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GROUND WATER QUALITY MONITORING AND EVALUATION IN JAMMU AND KATHUA DISTRICTS, J & K STATE (1998-99)

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ABSTRACT

In the present study, 36 water samples have been collected from open wells, two springs (Mandli, Ramkot) and two hand pumps (Bera, Jamral) during June, 1998 and February, 1999. The water quality parameters have been grouped in accordance with the standards of drinking and irrigation purposes. The ground water has also been classified on the basis of Piper, Stiff and U.S. Salinity Laboratory Classifications.

The study has shown alkaline nature of ground water. The pH values were within the prescribed limit for drinking purposes. The higher values of sodium above the prescribed limit of 50 mg/l were observed at about 31% of total wells during June, 1998 and about 25% of total wells during Feb., 1999, respectively. The hardness as $CaCO_3$ was observed above permissible limit at about 33% of wells during June, 1998 and 36% during Feb., 1999. Fluoride concentration was found below 0.6 mg/l at 78% wells and 0.6-1.2 mg/l at 22% wells during February, 1999.

The Piper's diagrams have shown about 83% wells under Ca^{2+}, Mg^{2+}, HCO_3^- hydrochemical facies, 11% under Na^+, K^+, HCO_3^- , 6% wells under Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} hydrochemical facies during June, 1998, and 91%, 3%, 6% wells under the above mentioned hydrochemical facies during February, 1999, respectively.

According to the Stiff classification, calcium bicarbonate was found dominant amounting to 67% and 80% of the total wells during June, 1998 and Feb., 99. However, sodium bicarbonate was present at 19% and 6% sites. The magnesium bicarbonate as well as calcium chloride were obtained at 11% and 3 % sites during both sampling programs.

According to the U. S. Salinity Laboratory Classification, the majority of water samples (72% and 75 % of total wells) lie under C3-S1 (high salinity- low SAR) category during June, 1998 and Feb., 1999, respectively. The C2-S1 (medium salinity- low SAR) category of wells lie at 11% and 22% sites during June, 1998 and Feb., 1999. The C4-S1 (very high salinity-low SAR) category of wells lie at 14% and 3% sites during June, 1998 and Feb., 1999, respectively. On the basis of SAR values, the water may also be classified under excellent category for irrigation purposes.

1.0 INTRODUCTION

Until recently, an ordinary Indian citizen was satisfied with availability of water. Today his concern is to have water which is devoid of chemical and bacteriological contamination. The quality of surface water and ground water are closely linked due to its circulatory phenomenon. The surface water and ground water are also affected due to artificial pollution. Due to release of wastes (e.g. industrial effluent) and also due to residual fertilizers and pesticides on account of intensive agricultural practice, the quality of water deteriorates, later causing high level of pollution due to the presence of nitrates and potassium.

The rapid pace of urbanization, industrialization as well as agricultural activities have made environmental pollution a growing concern globally. Of all the receptor systems exposed to the contaminants, ground water has received little attention in the past because of the common belief that ground water was pristine. The ground water pollution became a major issue in the management of the vital natural resource and protection of environment about a decade ago. As nearly one- fifth of all the water used in the world is obtained from ground water resources and in many areas ground water is only fresh source available, protection of ground water quality has become a high priority management goal.

Ground water pollution has usually been traced back to four main origins, namely; industrial, domestic, agricultural and over exploitation. The last category mainly accounts for sea water intrusion. Various studies carried out in India reveal that one of the most important cause of ground water pollution is unplanned urban development without adequate attention to sewage and waste disposal (CGWB, 1997). Industrialization without provision of proper treatment and disposal of wastes and effluent are other sources of ground water pollution. Excessive application of fertilizers for agricultural development coupled with over-irrigation and excessive pumping of fresh water in coastal aquifers are also responsible for ground water pollution.

In India, where more than half the population is dependent on ground water, the aspect of deterioration of water quality deserves serious consideration. The serious implications of this problem necessitate an integrated approach in explicit terms to undertake ground water pollution monitoring and abatement programs including identification of the kind of contaminating solutes, their sources and dispersal, the type of pollution they generate so that suitable measures could be planned, programmed and implemented to arrest, if not eliminate, the deleterious consequences of these hazards.

The monitoring and evaluation of ground water quality is a major issue to save the ground water from pollution. Ground water quality problems can be better understood by systematic and regular monitoring of water quality of a region. For last couple of years, members of the Regional Co-Ordination Committee of National Institute of Hydrology, Western Himalayan Regional Centre, Jammu have been suggesting to undertake water quality studies of the region. Therefore, the present study has been carried out on the similar lines aiming to assess the uses of ground water for drinking and irrigation purposes in Jammu & Kathua districts in the J. & K State.

2.0 REVIEW

The problem of pollution in ground water is much less than that of surface water, even though this problem nowadays is becoming a severe threat to public health (Pitchaiah, 1995). Handa (1994) has carried out groundwater contamination studies in various part of the country and disagreed on the fact that" the ground water is safe (free from pathogenic bacteria), does not contain harmful constituents and, is free from suspended matter in comparison to surface water". The above mentioned assumption regarding ground water need not to be correct under all circumstances (Cole, 1974; Furinam & Barton, 1971; Handa, 1994; Miller et al., 1974; Scalf et al., 1973).

The ground water pollution of all the three categories, viz., point, line and diffuse is also common in India. Wastes from municipal sources, such as; sewage effluent and sludge cause point, line and diffuse pollution, whereas, industrial effluent cause point pollution mostly, and when discharged on land may also cause line and diffuse pollution of ground water. Agricultural activities such as irrigation return flow, excessive use of fertilizers / soil amendments, pesticides and herbicides are conducive to cause diffuse pollution of ground water (Jain et. al, 1994-95).

The studies conducted in our countries have shown that ground water pollution from discharge of untreated or inadequately treated industrial effluent has reached alarming proportion in several parts of the country. Various studies have indicated that ground water, in India, has been severely affected due to the discharge of industrial wastes (Naram, 1981; Krishnaswamy, 1981; Das and Kidwai, 1981; Kachwaha, 1981). The studies have shown that most industries produce waste products also (gaseous, liquid and solid) as by-products, which can harm the environment, unless treated properly and conform to specified standards laid down by health authorities (CGWB, 1991b, Handa, 1994; Joshi et al., 1982; Moitra, 1991; Singh, 1986a).

In the J & K State, the erstwhile Ground Water Wing of the Geological Survey of India had taken up the monitoring of ground water regime way back in 1969 with only 9 National Hydrograph Network Stations to measure the condition and trends of ground water quality and quantity. The number of Hydrograph Network Stations was increased after Central Ground Water Board came into existence in 1972 by amalgamating Ground Water wing of Geological Survey of India into Exploratory Tubewell Organisation. As on December, 1997, there were 203 National Hydrograph Network Stations besides 19 number of peizometers in different districts (except Poonch, Doda, Kargil and Leh) of the Jammu and Kashmir State. However, in the year 1997 a total of 140 wells out of 203 Hydrograph stations were monitored by Ground Water Board, Northern Western Himalayan Region, Jammu.

Sangra (1987) has carried out hydrogeological investigations in Jammu District, J & K State, during 1974-78 & 1983, and observed that the concentration of chemical in ground water of shallow aquifer is comparatively higher than the deeper aquifers. It was also observed that the water table is deeper in Kandi along the outer most Siwalik hills than in the Sirowal part lying towards international border with Pakistan. It ranges between 2.20 and 30.65 m bgl during pre-monsoon and between 1.15 and 28.35 m bgl during the post monsoon period. Srivastava and Singh (1998) have prepared the Hydrological Year Book-1997, which deals with all the relevant data of National Hydrograph Network Stations, established in J & K State alongwith an analysis of the behavioral change in water levels and the ground water quality over the last decade as well as in the past one year.

The National Institute of Hydrology, Western Himalayan Regional Centre, Jammu, has envisaged the study to assess the suitability of ground water for drinking and irrigation purposes in Jammu district. The ground water quality monitoring program was also extended in Kathua district during the years 95-96, 96-97, 97-98. In general, these studies have shown relatively higher concentrations of calcium, magnesium, sodium, bicarbonate, sulphate and nitrate in certain number of sites of Jammu and Kathua districts. The concentration of fluoride was below desirable limit (0.6-1.2 mg/l) at most of the sites in Jammu and Kathua districts. The classification of water based on the Piper's diagram, shows majority of wells are under Ca^{2+}, Mg^{2+}, HCO_3^- hydrochemical facies, while, as per U.S. Salinity Laboratory Classification, the majority of wells lie either under high salinity-low SAR (C3-S1) or medium salinity-low SAR (C2-S1) categories of water (Jain et. al., 1994-95, Omkar et. al., 1995-96, 96-97, 97-98, 98).

3.0 STUDY AREA

3.1 General Description

The study area of Jammu and Kathua districts falls in Jammu region of J & K State, India (Fig. 1). The Jammu region comprises of six districts, e.g., Jammu, Kathua, Udhampur, Rajouri, Doda and Poonch. The Jammu region cover an area of 26,293 sq km and inhabited by 2.7 million people (as per 1981 census). Of this, Jammu district comprises an area of about 3097 sq km and is inhabitated by 943,395 person (as per 1981 census). The Jammu city is the winter capital of J & K State. The northern area forms a part of Himalayan foot hills zone with number of low lying ridges, strike and transverse valleys. The hills in general have comparatively gentle southern slope than the northern prominent hill scarp. The hills gradually merge in the plain where topography is gently undulating and flat.

3.2 Drainage System

The State of Jammu and Kashmir is a part of Indus system which has origin in the Western Himalaya. The landscape of Jammu & Kashmir is extensively dissected due to the presence of a number of drainage courses. The main rivers for drainage in the area are Chenab, Tawi, Basantar and Ujh. The Chenab river is perennial and snow fed. It leaves the Himalayas at Akhnoor (J&K), 290 km below Kishtwar and 640 km from the source. The river Tawi flows through Jammu city. The river Tawi falls into Chenab about 16 km to the west of Jammu city.

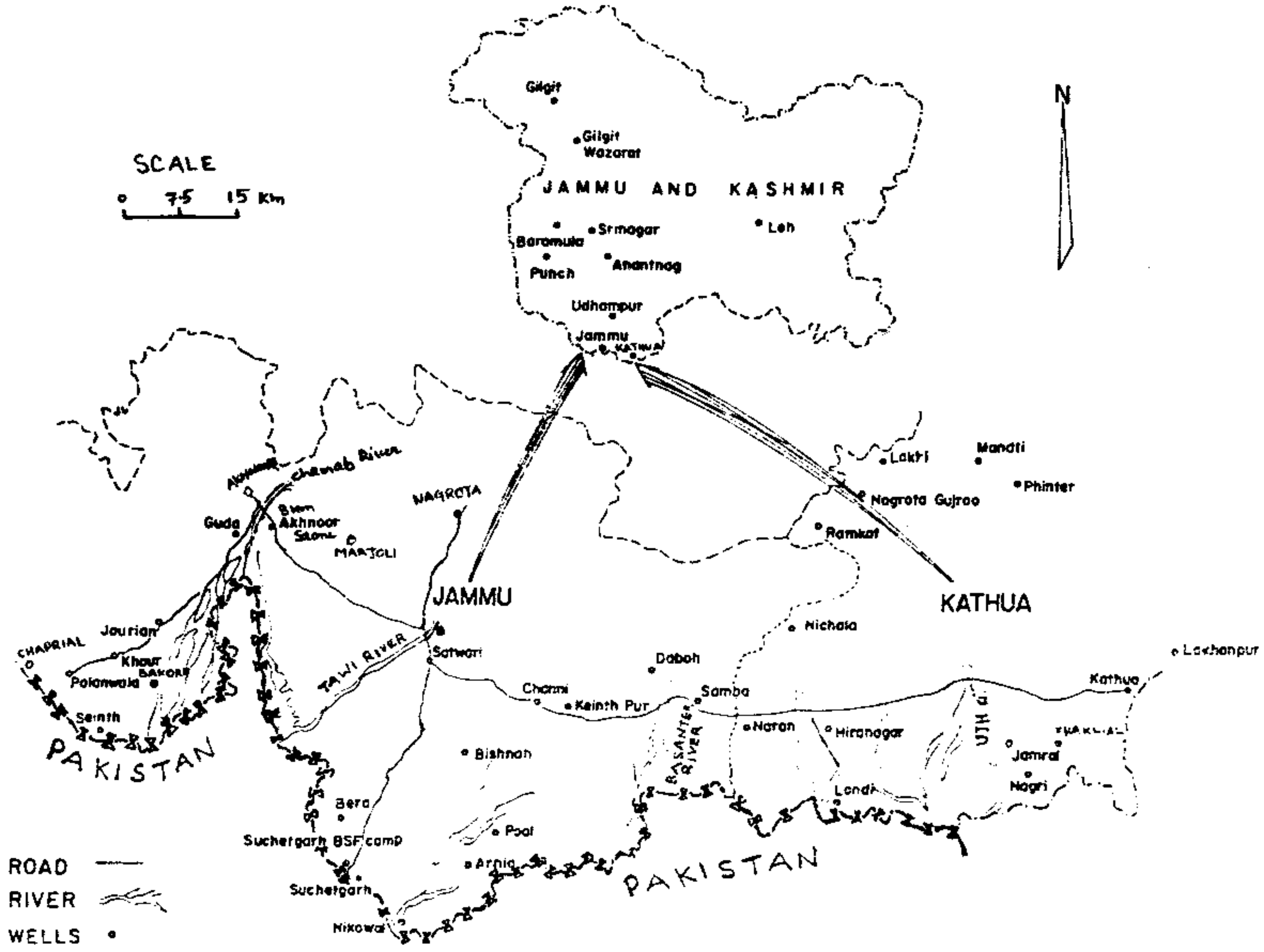


Fig.1 Location map of the Wells in Jammu & Kathua Districts

3.3 Climate and Rainfall

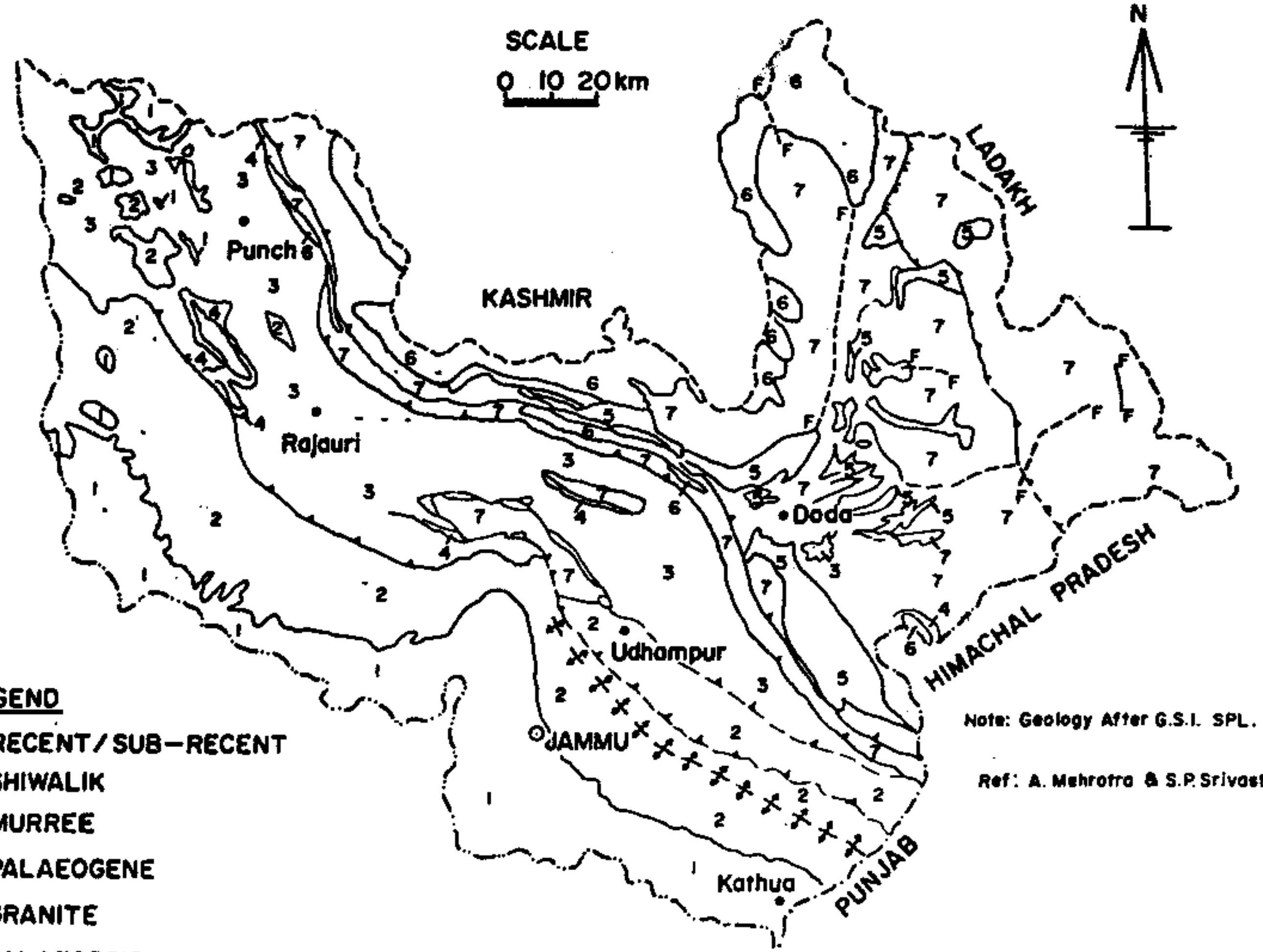
The climate of the area is of subtropical type, characterizing by three well defined seasons viz; winter, summer and monsoon . The monsoon sets by the beginning of July and continues till September. May and June are the hottest months and the maximum day temperature of 41.8 °C has been recorded during June, 1983. January is the coldest month with minimum temperature of 2.4 degree Celsius was recorded during 1984. The average temperature in the Jammu region varies from 4 to 40 degree Celsius. India Meteorological Department (IMD) has observed the normal annual rainfall about 1055 mm and 1177 mm at Jammu and Kathua stations, respectively.

3.4 Geology

The general geology of the study area consists of Siwalik system, and is mainly composed of sand stone, silt stone, red and purple and transported quartzite. The lower reaches, including the foot hill plain, consist of alluvial deposits brought down by seasonal rivulets and"choes". Parent material is mainly alluvium/colluvium on the foot hill plains. The geological map of the Jammu region is given in Fig-2 (Mehrotra and Srivastava, 1997). According to this Map, the general geology of the study area can be categorized into two groups e.g., Recent/ Sub-recent and Siwalik groups.

3.5 Lithology

The Central Ground Water Board, Northern Western Himalayan Region, Jammu has carried out detailed investigation of various exploratory sites in J & K. The lithology of the study area is generally non homogeneous and varies significantly from hilly areas to non hilly areas. The general lithostratigraphic sequence in the Kandi belt varies from clay to conglomerates with boulders, pebbles and gravels at many places. The general lithostratigraphic sequence in the plain areas of Jammu District (R.S. Pura/ Samba) was found as multi coloured clay with little sand/ silt and occasional clay hard plastic with gravels. The lithostratigraphic sequence of two sites representing the Kandi belt in Jammu and Kathua are given in Tables- 1 & 2, respectively.



LEGEND

1: RECENT / SUB-RECENT
2: SHIWALIK
3: MURREE
4: PALAEOGENE
5: GRANITE
6: PALAEOZOIC
7: PROTEROZOIC

Note: Geology After G.S.I. SPL. Pub. 26, 1989

Ref: A. Mehrotra & S.P. Srivastava, 1997

Fig. 2 Generalised Geological Map of Jammu Region

3.6 Ground Water Resources in J & K State

The ground water system in the state is very complicated because of varied hydrological parameters, topographical barriers, hydrological boundaries and diversified geological settings. The water resources of the J & K State can be broadly classified into five major classes based on the geological settings i.e. Piedmont deposits of outer plains of Jammu, Dun belt of outer Himalayas, isolated valley fill deposits of Lesser Himalayas, Fluvioglacial-lacustrine deposits of Kashmir valley, Moranic and fluvio glacial deposits of Ladakh (Dulloo, 1997). The study area is confined to Jammu & Kathua Districts. which lie in general within the Piedmont deposits of outer plains of Jammu and part of it under the Dun belt of outer Himalayas. The description is given below:

3.6.1 Piedmont Deposits of Outer Plains of Jammu: This plain, about 120 km long and 25 km wide lying between river Ravi in the east and river Munawar Tawi in the west, comprises mainly of unconsolidated to semi- consolidated sediments ranging in age from upper Pleistocene to the recent. The sediments towards north consist of coarse clastic varying in size from boulders to gravels loosely held in a clayey matrix and occasionally alternating with sand lenses of variable thickness. Kankar is also interspeared at various places at different depths and in variable amounts. The same deposits grade into finer sediments towards south and comprises of alternate layers of sands and clays with subordinate lenses of gravel and pebbles. Ground water in this plain occurs under four different regimes:

(a) Ground water in recent river terraces and present day flood plains.
(b) Ground water in the Kandi (Bhabar) zone.
(c) Ground water in Sirowal (Terai) zone.
(d) Ground water in the transitional zone between Kandi and Sirowals.

(a) Ground Water in Recent River Terraces and Present Day Flood Plains: Limited quantities of ground water are available in aquifers of limited thickness and areal extent in the recent river terraces and flood plains which can suffice the water supply requirements of few hutments in and around the ground water structures there. The ground water in this zone is found under perched water table conditions.

Table-1 Lithostratigraphic Details for the Well at Akhnoor in Jammu District (Sangra, 1987)

Depth Range (m) below ground level	Thickness of Stratum (m)	Lithostratigraphic Sequence
G.L.- 14.64	14.64	Boulders large size with Clay
14.64- 18.00	3.36	Conglomerate Soft
18.00- 19.52	1.52	Conglomerate Soft
19.52- 23.79	4.27	Conglomerate Hard
23.79- 28.06	4.27	Conglomerate Hard
28.06- 32.02	3.96	Conglomerate Soft
32.02- 38.12	6.10	Conglomerate Hard
38.12- 43.61	5.49	Conglomerate Hard
43.61- 87.23	43.62	Conglomerate with Sand fine to coarse grained Conglomerate

Table-2 Lithostratigraphic Details for the Well at Naran in Kathua District (Sangra, 1987).

Depth Range (m) below ground level	Thickness of Stratum (m)	Lithostratigraphic Sequence
G.L.- 12.19	12.19	Clay with Pebbles
12.19- 20.73	8.54	Conglomerate
20.73- 28.96	8.23	Clay
28.96- 59.76	30.80	Conglomerate
59.76- 60.35	0.59	Clay
60.35- 69.80	9.45	Conglomerate
69.80- 72.24	2.44	Clay
72.24- 75.59	3.35	Conglomerate
75.59- 78.64	3.05	Clay
78.64- 97.54	18.90	Conglomerate
97.54- 100.59	3.05	Clay
100.59- 114.91	14.32	Conglomerate
114.91- 117.04	2.13	Clay
117.04- 125.00	7.96	Conglomerate

(b) Ground Water in the Kandi (Bhabar) Zone: The area lying immediately to the foot slopes of Siwaliks is known as the Kandi zone. The average altitude of the area varies from 320 to 400 m above msl. Water level in the area is very deep seated and the discharge is less. The ground water in Kandi occurs mostly under deep water table conditions.

(c) Ground Water in Sirowal (Terai) Zone: The area lying south to the Kandi belt is known in the Indian stratigraphy as Terai zone and locally called as Sirowals. The area lies below the altitude of 300 m above mean sea level. The topographic gradient in this zone is very gentle. The water level is shallow and the ground water is found under confined as well as under un-confined conditions. The piezometric head of the confined aquifers in this zone stands higher than the water table of the area. This is the most potential ground water bank of the state.

(d) Ground Water in the Transitional Zone between Kandi and Sirowals: This is the belt in between the Kandi and Sirowal. It is through this belt that the Kandi pass into Sirowals. The area is located on the topographic contour of 300-320 m above mean sea level and there is a marked spring line almost all along 320 m contour line.

3.6.2 Dun Belt in the Outer Himalaya: The Dun belt occurs as a series of terraces across the outer most hills of Jammu and are enclosed within the Lesser Himalayas. This belt extends from Basholi (Kathua district) in the east to Reasi in the west. The sediments are deposited in variable depths and occur in the form of isolated sub-recent to recent valley fill deposits. They comprise of coarse clastic nature boulders, cobbles, and pebbles, interbedded with lenticular bodies of clays and silt, sand and gravels.

Ground water present in this area is limited and is found either as perched water bodies or localised water bodies. Minor seepage in the form of small springs and dug wells cater to the water supply of the adjoining areas.

3.7 Classification of Soils

The soils of Jammu region show a great heterogeneity. The soils of the foot hills and adjacent areas comprise of loose boulders and gravel with ferruginous clay. These types of soils are spreaded all over in the study area and are generally loamy but poor in clay content. Soils on the foothills and V-shape small valleys have been found to be deep to very deep and having medium to heavy texture. The plains of Jammu district are of alluvial nature. According to the Soil Survey Organization, Department of Agriculture, Jammu, the sub-surface soils around village Ramkot, Tehsil Billawar, which represents hilly and undulating area of Kathua district, are predominant in sandy clay loam texture. The soils of R.S. Pura Tehsil, which represents plains of Jammu district, was classified as Langotian (silty loam to silty clay loam), Bansultan (sandy loam to silt loam) and Kotli soil (silty clay loam to silty clay) series (Singh, 1986, 1991).

3.8 Infiltration Characteristics

Infiltration rates vary under different land uses and soil types in different hydroclimatic environments. Infiltration studies were carried out for bare, agriculture, grass and forest lands in the Jammu region. The results showed that initial infiltration rates vary from 12 to 18 , 17 to 24, 12 to 36 and 18 to 72 cm/hr for soils under bare, agriculture, grass and forest land uses, respectively. The final infiltration rates for these soils and land uses vary from 0.3 to 2.4, 1.2 to 3.0, 0.3 to 6.3 and 0.6 to 1.2 cm/hr (Omkar and Patwary, 1992-93 ; Patwary et al., 1997).

3.9 Classification of Land Use/ Land Cover

The land use/ land cover map of Jammu region prepared by Geological Survey of India (Mehrotra and Srivastava, 1997) using Landsat Imageries on 1: 250,000 scale, shows 31.75 % of total land area of the region is under cultivation, 37 % under forest cover, 29 % wasteland, 0.25 % under urban land and 2 % area comes under snow cover. The cultivated land in Jammu and Kathua district is 43 % and 37 %, respectively. Forest cover in Jammu district is only 24 % of the total geographical area of the region, which is below the minimum level of 33 % stipulated in the National Forest Policy, 1988. Jammu district has nearly 1 % of its area under urban land.

4.0 METHODOLOGY

Water quality data is necessary for water quality planning or management of flow for hydrologic design. Therefore, a given water resource must be measured, tested and evaluated to determine its suitability for use, and the nature and extent of changes occurring in the water due to the uses, should also be determined. The commonly used methods for performing this work are referred as water quality surveys. Water quality surveys may range from a program of monthly samples analysis with a portable field kit to a program of continuous monitoring supported by a sophisticated laboratory.

Sampling is one of the most important and foremost step in collection of representative water samples for water quality studies. In the present study, 36 ground water samples were collected from open wells, including two springs and two hand pumps, in the Jammu and Kathua Districts. The water samples were collected during June, 1998 and February, 1999. The depth of the water table from measuring point in the respective wells was also measured during sampling programs. Appropriate preventive measures were taken for preservation of samples analysed in the laboratory.

The physio-chemical analysis was performed by adopting standard methods (APHA, 1985; Jain and Bhatia, 1987-88). The water samples were analysed for pH, electrical conductivity, TDS, sodium, potassium, calcium, magnesium, chloride, sulphate, bicarbonate, nitrate, phosphate and fluoride. A few water quality parameters e.g., temperature, pH and EC were determined in field during sampling programs using portable thermometer, pH meter and portable water testing kit.

The total hardness and calcium hardness were also determined by Ethylene-diamine-tetra-acetic acid (EDTA) titrimetric method, and magnesium hardness was determined by deducting calcium hardness from total hardness. Calcium (as Ca^{2+}) was calculated by multiplying calcium hardness by 0.401, and Magnesium (as Mg^{2+}) by multiplying magnesium hardness by 0.243.

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

5.0 RESULTS AND DISCUSSION

In the present study, 36 water samples were collected from open wells, two springs (Mandli, Ramkot) and two hand pumps (Bera, Jamral) during June, 1998 and February, 1999. The water quality parameters have been grouped in accordance with the standards of drinking and irrigation purposes. The ground water has also been classified on the basis of Piper, Stiff and U.S. Salinity Laboratory Classifications.

5.1 Physico-Chemical Parameters of Water Quality : The analysis of water samples was carried out to determine concentration of sodium, potassium, calcium, magnesium, chloride, sulphate, alkalinity, nitrate, phosphate, fluoride, pH, electrical conductivity and TDS. The average and range of concentrations of chemical constituents of ground water samples of the study area are given in Table -3. The results have been summarized below:

The availability of the hydrogen ion in solution is measured by a chemical parameter called pH. The pH is an important measure of water quality because it represents the chemical nature of water (such as its corrosive tendencies) and the biological life which usually it supports. Low pH values are indicative of acid waters and high pH values are indicative of alkaline waters (HEC, 1972). In the present study, pH values vary from 7.12 to 8.8 (average, 8.16) during June, 1998 and 7.32 to 8.36 (average, 7.8) during, Feb., 1999. The average values of pH variation in the study area indicate that ground water in general is of alkaline nature. The variation of pH in the study area has been shown in Fig. 3.

The conductivity value is used for expressing the total concentration of soluble salts in water. In the present study, the EC values range from 470 to 3060 micro mho/cm at 25 ^{0} C (average, 1374) during June, 1998 and 540 to 2950 micro mho/cm at 25 ^{0} C (average, 1064) during Feb., 1999, with wide range of fluctuations at different locations. A plot showing variation in EC has been snown in Fig. 4.

Dissolved solids occur mainly because of the presence of inorganic salts and a small amount of organic material. It is a measure of all the nonfilterable solids in solution. Agricultural, domestic and industrial water users desire water with low concentrations of total dissolved solids (HEC, 1972). In the present study, TDS values vary from 301 to 1958 mg/l (average 879) during June, 1998 and 347 to 1888 mg/l (average, 681) during Feb., 1999. A plot showing variation in TDS has been shown in Fig. 5.

Alkalinity in natural water is caused by bicarbonates, carbonates and hydroxides, which can be ranked in order of their association with high pH values. However, bicarbonates represent the major form since they are formed in considerable amounts from the action of carbonates upon the basic materials in the soil. The bicarbonate content more than 60 mg/l in the water is necessarily attributed from the biological activities of plant roots, from the oxidation of organic matter included in the soils and in the rock, and from various chemical reactions (Mandel and Shiftan, 1981).The alkalinity values in the study area ranges from 90 to 590 mg/l (average, 329) during June, 1998 and 140 to 570 mg/l (average, 315) during February, 1999.

As a contaminant, sodium is important for both domestic and agricultural use of water. Sodium in drinking water is harmful to persons suffering from cardiac, renal or circulatory diseases. Sodium is extremely important in irrigation water, since high concentrations are toxic to plants (HEC, 1972). In the present study, the concentration of sodium varies from 8 to 204 mg/l (average, 41) during June, 1998 and 7 to 147 mg/l (average, 37) during Feb., 1999.

The main interest in calcium and magnesium is due to their adverse effect on household uses such as laundering and bathing (since they combine with soap and leave precipitates) and on cooking and water heating (since they cause incrustation). For irrigation waters, calcium and magnesium are also important parameters. In some situations they help offset the effects of sodium (HEC, 1972). In the present study, the concentration of calcium ranges from 11 to 152 mg/l (average, 71) and 42 to 241 mg/l (average, 85) during June, 1998 and Feb., 1999 respectively. The concentration of magnesium varies from 1 to 92 mg/l (average, 23) and 0.50 to 170 mg/l (average, 28) respectively.

Fig. 3 Variation of pH in Jammu and Kathua Districts during 1998-99

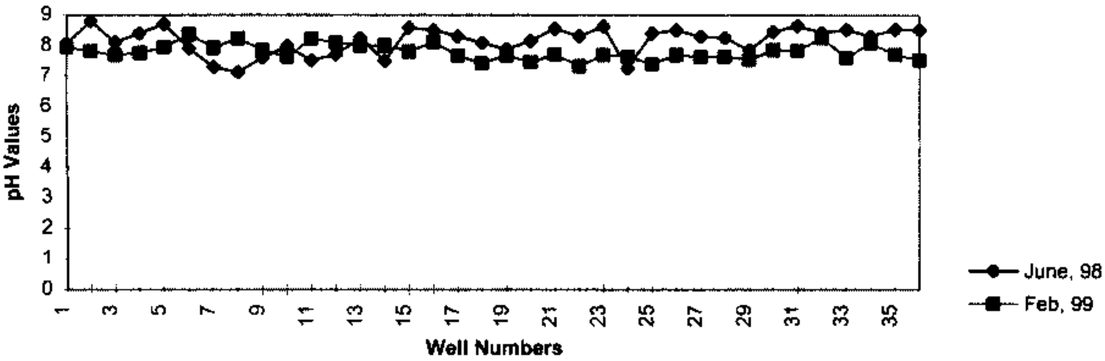


Fig. 4 Variation of EC in Jammu & Kathua districts during 1998-99

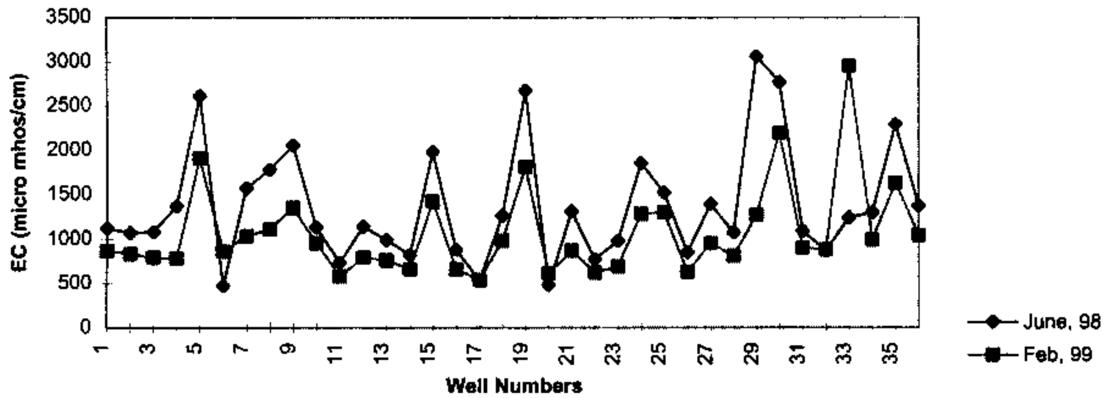
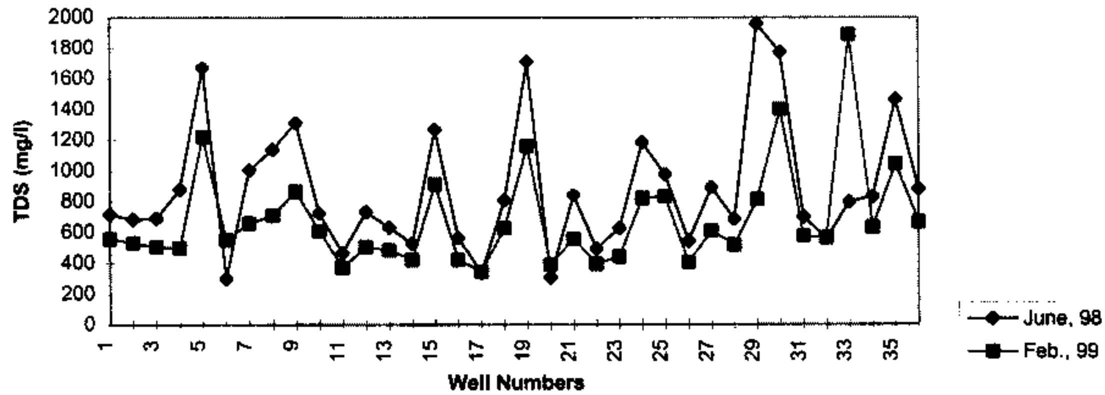


Fig. 5 Variation of TDS in Jammu and Kathua districts during 1998-99



Calcium and magnesium are often indexed by an empirical parameter called hardness. The hardness of water was originally defined in terms of its ability to precipitate soap. It is the property attributable to the presence of alkaline earths (Brown et al., 1970). Calcium and magnesium, alongwith their carbonates, sulphates and chlorides, make the water hard, both temporarily and permanent. In this study, total hardness as $CaCO_3$ varies from 72 to 760 mg/l (average, 270) during June, 1998 and 154 to 888 mg/l (average, 327) during Feb., 1999. A plot showing variation of total hardness as $CaCO_3$ has been shown in Fig. 6.

Chlorine is an important water quality parameter in both its elemental and chloride form. Elemental chlorine is very toxic to microorganisms, thus it is used in water purification. A chlorine residual may be toxic to fish and other aquatic life. Chlorides are usually found in, practically, all natural waters. Chlorides in drinking water are generally not harmful to human beings until its concentrations is high, although they may be injurious to people suffering from diseases of heart or kidneys. Chlorides are also harmful in irrigation water and are generally more toxic than sulphates to plants (HEC, 1972). The most important source of chlorides in water is the discharge of domestic sewage. In this study, the concentration of chloride varies from 4 to 302 mg/l (average, 48) during June, 1998 and 4 to 326 mg/l (average, 54) during Feb., 1999.

Sulphates occur naturally in water as a result of leaching from gypsum and other common minerals. They may also occur as the final oxidized stages of sulphides, sulphites, and thiosulphates which are usually discharged into the system from natural or man-made sources. Sulphate ions may cause the precipitation of calcium ions and lead to sodium poisoning of plants (HEC, 1972). The concentration of sulphate varies from 6 to 156 mg/l (average, 45) during June, 1998 and 1 to 145 mg/l (average, 29) during Feb., 1999.

Nitrates are the end product of the aerobic stabilization of organic nitrogen, and as such they occur in polluted waters that have undergone self-purification or aerobic treatment processes. Nitrates also occur in percolating ground water as a result of excessive application of fertilizer or leaching from cesspools. In few instances, nitrates are occurred to a stream or ground water by degradation of natural organic material or directly by inorganic industrial wastes, but such sources are relatively insignificant (HEC, 1972). The values of nitrate in the study area, range from 0.24 to 19 mg/l (average, 5) during June, 1998 and 0 to 84 mg/l (average, 10) during Feb., 1999.

The Bureau of Indian Standards (BIS, 1983), formerly knows as Indian Standards Institution (ISI), in view of the health problems has laid down the Indian Standards as 0.6 to 1.2 mg/l as the desirable limit for fluoride. The Indian Council of Medical Research (ICMR) has recommended the highest desirable level as 1.0 mg/l and maximum permisible limit as 1.5 mg/l. This means that the body may tolerate fluoride upto a limit of 1.5 mg/l depending upon the nutritional standards and body physiology. Though ICMR has laid down the upper limit as 1.5 mg/l, it is further specified that " lesser the better" as the fluoride causes not only the health problem in higher concentration but together are large number of cases where even 0.4 ppm fluoride in drinking water has caused dental fluorosis (Bhatia et. al, 1998). During 1940s, when fluoride was used for preventing a dental disease called dental carries, the possibility of harmful side effects were never considered nor sufficient scientific data were available. Sixty years later, it is well established that fluoride, when used in the name of prevention of carries through tooth paste, mouth rinses, tablets etc. is causing serious health problems. The practice of promoting fluoride in India, thus, needs to be carefully examined. In the present study, the concentration of fluoride varies from 0.08 to 0.86 mg/l (average, 0.45) during Feb., 1999.

Phosphorus is an essential nutrient for plant and animal growth, and like nitrogen, it passes through cycles of decomposition and photosynthesis. In nature, phosphorus is found in several minerals in the form of phosphates and is a constituent of fertile soils, plants, and the protoplasm, nervous tissue and bones of animal life. Phosphorus concentrations in excess of about 0.2 mg/l generally indicate that domestic wastes, industrial wastes, or fertilisers from agricultural use have entered the system (HEC, 1972). The phosphate concentration in the study area ranges from 0 to 0.52 mg/l (average, 0.08) during June, 1998 and 0 to 0.4 mg/l (average, 0.08) during Feb., 1999.

Potassium is usually found as ions in natural waters or in large salt deposits formed by the evaporation of brine. It is an essential element required for the plant growth. The concentration of potassium under the present study ranges from 0.8 to 223 mg/l (average, 19) during June, 1998 and 0.7 to 255 mg/l (average, 27) during Feb., 1999.

Table 3. Chemical Characteristics of Ground Water Samples in the Study Area.

Parameters	June, 1998			February, 1999		
	Max	Min	Mean	Max	Min	Mean
pH	8.8	7.12	8.16	8.36	7.32	7.8
EC, μ mhos/cm at 25 ^{0} C	3060	470	1374	2950	540	1064
TDS, mg/l	1958	301	879	1888	347	681
Alkalinity, mg/l	590	90	329	570	140	315
Total Hardness as $CaCO_3$, mg/l	760	72	270	888	154	327
Chloride, mg/l	302	4	48	326	4	54
Sulphate, mg/l	156	6	45	145	1	29
Phosphate, mg/l	0.52	0	0.08	0.4	0	0.08
Nitrate, mg/l	19	0.24	5	84	0	10
Calcium, mg/l	152	11	71	241	42	85
Magnesium, mg/l	92	1	23	170	0.5	28
Sodium, mg/l	204	8	41	147	7	37
Potassium, mg/l	223	0.79	19	255	0.7	27
Fluoride, mg/l	-	-	-	0.86	0.08	0.45

5.2 Water Quality Evaluation for Drinking Purposes: The various physico-chemical parameters of water quality have been compared with the Indian Standards (BIS, 1983) and WHO (1984) norms for drinking purposes (Table-4).

A pH range of 6.5 to 8.5 is normally acceptable as per guidelines suggested by WHO (1984) and BIS (1983). The results show that water of all wells are within the prescribed limit as per pH values are concerned under this study.

The concentration of sodium more than 50 mg/l makes the water unsuitable for domestic uses. The higher values of sodium than the prescribed limit of 50 mg/l were observed at about 31% of wells during June, 1998 and about 25 % of wells during Feb., 1999, respectively, under the present sampling program.

The upper limits for calcium and magnesium for drinking water are 75 and 30 mg/l respectively (BIS, 1983). The results indicate that the concentrations of calcium are above permissible limit at about 39% of wells during June, 1998 and 53% during Feb., 1999. Whereas, the concentrations of magnesium are obtained in excess at about 25% of wells during June, 1998 and 22% during Feb., 1999.

The total hardness limit of 300 mg/l has been recommended for potable waters (BIS, 1983). The concentrations of hardness as $CaCO_3$ are observed beyond permissible limit at about 33% of the wells during June, 1998 and 36% during Feb., 1999, respectively, under this study.

The chloride limit of 250 mg/l has been recommended for drinking purposes (BIS, 1983; WHO, 1984). The results show that almost all wells in the study area are within the prescribed limits for drinking purposes except at well number 29 during June, 1998 and at Well Numbers 19, 33 during Feb., 1999.

The sulphate is an important constituents of hardness with calcium and magnesium. A limit of 150 mg/l has been suggested for drinking purposes (BIS, 1983). The analysis of water samples show that the sulphate at all wells is within the limit for drinking purposes.

The limit of general acceptability of nitrate for drinking water is 45 mg/l (BIS, 1983). Nitrate at all wells was within the limit for drinking purposes except at well number 33 during February, 1999 under the present study.

The desirable range of fluoride for drinking water is 0.6 to 1.2 mg/l (BIS, 1983). However, the recent information reveal that even lesser concentration of fluoride may cause the dental fluorosis. The results of the present study have shown fluoride concentration below 0.6 mg/l at about 78% wells during February, 1999. Whereas, the concentration of fluoride was within the desirable limit (0.6-1.2 mg/l) at only 22% of wells in the study area during February, 1999.

5.3 Water Quality Evaluation for Irrigation Purposes: The irrigation water quality refers to its suitability for agricultural uses. A good quality water has the potential to cause maximum yield under good soil and water management practices. The suitability of an irrigation water depends upon many factors including the quality of water, soil type, salt tolerance characteristics of the plants, climate and drainage characteristics of the soil etc. However, the main soluble constituents of water which determine suitability of irrigation water are calcium, magnesium, sodium, chloride, sulphate and bicarbonate. In some cases, Boron content may also effect the suitability of water for irrigation for certain crops. In the present study, the irrigation water quality has been evaluated on the basis of the following criteria:

Table-4 Summary of Drinking Water Quality in Jammu & Kathua Districts.

Parameter	Limits (BIS-1983)	Wells Exceeding the Limits	
		June, 1998	February, 1999
pH	6.5 - 8.5		
Sodium	50 mg/l	2, 8-10, 19, 25, 27, 29, 30, 35, 36 (31%)	5, 8, 9, 15, 19, 25, 30, 33, 36 (25%)
Calcium	75 mg/l	1, 8, 9, 13, 15, 18, 19, 23-25, 29-31, 35 (39%)	1, 3, 5-10, 15, 18, 19, 24, 25, 28, 30, 32-35 (53%)
Magnesium	30 mg/l	2, 3, 5, 7, 9, 19, 21, 24, 29 (25%)	2, 9, 14, 29-31, 33, 35 (22%)
Total Hardness as CaCO3	300 mg/l	7-9, 15, 19, 21, 23-25, 29, 30, 35 (33%)	1, 2, 5, 7, 9, 14, 19, 24, 25, 29, 30, 33, 35 (36%)
Chloride	250 mg/l	29 (3%)	19, 33 (6%)
Sulphate	150 mg/l		-
Nitrate	45 mg/l	-	33
Fluoride	>1.5 mg/l	not determined	-
	0.6-1.2 mg/l		1, 2, 5, 9, 13, 25-27 (22%)
	< 0.6 mg/l		3, 4, 6-8, 10-12, 14-24, 28-36 (78%)

5.3.1 Total Concentration of Soluble Salts: Total concentration of soluble salts in irrigation water can be adequately expressed for evaluation of water for irrigation purpose in terms of electrical conductivity. Table-5 show that about 75% of wells lie under high salinity zone (i.e EC range, 750-2250 micro mho/cm), 14% under very high salinity zone (i.e EC range, 2250-5000 micro mho/cm) and 11% under medium salinity (i.e EC range, 250-750 micro mho/cm) during June 1998. Whereas, the results of water sample collected during Feb., 1999 show the sequence of 75%, 3% and 22% wells lying under above mentioned salinity zones. According to US Salinity Laboratory Staff (1954), water in the range of 750-2250 micro-mhos/cm at 25 ^{0} C are widely used, and a satisfactory crop growth is obtained under good management and favourable drainage conditions, but saline conditions will develop if leaching and drainage facilities are inadequate. The use of water with conductivity values above 2250 micro mhos/cm at 25 ^{0} C is exception and in this case more salt tolerant crops can be grown only if sub-soil drainage is good.

5.3.2 Sodium Adsorption Ratio (SAR): The sodium or alkali hazard of water to examine the suitability for irrigation is determined by the absolute and relative concentrations of cations, which is expressed in terms of sodium adsorption ratio (SAR). If the proportion of sodium is high, the alkali hazard is high; and conversely, if calcium and magnesium predominate, the hazard is less. If water used for irrigation is high in sodium and low in calcium, the cation exchange complex may become saturated with sodium. This can destroy the soil structure owing to dispersion of the clay particles. A simple method of evaluating the danger of high- sodium is the sodium- adsorption ratio (SAR), and the equation is given as:

Table-5 Classification of Water on the basis of Salinity Levels.

Zone	E.C.(μ mhos/ cm at 25 ^{0} C)	Well Numbers in Jammu and Kathua Districts	
		June, 1998	February, 1999
Low Salinity	< 250	nil	nil
Medium Salinity	250-750	6, 11, 17, 20 (11%)	11, 14, 16, 17, 20, 22, 23, 26 (22%)
High Salinity	750-2250	1-4, 7-10, 12-16, 18, 21-28, 31-34, 36 (75%)	1-10, 12, 13, 15, 18, 19, 21, 24, 25, 27-32, 34-36 (75%)
Very High Salinity	2250-5000	5, 19, 29, 30, 35 (14%)	33 (3%)

$$SAR = \frac{Na^+}{[(Ca^{++} + Mg^{++})/2]^{0.5}}$$

The sodium percentage (soluble sodium percentage, SSP) is calculated as:

$$Na\% = \frac{Na^+ + K^+}{Ca^{++} + Mg^{++} + Na^+ + K^+} * 100$$

In calculation of SAR and SSP, all ionic concentrations are expressed in milliequivalent per liter. The U.S. Salinity Laboratory, Department of Agriculture, USA has recommended the SAR as basis for classification of water for agriculture uses as given in the Table- 6. According to the present classification, the SAR values of all samples lie below 10 and, therefore, ground water in the study area may be classified under excellent category of water for irrigation as far as the alkali hazard is concerned. The values of SAR vary from 0.20 to 6.8 during June, 1998 and from 0.19 to 2.15 during Feb., 1999 respectively. Whereas, the values of soluble sodium percentage (SSP) or Na% vary from 8 to 72.2 during June, 1998 and from 7.9 to 54.56 during Feb., 1999, respectively (Table-7). The diagrams showing the variation of SAR and SSP values are given in Figures 7 & 8, respectively.

5.4 Classification of Ground Water: In the present study, the ground water has been classified on the basis of widely used graphical methods e.g., Piper, Stiff and U.S. Salinity Laboratory Classifications. The Ground Water Software (version-1, 1989) was used in preparing these classifications. The results have been summarized and are given in Table-8. The identification levels used for the present analysis are given in Table-9.

5.4.1 Piper's Classification: The Piper's diagram (1953) is used to identify similarity and dissimilarity in the chemistry of different water samples based on dominant cations and anions. Using this diagram, hydrochemical facies are classified on the basis of the dominant ions in the water. The term hydrochemical facies is used to describe the bodies of ground water, in an aquifer, that differ in their chemical composition (Fetter, 1988). The facies are a function of the lithology, solution, kinetics, and flow patterns of the aquifer (Back, 1960, 1966).

Fig. 6 Variation of total hardness as CaCO3 in Jammu & Kathua districts during 1998-99

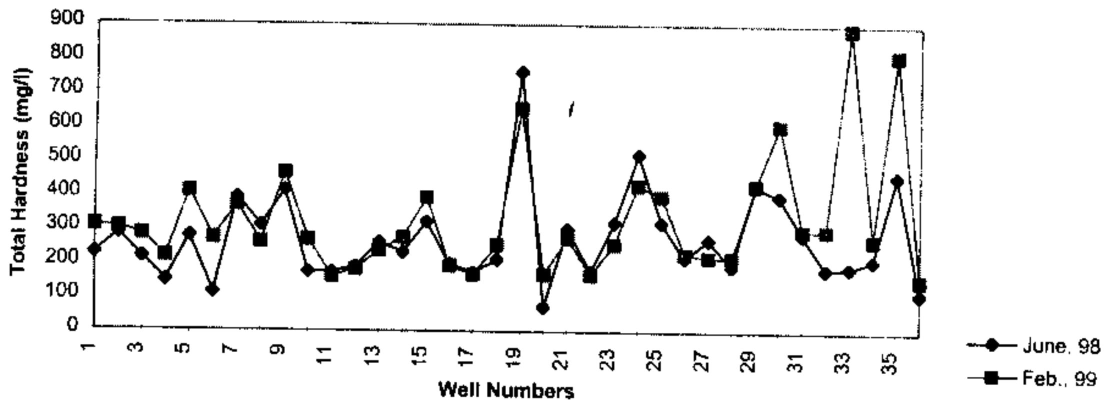


Fig. 7 Variation of SAR in Jammu & Kathua districts during 1998-99

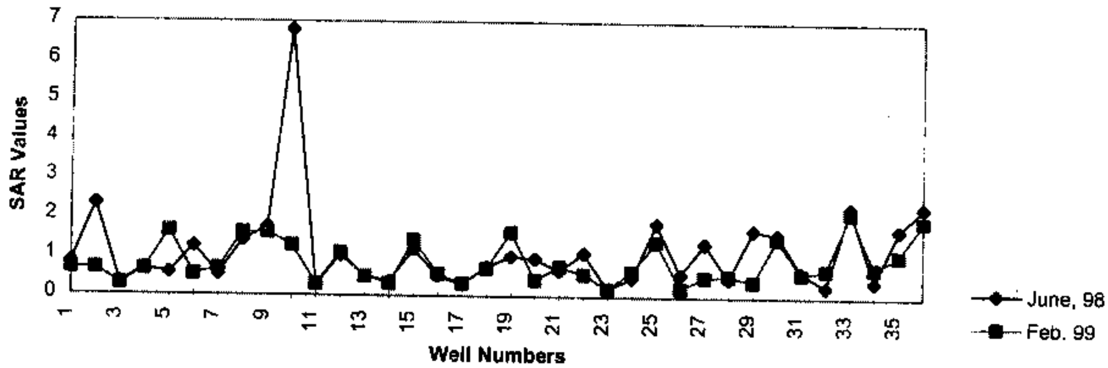
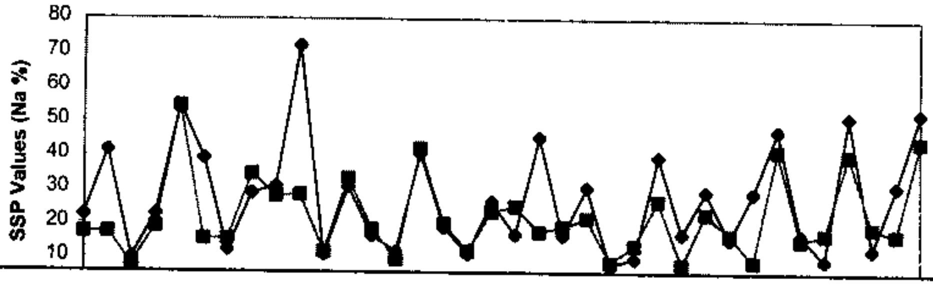


Fig. 8 Variation of soluble sodium percentage in Jammu & Kathua districts during 1998-99



The Piper's diagrams indicate that, 83% wells represent the Ca^{2+}, Mg^{2+}, HCO_3^- hydrochemical facies. 11% wells represent the Na^+, K^+, HCO_3^- and remaining 6% wells represent Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} hydrochemical facies for the observed data of June, 1998. However, the water sampling carried out during Feb, 1999 shows 91%, 3% and 6% of wells under the above mentioned categories of hydrochemical facies. The Piper diagrams for ground water analysis of Jammu & Kathua Districts for the months of June, 1998 and February, 1999, are given in Figures 9 & 10 respectively.

Table-6 Classification of Irrigation Water on the Basis of SAR Values (USDA, 1954)

Sodium Adsorption Ratios (SAR)	Water Class	No. of Wells in Jammu & Kathua Districts	
		June, 1998	Feb., 1999
< 10	Excellent	36	36
10-18	Good	-	-
18-26	Fair	-	-
>26	Poor	-	-

5.4.2 Stiff's Classification: Stiff (1951) pattern diagram represents chemical analyses in distinctive graphical shapes by plotting ions on parallel axis in meq/l. The scale is divided horizontally for cations on left side and anions on right side by indicating zero concentration in the middle. The analysis for Stiff classification was carried out using the Ground Water Software. The results are given in Table-8, which indicate that calcium bicarbonate dominates in the study area amounting to 67% and 80% of the total wells for the data of June, 98 and Feb., 99 respectively. The sodium bicarbonate was present at 19% and 6% of the total wells. Magnesium bicarbonate as well as calcium chloride were obtained at 11% and 3 % of the total wells during both sampling programs.

5.4.3 U.S. Salinity Laboratory Classification: The U.S. Salinity Laboratory Classification (U.S. Salinity Laboratory Staff, 1954) is used to study the suitability of water for irrigation purposes. The U.S. Salinity diagram is a combination of salinity and alkalinity (sodium) hazards plotted on X and Y axis respectively. The salinity hazards are expressed in terms of electrical conductivity of water in micro-mhos/cm at 25 °C and alkali hazards are expressed in terms of sodium adsorption ratio (SAR). The diagram has distinction

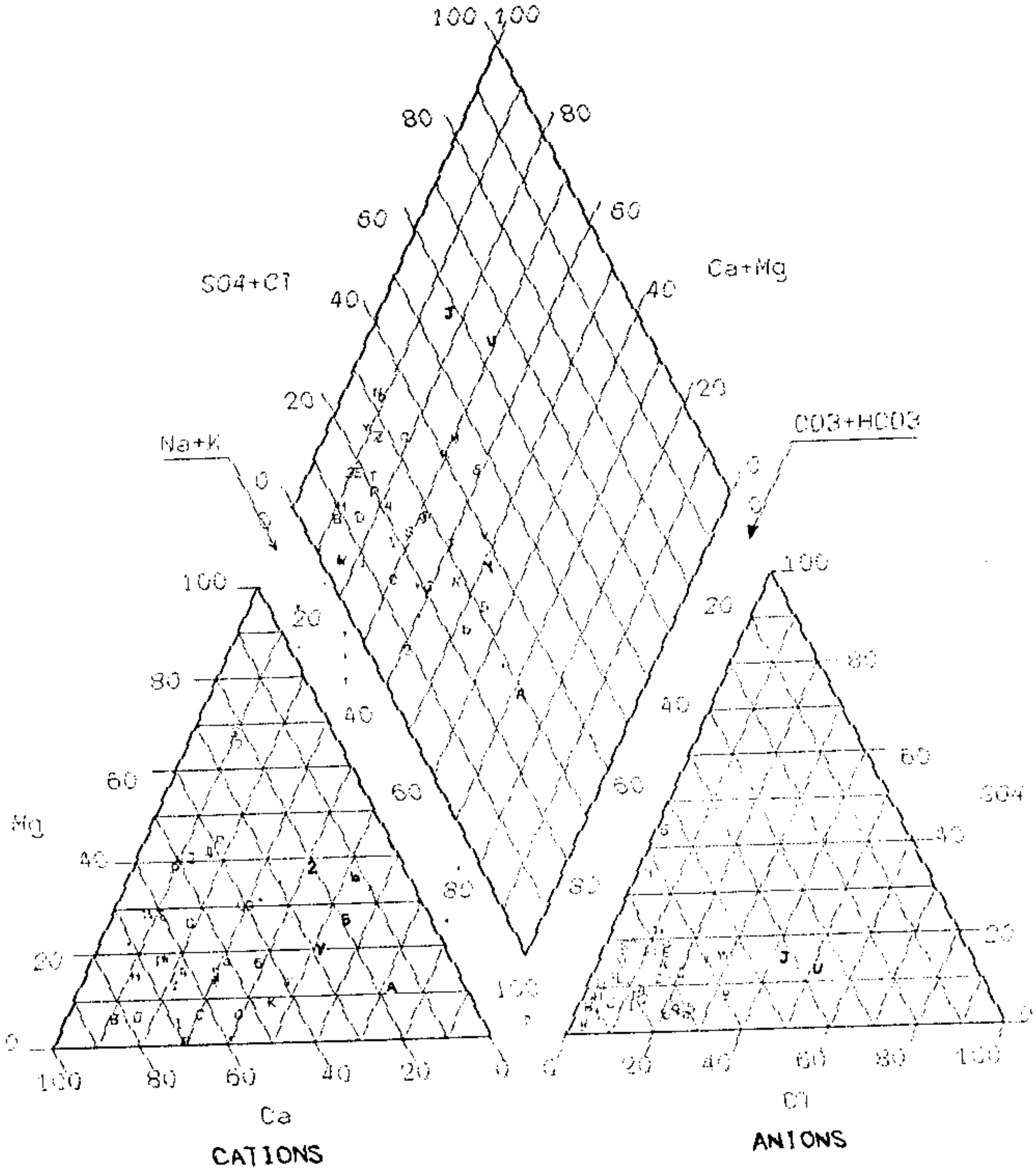


Fig. 9. Piper's Diagram for Jammu & Kathua Districts, June, 1998.

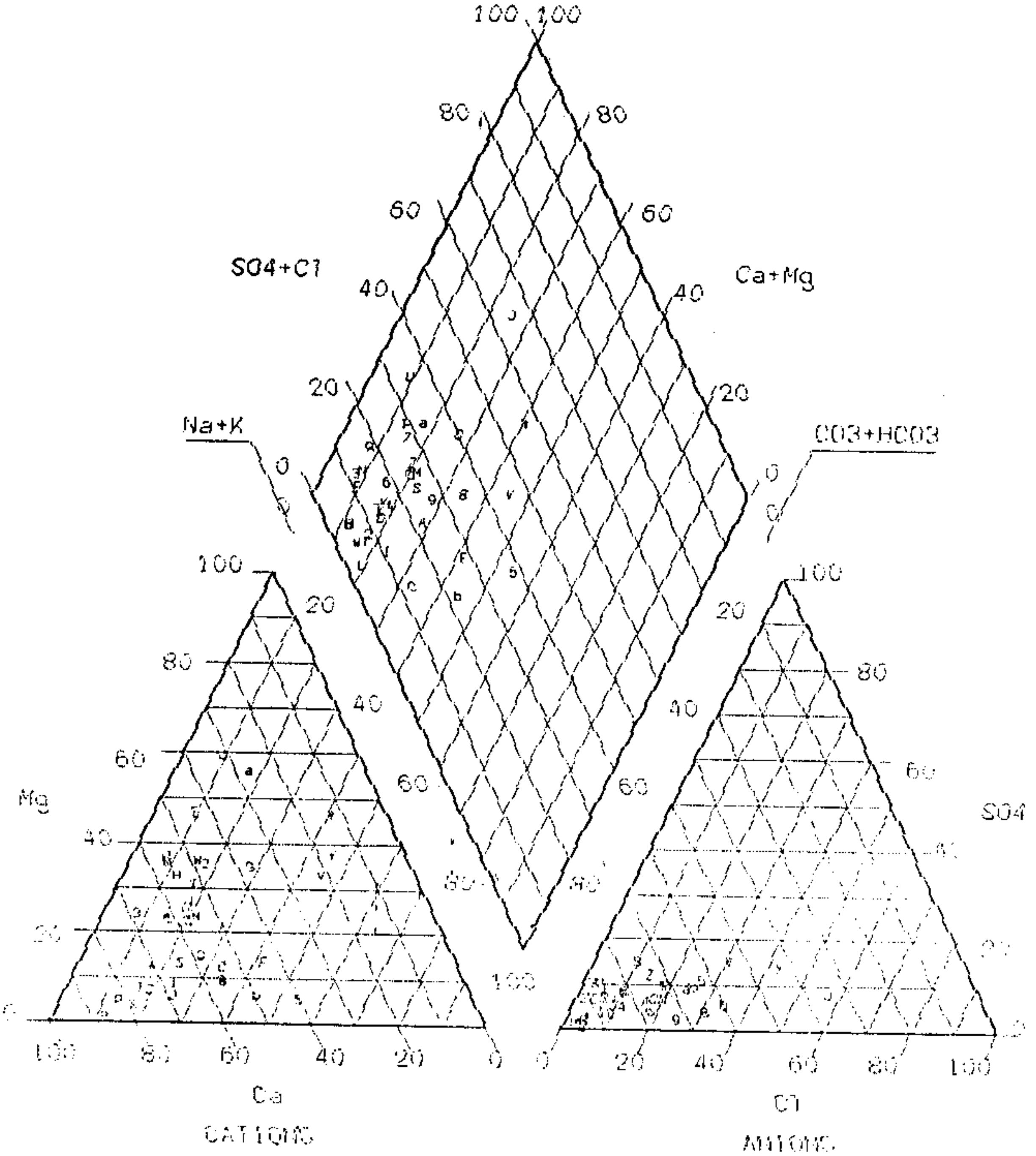


Fig. 10. Piper's Diagram for Jammu & Kathua Districts, Feb., 1999.

Table-7. Sodium Adsorption Ratio (SAR) & % Na for Jammu & Kathua Districts

S. N.	Wells	SAR Values		SSP or % Na	
		June, 1998	Feb., 1999	June, 1998	Feb., 1999
1.	BSF camp	0.82	0.69	22.34	17.37
2.	Suchetgarh	2.32	0.67	41.42	17.47
3.	Bera	0.3	0.28	9.94	7.9
4.	Keinthpur	0.66	0.66	22.74	19.11
5.	Bishnah	0.56	1.64	54.57	54.55
6.	Channi	1.24	0.52	39.18	15.50
7.	Daboh	0.54	0.68	12.26	15.55
8.	Samba	1.4	1.60	39.87	34.65
9.	Naran	1.74	1.60	31.01	28.17
10.	Londi	6.78	1.28	72.20	28.51
11.	Nichla	0.29	0.30	10.90	11.82
12.	Hiranagar	1.03	1.09	30.71	33.30
13.	Jamral	0.50	0.50	16.42	18.48
14.	Nagriparol	0.37	0.31	11.91	9.60
15.	Khakial	1.18	1.42	40.71	42.16
16.	Kathua	0.51	0.56	19.05	20.11
17.	Lakhanpur	0.3	0.31	11.2	12.13
18.	Ramkot	0.74	0.70	26.48	23.73
19.	Nagrota Gujru	1.01	1.63	16.19	25.22
20.	Lakri	0.95	0.42	45.51	17.68
21.	Mandli	0.66	0.76	16.73	19.25
22.	Phinter	1.07	0.57	30.69	21.75
23.	Akhnoor	0.2	0.19	8.03	8.8
24.	Guda	0.5	0.64	9.90	13.74
25.	Jourian	1.85	1.40	39.75	26.86
26.	Bakore	0.56	0.23	17.12	8.12
27.	Khour	1.36	0.50	29.56	23.15
28.	Palanwala	0.50	0.55	15.63	16.85
29.	Chaprial	1.67	0.39	29.19	9.03
30.	Seinth	1.58	1.50	47.55	41.61
31.	Nikowal	0.65	0.59	17.04	15.50
32.	BOP Camp	0.27	0.70	9.52	17.19
33.	Arnia	2.3	2.15	51.61	40.58
34.	Poal	0.4	0.75	12.79	19.15
35.	Nagrota	1.71	1.07	31.31	17.03
36.	Marjoli	**2.3**	**1.95**	**52.73**	**44.54**

Table-8 Summarized Results of Water Classification

Piper Classification (Hydrochemical facies)	Well Nos. in Jammu and Kathua Districts	
	June, 1998	Feb., 1999
Ca^{2+}, Mg^{2+}, HCO_3^-	1-4, 6-9, 11-18, 20-28, 30-32, 34, 35 (83%)	1-4, 6-18, 20-32, 34-36 (91%)
Na^+, K^+, HCO_3^-	5, 10, 33, 36 (11%)	5 (3%)
Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}	19, 29 (6%)	19, 33 (6%)
Na^+, K^+, Cl^-, SO_4^{2-}	-	-
Stiff Classification		
Calcium Bicarbonate	1, 4, 6, 8, 9, 11-19, 22-25, 27, 28, 31, 32, 34, 35 (67%)	1-4, 6-13, 15-18, 20-28, 31, 32, 34, 36 (80%)
Sodium Bicarbonate	2, 5, 10, 20, 30, 33, 36 (19%)	5, 30 (6%)
Magnesium Bicarbonate	3, 7, 21, 26 (11%)	14, 29, 33, 35 (11%)
Calcium Chloride	4	19
U.S. Salinity Laboratory Classification (U.S. Salinity Laboratory Staff, 1954)		
C2-S1	6, 11, 17, 20 (11%)	11, 14, 16, 17, 20, 22, 23, 26 (22%)
C3-S1	1-4, 7-9, 12-16, 18, 21-28, 31-34, 36 (72%)	1-10, 12, 13, 15, 18, 19, 21, 24, 25, 27-32, 34-36 (75%)
C3-S2	10 (3%)	-
C4-S1	5, 19, 29, 30, 35 (14%)	33 (3%)

Table-9 Sample Identification Levels for Piper and U.S. Salinity Diagrams.

S. N.	Wells	Sample Identification
1.	BSF camp	1
2.	Suchetgarh	2
3.	Bera	3
4.	Keinthpur	4
5.	Bishnah	5
6.	Channi	6
7.	Daboh	7
8.	Samba	8
9.	Naran	9
10.	Londi	A
11.	Nichla	B
12.	Hiranagar	C
13.	Jamral	D
14.	Nagriparol	E
15.	Khakial	F
16.	Kathua	G
17.	Lakhanpur	H
18.	Ramkot	I
19.	Nagrota Gujru	J
20.	Lakri	K
21.	Mandli	L
22.	Phinter	M
23.	Akhnoor	N
24.	Guda	P
25.	Jourian	Q
26.	Bakore	R
27.	Khour	S
28.	Palanwala	T
29.	Chaprial	U
30.	Seinth	V
31.	Nikowal	W
32.	BOP Camp	X
33.	Arnia	Y
34.	Poal	Z
35.	Nagrota	a
36.	Marjoli	b

to classify the irrigation water into 16 categories.

The U. S. Salinity diagrams show that majority of water samples (72% and 75 % of total wells) lie under C3-S1 (high salinity- low SAR) category during June, 98 and Feb., 1999, respectively. The category of wells under C2-S1 (medium salinity- low SAR) lie at 11% and 22% of total wells during June, 1998 and Feb., 1999, respectively. However, 14% and 3% of the total wells were under C4-S1 (very high salinity-low SAR) category during June, 1998 and Feb., 1999, respectively.

Whereas, the well number 10 was under the C3-S2 (high salinity-medium SAR) category during June, 98. The U.S. Salinity diagrams prepared under the present study for the months of June, 1998 and February, 1999 are given in Figures 11 & 12, respectively.

On the basis of the present investigations, it can be concluded that, in general, the ground water in the study area varies from medium salinity to very high salinity, having majority of wells under high salinity zone for the purpose of irrigation. Therefore, the irrigators are advised to ensure good land and water management practices in the fields, with particular emphasis on creating favourable leaching and drainage conditions to avoid further development of saline conditions in the area.

6.0 CONCLUSIONS

The present study has shown the alkaline nature of ground water since pH values were greater than 7.0 at all sites. The higher values of sodium above the prescribed limit of 50 mg/l were observed at about 31% of total wells during June, 1998 and about 25% of total wells during Feb., 1999, respectively. The results have shown the excess concentration of calcium at about 39% wells during June, 1998 and 53% during Feb., 1999. Whereas, the excess concentration of magnesium was obtained at about 25% wells during June, 1998 and 22% during Feb., 1999. The hardness as $CaCO_3$ was observed above permissible limit at about 33% of the wells during June, 1998 and 36% during Feb., 1999.

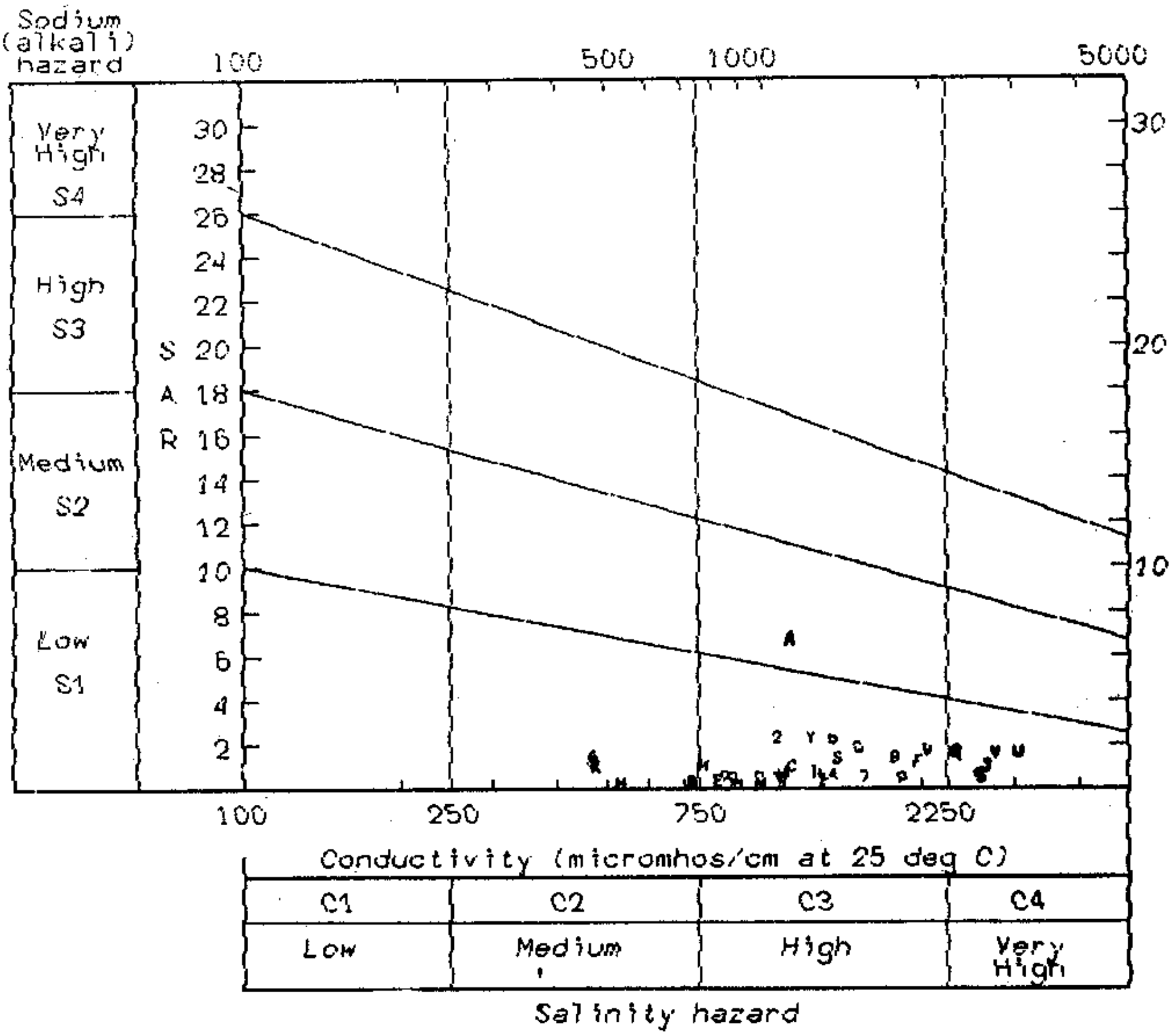


Fig. 11. U.S. Salinity Diagram for Jammu & Kathua Districts, June, 1998.

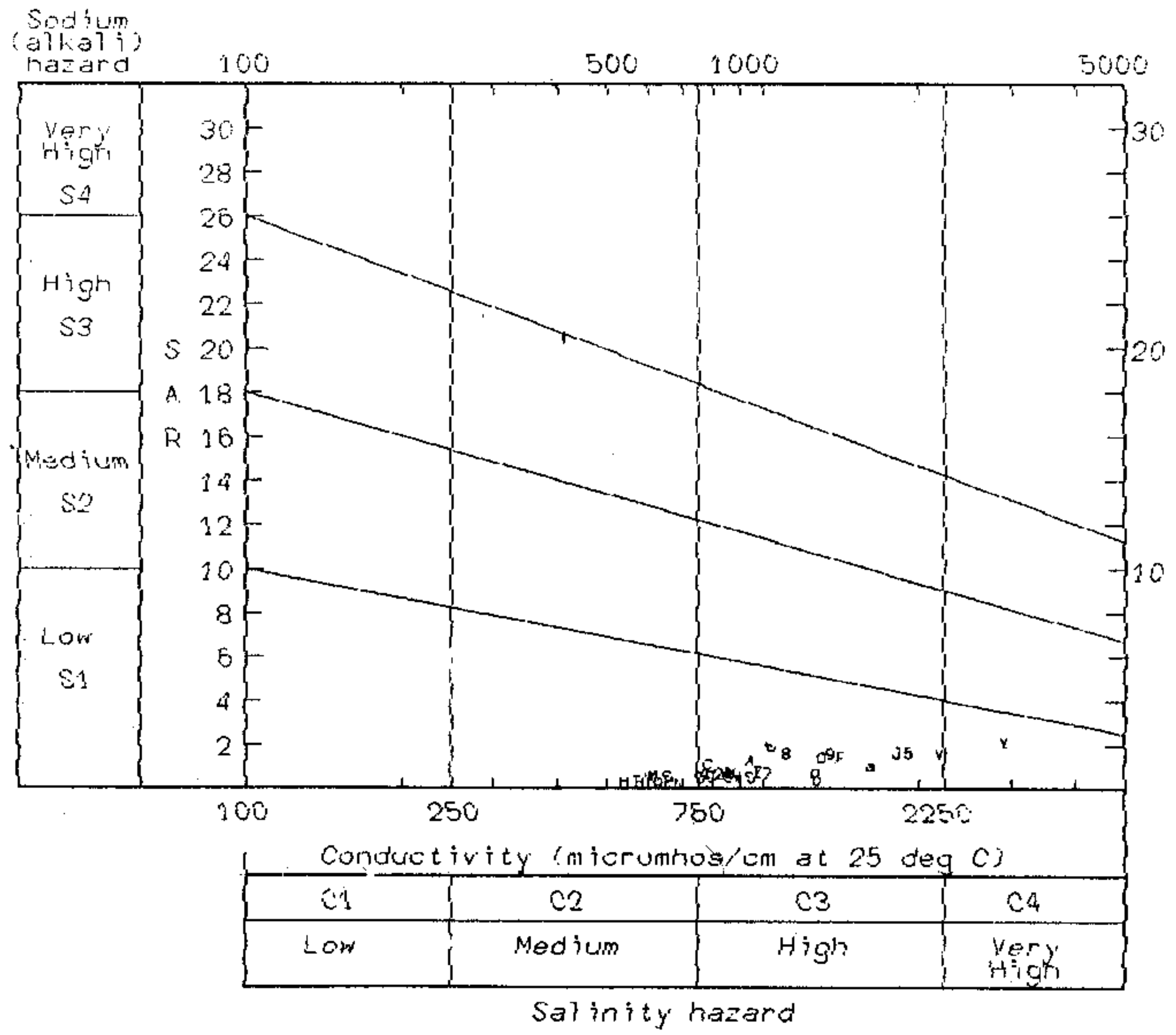


Fig. 12. U.S. Salinity Diagram for Jammu & Kathua Districts, Feb., 1999.

The concentration of chloride in ground water samples was within the prescribed limit for drinking purposes except at well number 29 during June, 1998 and well numbers 19, 33 during Feb., 1999. The higher concentration of chlorides at those wells could be due to the sources which are of mineral origin, human or animal wastes and agricultural salts. The concentration of sulphate was observed within the limit prescribed for drinking purposes at all sites. Nitrate concentration was found within the limit at all sites except at well number 33. Fluoride concentration was found below 0.6 mg/l at about 78% wells during February, 1999. As per BIS (1983) specifications, fluoride concentration was within limit (0.6-1.2 mg/l) at 22% wells during February, 1999.

The irrigation water quality has been evaluated on the basis of total concentration of soluble salts, SAR values and U.S. Salinity Laboratory Staff Classification. Based on the classification of total concentration of soluble salts, it was observed that about 75% of wells do lie under high salinity zone (i.e EC range, 750-2250 micro mho/cm). 14% under very high salinity zone (i.e EC range, 2250-5000 micro mho/cm) and 11% under medium salinity (i.e EC range, 250-750 micro mho/cm) during June 1998. Whereas, analysis made for the water sample collected during Feb., 1999 has shown 75%, 3% and 22% wells lying under above mentioned salinity zones, respectively. The possible reason for getting a decreasing trend of salinity levels during June, 1998 to Feb., 1999 may be due to mixing of ground water with rainwater during monsoon periods.

Suitability of water for irrigation on the basis of SAR values has shown all water samples lie below 10. According to this classification, the water may be classified as excellent category for irrigation purposes based on the alkali (sodium) hazards.

In the present study, the ground water has also been classified on the basis of widely used graphical methods e.g., Piper, Stiff and U.S. Salinity Laboratory Classifications. The Piper's diagrams show about 83% wells under Ca^{2+}, Mg^{2+}, HCO_3^- hydrochemical facies, 11% under Na^+, K^+, HCO_3^- and remaining 6% wells under Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} hydrochemical facies during June, 1998. Whereas, the analysis of water samples carried out for Feb, 1999 has shown 91%, 3% and 6% of total wells under the above mentioned hydrochemical facies.

According to the Stiff classification, calcium bicarbonate was found dominant amounting to 67% and 80% of the total wells during June, 98 and Feb., 99 respectively. However, sodium bicarbonate was present at 19% and 6% sites. The magnesium bicarbonate as well as calcium chloride were obtained at 11% and 3 % sites both sampling programs.

According to the U. S. Salinity Laboratory Classification, the majority of water samples (72% and 75 % of total wells) lie under C3-S1 (high salinity- low SAR) category during June, 98 and Feb., 1999 respectively. The C2-S1 (medium salinity- low SAR) category of wells lie at 11% and 22% sites during June, 1998 and Feb., 1999. The C4-S1 (very high salinity-low SAR) category of wells lie at 14% and 3% sites during June, 1998 and Feb., 1999 respectively. However, C3-S2 (high salinity-medium SAR) category was obtained for well number 10 during June, 98.

It may further, be concluded that the water quality parameters such as; calcium, magnesium and sodium among the main parameters, exceed the limits of drinking water standards at many site. The concentration of fluoride was below the desirable limit at the most sites. The ground water in the study area represents a wide range of salinity, which varies from medium salinity to very high salinity having majority of wells under high salinity zone.

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