CS(AR)-37/96-97

GROUND WATER QUALITY STUDIES IN JAMMU AND KATHUA DISTRICTS (J&K)

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INDIA
1996-97

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

In the present study, detailed investigations of the chemical quality of ground water in Jammu and Kathua districts (J&K) have been carried out to evaluate the suitability of water for various uses. The quality of ground water of the area has been studied based on the Physico-chemical analysis of thirty seven water samples collected from open wells during June and December, 1996. Various parameters, viz., pH, conductance, alkalinity, hardness, chloride, sulfate, sodium, potassium, calcium and magnesium have been determined for all the samples and compared with the standards to evaluate its suitability for drinking and irrigation purposes. Irrigation water quality on the basis of Doneen's Permeability Index and Residual Sodium Carbonate have also been computed. The higher values of certain parameters at certain locations indicate the contamination in ground water and make the water unsuitable for specific applications.

The pH values have shown that the ground water in the area is of alkaline nature. Majority of wells lie under high salinity zone (EC, 750-2250 micro mhos/cm). The variation of SAR values was observed from 0.113 to 5.1 and it indicate that water samples fall under the category of low sodium hazard and can be used for irrigating crops on almost all soils. Fluoride concentration was observed below 1.5 mg/l at all sites.

The ground water of the area has also been classified on the basis of Piper and U.S. Salinity Laboratory classifications. The results of Piper diagrams have shown that, majority of wells were lying under the Ca, Mg, HCO_3 hydrochemical facies in the study area except a few wells under Ca, Mg, Cl, SO_4 during both periods of the investigations. According to the U.S. Salinity Laboratory Classification of irrigation water, majority of the samples fall under C3-S1 (high salinity and low SAR) and then followed by C2-S1 (medium salinity and low SAR). Whereas, C4-S1 (very high salinity and low SAR) was also observed at Madun during June, 1996, Londi during June and December, 1996.

1.0 INTRODUCTION

The ground water is main source of water supply for domestic purposes in rural as well as in urban areas of the country. The role of ground water is equally important for agriculture, industries and various other uses. Ground water is regarded as the largest source of fresh water on the planet excluding the polar icecaps and glaciers. Till some time ago, the quality of ground water was considered to be relatively very good in comparison to surface water. However, nowadays the quality of ground water is becoming questionable for the various designated uses in the modern society.

The ground water is a precious and the most widely distributed resource of the earth. It gets annual replacement from the meteoric precipitation. The average annual rainfall of our country is about 119.4 cm which amounts to 392 million hectare metre (mhm) while considering its spread over the geographical area of 328 million hectare . This may be rounded of to 400 mhm including snowfall which is not yet fully quantified. It is estimated that out of the average annual precipitation (400 mhm), about 70 mhm is lost to the atmosphere, 115 mhm flows as surface runoff and the rest 215 mhm infiltrates into the soil. Of the infiltrated water (215 mhm), about 165 mhm is retained as soil moisture and is essential for the growth of vegetation. The remaining 50 mhm of the infiltrated water is percolated deep to the ground water aquifer after reaching the field capacity.

The contribution of rainfall to ground water in any area depends upon the intensity of rainfall, the depth and permeability of soils in different regions and the rainfall. It has estimated that for the country as a whole about 12.5 percent of the total precipitation infiltrates to the ground water table which has been estimated to 50 mhm. With the addition of 5 mhm of water from flood flows and 12 mhm from irrigation to the 50 mhm from precipitation, the total ground water excluding soil moisture, comes to 67 mhm. This on development of water resources, is likely to increase to 85 mhm.

Ground water is an economic resource and more than 85 percent of the public water supplies are obtained from wells. The people of rural areas are getting water for domestic uses directly from wells. This water may be contaminated due to improper disposal of liquid wastes, defective well construction and failure to seal the abandoned wells. These provide possible openings for the downward movement of water into sub-surface formations without the process of natural filtration. Contamination may also take place through movement of waste water through large openings such as animal burrows, fissures in rocks, course gravel formations or man-made excavations. Contaminated ground water may appear clear and may contain pathogenic organisms. Bacteria from the liquid effluent from septic tanks, cess pools, pit, etc. are likely to contaminate shallow ground water aquifers. Sewage effluent discharged directly into water-bearing formations through abandoned wells or soil absorption systems contaminate the ground water.

The depth of water table below ground level is a governing factor in determining pollution since, as the water table approaches nearer the ground surface, the greater is the risk of contamination. The number of harmful organisms is generally reduced to tolerable levels by percolation of water through 2-3 meter of fine grained soil.

Ground water quality problems can be understood only by regular monitoring of water quality of the region. The present study was carried out for Jammu and Kathua district (J & K). The main objectives of this study are:

1. Physico-chemical analysis of water to evaluate its quality for drinking and irrigation purposes.
2. Classification of ground water based on Piper and U.S.Salinity diagrams.

2.0 REVIEW OF LITERATURE

2.1 Ground Water Quality Studies

In India, the impact of pollution is generally due to the haphazard urban development without adequate attention to sewage and waste disposal, rapid industrialization without proper treatment and disposal of waste products, insanitary dumping of refuse and other solid wastes near aquifers, excessive use of fertilizers and pesticides for agricultural development and poor drainage in agricultural soils (Pitchaiah, 1995).

Pollution of ground water is the natural, physical, and chemical changes due to human activity, so that the water is no longer fit for a use for which it had previously been suited (Todd, 1980; Paliwal, 1991). The terms pollutant and contaminant require definition. Pollutant is a term which is applied usually for non-living, man made substances or other nuisances and it refers tc their being in excess in a particular location. Contaminant refers to something which causes a deviation from the natural composition of an environment. Contaminants are not classified as pollutants unless they have a significant role. Trace metals like Cu, Pb, Zn, Hg, Co, Ni, Mn, certain radioactive isotopes, nitrate, sodium, phosphorous and other elements, also pathogenic bacteria and viruses are the major pollutants. The problem of pollution in ground water is much less than that of surface water, even though this problem is nowadays becoming a severe threat to public health (Pitchaiah, 1995).

In J & K state, the establishment of hydrograph stations was initiated by the erstwhile ground water wing of Geological Survey of India in 1969 and later continued by the Northern Regional Office of Central Ground Water Board (CGWB) located at Lucknow from 1972 onwards. These stations were passed over to the North Western Region, Chandigarh in 1974. Presently, ground water quality and quantity monitoring work is carried out by Central Ground Water Board, North Western Himalayan Region, Jammu (Bhätnagar et al., 1987; Agashe et al., 1979) .

Western Himalayan Regional Centre of NIH, Jammu, has conducted ground water quality monitoring and evaluation study in Jammu district in 1994-95. The study was aimed at (i) to delineate the contaminated zones for drinking and for irrigation purposes, (ii) to monitor seasonal variation in the ground water quality, and (iii) to identify possible sources of pollution. Various physico-chemical parameters of water quality were determined in the study and were compared with Indian Standard norms for drinking purpose. In this study, ground water has also been classified on the basis of Piper and U.S. Salinity Laboratory Classifications. In the Piper diagram, majority of the ground water samples of the study area fall in the Ca-Mg- CO_3 -HCO_3 hydrochemical facies. According to the U.S. Salinity Laboratory Classification of irrigation water, most of the samples fall either under water type C2-S1 (medium salinity and low SAR) or C3-S1 (high salinity and low SAR). Few samples of the study area also falls under water type C3-S2 (high salinity and medium SAR), C4-S1 (very high salinity and low SAR) and C4-S2 (very high salinity and medium SAR). In addition, the values of sodium adsorption indicate that majority of samples fall under the category of low sodium hazards (Jain et al., 1994).

National Institute of Hydrology, Roorkee has carried out study to work out groundwater quality variations in Saharanpur district (UP). In the report, the results of the analysis of ground water samples have been presented in the form of Piper and U.S. Salinity diagrams. Temporal variation of ground water quality have also been marked. The main use of these shallow wells is for agriculture and domestic purposes. Therefore, suitability of water for irrigation and drinking purpose has been tested with reference to available standards. The results indicate that the quality of groundwater in the area under study is in general good for irrigation as well as for drinking purposes. There is not much variation in the quality of water pre-monsoon and post monsoon seasons due to less rainfall (Sudhir Kumar & et al., 1987).

Olania and Saxena (1977) have carried out groundwater pollution study of 25 wells near to the open refuse dumps at Jaipur during 1969 to 1971 in order to assess the extent of pollution by leachate. The results indicate that the pollution by total dissolved solids, chloride and iron salts is felt considerably upto a distance of about 450. The increase in hardness and COD are also perceptible upto about the same distance.

Subba D Rao and G. Krishna Rao (1990) have carried out groundwater pollution study in Visakhapatnam area, Andhra Pradesh. They have indicated that the intensity of pollution of groundwater was not so alarming upto 1975 in Visakhapatnam area, but after that it rapidly increased due to sweeping growth of industrial and urban activities and lack of environmental protection. Hydrochemical facies in 1975 are characterized by Na-HCO_3 type and in 1981 by Na-Cl type indicating that the salinity in groundwater increased from 1975 to 1981.

Singh, et al.(1991) has conducted groundwater pollution studies around North Railway City Station, Lucknow and his study reveals that the area is affected by high nitrate concentration and the main source of nitrate pollution is septic tanks which are located in the study area.

Kakar (1981) has observed the localised rise in nitrate concentration from 43 mg/l at Singhani to 1920 mg/l in Natural groundwater in a geohydrological investigation in northern and south western Haryana. In the absence of any geological source of nitrate in the area and non uniform distribution of nitrate along the direction of groundwater movement, nitrate pollution is likely to be caused by sewage and agricultural waste.

Kakar and Bhatnagar (1981) have conducted field studies in Ludhiana (Punjab) and concluded that groundwater at shallow depths of aquifer near bicycle factories had been polluted by hexavalent chromium and cynides in concentrations ranging from 3.5 to 12.9 mg/l and 0.05 mg/l to 0.98 mg/l respectively. Other trace elements such as copper, zinc, cadmium, cobalt, molybdenum, strontium, lithium and silver were also detected in groundwater in different concentrations, although below the permisible limits for drinking water.

Seth and Singhal (1994) have carried out studies in order to assess status of groundwater quality of upper Hindon Basin, Saharanpur (UP) due to large scale industrial and agricultural activities. The data of the analysis were plotted on Stiff and Hill-Piper diagrams for evaluation of their hydrochemical facies. The interpretation of the chemical data indicates that the groundwater of the area are only marginally affected, if at all, when compared to the quality criteria for drinking set by Regulatory Agencies like World Health Organization and Indian Standards Institution. However, the toxic metals (lead, cadmium and total chromium) show high but erratic concentration at few localities which is difficult to explain. Further, the groundwater of the study area, mainly belongs to Ca^{++}+ Mg^{++}-Na^{+}+K^{+}- HCO_3^{-} -Cl^{-} + SO_4^{--} hydrochemical facies indicating their common attributes of dominance of alkaline earths.

Handa (1994) has carried out groundwater contamination studies in various part of the country and disagrees on the fact that" the groundwater is safe (free from pathogenic bacteria), does not contain harmful constituents and is free from suspended matter in comparison to surface water". The studies have shown that such an assumption need not to be correct under all circumstances (Cole, 1974; Furinam & Barton, 1971; Handa, 1978a,b, 1986,1987, 1988b, 1992, 1993b; Miller et al., 1974; Scalf et al., 1973).

Groundwater pollution from discharge of untreated or inadequate treated effluent has reached alarming proportions in several parts of India. Most of the industries pass the effluent without proper treatment into unlined channels resulting in accumulation of waste water near these factories or depressions leading to percolation of industrial wastes into groundwater systems. Various researchers have found in their case studies that ground water has been severely affected due to industrial pollution in India (Naram, 1981; Krishnaswamy, 1981; Das and Kidwai, 1981; Kachwaha, 1981). 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, 1978b, 1986, 1988b,c, 1992; Joshi et al., 1982; Moitra, 1991; Singh, 1986).

Chidambram (1990) carried out studies on the effect of irrigated agriculture on groundwater quality in north of Madras state. According to him, intensive irrigation in about 20 years had raised the Cl concentration of ground water from pre-irrigation level of 110-125 mg /l to 210-240 mg/l, in the post irrigation period, an annual increase of about 4-5 mg/l.

Apart from groundwater quality and pollution problems emanating due to activity of man, there are water quality problems due to natural causes in several areas of the country. Fluoride concentrations in groundwater are high in several parts of the country particularly in semi-arid and arid tracts. In parts of Rajasthan, Southern Punjab, Haryana, U.P., Gujrat, A.P., Tamil Nadu and Karnataka, high concentrations of fluoride in ground water have been reported and there are cases of mottling of teeth, dental and skeletal fluorosis at many places. In certain exceptional cases like Sagalia in Gujrat, the fluoride concentration has been found to be 19 mg/l (Raghava Rao, 1977).

3.0 STUDY AREA

The present study was conducted for Jammu and Kathua district in J & K state, India. The study area falls in Jammu Province. Agricultural and industrial activities are dominant in the area. Jammu and Kathua are well connected by road and train facilities. This region is important place for pilgrims and tourists. The well locations are given in Fig.1.

3.1 Physiography, Relief and Drainage

This study area comprises of flat land to small hills. Jammu, Samba, Kathua and Akhnoor Tehsils are adjacent to the lower Siwaliks and vary from flat to partly hilly. The topography of R.S Pura and Hiranagar tehsil is mostly flat with partly undulations. In general, Billawar and Basholi Tehsils of Kathua district represent undulating topography.

The altitude in the area varies considerably from one well location to another. The reduced levels (R.L.) of open wells above m.s.l. at measuring point in Jammu (Satwari), R.S. Pura, Samba, Akhnoor, Hiranagar and Kathua are 291.15 m, 273.68 m, 356.80 m, 314.78 m, 326.85m and 315.66 m respectively.

The major natural drainage systems in the area are Chenab, Tawi, Basantar, Ujh and Aik rivers/nalla. 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.

3.2 Climate and Rainfall

The climate of the area is of subtropical type, characterized by three well defined seasons viz; winter, summer and Monsoon . The monsoon sets in by the beginning of July and continues till September. Winter starts in November and continues till April , when summer season sets in 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 when days minimum temperature was found to be 2.4 C during 1984. The rainfall (mm) normals at few places in the study area are given in Table-1.

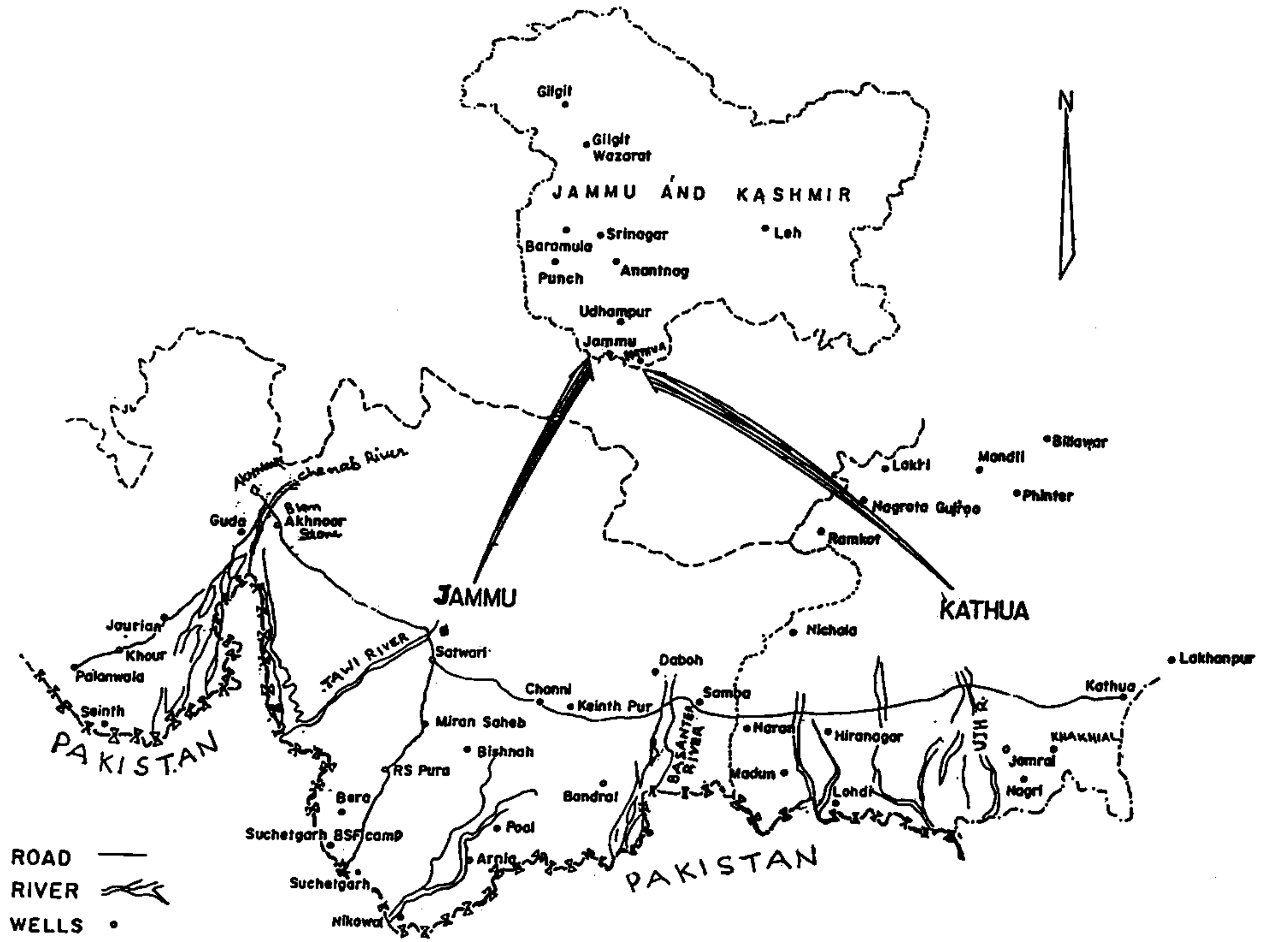


Fig. I Location map of the Wells in Jammu & Kathua Districts

Table-1

Rainfall (mm) Normals in the Study Area (Source: IMD)

Months	Rainfall Stations		
	Jammu	Samba	Kathua
January	64.8	65.5	72.6
February	64.8	52.6	62.7
March	56.4	50.5	52.0
April	32.3	23.4	27.4
May	23.1	23.9	17.0
June	69.3	53.1	51.0
July	327.4	312.9	339.9
August	299.5	338.6	352.5
September	123.7	106.2	140.7
October	15.5	14.2	21.3
November	6.6	6.6	5.6
December	33.0	31.5	34.3
Annual R/F	1055.5	1079.0	1177.9

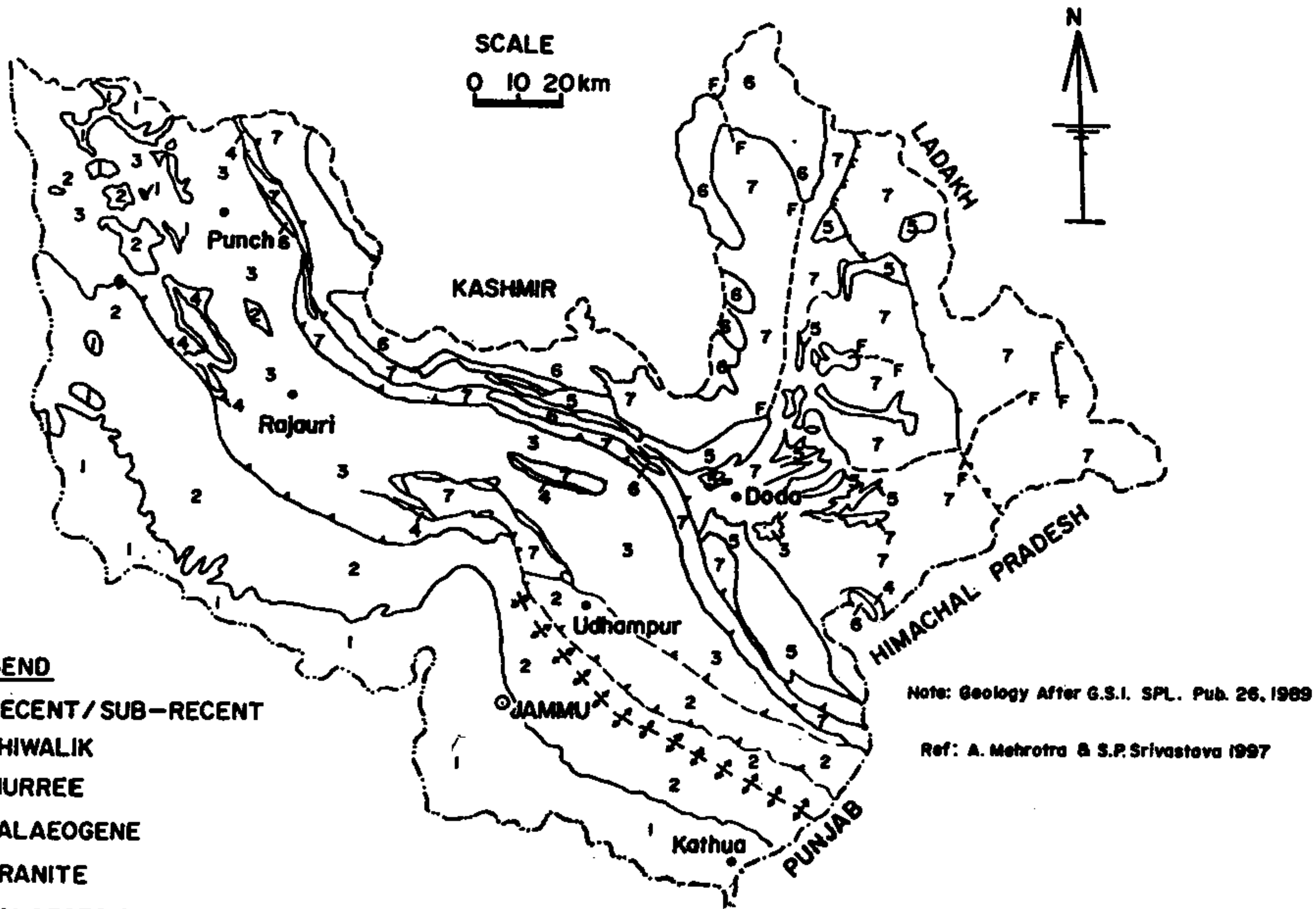
3.3 Geology and Ground Water Resources

3.3.1 Geology

The geology of the area consists of Shivalik system and is mainly composed of sand stone, silt stone, red and purple & transported quartzite. The lower reaches including the foot hill plain consist of alluvial deposits brought down by seasonal rivulets and"choas". Parent material is mainly alluvium/colluvium on the foot hill plains. The geological Map of the Jammu region is given in Fig-2 (Source: Mehrotra & Srivastava, 1997). Accordingly, the study area is classified into recent/sub-recent and Shivalik groups.

3.3.2 Status of Ground Water Resources

The occurrence of ground water in the state is very complicated because of varied hydrological parameters, the topographical barriers, hydrological boundaries and diversified geological settings. The water resources of the state J. & K can be broadly



LEGEND

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

Fig. 2 Generalised Geological Map of Jammu Region 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, S.N., 1997). The geological settings of the Jammu region are given in the geological map as shown in Fig. 2.

The study area lie within the Piedmont deposits of outer plains of Jammu and some extent to the Dun belt of outer Himalayas. The description is given below:

3.3.2.1 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 clastics 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 interspearesed at various places at different depths and 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:

(i) Ground water in recent river terraces and present day flood plains.
(ii)Ground water in the Kandi (Bhaber) zone.
(iii) Ground water in Sirowal (Terai) zone.
(iv) Ground water in the transitional zone between Kandi and Sirowals.

(i) Ground water in recent river terraces and present day flood plains

The 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. These terraces are deposited over the Siwaliks and because of limited thickness and areal extent of these overlying deposits, the composition of Siwalik formations, the rugged topography, steep gradient resulting in major runoff and many other negative factors for ground water replenishment of these flood plains and terraces and also the underlying Siwaliks are not feasible for large scale ground water development.

(ii) Ground water in the Kandi (Bhaber) zone

The area lying immediately to the foot slopes of Siwaliks is known as 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 kandis occur mostly under deep water table conditions.

(iii) Ground water in Sirowal (Terai) zone

Lying south to the kandis is what is known in the Indian stratigraphy is Terai zone and locally called as Sirowals. The area lies below the altitude of 300 m above mean sea level. Topographic gradient 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.

(iv) Ground water in the transitional zone between Kandi and Sirowals

This is the belt in between the kandis and Sirowal. It is through this belt that the kandis 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.

3.3.2.2 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 Basoli (Kathua district) in the east to Reasi in the west. The sediments are a few meters to few tens meters thick occurring in the form of isolated sub recent to recent valley fill deposits. They comprise of coarse clastics nature of the boulders, cobbles, and pebbles interbedded with lenticular bodies of clays and silt, sand and gravels.

Ground water present in this area is limited 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 respective areas.

3.4 Soils of the Area

The soils of Jammu region show a great heterogeneity. The soils of the foot hills and areas adjacent to them comprises of loose boulders and gravel with ferruginous clay. These types of soils are spread 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, K., 1986, 1991: Report Nos. 9, 15 and 16).

3.5 Land Use/ Land Cover

The land use/ land cover map of Jammu region prepared by GSI (Mehrotra & Srivastava, 1997) using Landsat Imageries on 1: 250,000 scale have shown that around 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 by National Forest Policy, 1986. Jammu district has nearly 1 % of its area under urban land. Jammu and Kathua districts are free snow fall.

Mehrotra & Srivastava (1997) have prepared crop pattern Map (Fig. 3) in Jammu region based on the data of Agriculture Department, Jammu, J & K. The main crops grown in the study area are wheat and millet. The map has shown that rice, Bajra and maize are supporting crops in the study area.

3.6 Infiltration Characteristics

Infiltration rates vary under different land uses and soil types in different hydroclimatic environments. The National Institute of Hydrology carried out infiltration studies as a part of hydrological studies taken up by the regional Centre at Jammu for bare, agriculture, grass and forest lands in Jammu region. The results have shown that initial infiltration rates vary from 18 to 12 , 17 to 24, 12 to 36 and 18 to 72 cm/hr for different 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 et al., 1992 ; Patwary et al., 1997).

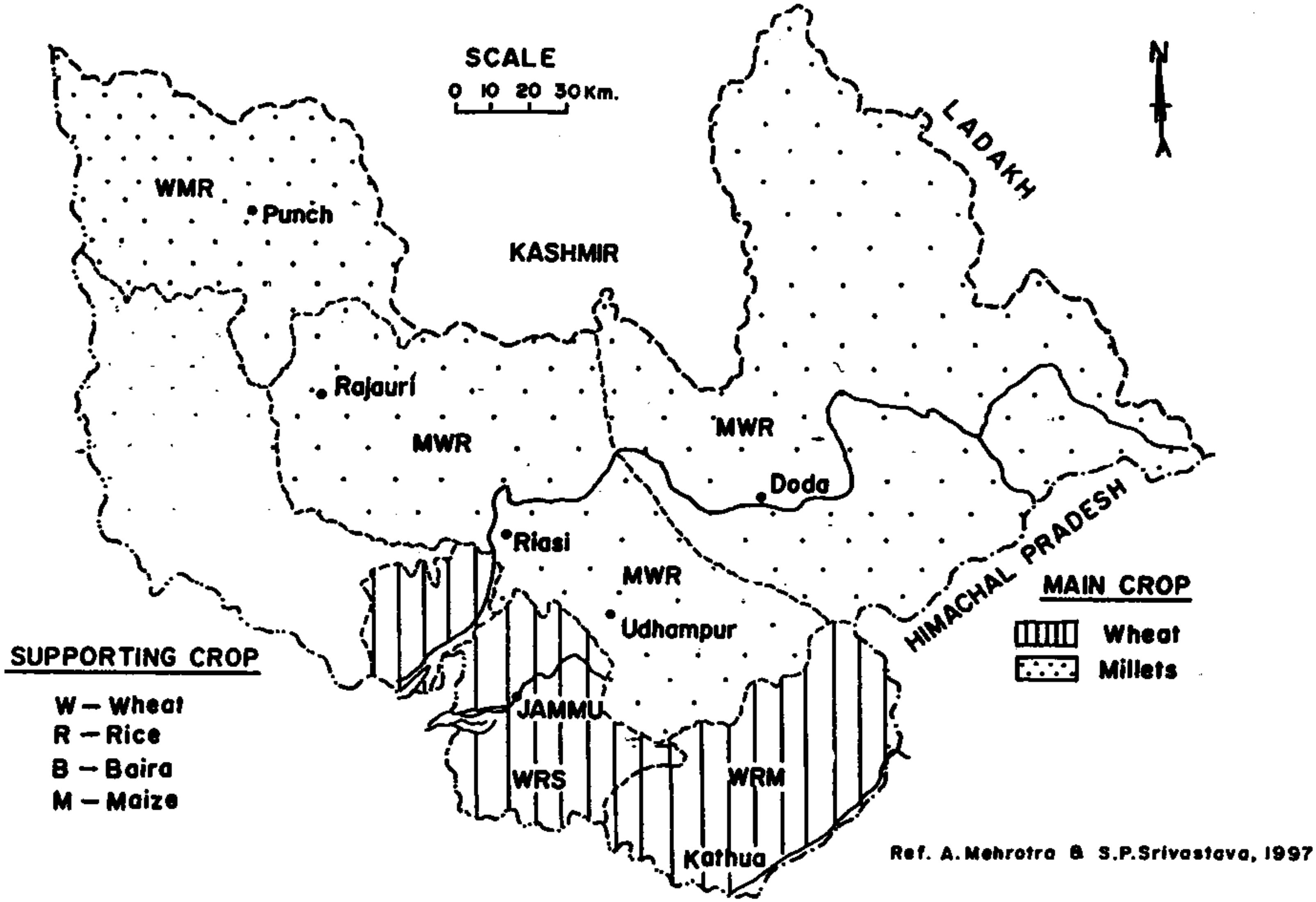


Fig. 3 Crop Pattern Map of Jammu Region

4.0 MATERIALS AND METHODS

4.1 Sampling and Preservation

In the present study 37 ground water samples were collected from open wells covering Jammu and Kathua district in J & K state for evaluating the quality of ground water of the area. Sampling was carried out in the months of June and December, 1996. The samples were collected in clean plastic bottles fitted with screw caps. The depth of the water table in the respective wells was measured during each visit. Some parameters like temperature, pH and EC were measured in the field at the time of sample collection. For other parameters, samples were preserved by adding an appropriate reagent (Jain and Bhatia, 1987) and brought to the laboratory for detailed chemical analysis.

4.2 Methods of Analysis and Equipment Used

Physico chemical analysis was conducted following standard methods (Jain and Bhatia, 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, pH meter and portable water testing kit (Naina model NPC - 361 D).

The total hardness and calcium hardness was determined by 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 with o.401 and Magnesium (as Mg^{2+}) by multiplying magnesium hardness with 0.243.

Sodium and potassium were determined by flame emission method using Flame Photometer. Chloride concentration was determined by argentometric method in the form of silver chloride. Acidity/alkalinity was determined by titrimetric method using phenolphthalein and methyl orange indicators.

Phosphate, nitrate and fluoride concentrations were determined using UV-VIS Spectrometer (Chemito 2000). Sulphate was determined by gravimetric method.

5.0 RESULTS AND DISCUSSION

The present report deals with ground water quality study carried out for Jammu and Kathua districts in J. & K. during 1996-97. Sampling was carried out in the months of June and December, 1996. Thirty seven water samples were collected from different open wells including one spring at Mandli in the study area. The samples were analysed for sodium, potassium, calcium, magnesium, chloride, sulphate, alkalinity, nitrate, phosphate, fluoride, total dissolved solids, pH and electrical conductivity. The mean and range of concentrations of chemical constituents of ground water samples in the study area are given in Table -2.

5.1 Water Quality for Domestic Uses

Domestic use of water mainly includes use for water for drinking, cooking, washing, bathing etc. The toxicity is due to excessive total dissolved solids, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium etc. The level of concentration and toxicity caused by these constituents is discussed below:

5.1.1 pH of Water

pH is the measure of the intensity of acidity or alkalinity and measures the concentration of hydrogen ion in water. pH has no direct adverse affect on health, however, a low value below 4.0 will produce sour taste, and higher value above 8.5 and alkaline taste.

A pH range of 6.5 to 8.5 is normally acceptable as per guidelines suggested by WHO (1984) and BIS (1983). The pH value in the study area lie in the range of 7.2 to 8.2 during June, 1996 and 7.1 to 8.17 during, Dec., 1996 which is within the prescribed limits. It has shown alkaline nature of ground water in the study area. The variation of pH in the study area is shown in Fig. 4 & 5 for Jammu & Kathua districts respectively.

5.1.2 Electrical Conductivity (EC)

Conductivity is the measure of capacity of a substance or solution to conduct electrical current. It is the reciprocal of the resistance, in ohms, of a conductor, metallic or

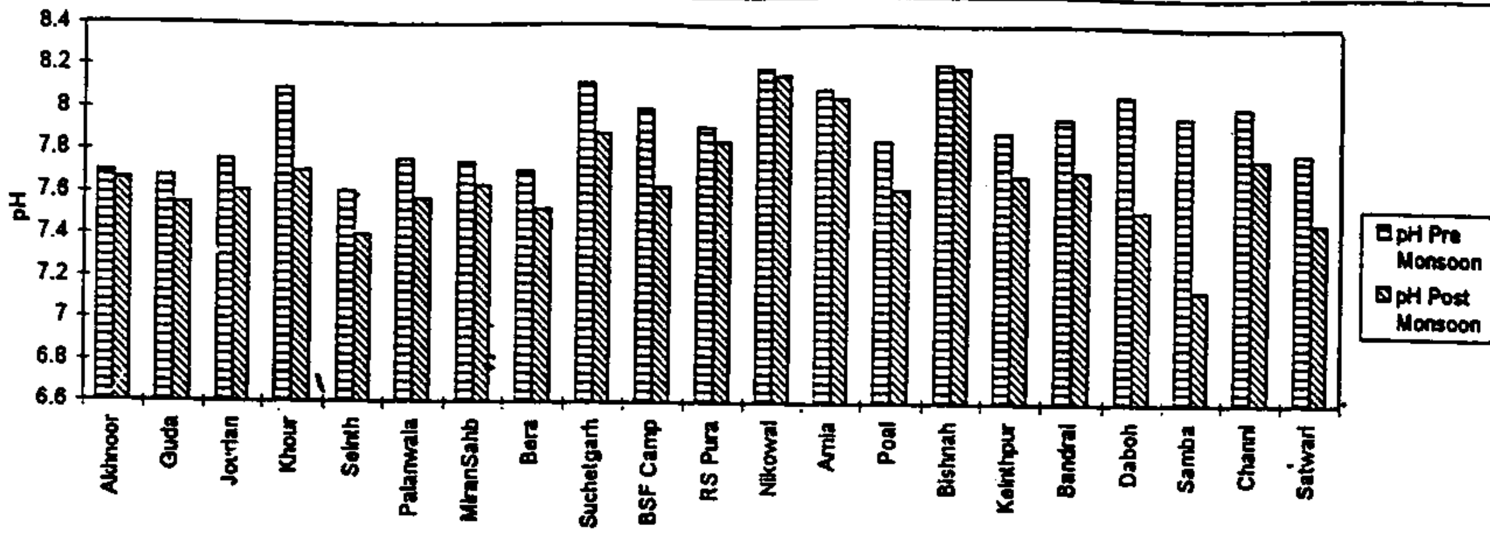


Fig 4 pH variation in the wells of the Jammu District

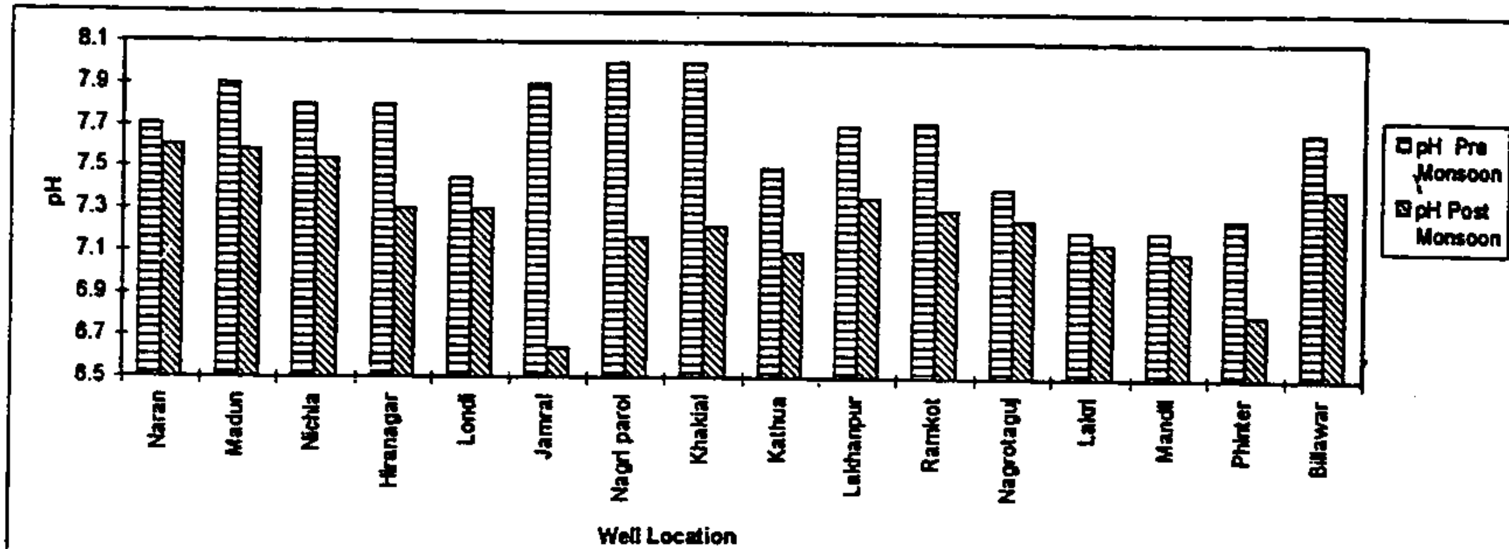


Fig. 5 pH variation in the wells of the Kathua District electrolyte, which is one cm long and has a cross sectional area of 1 sq cm. As most of the salts in water are present in the ionic forms and capable of conducting current, conductivity is a good and rapid measure of the total dissolved solids.

The conductivity value is used as a criterion for expressing the total concentration of soluble salts in water. The conductance values in the study area ranges from 420 to 2880 micro mho/cm during June, 1996 and 420 to 2470 micro mho/cm during Dec., 1996 with wide range of fluctuations at different locations. The variation in EC is shown in Fig. 6 & 7 for Jammu & Kathua districts respectively.

5.1.3 Alkalinity

The alkalinity of water is a measure of its capacity to neutralize acids. Alkalinity values provide guidance in applying proper doses of chemicals in water and waste water treatment processes particularly in coagulation, softening and operational control of anaerobic digestion. The alkalinity in natural water is caused by bicarbonates, carbonates and hydroxides which may 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 alkalinity values in the study area ranges from 108 to 722 mg/l during June, 1996 and 78 to 672 mg/l during Dec., 1996.

5.1.4 Sodium

Sodium concentration more than 50 mg/l makes the water unsuitable for domestic use. The sodium concentration in the ground water in the study area varies from 3.8 to 277 mg/l during June, 1996 and 7.0 to 421 mg/l during Dec., 1996. The high values of sodium than the prescribed limit of 50 mg/l is observed at Arnia (Jammu district), Samba (Jammu), Naran (Kathua), Madun (Kathua) during June, 1996 and Guda (Jammu), Seinth (Jammu), Miran Saheb (Jammu), Suchetgarh (Jammu), Nikowal (Jammu), Arnia (Jammu), Bishnah (Jammu), Samba (Jammu), Naran (Kathua), Madun (Kathua), Londi (Kathua), Khakhial (Kathua), Nagrota Gujru (Kathua) during Dec., 1996.

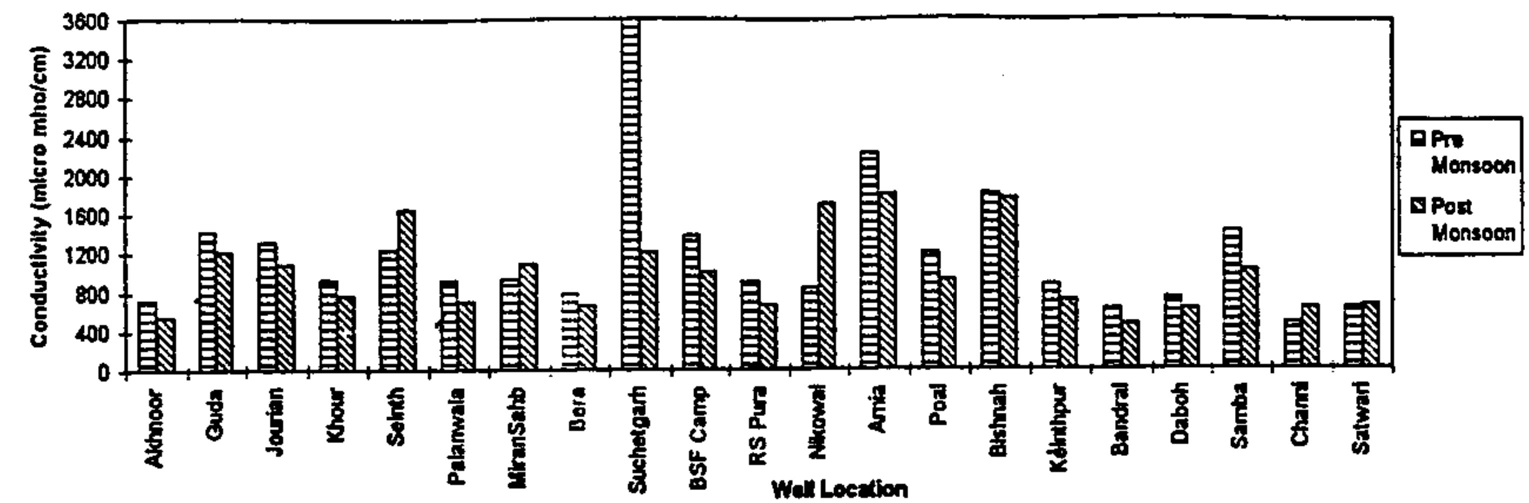


Fig. 6 Ec variation in the wells of the Jammu District

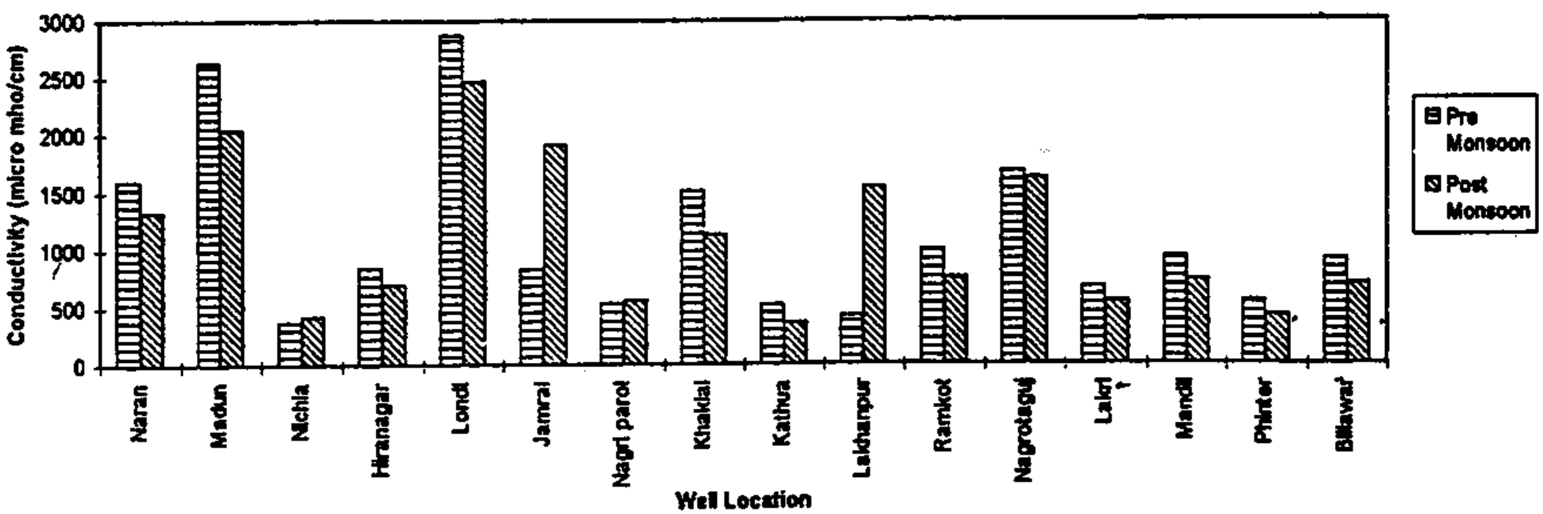


Fig 7 Ec variation in the wells of the Kathua District

5.1.5 Calcium, Magnesium and Total Hardness

Calcium, magnesium and total hardness in the water are inter-related and therefore, a combined discussion is presented in this report. The upper limits for calcium and magnesium for drinking water are 75 and 30 mg/l respectively (BIS, 1983). In the present study, calcium and magnesium ranges from 5 to 183 mg/l and 5 to 73 mg/l respectively during June, 1996, 31 to 449 mg/l and 5 to 42 mg/l during Dec., 1996. The wells which exceeds the limits of calcium and magnesium in water were located at Guda, Suchetgarh, Khour, Seinth, Miran Saheb, Bera, Suchetgarh, Arnia, Bisnah, Daboh, Samba, Akhnoor, Jourian, Palanwala, R.S. Pura, Nikowal, Poal, Keinthpur, Satwari, Naran, Madun, Hiranagar, Londi, Nagri Parol, Nagrota Gujru, Jamral, Khakhial, Ramkot, Lakri, Mandli and Billawar during the present study.

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 along with their carbonates, sulphates and chlorides makes the water hard, both temporarily and permanent. A limit of 300 mg/l has been recommended for potable waters (BIS, 1983). Total hardness as $CaCO_3$ in the study area ranges between 118 to 630 mg/l during June, 1996 and 110 to 1250 mg/l during Dec., 1996. A very high value of hardness was observed at Arnia during Dec., 1996. Keeping in view the upper limit of hardness (300 mg/l) for drinking purposes, the wells located at Guda, Seinth, Suchetgarh, Arnia, Bishnah, Madun, Londi during June, 1996 and Guda, Jourian, Seinth, Khour, Miran Saheb, Bera, Suchetgarh, R.S. Pura, Nikowal, Arnia, Poal, Bishnah, KeinthPur, Samba, Naran, Madun, Londi, Khakial, Ramkot, Nagrota Gujroo, Mandli, Billawar during Dec., 1996 respectively have shown higher values and therefore, are not suitable for domestic applications.

5.1.6 Chloride

Chlorides occur naturally almost in all types of waters. The most important source of chlorides in water is the discharge of domestic sewage. A limit of 250 mg/l has been recommended for drinking purposes (BIS, 1983; WHO, 1984). The chloride concentration in the study area lies in the range from 2 to 370 mg/l during June, 1996 and 4 to 284 mg/l during Dec., 1996. The wells which exceeds the limit are Suchetgarh, Arnia, and Londi under the present investigation. The maximum value of chloride was observed at Arnia during Dec., 1996 in Jammu district.

5.1.7 Sulphate

Sulphate is naturally occurring anion in all kind of natural waters. It is an important constituents of hardness with calcium and magnesium. A limit of 150 mg/l has been suggested for drinking purposes (BIS, 1983). Sulphate produces an objectional taste at 300-400 mg/l. Above 500 mg/l, a bitter taste is produced in the water. At concentrations around 1000 mg/l, it is laxative. The water of most wells was within limits (150 mg/l) except wells located at Suchetgarh, Arnia during June, 1996 and Suchetgarh during Dec., 1996 respectively.

5.1.8 Nitrate

Nitrates are widely present in substantial quantities in soil, in most waters, and in plants, including vegetables (WHO, 1978). It has been documented that, in some countries, water supplies containing high levels of nitrate have been responsible for cases of infantile methemoglobinemia and death (USEPA, 1977). This problem does not arise in adults. Limit of general acceptability of nitrate for drinking water is 45 mg/l (WHO, 1963). The values of nitrate in the study area ranges from 0.1 to 66 mg/l during June, 1996 and 0.15 to 85 mg/l during Dec., 1996. Almost all wells were within the limit except one well located at Londi exceeded the limit during June and Dec.,1996 respectively.

5.1.9 Fluoride

Fluoride has been fairly conclusively demonstrated to be an essential element for some animal species (Underwood, 1977). In little quantities it can reduce dental caries. Long term consumption of water containing 1 mg/l may lead to mottling (NRC, 1977). Skeletal fluorosis has been observed in persons when water contains more than 3 to 6 mg/l. In high doses, fluoride is actually toxic to man. The recommended upper limit of fluoride for drinking purpose is 1.5 mg/l (BIS). In study area all wells were observed well within this limit.

Table 2. Chemical Characterstics of Ground Water Samples in the Study Area

Parameters	June 1996			December 1996		
	Max	Min	Mean	Max	Min	Mean
pH	8.2	7.2	7.8	8.2	6.6	7.5
EC, μ mho/cm	2880	360	1097	2470	410	1029
Alkalinity, mg/l	722	108	333	946	78	315
Hardness, mg/l	630	118	230	1250	110	410
Chloride, mg/l	370	2	55	776	4	90
Sulphate, mg/l	345	6	54	246	4	41
Phosphate, mg/l	0.48	0.01	0.11	0.44	0.03	0.14
Nitrate, mg/l	66	0.1	9	85	0.15	10
Calcium, mg/l	183	5	43	449	31	134
Magnesium, mg/l	73	5	29	51	5	18
Sodium, mg/l	277	4	38	421	7	73
Potassium, mg/l	250	0.2	29	868	1.4	58
Flouride, mg/l	1.24	0.12	0.4	1.77	0.01	0.53

5.2 Water Quality for Irrigation Purposes

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 water which determine suitability of irrigation water are calcium, magnesium, sodium, chloride, sulphate and bicarbonate. Boron content may also affect the suitability of water for irrigation for certain crops. In this reports usefulness of water for irrigation is mainly evaluated based on the following criteria:

- Total concentration of soluble salts.
- Sodium Adsorption Ratio (SAR).
- Doneen's Permeability Index.

- U.S. Salinity Laboratory Classification.
- Residual Sodium Carbonate (RSC).

5.2.1 Total Concentration of Soluble Salts

Total salt concentration of soluble salts in irrigation water can be adequately expressed for the purpose of diagnosis and classification in terms of electrical conductivity (Table-3).

Table-3

Classification of Water on the basis of Salinity Levels.

Zone	E.C. (micro mhos/cm)	No. of Wells in Jammu District		No. of Wells in Kathua District	
		June, 1996	Dec., 1996	June, 1996	Dec., 1996
Low Salinity Zone	< 250	nil	nil	nil	nil
Medium Salinity Zone	250-750	5	9	6	8
High Salinity Zone	750-2250	16	12	8	7
Very High Salinity Zone	2250-5000	nil	nil	2	1

It is evident from the above Table that the majorty of wells lie under high salinity zone. Remaining few wells are under medium salinity zone. In the present investigation, the wells lie under medium salinity zone were observed at Akhnoor, Bandral, Daboh, Chhanni, Satwari, Nichla, Nagri Parol, Kathua, Lakhanpur, Lakri and Phinter during June, 1996. However, wells at Londi and Madun were under very high salinity zone during June, 1996. The results of another sampling carried out during Dec., 1996 have also shown that most wells lie under high salinity zone except wells at Akhnoor, Palanwalla, Bera, R.S.Pura, KeinthPur, Bandral, Daboh, Chhanni, Satwari, Nichla, Hiranagar, Nagri Parol, Kathua, Lakri, Mandli, Phinter, Billawar under medium salinity zone and one well at Londi under very high salinity zone.

In general, water 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 use of irrigation water having conductivity values in the range of

250-750 micromhos/cm (USDA, 1954). Water in the range of 750-2250 micromhos/cm are widely used, 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 is exception and in this case more salt tolerant crops can be grown only if sub-soil drainage is good.

5.2.2 Sodium Adsorption Ratio (SAR)

The sodium or alkali hazard in the use of a water for irrigation is determined by the absolute and relative concentrations of cations and 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 (Richards, 1954). The SAR can be calculated by using the following equation:

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

Where, all ionic concentrations are expressed in milliequivalent per liter. Calculation of SAR for a given water provides a useful index of the sodium hazard of that water for soils and crops. The U.S. Salinity Laboratory, Department of Agriculture, USA recommended the SAR as basis for classification of water for agriculture uses as given in the Table-4.

According to this classification, SAR values of all samples in the study area lie below 10 and may be classified under excellent category of water for irrigation. The variation of SAR values was 0.113 to 5.1 during June, 1996 and from 0.183 to 6.0 during Dec., 1996 respectively in the study area (Table-5). The spatial variability map of the SAR values are depicted in the Fig. 8 and 9 for Jammu and Kathua districts respectively.

Table-4 Classification of Water for Irrigation based on SAR Values (USDA, 1954).

Sodium Adsorption Ratios (SAR)	Water Class	No. of Wells in Jammu District		No. of Wells in Kathua District	
		June, 1996	Dec., 1996	June, 1996	Dec., 1996
< 10	Excellent	21	21	16	16
10-18	Good	nil	nil	nil	nil
18-26	Fair	nil	nil	nil	nil
>26	Poor	nil	nil	nil	nil

Table 5. Values of Sodium Adsorption Ratio (SAR) for Jammu & Kathua.

Serial No.	Jammu District			Kathua District		
	Well Location	June, 1996	Dec., 1996	Well Location	June, 1996	Dec., 1996
1.	Akhnoor	0.113	0.183	Naran	2.208	2.288
2.	Guda	0.352	1.359	Madun	5.089	6.034
3.	Jourian	1.167	0.881	Nichla	0.192	0.239
4.	Khour	0.598	0.322	Hiranagar	0.854	1.036
5.	Seinth	0.495	1.289	Londi	2.044	3.217
6.	Palanwalla	0.223	0.395	Jamral	0.548	0.247
7.	Miran Saheb	1.354	2.041	Nagri Parol	0.379	0.324
8.	Bera	0.245	0.266	Khakhial	1.190	1.561
9.	Suchetgarh	0.953	5.820	Kathua	0.398	0.465
10.	Suchetgarh (BSF)	0.876	2.029	Lakhan Pur	0.515	0.258
11.	R.S.Pura	0.636	0.846	Ramkot	0.332	0.542
12.	Nikowal	1.048	3.951	NagrotaGuj	0.764	1.590
13.	Arnia	1.664	4.047	Lakri	0.594	0.299
14.	Poal	0.363	0.570	Mandli	1.290	0.883
15.	Bishnah	0.945	1.576	Phinter	0.306	0.440
16.	Keinth Pur	1.643	0.534	Billawar	1.016	0.692
17.	Bandral	1.411	0.547			
18.	Daboh	0.876	0.313			
19.	Samba	2.731	1.095			
20.	Chhanni	0.726	0.774			
21.	Satwari	1.026	0.615			

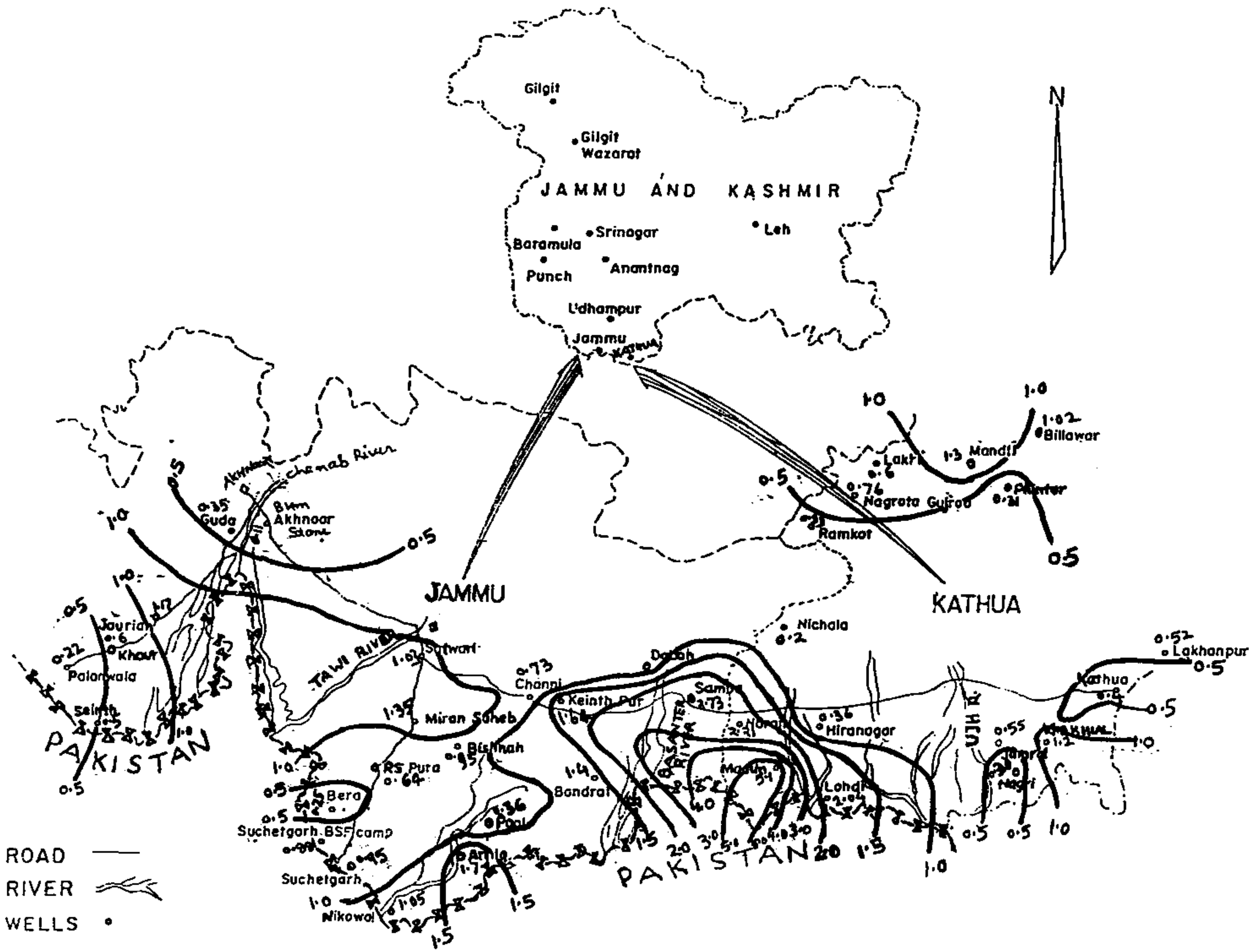


Fig.8 Spatial Variation of SAR Values during June, 1996.

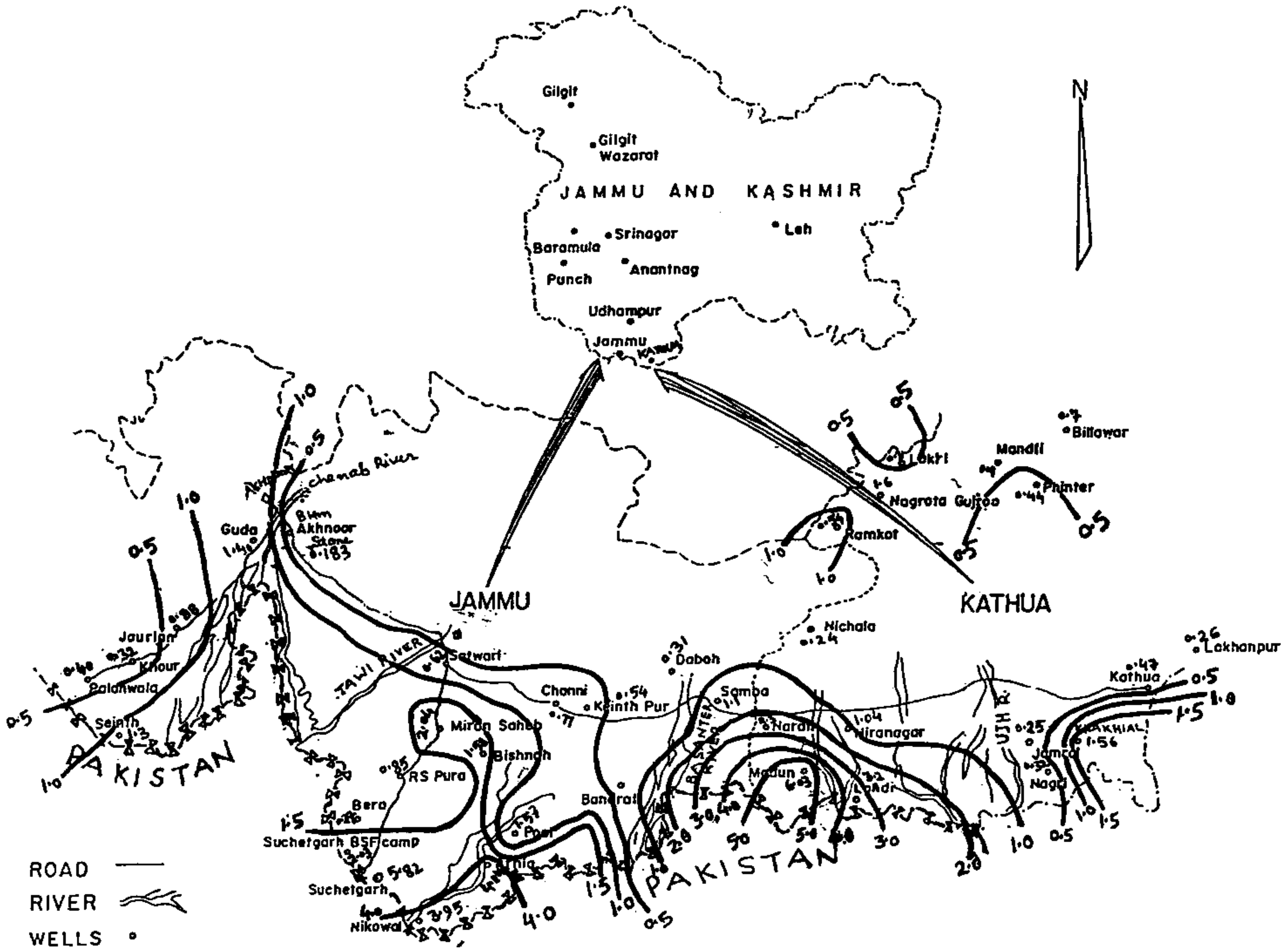


Fig.9 Spatial Variation of SAR Values during December, 1996.

5.2.3 Doneen's Permeability Index

The soil permeability is affected by long term use of irrigation water. It is influenced by sodium, calcium, magnesium and bicarbonate contents of the soil (Chandu, S.N. et al., 1985). Doneen (1964) has developed a graph based on the permeability index (PI) and total salt concentration for classification of irrigation water. Permeability Index is defined as below:

$$PI = \frac{Na^{+} + (HCO_3^{-})^{0.5}}{Ca^{++} + Mg^{++} + Na^{+}} * 100$$

The ionic concentrations are expressed in meq./l. In this classification, water is considered good for irrigation if it belongs to class I or class II in the Doneen's Chart as given in Fig.- 10 (Raghunath, 1982). The analysed results are given in Tables- 6 & 7.

Table-6 Classification of Irrigation Water based on PI Values for Kathua District.

Wells	June 1996			December, 1996		
	Total Ions	Permeability Index	Class	Total Ions	Permeability Index	Class
Naran	25.66	75.30	I	26.77	49.83	I
Madun	43.83	66.44	I	42.16	68.30	I
Nichla	4.84	59.91	II	6.18	43.69	I
Hiranagar	11.57	64.14	I	11.62	46.03	I
Londi	36.87	45.68	I	50.01	44.11	I
Jamral	9.65	85.28	II	10.84	7.01	I
Nagri Parol	8.38	58.53	I	10.13	43.33	I
Khakhial	23.74	82.24	I	23.20	54.61	I
Kathua	6.43	66.60	II	4.70	60.20	I
Lakhan Pur	6.43	71.71	II	8.92	40.11	II
Ram kot	13.04	62.70	I	15.01	39.79	I
Nagrota Guj	18.92	48.53	I	31.42	37.67	I
Lakri	9.85	70.91	I	8.38	39.74	I
Mandli	12.59	101.35	III	12.42	41.44	I
Phinter	7.38	50.62	I	6.74	50.96	I
Billawar	12.88	71.92	I	13.50	47.44	I

Table-7

Classification of Irrigation Water based on PI Values for Jammu District.

Wells	June 1996			December, 1996		
	Total Ions	Permeability Index	Class	Total Ions	Permeability Index	Class
Akhnoor	9.10	47.19	I	10.86	37.79	I
Guda	17.71	43.23	I	27.75	38.11	I
Jourian	14.91	79.8	I	23.12	37.26	I
Khour	10.17	68.62	I	14.00	33.91	I
Seinth	17.67	44.23	I	31.98	39.62	I
Palanwala	8.88	81.78	II	10.24	48.38	I
Miran Saheb	12.21	63.14	I	20.62	55.86	I
Bera	10.06	45.59	I	12.66	39.26	I
Suchet garh	41.52	64.32	I	79.88	57.71	I
Suchet garh (BSF)	13.80	55.63	I	21.15	51.67	I
R.S. Pura	9.81	74.15	I	12.64	45.38	I
Nikowal	11.98	63.96	I	32.43	58.23	I
Arnia	33.58	57.48	I	104.36	46.40	I
Poal	12.95	53.55	I	14.52	37.16	I
Bishnah	26.38	54.79	I	33.2	51.84	I
KeinthPur	13.50	83.68	II	13.17	43.26	I
Bandral	9.83	68.37	I	7.88	49.53	I
Daboh	9.12	68.06	I	10.78	47.67	I
Samba	16.65	84.09	II	16.24	33.33	I
Chhanni	6.89	68.71	II	10.68	45.98	I
Satwari	9.09	65.35	I	12.28	46.23	I

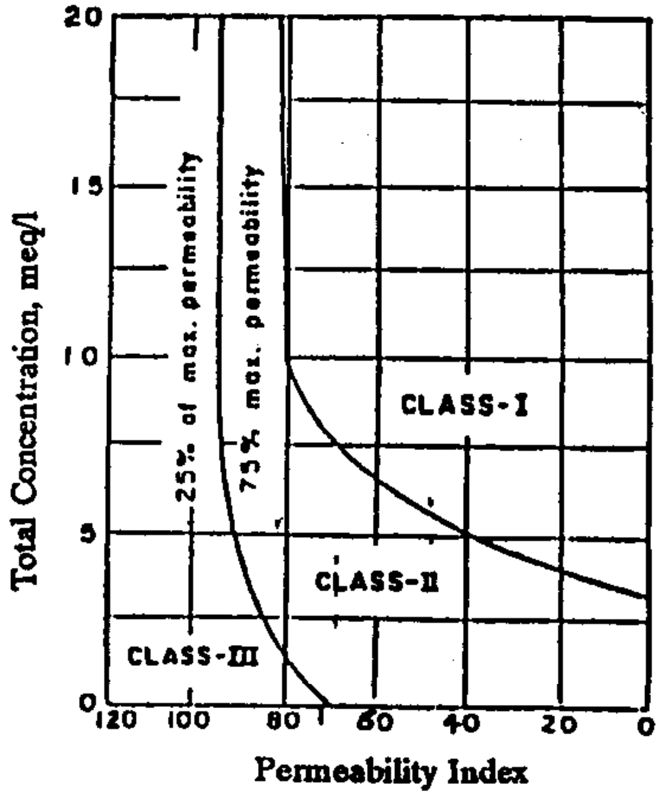


Fig. 10. Classification of Irrigation Water based on Permeability Index

(Doneen, 1964).

The analysis as per Doneen's classification, has shown that most wells in the study area lie either under Permeability class-I or II and in general water may be considered good for irrigation except at Mandli during June, 1996.

5.2.4 U.S. Salinity Laboratory Classification:

Sodium concentration is an important criterion in irrigation water classification because sodium reacts with the soil to create sodium hazards by replacing other cations. The extent of this replacement is estimated by Sodium Adsorption Ratio (SAR). The U.S. Salinity Laboratory Classification (USDA, 1954)is most accepted criteriaon for evaluating suitability of ground water for irrigation purposes is based on Sodium Adsorption Ratio (SAR) and Conductivity of water expressed in micromhos/cm.

The chemical analysis data were plotted district wise on U.S.Salinity diagram with the data of June and Dec., 1996 respectively for Jammu and Kathua (Fig. 11-14). Accordingly, majority of water samples are lying under C3-S1 (High Salinity- Low SAR) category. After that some samples lie under C2-S1 (Medium Salinity- Low SAR). In the present study, C4-S1 (Very High Salinity- Low SAR) was observed at Madun during June, 1996 , Londi during June as well as December, 1996 also. The results have been summarized and are given in Table-8.

5.2.5 Residual Sodium Carbonate

The quality of water for irrigation can also be assessed by the quantity, Residual Sodium Carbonate (RSC) and it is considered an additional criterion for determining the suitability of irrigation water. United States Salinity Laboratory Staff (1954) observed that the water containing more than 2.5 meq/l of RSC is generally not suitable for irrigation. Water containing 1.25 to 2.5 meq/l RSC is marginal and that contains less than 1.25 meq/l is absolutely safe (Chandu, S.N. et al., 1995).

The quantity of bicarbonate concentration of water play a significant role in RSC. If water contains high concentration of bicarbonate ion, there is a tendency for calcium ions to precipitate as carbonates. As a consequence, the relative proportion of sodium ion increases and gets fixed in the soil by the process of base exchange thereby decreasing the soil permeability. The RSC is calculated using the following equation:

$$RSC = [CO_3^{--} + HCO_3^{-}] - [Ca^{++} + Mg^{++}]$$

The residual sodium carbonate values for all samples were determined and given in Table-9. The number of suitable and unsuitable wells for the purpose of irrigation were 22 and 5 during June, 1996 respectively in the study area. However, during December, 1996, suitable and unsuitable wells were 6 and 15. The wells under marginal category were 10 and 16 during June and Dec., 1996.

Table-8 U.S. Salinity Classification of Irrigation Water in Jammu and Kathua Districts

S.No.	Jammu			Kathua		
	Location	June, 1996	Dec., 1996	Location	June, 1996	Dec.,1996
1	Akhnoor	C2-S1	C2-S1	Naran	C3-S1	C3-S1
2	Guda	C3-S1	C3-S1	Madun	C4-S1	C3-S1
3	Jourian	C3-S1	C3-S1	Nichla	C2-S1	C2-S1
4	Khour	C3-S1	C3-S1	Hiranagar	C3-S1	C2-S1
5	Seinth	C3-S1	C3-S1	Londi	C4-S1	C4S1
6	Palanwalla	C3-S1	C2-S1	Jamral	C3-S1	C3-S1
7	Miran Saheb	C3-S1	C3-S1	Nagri Parol	C2-S1	C2-S1
8	Bera	C3-S1	C2-S1	Khakial	C3-S1	C3-S1
9	Suchetgarh)	C3-S1	C3-S1	Kathua	C2-S1	C2-S1
10	Suchetgarh (BSF)	C3-S1	C3-S1	Lakhan Pur	C2-S1	C3-S1
11	R.S. Pura	C3-S1	C3-S1	Ramkot	C3-S1	C3-S1
12	Nikowal	C3-S1	C3-S1	NagrotaGuj	C3-S1	C3-S1
13	Arnia	C3-S1	C3-S1	Lakri	C2-S1	C2-S1
14	Poal	C3-S1	C3-S1	Mandli	C3-S1	C2-S1
15	Bishnah	C3-S1	C3-S1	Phinter	C2-S1	C2-S1
16	KeinthPur	C3-S1	C2-S1	Billawar	C3-S1	C2-S1
17	Bandral	C3-S1	C2-S1			
18	Daboh	C2-S1	C2-S1			
19	Samba	C2-S1	C3-S1			
20	Chhanni	C2-S1	C2-S1			
21	Satwari	C2-S1	C2-S1			

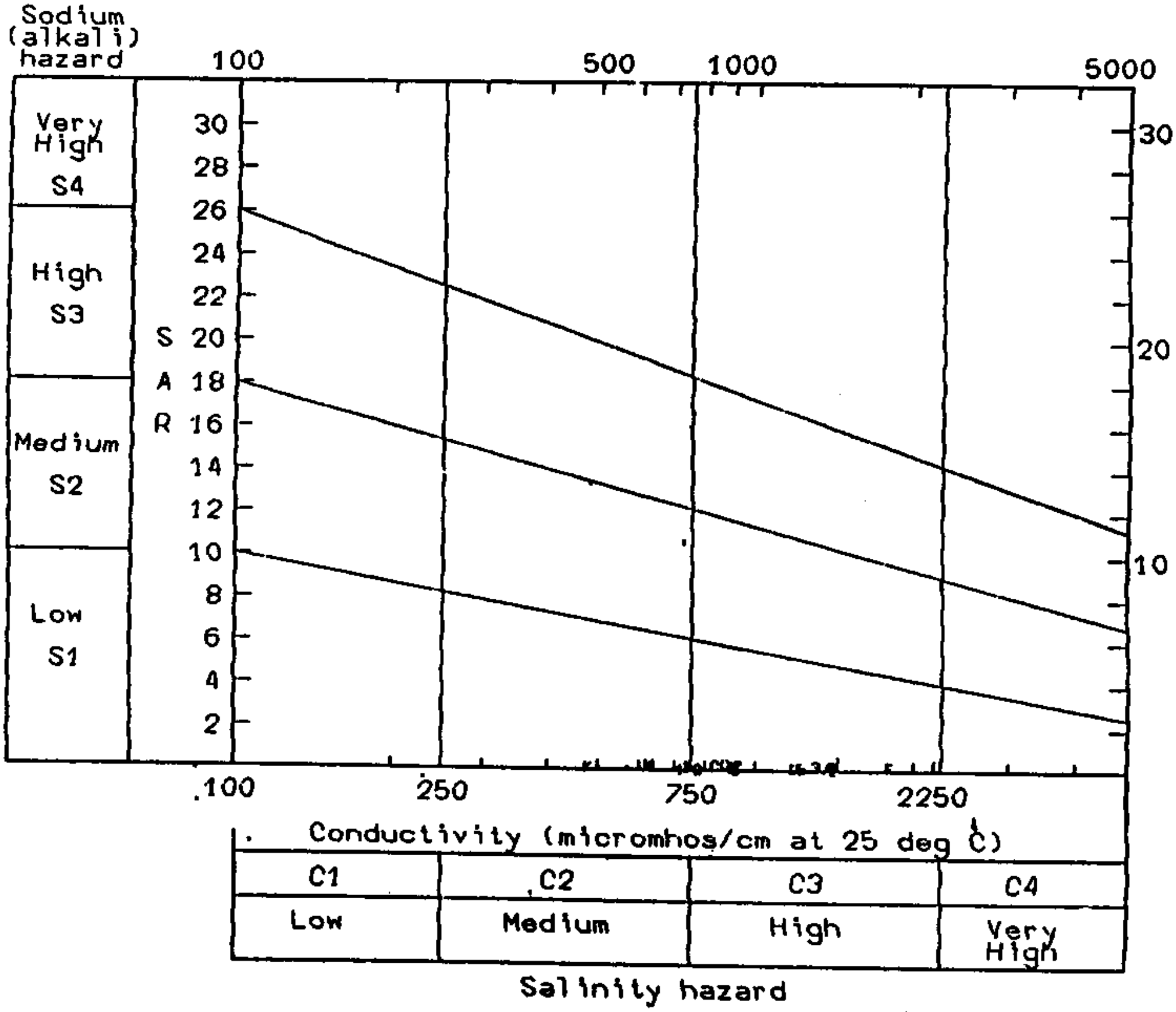


Fig.11 Classification of Irrigation Water for Jammu (June,1996)

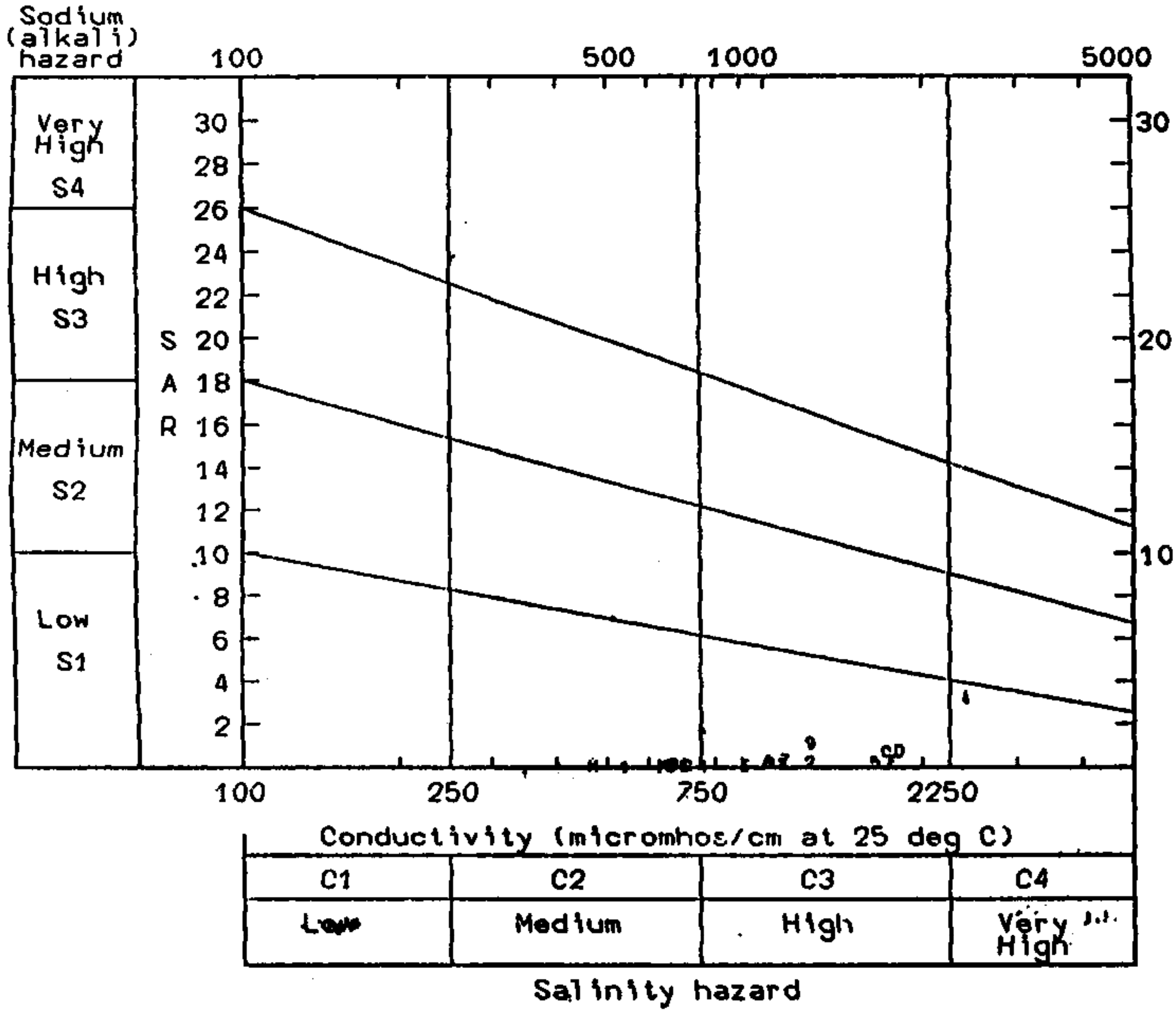


Fig.12 Classification of Irrigation Water for Jammu (Dec.,1996)

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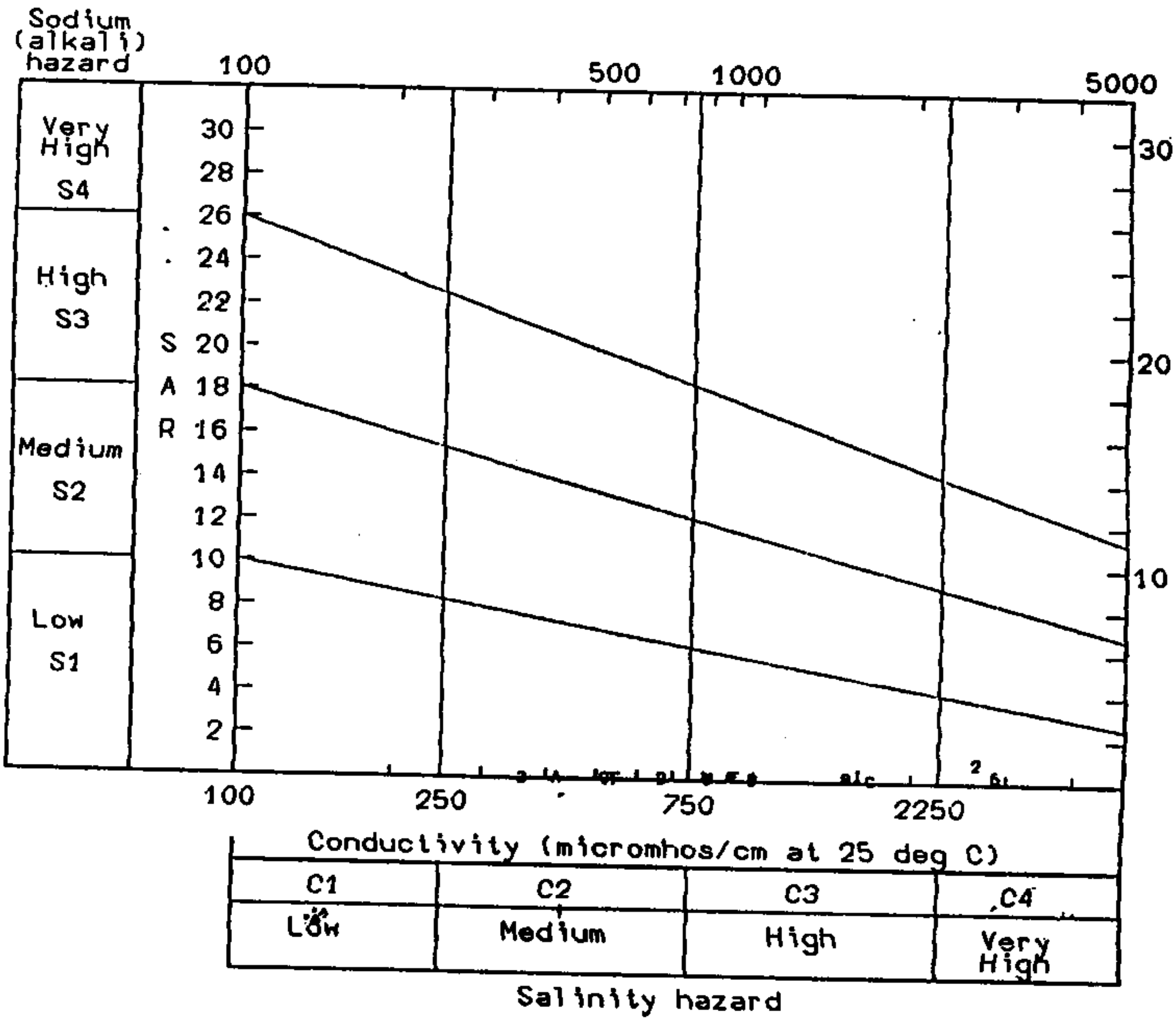

Fig. 13 Classification of Irrigation Water for Kathua (June, 1996)

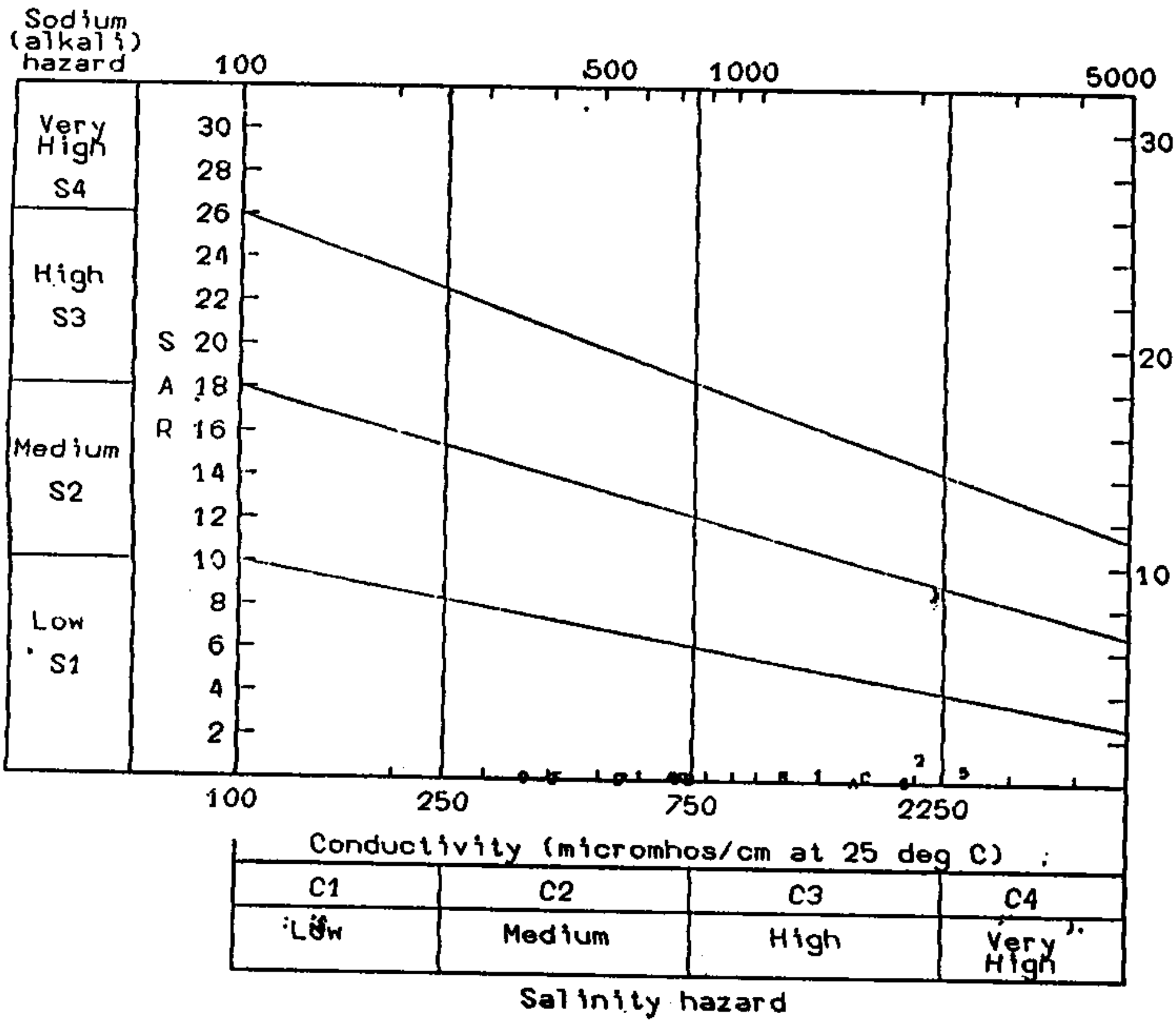

Fig.14 Classification of Irrigation Water for Kathua (Dec.,1996)

Table-9

Classification of Irrigation Water on the Basis of RSC

Category	RSC (meq/l)	No. of the samples in the study area			
		Jammu, June-1996	Jammu, Dec.-1996	Kathua, June-1996	Kathua, Dec.-1996
Safe	< 1.25	14	3	8	3
Marginal	1.25-2.5	5	9	5	7
Unsuitable	>2.5	2	9	3	6

5.3 Determination of Hydrochemical facies

Hill (1940) proposed the Trilinear diagram for the first time and refined by Piper (1944). Piper classification (1953) is used to express similarity and dissimilarity in the chemistry of different water samples based on dominant cations and anions. The Piper diagram combines three distinct fields for plotting, two triangular fields at the lower left and lower right respectively, and an intervening diamond shaped field.

Each apex of a triangle represents a 100 percent concentration of one of three chemical constituents. Major ions are plotted in the two base triangles of the diagram as cation and anion percentages of milli-equivalent per litre. Total cations and total anions are each considered as 100 percent. The respective cation and anion locations for an analysis are projected into the diamond shaped area which represents the total ion relationship. A circle can be drawn at this point with its area proportional to the dissolved solids.

Hydrochemical facies can be classified on the basis of the dominant ions in the facies by means of the Piper diagram. 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).

The chemical analysis data were plotted district wise on Trilinear diagram with the data of June and Dec., 1996 respectively for Jammu and Kathua (Fig. 15 to 18). The results of Trilinear diagrams have shown that majority of wells are falling under Ca, Mg, HCO_3 hydrochemical facies except a few wells under Ca, Mg, Cl, SO_4 during both sampling periods in the study area. However, Na, K, HCO_3 hydrochemical facies was also obtained for one well located at Madun in Kathua district during December, 1996. The results have been summarized and are given in Tables- 10, 11 & 12.

Table- 10. Summary of Hydrochemical Facies for Jammu District.

Well Sl. No.	Well Location	Hydrochemical facies in June-1996	Hydrochemical facies in Dec.-1996
1.	Akhnoor	Ca, Mg, HCO_3	Ca, Mg, HCO_3
2.	Guda	Ca, Mg, HCO_3	Ca, Mg, HCO_3
3.	Jourian	Ca, Mg, HCO_3	Ca, Mg, HCO_3
4.	Khour	Ca, Mg, HCO_3	Ca, Mg, HCO_3
5.	Seinth	Ca, Mg, HCO_3	Ca, Mg, HCO_3
6.	Palanwala	Ca, Mg, HCO_3	Ca, Mg, HCO_3
7.	Miran Saheb	Ca, Mg, HCO_3	Ca, Mg, HCO_3
8.	Bera	Ca, Mg, HCO_3	Ca, Mg, HCO_3
9.	Suchetgarh	Ca, Mg, Cl, SO_4	Ca, Mg, Cl, SO_4
10.	Suchetgarh (BSF)	Ca, Mg, HCO_3	Ca, Mg, HCO_3
11.	R.S. Pura	Ca, Mg, HCO_3	Ca, Mg, HCO_3
12.	Nikowal	Ca, Mg, HCO_3	Ca, Mg, Cl, SO_4
13.	Arnia	Ca, Mg, Cl, SO_4	Ca, Mg, Cl, SO_4
14.	Poal	Ca, Mg, HCO_3	Ca, Mg, HCO_3
15.	Bishnah	Ca, Mg, HCO_3	Ca, Mg, HCO_3
16.	Keinth Pur	Ca, Mg, HCO_3	Ca, Mg, HCO_3
17.	Bandral	Ca, Mg, HCO_3	Ca, Mg, HCO_3
18.	Daboh	Ca, Mg, HCO_3	Ca, Mg, HCO_3
19.	Samba	Ca, Mg, Cl, SO_4	Ca, Mg, Cl, SO_4
20.	Chhanni	Ca, Mg, HCO_3	Ca, Mg, HCO_3
21.	Satwari	Ca, Mg, HCO_3	Ca, Mg, HCO_3

Table -11

Summary of Hydrochemical Facies for Kathua District.

Well Sl. No.	Well Location	Hydrochemical facies in June-1996	Hydrochemical facies in Dec.-1996
1.	Naran	Ca, Mg, HCO_3	Ca, Mg, HCO_3
2.	Madun	Ca, Mg, Cl, SO_4	Na, K, HCO_3
3.	Nichla	Ca, Mg, HCO_3	Ca, Mg, HCO_3
4.	Hira Nagar	Ca, Mg, HCO_3	Ca, Mg, HCO_3
5.	Londi	Ca, Mg, SO_4	Ca, Mg, Cl, SO_4
6.	Jamral	Ca, Mg, HCO_3	Ca, Mg, Cl, SO_4
7.	Nagri Parol	Ca, Mg, HCO_3	Ca, Mg, HCO_3
8.	Khakhial	Ca, Mg,HCO_3	Ca, Mg, HCO_3
9.	Kathua	Ca, Mg, HCO_3	Ca, Mg, HCO_3
10.	Lakhan Pur	Ca, Mg, HCO_3	Ca, Mg, Cl, SO_4
11.	Ram Kot	Ca, Mg, HCO_3	Ca, Mg, HCO_3
12.	Nagrota Gujru	Ca, Mg, Cl, SO_4	Ca, Mg, Cl,SO_4
13.	Lakri	Ca, Mg, HCO_3	Ca, Mg, HCO_3
14.	Mandli	Ca, Mg, HCO_3	Ca, Mg, HCO_3
15.	Phinter	Ca, Mg, Cl, SO_4	Ca, Mg, HCO_3
16.	Billawar	Ca, Mg, HCO_3	Ca, Mg, HCO_3

Table -12

Sample Identification Levels of Piper and U.S.Salinity Diagrams in Jammu and Kathua Districts.

Sl. No.	Sample Identification Level	Well Location in Jammu District	Well Location in Kathua District
1.	1	Akhnoor	Naran
2.	2	Guda	Madun
3.	3	Jourian	Nichla
4.	4	Khour	Hira Nagar
5.	5	Seinth	Londi
6.	6	Palanwalla	Jamral
7.	7	Miran Saheb	Nagri Parol
8.	8	Bera	Khakhial
9.	9	Suchetgarh	Kathua
10.	A	Suchetgarh (BSF)	Lakhan Pur
11.	B	R.S. Pura	Ram Kot
12.	C	Nikowal	Nagrota Gujru
13.	D	Arnia	Lakri
14.	E	Poal	Mandli
15.	F	Bishnah	Phinter
16.	G	Keinth Pur	Billawar
17.	H	Bandral	
18.	I	Daboh	
19.	J	Samba	
20.	K	Chhanni	
21.	L	Satwari	

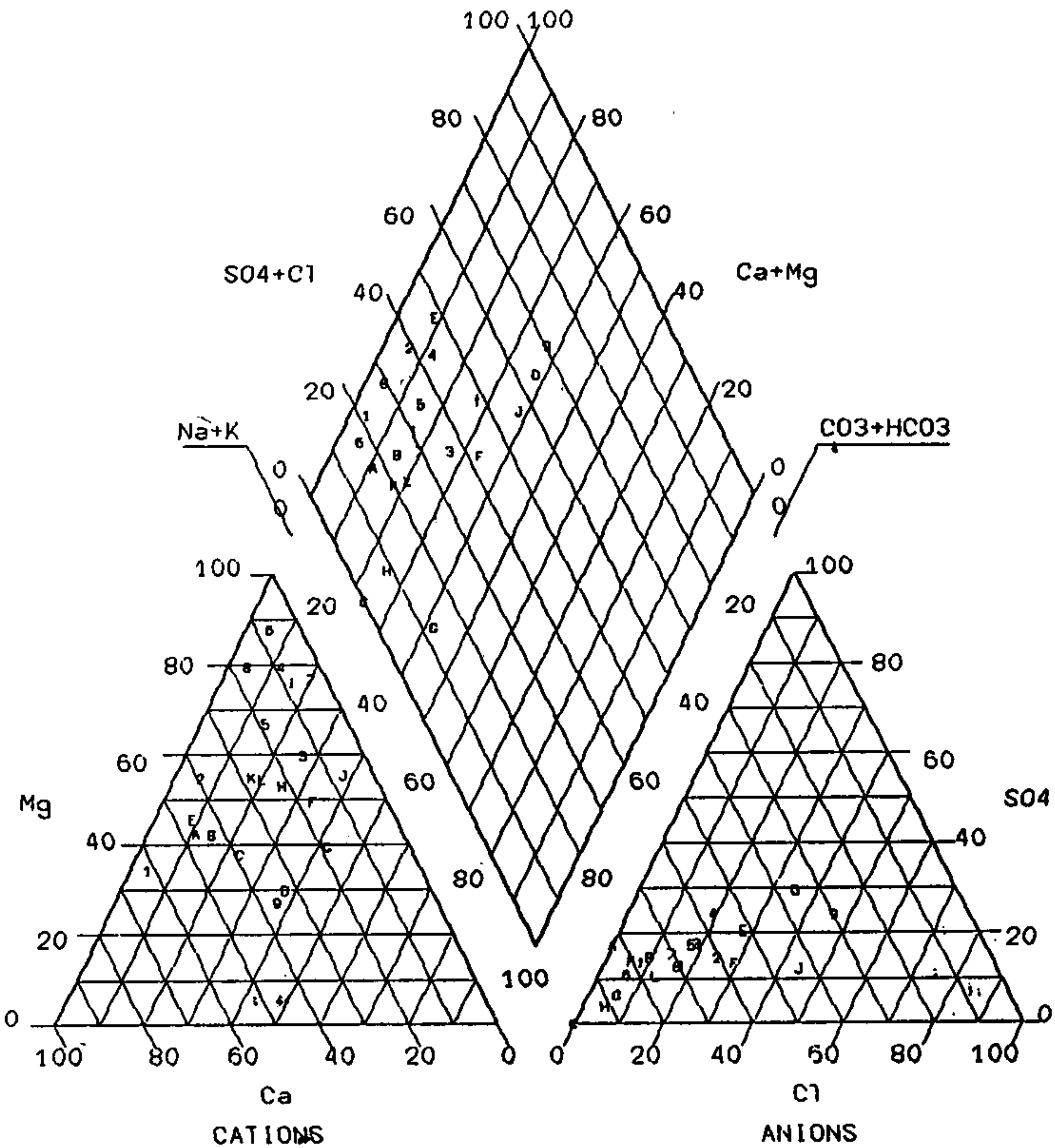

Fig. 15. Piper Trilinear Diagram for Jammu Dist. (June 1996)

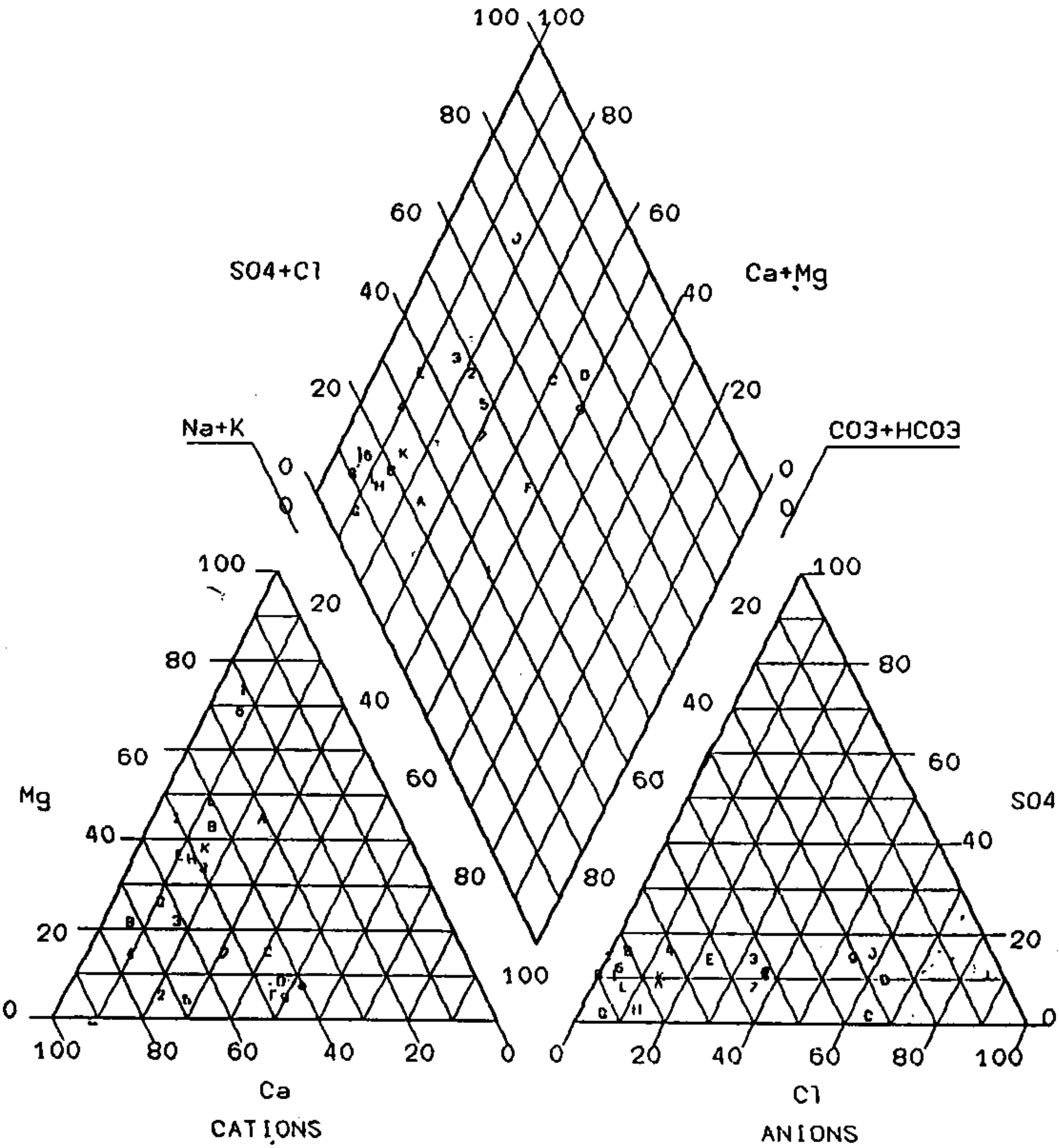

Fig.16 Piper Trilinear Diagram for Jammu Dist. (Dec., 1996)

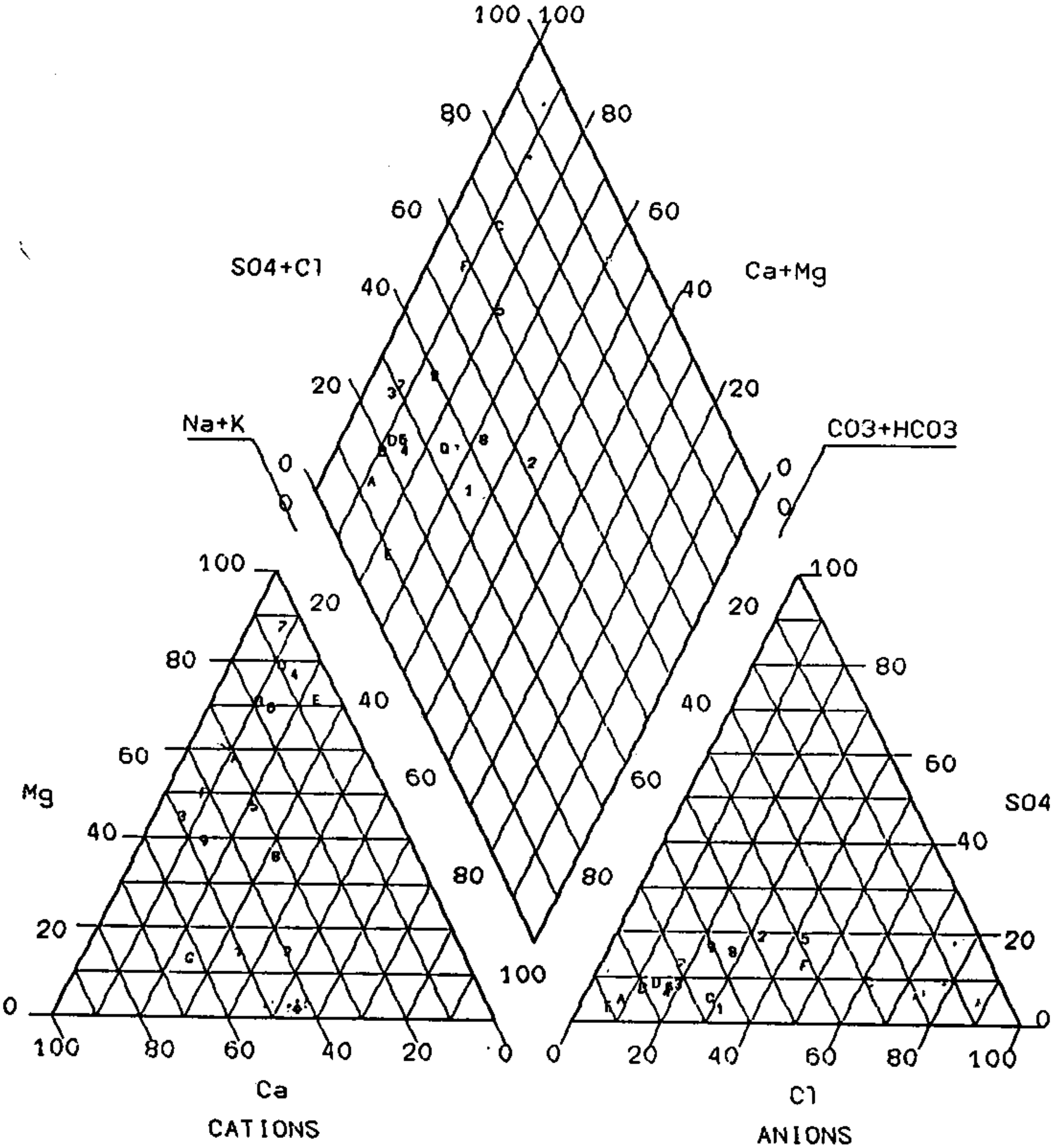

Fig.17 Piper Trilinear Diagram for Kathua Dist. (June, 1996)

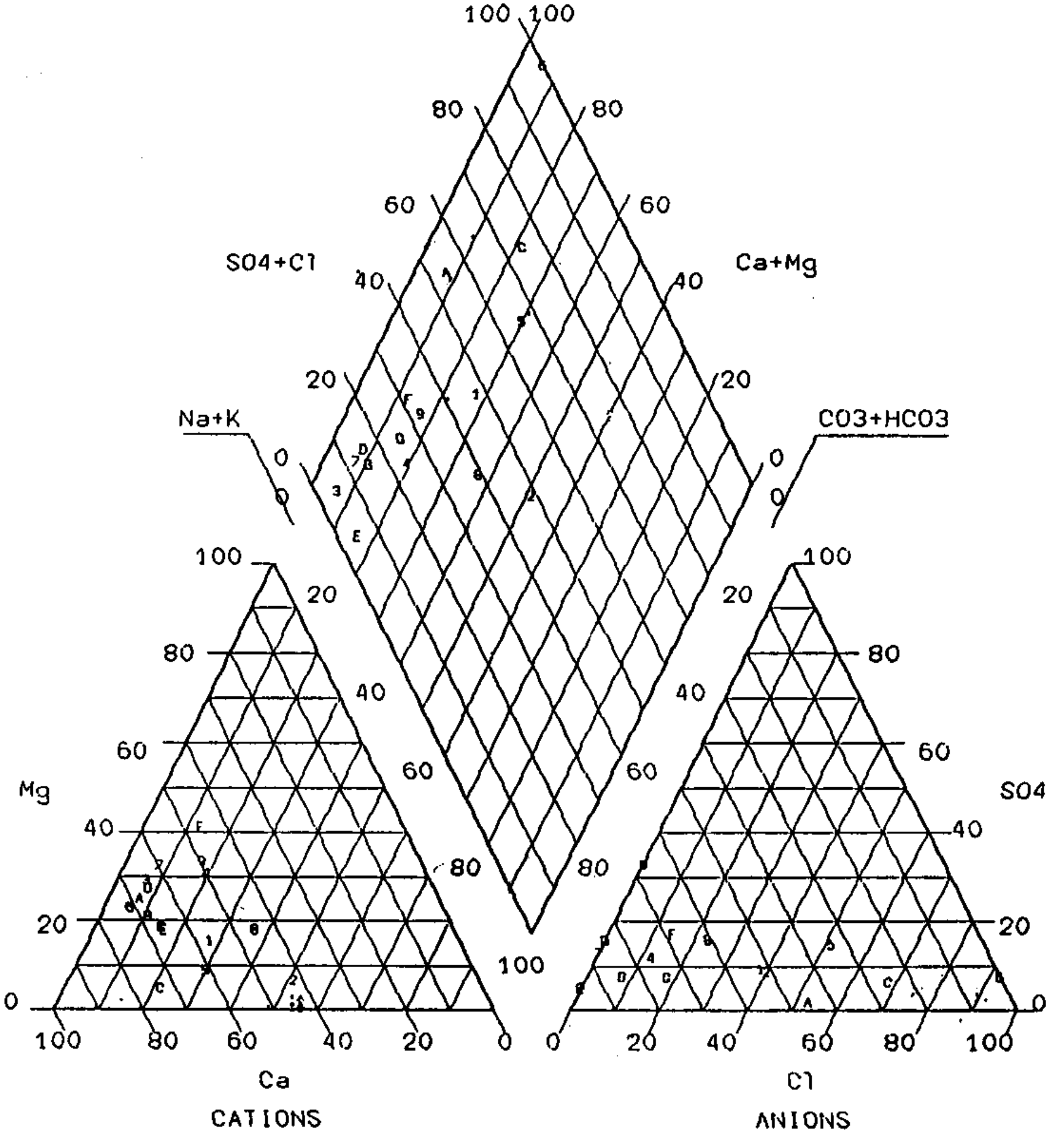

Fig.18 Piper Trilinear Diagram for Kathua Dist. (Dec., 1996)

6.0 CONCLUSIONS

The chemical characteristics of ground water of Jammu and Kathua districts have been studied on the basis of chemical characteristics of water samples collected from thirty seven open wells during June and December, 1996. The following conclusions could be drawn in this study:

(i) The pH value ranges from 7.2 to 8.2 during June, 1996 and from 7.1 to 8.17 during December, 1996 which is within the prescribed limits. It has shown that water is of alkaline nature in the study area.

(ii)The conductance values in the study area ranges from 420 to 2880 micro mho/cm during June, 1996 and 420 to 2470 micro mho/cm during Dec., 1996 with wide range of fluctuations at different locations.

(iii) The alkalinity values in the study area ranges from 108 to 722 mg/l during June, 1996 and 78 to 672 mg/l during Dec., 1996.

(iv) The sodium concentration in the ground water in the study area varies from 3.8 to 277 mg/l during June, 1996 and 7.0 to 421 mg/l during Dec., 1996.

(v) In the present study, calcium and magnesium ranges from 5 to 183 mg/l and 5 to 73 mg/l respectively during June, 1996, 31 to 449 mg/l and 5 to 42 mg/l during Dec., 1996.

(vi) Total hardness as $CaCO_3$ in the study area ranges between 118 to 630 mg/l during June, 1996 and 110 to 1250 mg/l during Dec., 1996.

(vii) The chloride concentration in the study area lies in the range from 2 to 370 mg/l during June, 1996, 4 to 284 mg/l during Dec., 1996.

(viii) The water of most wells was observed within limits in case of sulphate (150 mg/l of sulphate) except wells located at Suchetgarh, Arnia during June, 1996 and Suchetgarh during Dec., 1996 respectively.

(ix) The values of nitrate in the study area ranges from 0.1 to 66 mg/l during June, 1996 and 0.15 to 85 mg/l during Dec., 1996. Almost all wells were well within the limit except one well located at Londi exceeded the limit during June and Dec.,1996 respectively.

(x) The recommended upper limit of fluoride for drinking purpose is 1.5 mg/l (BIS). In study area all wells were observed well within this limit.

(xi) In the study area most wells lie under high salinity zone (E.C. range 750-2250 micro mhos/cm). Remaining few wells are under medium salinity zone (E.C. range 250-750 micro mhos/cm).

(xii) The SAR values ranges from 0.113 to 5.1 during June, 1996 and from 0.183 to 6.0 during Dec., 1996 respectively in the study area. All SAR values were less than 10 and according to the USDA classification water is excellent for the irrigation.

(xiii) The analysis as per Doneen's classification, has shown that most wells in the study area lie either under Permeability class-I or II and in general water may be considered good for irrigation except at Mandli during June, 1996.

(xiv) The quantity, Residual Sodium Carbonate has shown that the number of suitable and unsuitable wells for the purpose of irrigation were 22 and 5 during June, 1996 respectively in the study area. However, during December, 1996, suitable and unsuitable wells were 6 and 15. The wells under marginal category were 10 and 16 during June and Dec., 1996.

(xv) The results of Piper diagrams have shown that majority of wells are falling under Ca, Mg, HCO_3 hydrochemical facies except a few wells under Ca, Mg, Cl, SO_4 during both sampling periods in the study area. However, Na, K, HCO_3 hydrochemical facies was also obtained for one well located at Madun in Kathua district during December, 1996.

(xvi) The chemical analysis data were plotted district wise on U.S.Salinity diagram with the data of June and Dec., 1996 respectively for Jammu and Kathua. Majority of water samples are lying under C3-S1 (High Salinity- Low SAR) category. After that some samples lie under C2-S1 (Medium Salinity- Low SAR). In the present study, C4 - S1 (

Very High Salinity- Low SAR) was observed at Madun during June, 1996 , Londi during June as well as December, 1996 also.

Seasonal variation in the values of water quality parameters is clearly evident in the present study. It is shown that higher values of certain constituents at certain locations indicate that the water is not suitable for domestic and irrigational applications. Hence, regular monitoring of water quality parameters is recommended in the study area.

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ACKNOWLEDGEMENT

The authors would like to thank to the Central Ground Water Board, North Western Himalayan Region, Jammu, for their kind cooperation from time to time for carrying out the present investigations. Thanks are also due to the Geological Survey Of India, Jammu, for their kind help for referring geological information.

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