent eutrification, a regular monitoring of its water quality is necessary. Therefore, with this objective, Western Himalayan Regional Centre (NIH), Jammu has undertake the water quality monitoring and evaluation of Surinsar Lake in Jammu region during 1994-95.

The report has been prepared by Shri Om Kar, Scientist"B" and Shri M.K. Sharma, SRA under the guidance of Dr. K.S. Ramasastri, Scientist"F" and Head. Shri Vishal Gupta, JRA assisted in the report.

(S. M. Seth)

Director

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Surinsar lake is a historical and ecological asset of Jammu region. The catchment area of the lake is badly degraded which has caused a lot of siltation into the lake. Rapid growth of human activities in the catchment area are also responsible for deterioration of its water quality. Therefore, water quality monitoring of the lake was carried out during September, October(94), January and March (95). The grab samples of the lake water were collected from eight locations (P1 to P8) along its periphery. The physico- chemical analysis of various water quality parameters including Temp., pH, EC, TDS, Ca, Mg, K, Na, nitrate, phosphate, bicarbonate, sulphate, chloride, DO, BOD, calcium hardness and magnesium hardness were performed.

The study showed that pH of the lake water varied from 8.27 to 8.43 during September,94 to March,95. The lake water contains variable amounts of Ca, Mg, Na, K, chloride, sulphate, bi-carbonate, nitrate, phosphate etc. However, the concentrations of these parameters were found well below the levels prescribed for class - A drinking water standards (Indian Standards for Inland Surface Waters). The DO and BOD values of water were also found within the limit for drinking purposes.

The average SAR values of the lake water were varied from 0.27 to 0.38 from September,94 to March, 95 . These values were well below the limit (less than 10.0, USDA,1954) prescribed for very good quality of irrigation water. According USDA (1954) classification, the lake water falls under C1-S1 (low salinity-low sodium) during September/October and January/March,95 respectively. As per Doneen's classification, the lake water falls under class II type of irrigation water. These both classification showed that lake water is good for irrigation purposes.

1.0 INTRODUCTION

There are about three million lakes in the world and most of them are located in the Northern Hemisphere. According to Zumberge and Ayers (vide Chow,1964) a lake is defined as an inland basin filled or partially filled by a water body whose surface dimensions are capable of producing a barren wave swept shore.

Lakes are the potential source of fresh water at high altitudes. The water stored in them is used for drinking purpose, for factories, for hydro-electric power generation and for irrigating the fields. In addition , lakes yield valuable supply of fish, which is used both as food and fertilizer. The salt water lakes yield common salt. Some times due to the presence of lakes, roads and railways have to make wide detours but in providing navigational waterways, lakes remain supreme.

In addition, lakes modify the local climate. Their role in making the climate mild and pleasant is very important. The lakes cool the air in summer and warm it during winter. They also increase the humidity in the atmosphere. Lakes also tend to modify the rainfall and in their neighbourhood as the quantity of precipitation is usually higher. The lakes often bring about the establishment of important health and pleasure resorts which attracts the tourists.

Lakes in general represents additional storage capacity of hydrologic systems. Natural or artificial changes in storages either in quality or quantity of water alter not only the stream flow regime but also the water balance in the region. Alteration of flow regime and quality of lake water, a common problem faced everywhere, arising from increase in demand and several developmental activities, result in the hampering of activities supported by lakes. There are also side effects of ecological imbalances in the region.

Lakes are considered to undergo a process of aging , which has been characterized by three qualitatively defined conditions. The initial condition of a lake is termed 'oligotrophic' and is normally associated with deep lakes, where waters at the bottom of the lake are cold and relatively contain high level of dissolved oxygen throughout the year. Oligotrophic lakes are poorly fed, have a low concentration of nutrient elements such as nitrogen, and phosphorus productivity in terms of population levels of phytoplankton, rooted aquatic plants and zooplankton. On the other hand, eutrophic or 'well fed' lakes have high concentration of plant nutrients and large concentrations of phosphorus plankton due to high organic productivity. Eutrophic lakes may be either shallow or deep. These are characterized by high concentrations of suspended organic matter in the water column and by relatively large sediment depths with high organic contents particularly in the upper layers of sediment. Biological productivity is high and the diversity of biological population may be some what limited.

A third lake condition is mesotrophic which is an intermediate state between oligotrophic and eutrophic. Mesotrophic lakes have intermediate level of biological productivity and can have some reductions in bottom dissolved oxygen levels. Two nutrients, nitrogen and phosphorus are of greatest concern in the growth of biological organic matters in the lake . In addition to these nutrients, phyto plankton requires carbon dioxide and a host of minor elements (potassium, sodium) and trace elements (iron, cobalt, manganese, copper, zinc, boron etc.).

Of the nutrient elements needed for photosynthesis, hydrogen and oxygen are readily available and also carbon is generally available from atmospheric carbon dioxide. The major elements that are not always available are nitrogen and phosphorous. Phosphorous input can increase during cultural eutrophication of lakes. The primary source of phosphorous and nitrogen in lakes are direct rainfall and snowfall on the lake and runoff from the surrounding drainage area. In oligotrophic lakes most phosphorous in runoff comes from rock weathering and soil transport. Atmospheric precipitation may be a very important source of phosphorous for oligotrophic, particularly those in areas of granitic terrain with low contributions of nutrients from weathering and those lakes whose area is large compared to the drainage area.

There are several natural lakes surrounded by natural vegetation in the high altitudes regions of the Himalayas. These include Wular, Dal, Nagin, Manasbal, Mansar, Surinsar and Sanasar lakes in J & K (India). Of these the lakes of Kashmir region have attracted tourists since ancient time.

However, the lakes of Jammu region are still to be developed for the purpose of increasing tourism in the state. Infact, the various lakes of the region are fast shrinking due to siltation, manifestation of weeds and various encrochments by the local people etc. The residents living around the lakes use the lake waters for their domestic uses. They also through garbage on the already dry areas of the lakes from their restaurants, houses and agricultural fields. There also exists a malpractice of large scale felling of trees in the watersheds which consequently resulted a severe problem of soil erosion over the years and causing siltation / choking of the lakes.

In order to keep lakes in healthy condition and to prevent eutrification a regular monitoring of its water quality is necessary. Therefore, the present study was carried out for Surinsar lake (Jammu region) by taking grab samples along the periphery of the lake during months of September, October (1994), and January, March (1995). The main objectives of the study are:

(i) to monitor physico-chemical parameters of water quality of lake.

(ii) to evaluate the quality of lake water for drinking and irrigation purposes.

(iii) to evaluate DO and BOD levels in the lake water.

2.0 REVIEW OF THE LITERATURE

Knowledge of hydrology of lake is essential for their proper use and conservation. Lakes provide water for domestic and industrial uses, fisheries, transport and recreation. Lakes are transitory features of the earth surface and each has a birth, life and death related to certain geological and biological processes. Their life expectancy may vary from a short spell of two floods to millions of years.

2.1 Hydrologic Definition of Lake

The matter of a precise definition of a lake has received insufficient attention and a unique definition of a lake does not exist (Kuusisto, 1985). But a lake is easy to visualize because it has definite boundaries. Such boundaries are not always definitive in other types of storage in the hydrological cycle. From the geologic point of view, a lake consists of two distinct parts, the basin and the water body. It is obvious that the latter could not exist without the former and both should be taken into account in any workable definition. From the hydrological point of view, a lake should be distinguished from a wide river section.

In Finnish practice, the minimum area of a lake is considered to be 0.01 Sq.Km. Instead of the area, a requirement of the maximum length exceeding 200m has been used. As a summary, a water body should fill the following requirements to be a lake:

(i) It should fill or partially fill a basin or several connected basins.

(ii) It should have essentially the same water level in all parts with the exception of relatively short occasions caused by wind, thick ice cover , large inflows, etc.

(iii) It should have so small an inflow to volume ratio that considerable portion of suspended sediment is captured.

(iv) It should have a size exceeding a specified area, e.g. 0.01 Sq. km, at mean water level.

2.2. Lake as a Hydrologic Unit

Nature circulates water from the oceans through the atmosphere and returns it both overland and underground back to sea through devious paths- some short and some long in terms of both time and space. Lake with its definite boundary can be postulated as one of the devious paths for the circulation of water in nature.

Lake has its hydrologic response. It has cause and effect relationship with the adjoining catchment. Because of storage of large mass of water, it moderate flood and climatic factors in the region. Also the deforestation, conversion of grassland to cropland, intensification of agricultural production, land amelioration etc. in the nearby catchment area affects the microclimatic and reduces evapotranspiration thereby increasing rain runoff and rates of erosion and siltation. Accelerated nutrient cycles and faster transport of soil particles increase sedimentation rate and lead to enrichment of lake water. So, various physical, chemical and biological inputs manifested through the hydrology of the catchment area and lake affects the quality and quantity of lake water.

2.3 Difference between Lake, Pond and Reservoir

The lake is a natural body of water having an area of open, relatively deep water, sufficiently large to produce a barren wave swept shore on its periphery where as ponds are very small, shallow bodies of standing water which is extensively occupied higher aquatic plants. On the other hand a reservoir may be natural valley that is dammed artificially of a concrete feveed artificial lake not associated with natural catchment. A lake is filled by stream flow or precipitation only whereas ponds and reservoirs are filled either by natural flow (impounding type) and / or by water pumped from neighbouring catchments (pumped storage type). The lakes, like the other naturally formed water bodies, exhibit the shore line formation characteristics. Artificially produced reservoirs and ponds do not have a well defined shore. So, according to the hydrologic definition of lake envisazed by Zumbarge and Ayers (vide Chow, 1964) reservoirs created by damming rivers, ponds, tanks etc. should not be categorized as lake.

Inputs and outputs of the natural lakes are near the surface whereas outlets of a reservoir or a pond is at one of the several depths or from two or three levels simultaneously. The lower depression in a natural lake may occur anywhere in its basin but the maximum depth of the reservoir bottom is always near the dam, unless a natural lake is included in the impoundment area. A reservoir bottom has a regular slope from head to tail that was established by the river before damming. In case of natural lakes the basins are scooped out below river level and hence bottom slope is not uniform. Natural lakes normally begin as oligotrophic bodies of water having low productivity on the other hand reservoirs inundate rich bottom lands and fertile top soil on river slopes and so normally begin with high productivity potential. With passage of time natural lakes tend to become productive unlike reservoirs which tend to suffer productivity decrease with time.

Reservoirs are generally constructed either to store or control the flow of rivers and stream, primarily in regions where there is excess or scarcity of water. As a result, reservoirs are geologically younger than natural lakes. The world wide distribution pattern for lakes shows a bimodel pattern. In contrast,the reservoirs do not exhibit this bimodel distribution.

Natural lakes are located in the centre of relatively symmetrical and contiguous drainage inputs entering the lake at several points around the lake whereas reservoirs are usually constructed at the downstream boundary of a drainage basin. Thus, the reservoir drainage basins are often narrow and elongated with only a small portion of the basin being contiguous with reservoir.

2.4 Origin of Lakes

In coming to the question of origin of lakes, it is apparent that depressions are first of all formed on the earth's surface under favorable conditions, some of these hollows contain water and are therefore, described as lakes. The topographic depressions which accommodate lakes are known as lake basins. Lakes can be created by different number of various natural events.

Most lakes however have been produced by glacial, volcanic or tectonic processes. Tectonic basins are depressions caused by the deep movements that resulted in faulting of earth's crust. Volcanic activity has created many crater lakes. Glacial activity during the most recent period of major ice advance and retreat resulted in a abundance of lakes in N America and Europe. Great Lakes, which collectively form the largest continuous volume of fresh water in the world, were formed by ice scour, water erosion and subsidence under massive ice sheets (Hammer, 1977).

2.5 Classification of Lakes

2.5.1 General

There is no unique and uniform method of classification of lakes. Different scientists have classified lakes into various ways, on the basis of their origin, thermal behaviour, biological and chemical characteristics, presence or absence of outlets, geometrical shapes of lakes, water balance of lakes etc. The present report includes classification based on biological and chemical characteristics of lakes.

2.5.2 Classification Based on Biological Properties of Lakes

Naumann (Thurman, 1985) classified the lakes according to their trophic states.It includes oligotrophic, eutrophic, dystrophic and mesotrophic lakes based either on the concentration of the plant nutrients or on the productivity of the organic matter or algal population.

2.5.2.1 Oligotrophic Lakes

Oligotrophic lakes are at their lowest trophic level and are usually deep with large volumes of relatively clear water. They have a low concentration of nutrient elements such as nitrogen and phosphorous. Rock weathering, soil transport and atmospheric precipitation are the major sources of phosphorous for an oligotrophic lake (Berner et al., 1987). The dissolved organic carbon content of oligotrophic lakes is very less generally in the range of 1 to 3 mg/ litre. Its total dissolved amino acid concentration is 30 to 300 micron grams / litre. The lack of nutrients results in few plants and hence a low rate of organic matter production by photosynthesis.

The depth of water is usually above 15 to 25 m (Berner et al., 1987). They have a large hypolimnion and narrow epilimnion with a thermocline and broad metalimnion. Oligotrophic lakes usually have an orthograde (vertical) oxygen curve indicating an even distribution of oxygen throughout the water column due to low productivity and subsequent absence of oxygen depleting organic matter. In addition, oligotrophic lake water have deeper oxygen generating zones than eutrophic lakes because of penetration of light to a relatively greater depth thereby reducing the depth at which photosynthesis can occur (Pinto,1981).

2.5.2.2 Eutrophic Lakes

Eutrophic lakes are at the highest trophic level and are rich in nutrients with high concentration of plankton due to high productivity. Phosphorous is above 20 micro grams per litre (Berner et al., 1987). Organic matter is either autochthonous (produced in lakes) or allochthonous (transported from environment) (Reid & Wood, 1976).

The water of these lakes is murky with suspended plankton and often depleted in oxygen at depth (Berner et al., 1987). They have a narrow hypolimnion and large epilimnion. Hypolimnion is poor in oxygen due to high biological demand to decompose organic matter (Berner et al., 1987). Microscopic algae and aquatic weeds are the major phytoplankton (Hammer, 1977). Bottom fauna are tolerant of low oxygen conditions. Deep water fishes are absent. Sediments are mostly organic rich in nitrogen (Berner et al.,1987). The dissolved oxygen content of eutrophic lake is 3 to 34 mg/ litre.

2.5.2.3 Mesotrophic Lake

This is a transient state of lake from oligotrophic to eutrophic state. These lakes have intermediate properties between those of oligotrophic and eutrophic lakes (Berner et al., 1987). Their major properties are moderate fertility,low aquatic plant population, greenish water and moderate production of fish (Hammer, 1977). The dissolved oxygen content is 2 to 4 mg/ litre.

2.5.2.4 Dystrophic Lakes

These are shallow brown water lakes. Brown colour is due to the organic compounds. They have either very few or no organisms except a few aquatic insects occasionally. They contain hydrogen sulfide and ammonia. Their N/P ratio is very high. They have a low pH. Metallic pollution is present. Dissolved oxygen content is 20 to 50 mg/litre. Fishes are absent. Diptera and cloeptera are the major biological indicators of these lakes.

2.5.3 Classification Based on the chemical Properties of Lakes

2.5.3.1 General

Lakes have been variously classified on the basis of the chemical nature of its water, its carbon dioxide and calcium contents. These classifications are given below.

2.5.3.2 Classification Based on the Chemical Nature of Lake Water

On the basis of the chemical nature of their waters, lakes can be classified as :

2.5.3.2.1 Acid Lakes

The water of these lakes generally have pH values of 6 or less (Berner et al., 1987). Acid lakes have a distinctive chemical composition. They have hydrogen-calcium-magnesium-sulfate waters. Sulfate concentration is generally 3 to 5 times than that in the fresh water lakes (Berner et al., 1987).

Fresh water lakes may become acid lakes due to acidification of dilute fresh waters or because of acid precipitation. Acidification of lakes occur in areas that are sensitive to acid precipitation because of a characteristic bedrock geology and soil. Acid lakes are characterized by steep slopes and exposed bedrock with little vegetation and soil development. In this way they receive precipitation virtually unaffected by the soil.

2.5.3.2.2 Saline Lakes

All saline lakes are formed by closed lakes under desert or semi arid conditions where the evaporation rate is too high and there is a lack of outflow to present the subsequent discharge of salts to the seas.

There is no definite boundary to define saline lakes.

According to Hardie et al., (1978), lakes with more than 5000 ppm dissolved solutes are considered as saline lakes. Saline lakes are often highly alkaline and exhibit a high pH which is higher than 10 (Berner et al., 1987). Saline lakes may contain a variety of salts and unusual aquatic life that have extraordinary tolerance to high salt concentrations. Saline lakes are the sources of economically important chemicals such as lithium, borax, potassium, zeolite etc..

2.5.3.2.3 **Fresh Water Lakes**

All naturally occurring lakes are mostly fresh water lakes. These lakes also differ widely in contents but tend to assume the composite dissolved solid characteristic of the water of the inflowing streams. This is because of the balance between the inflow and outflow. The pH of fresh water lakes ranges from 6 to 8 and they generally have calcium - magnesium- bicarbonate waters (Berner, 1987).

2.5.3.3 Chemical Classification of **Lakes Based on their Carbon** dioxide **Content**

Reid et al. (1976) have classified the lakes based on their carbon dioxide content as below :

2.5.3.3.1 **Soft Water Lakes**

These lakes are common in regions of low lands. They have a pH of 4 to 6. Their waters have a high free carbon dioxide content; nearly about 200 ppm. The bound carbon di-oxide as carbonate is low ; usually less than 9 to 10 ppm (Reid & wood, 1976).

2.5.3.3.2 **Medium Water Lakes**

These lakes have a pH value which is around seven. The free gaseous carbon dioxide in these lakes varies widely, frequently showing supersaturation relative to the partial pressure of the gas in the atmosphere. The bound carbon dioxide of these lakes is upto 30 to 35 ppm (Reid & Wood, 1976). The medium water lakes, though contain a relatively less mass of living matter per unit area, often harbour a greater variety of plants and animals. (Reid & Wood , 1976).

2.5.3.3.3 Hard Water Lakes

These lakes occur in regions where the substrata contain easily dissolved minerals. These lakes are characterized by negative values for free carbon dioxide due to withdrawal of bicarbonates at a higher rate than the carbonates are precipitated. These lakes have a high pH values of 8.5 and above. Bound carbon dioxide of these lake waters is over 35 to 40 ppm, often reaching 200 ppm or even more.

These lakes contain high living matter per unit area than soft water lakes. The percentage of calcium and magnesium are 53% and 34 % of the total cations present respectively. The increase of these ions in hard water as compared to the soft waters, takes place at the expense of two alkali metals ; sodium and potassium. The hypolimnion of hard water lakes characteristically contains a greatly increased load of calcium (Reid &Wood 1976).

R. Cushmann et al,. (1980) have used following boundary values :

i) Very Hard Water lakes : 180 to above 240 mg of calcium carbonate/litre.

ii) Hard water Lakes : 120 to 180 mg of calcium carbonate/litre.

iii) Moderate water Lakes : 60 to 120 mg of calcium carbonate/litre.

iv) Soft water lakes : Less than 60 mg of calcium carbonate/litre.

2.5.3.4 Classification of Lakes on the Basis of Calcium Content

Reid & Wood (1976) have reported that W. Ohle, a German limnologist, proposed a following scheme of lake classification in 1934 on the basis of their calcium content.

(i) Poor Lakes: Calcium content is less than 10 mg/litre.

(ii) Medium Lakes: Calcium content varies from 10 to 25 mg/litre.

(iii) Rich Lakes: Calcium content is more than 25 mg/litre.

3.0 STUDY AREA

3.1 Location

The Surinsar lake is situated about 40 Km to the North East of Jammu city at an elevation of 605 m above mean sea level and lies at 75°02' 30" East longitude and 32°46' 30" North latitude (Fig-1). It is a fine picturesque sweet water lake with a circumference of 2.496 Km. The maximum length, breadth and depth of the lake are 888 m, 444 m and 24.05 m respectively. The spread of the lake varies from 27.92 to 29.14 hectares. The water level of the lake oscillates by 1.20 m and touches its peak during August. The excess water flows towards the western side of the lakes and goes into a nalla lying by its side. The lake does not have any permanent inlet. The main sources of water is monsoon which is aided by certain natural springs. The water usually comes from the surface drainage and runoff from the watershed surrounding the lake. There are agriculture fields lying towards eastern side of the lake and fine covered hills are situated towards the Northern and Western side of the Lake.

Lake surinsar is almost oval in contour with a deep notch towards its north West. A small Island is placed ex-centrically within the lake, more towards its North East and is rich in terrestial flora and fauna. The littoral zone of the lake has a thick vegetation cover of emergent floating, submerged plants providing suitable cover for roosting migratory and nesting of the resident water fowl(Known as Murgabi and Jal Moorgi in the local language) in the lake.

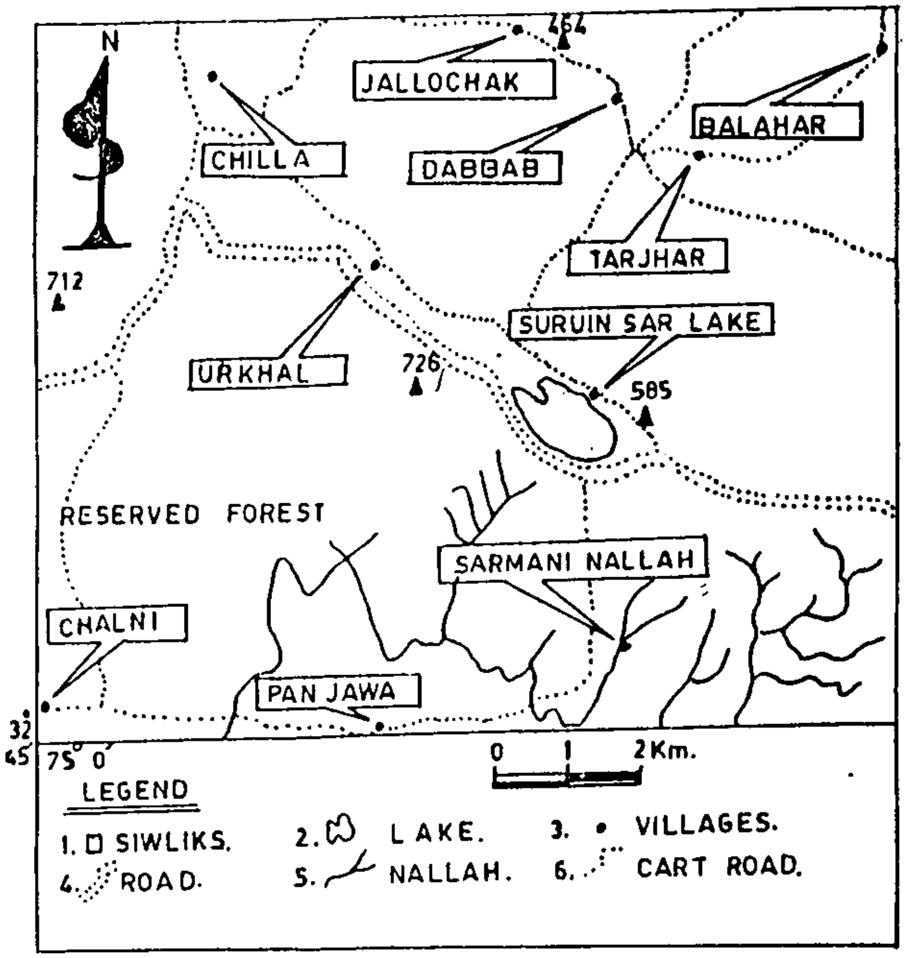


Fig.1. Index Map showing location of Surinsar Lake.

3.2 Geology of the Area

The lake surinsar is situated in the lower Siwalik ranges of the Western Himalayas. These outer hills are formed entirely of the younger tertiary rocks. The geological studies of the area mainly comprises of anticlines. The rocks surrounding the lake are lower Siwalik and mainly composed of sand stone, silt stones, shales of maroon to buff colour.

3.3 Climate of the Area

The climate of the area is subtropical . Monsoon rains are received from July to September. The average rainfall is 150 cm. Winters are mostly dry with occasional rains during the month of January. The temperature the atmosphere and the water remains well above the freezing point. The atmosphere temperature during summer ranges from 35^{c} to 40^{o} c. The temperature of the water surface ranges from 17 to 29 c. The wind speed is ranging from 1.5 to 5 Km per hour throughout the year.

3.4 Sedimentation and Silting of the Lake

The catchment area of the Surinsar lake is badly degraded which has caused lot of siltation into the lake. It is mainly due to large scale deforestation and denundation of the surrounding areas. The precipitation received in the form of rain and snow can not be trapped in absence of vegetative cover. The top loose soil gets eroded and finds its way into water body as surface run off. The silt starts settling down at the bottom of the lake and consequently reduces water spread area of the lake.

3.5 Biological Features of the Lakes

Microphytic vegetation is present in large quantities in the lake all along its bank. Various species of phyto-planktons are present in the Surinsar lake. These species falls in the following categories.

(A) Zoo-plankton

(i) Protozoa

(ii) Coelenterata

(iii) Rotifera

(iv) Cladocera

(v) Copepoda

(vi) Insecta

(B) Phyto-plankton

(i) Cyanophyceae

(ii) Chlorophyceae

(iii) Ulotrichales

(iv) Oedogonales

(v) Bacillariophyceae

(vi) Euglenophyceae

(vii) Zygnematales

(viii) Cladophorales

3.6 Lake Fauna

There is an intimate association of the lake with various species of water fowl. It serves as resting flyway for north bound ducks in late winter/early spring, and south bound ducks in autumn. As many as 13 different species of water birds have been so far identified which uses the lake as its habitat during different season. These includes Coot, Moorhen, Dabchick, White Breasted Hen, Black Necked Grebe, Great Crested Grebe, Gargany, Gadwell, European Pochard and Tufted Duck. The lake serves as breeding ground for Dabchick and white breasted hen during the summer.

4.0 MATERIALS AND METHODS

Water quality monitoring is an important aspect of overall water quality management and water resources development. A well planned and well managed water quality monitoring system is required to predict changes or trends of changes in the quality of a particular water body, so that curative or preventive measures can be taken to restore and maintain ecological balance in the water body. Monitoring is also needed to ensure that standards and criteria set by the regulatory agencies for a particular type of water and for a particular use of water are maintained on a continuing basis.

4.1 Water Quality Monitoring

The word " monitoring" in true sense, implies watching the ongoing of any matter to ensure no laws or rules are broken. However, in case of water, the monitoring refers sampling, measurement and prediction of quality variables at different time and space.

In a more realistic manner it can be emphasized that water quality monitoring is a systematic process of collecting, preserving and analysing water samples to identify quantitative and qualitative characteristics of water. Water quality characteristics depend on both hydraulic and hydrological conditions prevailing in the regime area of the water body and on the water that drains to the particular body. These characteristics can be classified into physical, chemical biological and radiological parameters.

4.2 Water Sampling

Sampling is a vital part of studies of natural water composition and is perhaps the major source of error in the whole process of obtaining water quality information. In any type of study in which only small samples of the whole substances under consideration may be examined, there is inherent uncertainty because of possible sampling error. The extent to which a small sample may be considered to be reliably representative of a large volume of material depends on several factors. These include, the homogeneity of the material being sampled, the number of samples, the manner of collection and the size of the individual samples.

The sampling from lakes is not so easy due to the heterogeneity of the water mass. Thermal stratification and associated changes in water composition are among the most frequently observed effects. A single sample from a lake can be assumed to represent only the spot within the water body from which they come. In order to overcome this difficulty , lake may be divided into different zones and series of samples may be taken from each zone. Water samples may be classified as below:

(i) Grab Samples : Grab samples are collected at particular time and place. These samples may be collected at different places and at different time interval. These samples are analysed separately.

(ii) Composite Samples : Composite samples are the mixture of many grab samples collected at fixed points over a period of time. These are used for determining those parameters which remain unchanged with time.

(iii) Integrated Samples : Integrated samples are the mixture of grab samples collected from different sampling points at a fixed time.

4.3 Sampling Procedure

In the present study grab samples were collected from eight pre selected locations P1 to P8 (Fig-2) along the periphery of the lake during months of September,October (94), January and March (1995) . The water samples were collected in high density polythene bottles of Torson's make. Before collecting the samples, bottles were rinsed with dilute nitric acid and then with double distilled water and finally with water samples. The following plastic bottles were filled at every sampling location.

(i) 500 ml for measurement of temperature, pH, electrical conductivity and total dissolved solids in the field.

(ii) 250 ml for chemical analysis of nitrate.

(iii) 1000 ml for the analysis of acidity/alkalinity, hardness, chloride, sulphate, phosphate, sodium, potassium, calcium and magnesium etc.

(v) 125 ml for the analysis of DO and BOD.

4.4 Samples Handling & Preservation

The samples for nitrate were preserved by adding 2.0 ml conc. sulfuric acid per litre. The samples for DO and BOD analysis were collected in airtight bottles (Torson's make) and were kept in BOD Incubator for five days at 20°+1 degree Celsius temperature for their final analysis.

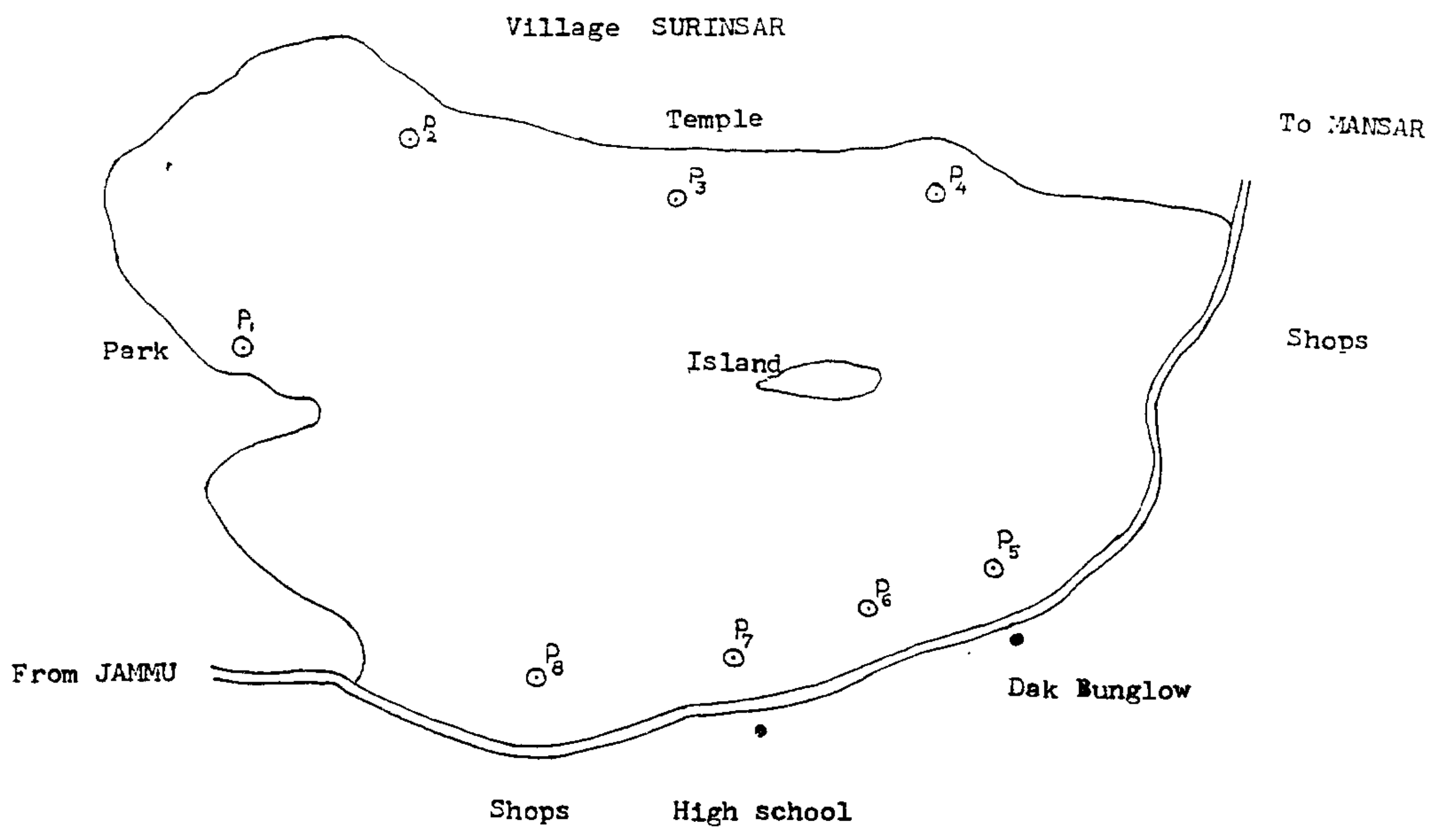


Fig.2. Map of Surinsar Lake showing sampling stations (P1 to P8)

4.5 **Method of Analysis and Equipment used :-**

Physico- chemical analysis was conducted following standard methods (APHA,1987).The physical parameters such as temperature, pH and electrical conductivity were determined in the field at the time of sample collection using Portable Thermometer, Portable PH meter (both procured from M/s Eijkalkamp, the Netherlands under UNDP project) and Portable water testing kit (NPC-361 D). Total dissolved solids (TDS) were also determined in the field using portable water testing kit.

The total hardness and calcium hardness were determined by EDTA titrimetric method, while magnesium hardness determined by deducting calcium hardness from total hardness. Calcium (as Ca^{++} ions) was calculated by multiplying calcium hardness with 0.401 while magnesium (as Mg^{++} ions) by multiplying magnesium hardness with 0.243.

Sodium and potassium were determined by flame-emission method using Flame Photometer. Chloride was determined by argentometric method in the form of silver chloride. Acidity/ alkalinity was determined by titrimetric method using phenolphthalein and methyle orange indicators. Phosphate and nitrate were determined using UV-VIS Spectrophotometer. The sulphate was determined using Turbidimetric method.

For the analysis of DO and BOD the water samples were collected in BOD bottles.The dissolved oxygen (DO) of water samples was obtained in the laboratory using titration method. For the analysis of bio-chemical oxygen demand (BOD) the samples were incubated using BOD Incubator for the standard five day period at 20+1 degree Celsius. The DO was determined initially and after the incubation. The BOD was computed from the difference between initial and final DO values.

Summary of analytical methods and equipment required for the analysis of various parameters is given in Table-1.

Table- 1

List of Equipment used for Analysis of various parameters

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

5.0 RESULTS AND DISCUSSION

The present study deals with the monitoring of water quality of Surinsar lake by collecting grab samples (from P1 to P8 locations) along its periphery during September, October(1994), January & March(1995). The various physico-chemical parameters of water quality were determined. These includes temperature, pH, EC, TDS, Ca, Mg, Na, K, bi-carbonate , sulphate , chloride, nitrate, phosphate, DO, BOD and total hardness . The variation of these parameters in the lake are described as follows.

5.1 Variation of Physical Parameters in Surinsar Lake

The parameters such as Temp., pH, EC and TDS were determined at the respective sampling locations (P1 to P8) using Portable Water Testing Kit and other portable equipments. The results are given in Table-2. The average pH the lake water were obtained 8.27, 8.40, 8.43 and 8.43 during sept., Oct. (1994), January and March (1995) respectively . The average electrical conductivity values were obtained 228.75, 235.0, 258.8 and 545.0 micro mhos per centimeter during the sampling periods as mentioned above. The average total dissolved solids were obtained 144.75, 151.25, 152.75 and 350.25 mg/l respectively. On other hands , the average temperature of the lake water were recorded 27.25, 25.31, 13.28 and 16.10 degree celsius during sept , oct.,(1994) , January and March (1995) respectively. It is also evident that monsoon has significant effect on concentration of various water quality parameters in the lake water. The EC, TDS and pH values of post monsoon period (Sept.94) are minimum, which may be due to the

Table-2

Variation of Physical Parameters in Surinear Lake

Sampling Locations	Temperature, Degree Celcius				pH Values				EC, micro mhos/Cm				TDS, mg/l			
	Sep	Oct.94	Jan	Mar.95	Sep	Oct.94	Jan	Mar.95	Sep	Oct.94	Jan	Mar.95	Sep	Oct.94	Jan	Mar.95
P1	26.5	24.1	13.0	15.8	7.34	7.88	7.20	8.86	220	220	265	600	140	140	165	380
P2	25.8	25.0	13.6	16.8	8.15	8.28	8.0	8.20	250	230	280	540	150	150	149	350
P3	25.2	25.7	13.8	16.5	8.20	8.37	8.51	8.39	230	230	240	530	145	150	142	340
P4	27.4	26.4	13.7	15.9	8.30	8.58	8.78	8.68	230	230	235	510	146	150	136	310
P5	30.1	26.5	13.0	16.0	8.79	8.92	8.81	8.85	230	250	270	540	142	160	180	342
P6	27.6	25.6	12.9	16.0	8.29	8.40	8.78	8.50	220	230	260	530	142	150	158	340
P7	28.2	24.6	13.1	16.3	8.83	8.37	8.58	8.64	220	240	240	560	148	150	144	375
P8	28.1	24.6	13.2	15.5	8.68	8.42	8.82	8.62	230	250	275	550	145	160	168	365
Average	27.25	25.31	13.28	16.1	8.27	8.40	8.43	8.43	228.75	235	258.13	545	144.75	151.25	152.75	350.25

Table-3

Variation of Major Cations (mg/l) in Surinear Lake

Sampling Locations	Calcium				Magnesium				Sodium				Potassium			
	Sep	Oct.94	Jan	Mar.95	Sep	Oct.94	Jan	Mar.95	Sep	Oct.94	Jan	Mar.95	Sep	Oct.94	Jan	Mar.95
P1	19.25	18.45	28.87	48.12	6.32	6.32	1.94	4.86	5.6	6.20	6.9	9.8	2.7	3.0	3.2	4.0
P2	20.05	18.45	32.08	40.10	6.80	6.80	9.72	12.15	4.9	5.7	7.3	10.0	1.9	2.6	3.3	3.6
P3	19.25	19.25	24.06	32.08	7.29	6.80	11.66	19.44	5.3	7.2	7.0	10.0	3.2	3.0	3.2	3.6
P4	19.25	18.45	28.87	48.12	6.80	6.80	7.78	-	6.0	6.69	7.0	10.4	1.6	2.4	3.3	3.7
P5	20.05	19.25	28.87	32.08	5.83	6.32	7.78	19.44	7.2	6.8	7.0	10.0	2.8	3.4	3.6	3.8
P6	19.25	18.45	28.87	32.08	6.80	7.29	9.72	14.58	5.4	6.9	7.1	11.0	2.6	3.2	3.2	5.9
P7	19.25	18.45	30.48	32.08	7.29	6.80	7.78	9.72	4.6	7.0	7.1	10.0	3.4	3.2	3.6	3.9
P8	20.05	18.48	30.48	40.10	7.29	7.29	10.69	-	5.1	5.5	6.8	10.0	3.9	3.5	3.7	3.6
Average	19.55	18.65	29.10	38.10	6.80	6.80	8.38	13.37	5.51	6.58	7.03	10.15	2.64	3.04	3.39	4.01

dilution of lake water by rains during monsoon period.

5.2 Variation of Major Cations in Surinsar Lake

The cations such as calcium , Magnesium, Sodium and Potassium were determined in the laboratory . These results are given in Table-3. The average values of these Cations (mg/l) were plotted as bar diagram (Fig-3). In the present studies the average values of calcium were found 19.55, 18.65, 29.10 and 38.10 mg/l during September , October (1994) , January and March (1995) respectively . The average Magnesium concentrations were obtained 6.80, 6.80, 8.38 and 13.37 mg/l in the lake water during periods as mentioned above. However, the sodium and potassium concentrations were varied from 5.51 to 10.15 mg/l and 2.64 to 4.01 mg/l respectively from post monsoon period to late winter(September,94 to March,95). The analysis also reveals that cation concentrations during post monsoon period (September,94) are also smaller than late winter (March,95).

5.3 Variation of Major Anions in Surinsar Lake

The chemical analysis of lake water for anions such as chloride, nitrate, phospate, bi-carbonate and sulphate were carried out in the laboratory. The results are given in Table-4. The average values of these anions during September, October(94), January and March (95) were plotted in the form of bar chart (Fig-4). The average values of chlorides were obtained 3.75, 5.75, 8.38 and 9.75 mg/l during September, October (94), January and March (95) respectively. The average sulphate concentrations for the same period were obtained 6.48, 7.24, 9.29 and 11.26 mg/l respectively. The average bi-carbonate concentrations were

Fig.3 Variation of Major Cations (mg/l).

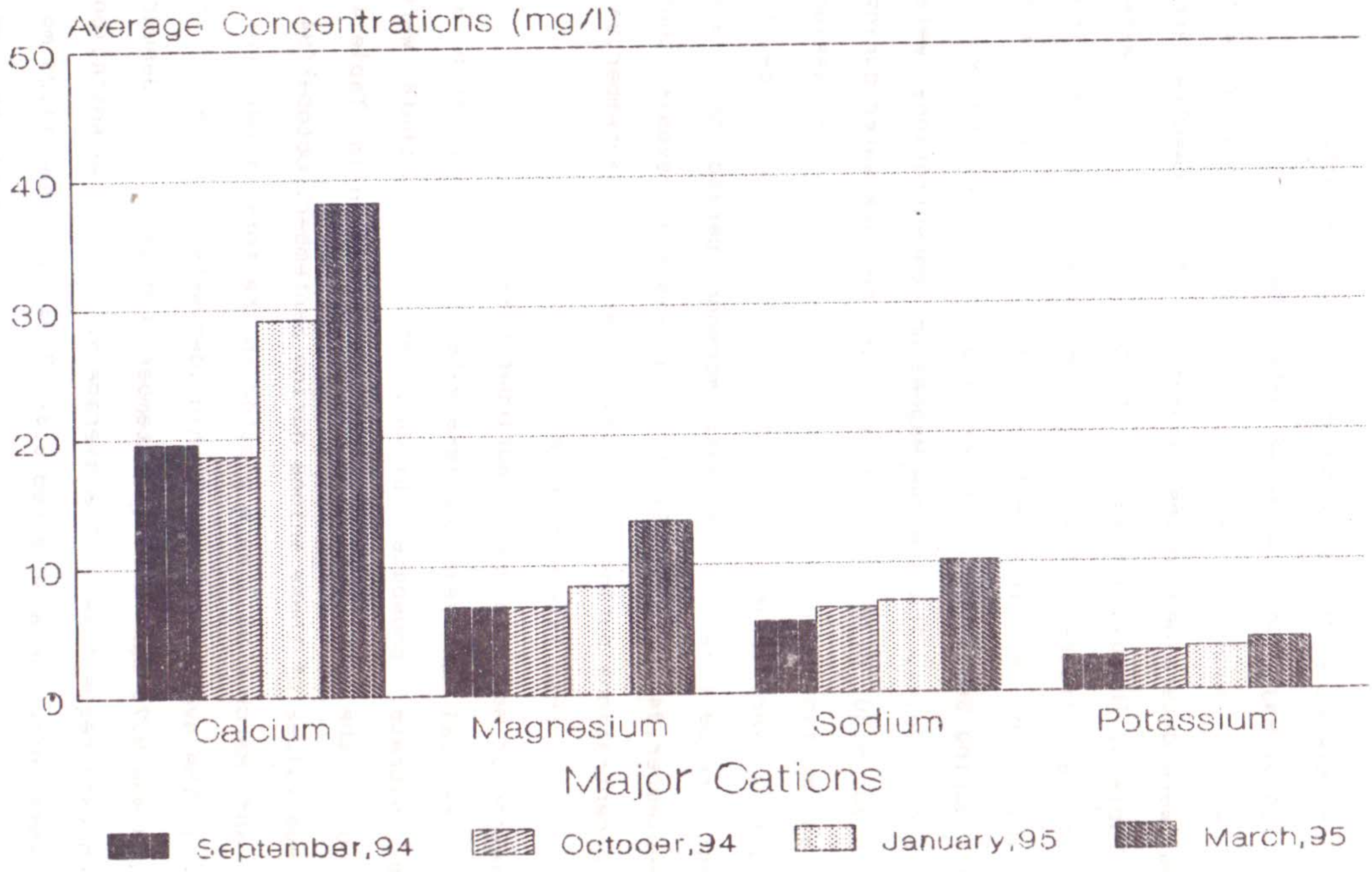


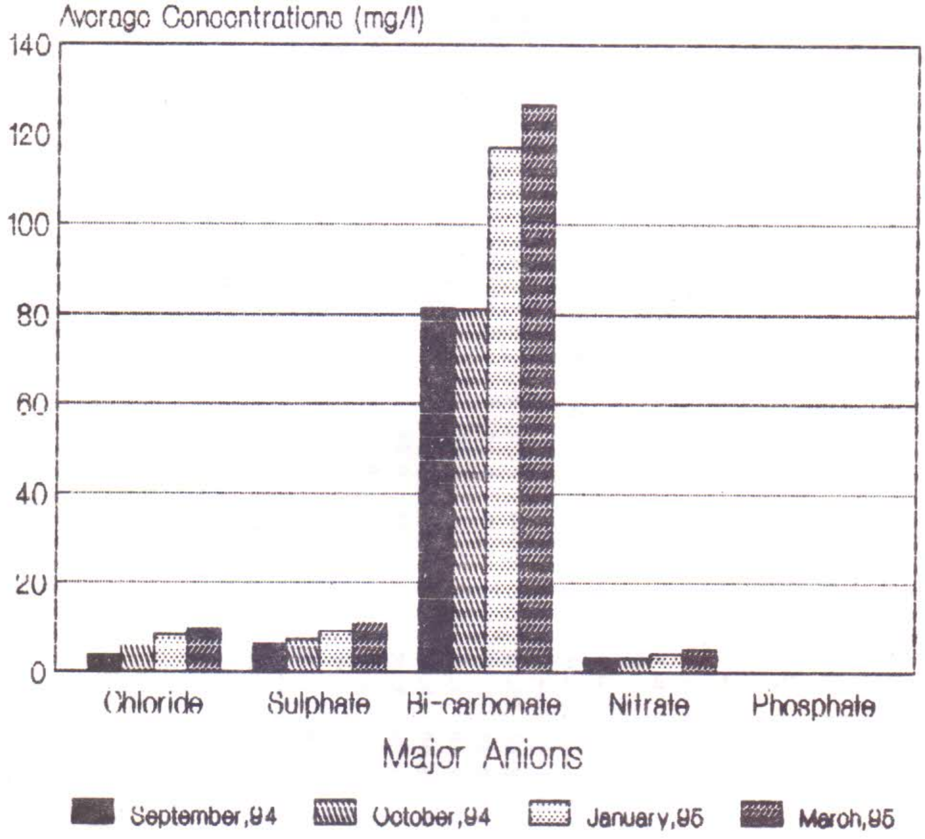
Fig.6 Variation of Hardness (mg/l).

Table-4

Variation of Major Anions (mg/l) in Surinsar Lake

Sampling locations	Chloride				Nitrate				Phosphate				Bicarbonate				Sulphate			
	Sep	Oct.94	Jan	Mar.95	Sep	Oct.94	Jan	Mar.95	Sep	Oct.94	Jan	Mar.95	Sep	Oct.94	Jan	Mar.95	Sep	Oct.94	Jan	Mar.95
P1	6.0	8.0	10.0	12.0	3.60	3.70	5.65	5.80	0.01	0.02	0.02	0.04	80.0	80.0	108.0	120.0	6.21	6.40	8.92	11.65
P2	4.0	6.0	10.0	10.0	2.30	2.30	4.00	5.25	0.01	0.04	0.08	0.11	84.0	80.0	128.0	140.0	6.70	7.10	10.00	10.70
P3	4.0	10.0	14.0	10.0	3.40	3.40	5.60	5.65	0.01	0.02	0.04	0.04	80.0	84.0	120.0	124.0	6.60	7.00	8.70	11.52
P4	2.0	4.0	6.0	9.0	3.80	3.60	3.35	4.90	0.01	0.01	0.02	0.04	82.0	82.0	120.0	128.0	6.12	7.25	9.20	11.52
P5	2.0	4.0	8.0	12.0	2.50	3.20	2.20	4.65	0.03	0.02	0.03	0.05	80.0	80.0	120.0	124.0	7.00	7.14	8.20	8.23
P6	4.0	4.0	9.0	7.0	3.40	3.00	5.99	4.70	0.03	0.01	0.04	0.04	80.0	82.0	120.0	128.0	6.16	8.40	12.40	17.99
P7	2.0	4.0	6.0	10.0	3.60	3.60	3.45	3.90	0.10	0.02	0.05	0.05	84.0	80.0	116.0	124.0	6.20	7.10	8.66	9.88
P8	6.0	6.0	4.0	8.0	2.50	3.10	4.60	5.55	0.03	0.02	0.08	0.03	82.0	80.0	104.0	124.0	6.81	7.12	8.22	8.57
Average	3.75	5.75	8.38	9.75	3.14	3.24	4.32	5.05	0.015	0.02	0.045	0.05	81.5	81.0	117.0	126.5	6.48	7.24	9.29	11.26

Fig.4 Variation of Major Anions (mg/l).



obtained 81.50, 81.0, 117.0 and 126.50 mg/l during the sampling months as mentioned above. The average values of nitrate and phosphate were varied from 3.14 to 5.05 mg/l and 0.015 to 0.05 mg/l during post monsoon period (September,94) to late winter (March,95). It may be examined that anion concentrations for post monsoon (September,94) are minimum. However, the maximum values of these anions were found during March,95.

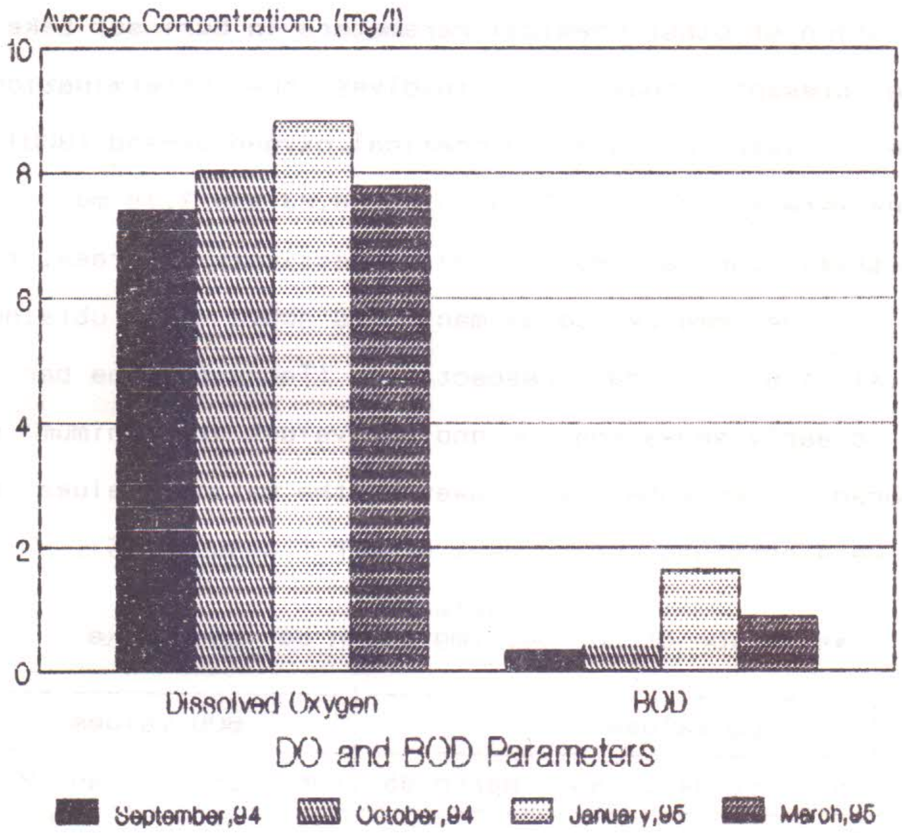
5.4 Variation of Other Chemical Parameters in Surinsar Lake

The present study also involves the determination of dissolved oxygen (DO) and bio-chemical oxygen demand (BOD). The DO values were found to be 7.39, 8.03, 8.83 and 7.78 mg/l during Sept., Oct(94), Jan. and March (95) respectively. Whereas, the BOD values for the same period as mentioned above were obtained as 0.33, 0.41, 1.63 0.88 mg/l respectively (Table-5). The bar chart (Fig-5) clearly shows that DO and BOD values are minimum during post monsoon (September,94). However, the maximum values of DO and BOD were obtained during peak winter (January,95).

Table-5
Variation of DO- BOD (mg/l) in Surinsar Lake

Sample Numbers	DO Values				BOD Values			
	Sep	Oct 94	Jan	March 95	Sep	Oct 94	Jan	March 95
P1	7.8	8.0	8.6	7.4	0.3	0.4	1.2	0.8
P2	7.4	8.0	8.6	7.2	0.2	0.3	2.0	0.6
P3	7.4	8.0	8.4	7.2	0.3	0.4	1.6	0.6
P4	7.2	8.0	9.0	8.4	0.2	0.5	0.4	0.8
P5	7.2	8.0	9.0	8.6	0.3	0.4	2.0	1.2
P6	7.6	8.0	9.0	8.6	0.4	0.4	2.0	1.2
P7	7.3	8.0	9.0	7.4	0.4	0.3	1.8	0.8
P8	7.2	8.2	9.0	7.4	0.5	0.6	2.0	1.0
Average	7.39	8.03	8.83	7.78	0.33	0.41	1.63	0.88

Fig.5 Variation of DO and BOD (mg/l).



The hardness due to calcium and magnesium was also determined in the laboratory. The average values of calcium hardness were obtained as 48.75, 46.50, 72.50 and 95.0 mg/l during September, October (94), January and March (95) respectively. The average values of magnesium hardness were obtained 28.0, 28.0, 34.50 and 55.0 mg/l respectively during the periods mentioned as above (Table- 6). It is evident that average values of calcium and magnesium hardness are minimum during post monsoon(September and October,94) (Fig-6).

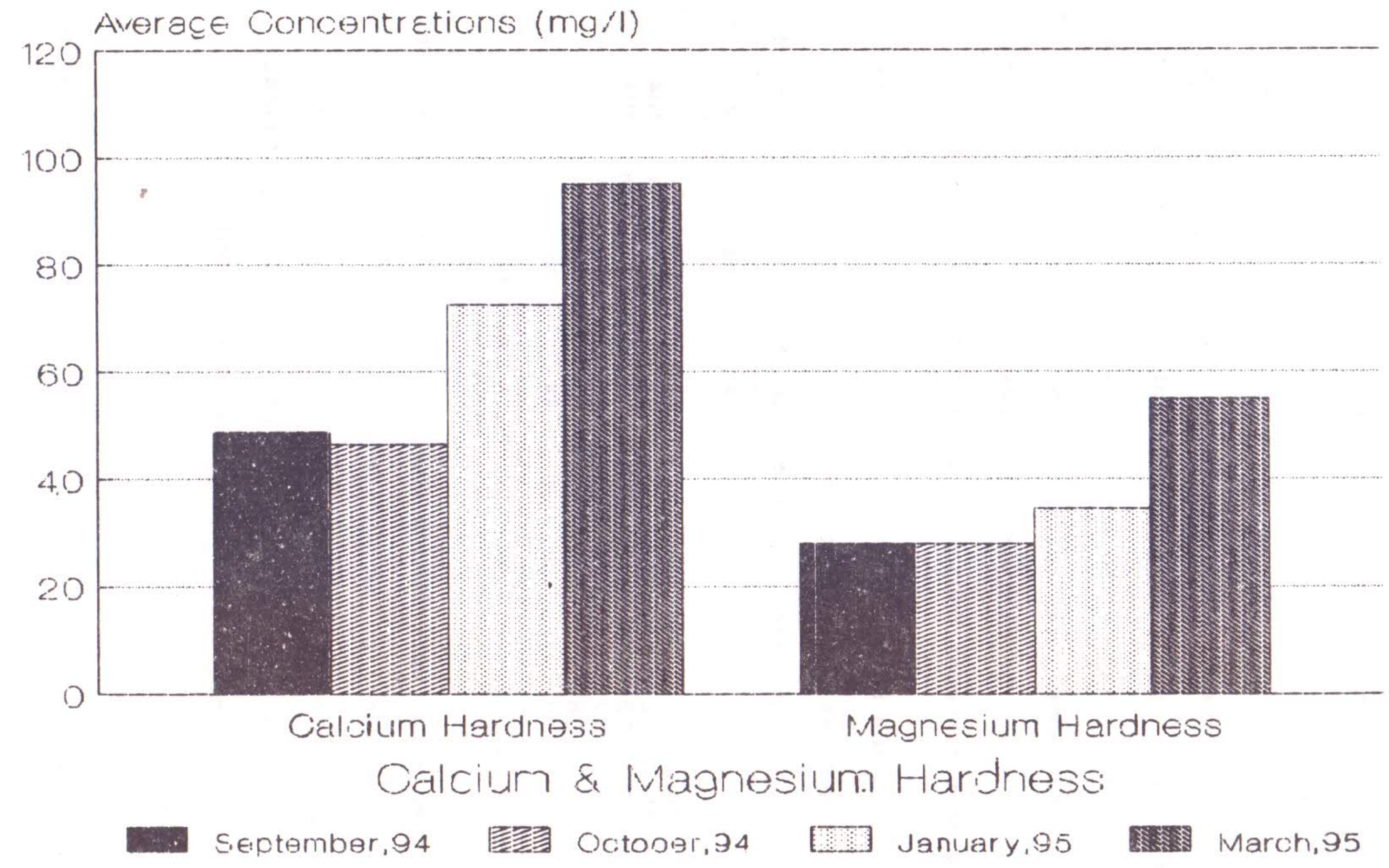
Table-6
Variation of Hardness(Ca & Mg,mg/l) in Surinsar Lake

S.N.	Ca Hardness				Mg Hardness				Total Hardness			
	Sep	Oct	Jan	Mar	Sep	Oct	Jan	Mar	Sep	Oct	Jan	Mar 95
P1	48	46	72	120	26	26	08	20	74	72	80	140
P2	50	46	80	100	28	28	40	50	78	74	120	150
P3	48	48	60	80	30	28	48	80	78	76	108	160
P4	48	46	72	120	28	28	32	-	76	74	104	120
P5	50	48	72	80	24	26	32	80	74	74	104	160
P6	48	46	72	80	28	30	40	60	76	76	112	140
P7	48	46	76	80	30	28	32	40	78	74	108	120
P8	50	46	76	100	30	30	44	-	80	76	120	100
Av.	48.75	46.5	72.5	95	28	28	34.5	55	76.75	74.5	107	136.25

5.5 Criteria for Determining the Suitability ofIrrigation Water

The suitability of an irrigation water depends upon many factors. However, the quality of irrigation water, soil type, salt tolerance characteristics of the plants, climate and drainage characteristics of the soil profoundly influence the suitability of a particular water for irrigation.

The main soluble constituents of surface water which determine suitability of irrigation water are calcium, magnesium,


Average Concentrations (mg/l)
120
100
80
60
40
20
0
Calcium Hardness
Magnesium Hardness
Calcium & Magnesium Hardness
September,94
October,94
January,95
March,95

sodium, chloride, sulphate and bicarbonates. In the present report the following criteria were followed to determine the suitability of lake water for irrigation purposes:

(a) Total Salt Concentration, as measured by electrical conductivity.

(b) Relative Proportion of Sodium to other Cations, (Sodium Adsorption Ratio, SAR).

(c) Classification of Irrigation Water Based on Doneen's Permeability Index (PI).

(a) Total Salt Concentration of Soluble Salts

Total salt concentration of soluble salts in irrigation waters can be adequately expressed for the purpose of diagnosis and classification in terms of electrical conductivity. In general, waters with conductivity values below 750 micromhos/Cm are satisfactory for irrigation in so far salt content is concerned, although salt sensitive crops may be adversely affected by the use of irrigation waters having conductivity values in the range 250 to 750 micromhos/ Cm (USDA,1954). Waters in the range of 750 to 2250 micromhos/Cm are widely used, an satisfactory crop growth is obtained under good management and favorable drainage conditions, but saline conditions will develop if leaching and drainage are inadequate. Use of waters with conductivity values above 2250 micro mhos/Cm, is the exception, and very few instances can be cited where such waters have been used successfully. However, in this case the more salt tolerant crops can be grown with such waters, only if sub- soil drainage is good.

In addition, for best quality of irrigation water total dissolve solids should be below 800 mg/l (Jermar,1987). In general water is good for irrigation, if total dissolved solids are below 1000 mg/l. However, this limit can be increased to 1700 mg/l, in case calcium forms 25% of the total bases (Na+Ca) in the irrigation water(Raghunath,1982).

(b) Sodium Adsorption Ratio (SAR)

The proportion of sodium to other cations or the sodium hazard of the water is indicated by the sodium- adsorption ratio, or SAR, Calculated from :-

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{++} + Mg^{++})/2}} \qquad ...(1)$$

where Na^{+}, Ca^{++} and Mg^{++} represent the concentrations in milli equivalents per litre of the respective ions. Irrigation water with a low sodium adsorption ratio is desirable. USDA (1954) have Classified the irrigation water on the basis of conductivity and sodium adsorption ratio (Fig-7) . In this classification waters are divided into four classes with respect to conductivity, the dividing points between classes being at 250 , 750 and 2250 micro mhos/Cm. In general water is good if its position in the USDA diagram (Fig-7) is within the zone of good or moderate waters. The significance and interpretation of the irrigation water quality ratings on the diagram are summarsized below :

(i) Conductivity

Low-salinity water (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under

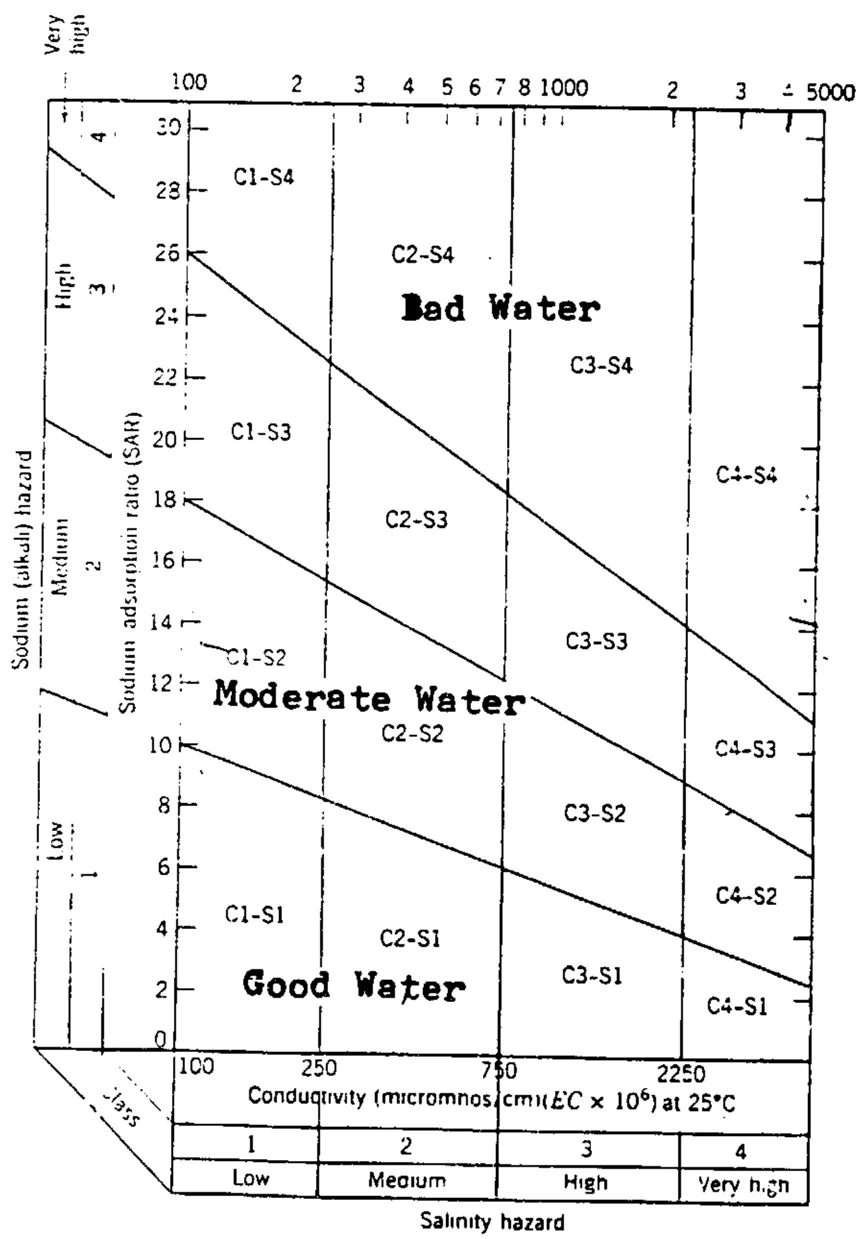


Fig.7. Classification of Irrigation Waters Based on SAR and salinity Hazards (USDA, 1954).

normal irrigation practices except in soils of extremely low permeability.

Medium- salinity water (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

High salinity water (C3) can not be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

Very high salinity water (C4) is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt tolerant crops should be selected.

(ii) Sodium

The classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of the soil. Sodium sensitive plants may, however, suffer injury as a result of sodium accumulation in plant tissues when exchangeable sodium values are lower than those effective in causing deterioration of the physical condition of the soil.

Low sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium.

Medium sodium water (S2) will present an appreciable sodium hazard in fine textured soils having high cation exchange capacity, especially under low leaching conditions, unless gypsum is present in the soil. This water may be used on coarse textured or organic soils with good permeability.

High sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management, good drainage, high leaching, and organic matter additions. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

Very high sodium water (S4) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or use of gypsum or other amendments may make the use of these waters feasible.

(C) Doneen's Permeability Index

Doneen's has developed a chart based on permeability index (PI) for classification of irrigation waters for soils of medium permeability (Raghunath, 1982). The Permeability Index (PI) is calculated as below:

$$PI = \frac{Na^{+} + \sqrt{HCO_3^{-}}}{Ca^{++} + Mg^{++} + Na^{+}} \times 100 \qquad \ldots (2)$$

where all the ionic concentrations are expressed in milli equivalent per litre. According to this classification, the water is good for irrigation if it belongs to class I or II in the Doneen's chart (Fig- 8).

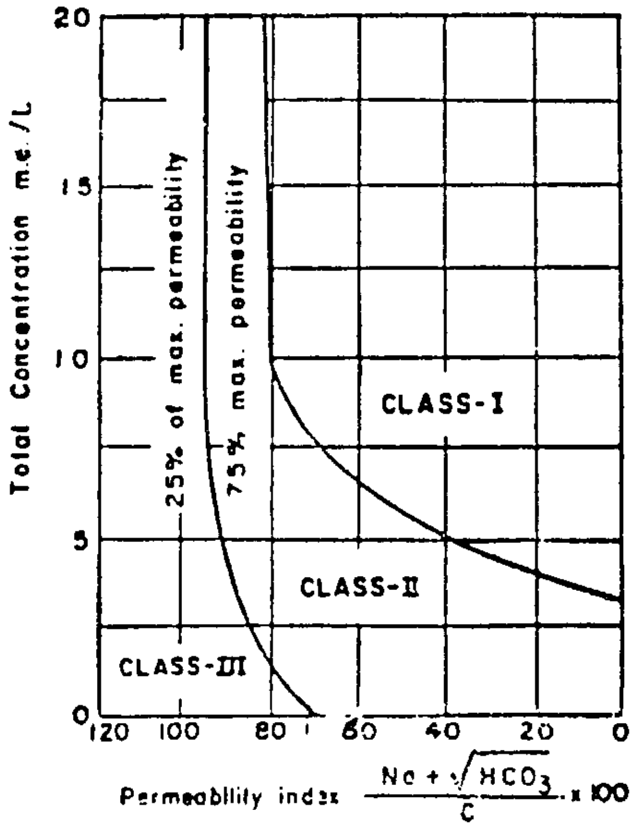


Fig.8. Classification of Irrigation waters based on Permeability Index (Doneen).

5.6 Irrigation Water Quality of Surinsar Lake

The water quality of the Surinsar lake for irrigation purposes has been evaluated based on the total salt concentration, USDA (1954) chart (chart based on EC and SAR values) and Doneen's chart of Permeability Index (PI).

The average electrical conductivity values in the lake water were well below the limit for satisfactory quality of irrigation water(ie. below 750 micro mhos/Cm, USDA,1954) during all sampling stages (Table-2). Further, total dissolved solids (TDS) were also within 800 ppm , the limit for best quality of irrigation water (Jermar,1987). Therefore, the lake water under present study is good for irrigation purposes .

According to USDA (1954) classification (Fig- 7) , the lake water during September and October (1994) was classified as C1 - S1 (low salinity and low sodium) class. Whereas, during January & March (1995) the lake water was categorized under C2-S1 (medium salinity and low sodium) class. Therefore, water in the lake under study is good for irrigation because both classes (C1-S1 and C2-S1) were classified as good waters for irrigation.

The average SAR values of the lake water were varied from 0.27 to 0.38 during post monsoon(September,94) to late winter sampling (March,95) (Table-7). These values were well below the limit of excellent waters for irrigation (ie.less than 10.0, USDA,1954). Therefore, the water of the lake under present investigation is good for irrigation.

Table-7
Variation of SAR Values for Surinsar Lake

Sampling Locations	Sodium Adsorption Ratios, SAR			
	Sept,94	Oct,94	Jan,95	March,95
P1	0.28	0.32	0.34	0.36
P2	0.24	0.29	0.29	0.35
P3	0.26	0.36	0.29	0.34
P4	0.30	0.35	0.29	0.41
P5	0.36	0.38	0.29	0.34
P6	0.26	0.34	0.30	0.41
P7	0.23	0.35	0.30	0.39
P8	0.25	0.30	0.26	0.43
Average	0.27	0.34	0.30	0.38

The Permeability Index (PI) were also calculated to determining the suitability of lake water for irrigation purposes. Their average values were found to be 78.60, 80.94, 69.76, and 60.39 during September, October,(1994), January, and March (1995) respectively (Table-8). According to Doneen's classification chart (Fig- 8) the lake water under this study was classified as class-II, having good quality of irrigation water for all sampling stages.

Table-8
Doneen's Permeability Index (PI) for Surinsar Lake

Sampling Locations	PI Values			
	Sep,94	Oct,94	Jan,95	March,95
P1	80.50	82.72	85.81	56.76
P2	78.23	80.60	65.04	56.82
P3	76.79	81.13	69.25	51.10
P4	79.64	81.87	71.58	66.64
P5	81.26	81.05	71.58	51.10
P6	78.75	80.09	67.20	58.82
P7	78.11	81.15	68.36	65.54
P8	75.69	78.91	59.25	76.33
Average	78.60	80.94	69.76	60.39

5.7 Drinking Water Quality of Surinsar Lake.

The average values of physico- chemical parameters such as pH, electrical conductivity, dissolved oxygen, bio- chemical oxygen demand, total dissolved solids, total hardness, calcium hardness, magnesium hardness, chloride, sulphate, nitrate etc. were compared with class A type of water (Indian Standards for Inland Surface Waters for Use as Drinking Water Source Without Conventional Treatment but after Disinfection). The results are given in Table -9.

Table-9

Comparison of Surinsar Lake Water with Class- A

Inland Water for Drinking Purposes

Sl. No.	Characteristics	Tolerance Limit of Class A	Average Values of Lake Waters			
			Sep,94	Oct,94	Jan,95	March 95
1.	pH value	6.5 - 8.5	8.27	8.40	8.43	8.43
2.	Dissolved Oxygen, mg/l, min.	6.0	7.39	8.03	8.83	7.78
3.	B.O.D., mg/l,max.	2.0	0.33	0.41	1.63	0.88
4.	TDS, mg/l, max.	500	144.75	151.25	152.75	350.25
5.	Total hardness, mg/l, max.	300	76.25	74.50	107.0	136.25
6.	Calcium hardness, mg/l, max.	200	48.75	46.50	95. 0	72.50
7.	Magnesium hardness, mg/l, max.	100	28. 0	28. 0	55.0	34.50
8.	Chlorides, mg/l, max	250	3.75	5.75	8.38	9.75
9.	Sulphate, mg/l, max.	400	6.48	7.24	9.29	11.26
10	Nitrates, mg/l max.	20	3.14	3.24	4.32	5.05

Class A: Inland Surface Water for Use as Drinking Water Source Without Conventional Treatment but After Disinfection.

The analysis showed that average pH values of water were within range of 6.5 - 8.5 during Sep, Oct.(94), January and March (1995). The average BOD values varied from 0.33 mg/l to 1.63 mg/l which were also within range of class A type of water. The minimum value of average DO was found to be 7.39 mg/l against minimum prescribed value (6.0 mg/l) for class-A drinking water under this study. The average total dissolved solids were varied from 144.75 mg/l to 350.25 mg/l. The average TDS values were also well below 500 mg/l as prescribed for class-A drinking water.

The total hardness, calcium hardness and magnesium hardness were also within limit. The average chloride values were varied from 3.75 mg/l to 9.75 mg/l during September,94 to March,95 respectively. The average chloride values were also well below the maximum limit (250 mg/l) as prescribed for A water. The average sulphate and nitrate concentrations were varied from 6.48 to 11.26 mg/l and 3.14 to 5.05 mg/l respectively, which were within the range of class- A drinking water.

Thus, it is evident from the present physico-chemical analysis that water of the Surinsar Lake can be used for drinking purposes. However, as per recommendations of Indian Standards for Inland Surface Water under Class-A, the water should be disinfected before using for drinking purposes.

6.0 CONCLUSIONS

The following conclusions were drawn from the present study:

(i) The average pH values of the lake water were varied from 8.27 to 8.43 during post monsoon (Sep, 94) to late winter (March 1995). Therefore, the water in the lake is alkaline in nature.

(ii) The average concentrations of major cations including calcium, magnesium sodium and potassium were varied from 19.55 to 38.10 mg/l, 6.80 to 13.37 mg/l, 5.51 to 10.15 mg/l and 2.64 to 4.01 mg/l respectively during post monsoon (Sept.94) to late winter (March, 95).

(iii) The average concentrations of major anions such as chloride, sulphate, bi-carbonate, nitrate and phosphate were varied from 3.75 to 9.75 mg/l, 6.48 to 11.26 mg/l, 81.50 to 126.50 mg/l, 3.14 to 5.05 mg/l and 0.015 to 0.05 mg/l respectively during post monsoon (September, 94) to late winter (March,95).

(iv) In this study the minimum value of average DO was obtained 7.39 mg/l against prescribed minimum value (6.0 mg/l) for Class-A drinking water(Indian Standards). The maximum value of BOD was found to be 1.63 mg/l during peak winter(January, 95).

(v) The average values of calcium and magnesium hardness were varied from 48.75 to 95.0 mg/l and 28.0 to 55.0 mg/l respectively during post monsoon (September, 94) to late winter (March,95).

(vi) The average SAR values of the lake water were varied from 0.27 to 0.38 during September, 94 to March 95. Therefore, the SAR values were well below the limit (less than 10.0) for very good quality of irrigation water(Unite States Salinity Laboratory Staff, USDA,1954).

(vii) According to USDA (1954), the lake water under this study was good for irrigation purposes, because it falls under C1-S1 (low salinity- low sodium) and C2-S1 (medium salinity low sodium) classes in the USDA (1954) chart (Fig-7) during September/October(94) and January/March(95) respectively.

(viii) According to Doneen's classification (based on Doneen's Permeability Index), the lake water falls under class-II water for irrigation under present study. Therefore, it was concluded that the water in the Surinsar lake is good for irrigation purposes.

(ix) The various physico-chemical parameters of lake water including pH, EC, DO, BOD, TDS, total hardness, calcium hardness, magnesium hardness, chloride, sulphate and nitrate etc. were found within limits of class-A drinking water (Indian Standards for Inland Surface Waters for Use as Drinking Water Source Without Conventional Treatment but After Disinfection).

7.0 REFERENCES

1.APHA, (1987), Standard Methods For the Examination of Water and Waste Water, Seventeenth Ed.,Washington, DC.

2. ANONYMOUS (1993), Ecological Development of Surinsar Lake of Jammu Region, Unpublished Project Report of Directorate of Environment and Remote Sensing, J&K(India).

3. Berner, R.A.(1971), Principles of Chemical Sedimentology, Mc Graw Hill Publ, New York.

4. Berner, E.K. and R.A. Berner (1987), The Global Water Cycle: Geochemistry and Environment, Englewood Cliffs, Prentice Hall, New Jersey, pp. 244 -247.

5. Chow, V.T. (1964), Hand Book of Applied Hydrology, Mc. Graw-Hill Book Company.

6.Durani, S. (1993), chemical and Pollution Studies of some Springs and Lakes of Jammu & Kashmir state, unpublished Ph.D Thesis, Jammu University, Jammu.

7. Hasnain, S.I., Subramanian, V. and Dhanpal, K. (1989), Chemical Characteristics and Suspended Sediment Load of Melt Waters from a Himalayan Glacier in India, J. of hydrol, Vol. 106, pp 99-108.

8. Hammer, M.J (1977) , Water and Waste Water Technology, John Wiley and Sons, New York pp. 162-167.

9. Hardie, L.A., Smoot, P. and Eugster, H.P. (1978), Saline Lakes and their Deposits : A Sedimentological Approach, Modern and Ancient Lake sediments, Edited by A. Mater and M.E. Tucker, Special Publication No.2 of Int. Asso. of sedimentologist, Blackwell scientific Publication, Oxford.

10. Jain, C.K., Bhatia, K.K.S. (1987-88), Physico-Chemical Analysis of Water and Waste Water, NIH, Roorkee (India), UM-26.

11. Jermar, M.K., Water Resources and Water Management, Elsevier Science Publishers, Amsterdam, The Netherlands, pp.169-207.

12. Kireet Kumar, Rawal, D.S. and Joshi, Ranjan, Study of Chemical Characteristics of the Water of Naukuchia Tal- A Central Himalayan Lake, Int. Symp. on Hydrology of Mountain Areas, Shimla. (India), may 28-30, 1992 pp.297-304.

13. Kuusisto, E.E. (1985), Lakes : Their Physical Aspects, Facets of Hydrology - vol II, Edited by J.C. Rodda, John Wiley & Sons Ltd., New York, pp. 159-162.

14. Pinto, Lo W.C. (1981), Eutrophication of Lakes and Estuaries, Pollution and Water Resources , Columbia Univ. Seminar Series, Edited by G.J. Halasikun, pp. 123-124.

15. Raghunath, H.M. (1982), Geochemical Survey and Water Quality, Ground Water, Wiley Eastern Ltd., pp. 344- 369.

16. Reid, G.K. and Wood, R.D. (1976), Ecology of Inland Waters and Etuaries, D. Van Nostrand Company, New York, pp 31- 68, 157, 207.

17. Thurman E.M. (1985), Developments in Biochemistry : Organic Chemistry of Natural Waters, Martinus Nijhoff/ Dr. W. Junk Publishers, Boston.

18. USDA (1954) , Diagnosis and Improvement of Saline and Alkali Soils, Handbook No. 60, U.S. GPO, Washington, D.C.

DIRECTOR : Dr S M Seth

GUIDED BY : Dr K S Ramasastri
Scientist "F" & Head

PREPARED BY : Sh Om kar
Scientist"B"

Sh M K Sharma, SRA

ASSISTED BY : Sh Vishal Gupta, JRA

Sh V K Agarwal, RA

Supporting Staff

Sh Suraj Prakash Kotwal
Attendant