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

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ABSTRACT

In the present study ground water samples were collected from 53 open wells in Jammu and Kathua districts during June/ July and November, 1995. The report also includes discussion based on water quality parameters obtained from 47 open wells in Jammu district during Aug., Dec., 1994 and March, 1995.

The study has shown that most water quality parameters were within the prescribed norms for drinking purposes except at a few well locations in the study area. The concentration of calcium among cations and bicarbonate among anions was found to be relatively higher. The fluoride concentration was within acceptable limit (1.0 - 1.7) in Kathua district under the present study. The SAR values were well within limit of excellent water for irrigation. The EC values were found to be exceeding 750 micro mhos/cm at many places. Therefore, better drainage conditions should be provided in the study area while irrigating with the present quality of water.

The results of Piper's Trilinear diagram indicate that majority of wells are falling under Ca-Mg-CO_3 - HCO_3 hydrochemical group. The results of Wilcox diagram have shown that majority of water samples lie under C3-S1 (high salinity- low SAR) during June/July, 1995. However, during post-monsoon period majority of wells were under the category of C2-S1 (medium salinity- low SAR).

The Principal Component analysis was also carried out for the Jammu district. It could be concluded from this analysis, that the first three components contribute more than 77 % of the total variance of the data. It may be observed that the first principal component has high loading on almost all water quality parameters. However, the remaining components have shown decreasing trends of the loading effect. The analysis has shown that management decision regarding water quality can be made effectively using thsese results.

1.0 INTRODUCTION

Water is an integral part of man's environment. It is one of the most essential natural assets necessary for sustenance of all living organism. From the very beginning, man realized the efficacy and essentiality of water for his daily life. In addition to drinking and personal hygiene, water is also needed for agricultural production, industrial and manufacturing process, hydro-electric power generation, waste assimilation, recreation and wild life etc.

There are about 5.5 Lakh villages in our country. A large number of them still do not have adequate and safe drinking water. It has been estimated that out of the average annual precipitation of 400 million hectare meter in our country, about 215 million hectare meter is soaked into the ground which eventually joins the aquifers. Therefore, it may be said that India is blessed with a comparatively large resource of ground water.

The use of ground water is also increasing due to its being better in quality, quantity, economical, and its availability almost in uniform quantity as compared to surface water resources. However, on account of indiscriminate utilization, both the quality and quantity of this precious renewable resource have been deteriorating very fast due to various influences of man's activities on the earth.

The exponential growth of population is a prominent factor causing water pollution. The waste generated from the communities and industries is generally disposed into the flowing water bodies which deteriorates the surface and ground water. However, it has also been seen that there is a bad practice of disposing industrial effluent directly into the wells without passing through filtration plant. This process may rapidly lead to the ground water contamination upto extreme state and it will be very difficult to re-juvinate the ground water aquifer.

Besides above, the use of fertilizers, pesticides and insecticides in agriculture are also contaminating the water to a certain extent. It is because that the chemicals and pesticides used in the agriculture field either percolate to the ground water aquifer or move to the river through surface run-off and finally contribute to the pollution of water bodies. Constant pressure on the agriculture land and conversion of vegetative land to fertile land is causing serious soil erosion problem. Soil eroded from agricultural land also causes water

pollution because it contains considerable amount of suspended matters and nutrients such as phosphorus, nitrogen and significant amounts of salts, pesticides and heavy metals.

The intensive use of natural resources and the large production of wastes in modern society often pose a threat to ground water quality and has already resulted in many incidents of ground water pollution. Degradation of ground water quality can take place over large areas from plane or diffuse sources like deep percolation from intensively from fields, or it can be caused by point source such as septic tanks, garbage disposal sites, mine spots, oil spills etc.

Among soluble constituents, calcium, magnesium, sodium, chloride, sulphate, bicarbonate and boron are of prime importance in determining the suitability for irrigation purposes. The concentration of chloride, sulphate and sodium ions used to be generally high in contaminated ground water. High levels of nitrate (more than 100 mg/l, European Drinking Water Standards,1970) may cause methemoglobinemia or blue baby diseases, and fluoride more than 1.5 mg/l can cause dental, skeletal and non skeletal manifestations. High levels of sulphate (250 mg/l, EDWS, 1970) in drinking water may cause gastrointestinal irritation problems. High levels of sodium ion can be hazardous to the crops. Hence, it becomes necessary to monitor the ground water quality in the area to assess its suitability for various uses.

The present report deals with the monitoring and evaluation of water quality of selected open wells in Jammu and Kathua Districts. The report includes results obtained during 1994 for Jammu district in addition to the latest investigations for Jammu & Kathua during 1995.

2.0 REVIEW

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 Pollutant is a term which is applied usually for non-living, man made substances or other nuisances and it refers to 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 threaten to public health (Pitchaiah, 1995).

Central Ground Water Board (CGWB) is monitoring wells throughout the country to measure the condition and trends of ground water quality and quantity. In Jammu and Kashmir CGWB is monitoring depth of water levels four times in a year in open wells during January, May, August and November since 1986 for Jammu, Kathua, Udhampur, Srinagar, Phulwama, Budgam, Kupwada, Anantnag and Baramula districts. Some important water quality parameters were also determined by CGWB through their periodic field investigations in J & K.

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 trilinear and U.S. Salinity

Laboratory Classifications. In the piper trilinear 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 Trilinear 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 premonsoon and post monsoon seasons due to less rainfall (Kumar, S. et al., 1988).

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).

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).

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 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).

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 average temperature in the Jammu region varies from 4° to 40 ° Celsius. The rainfall (mm) normals at few places in the study area are given in Table-1.

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

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.

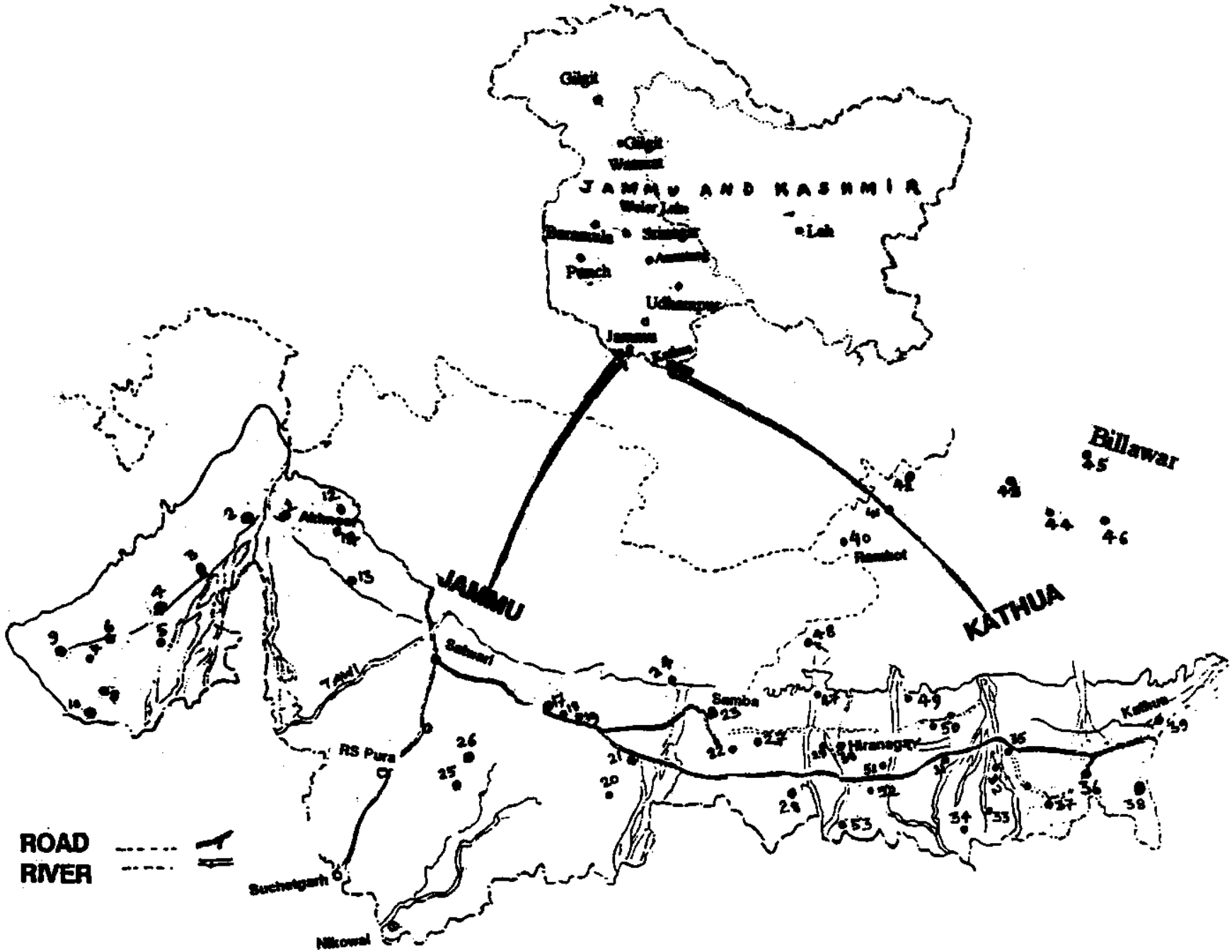


Fig. 1 Location Map of Wells in Jammu and Kathua District.

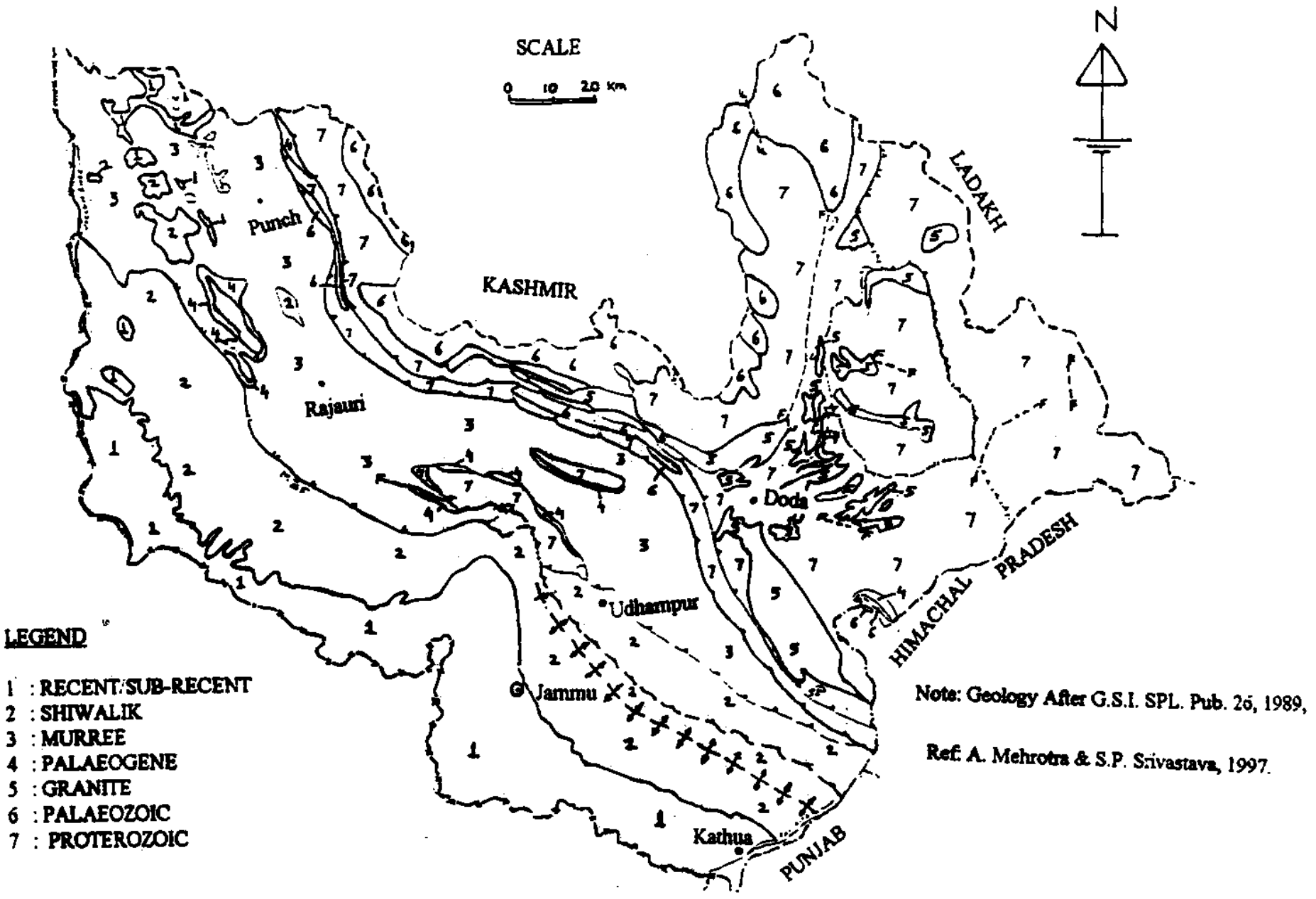


Fig. 2 Generalised Geological Map of Jammu Region.

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 & 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. The main crops grown in the study area are wheat and millet. Rice, bajra and maize are supporting crops in the study area.

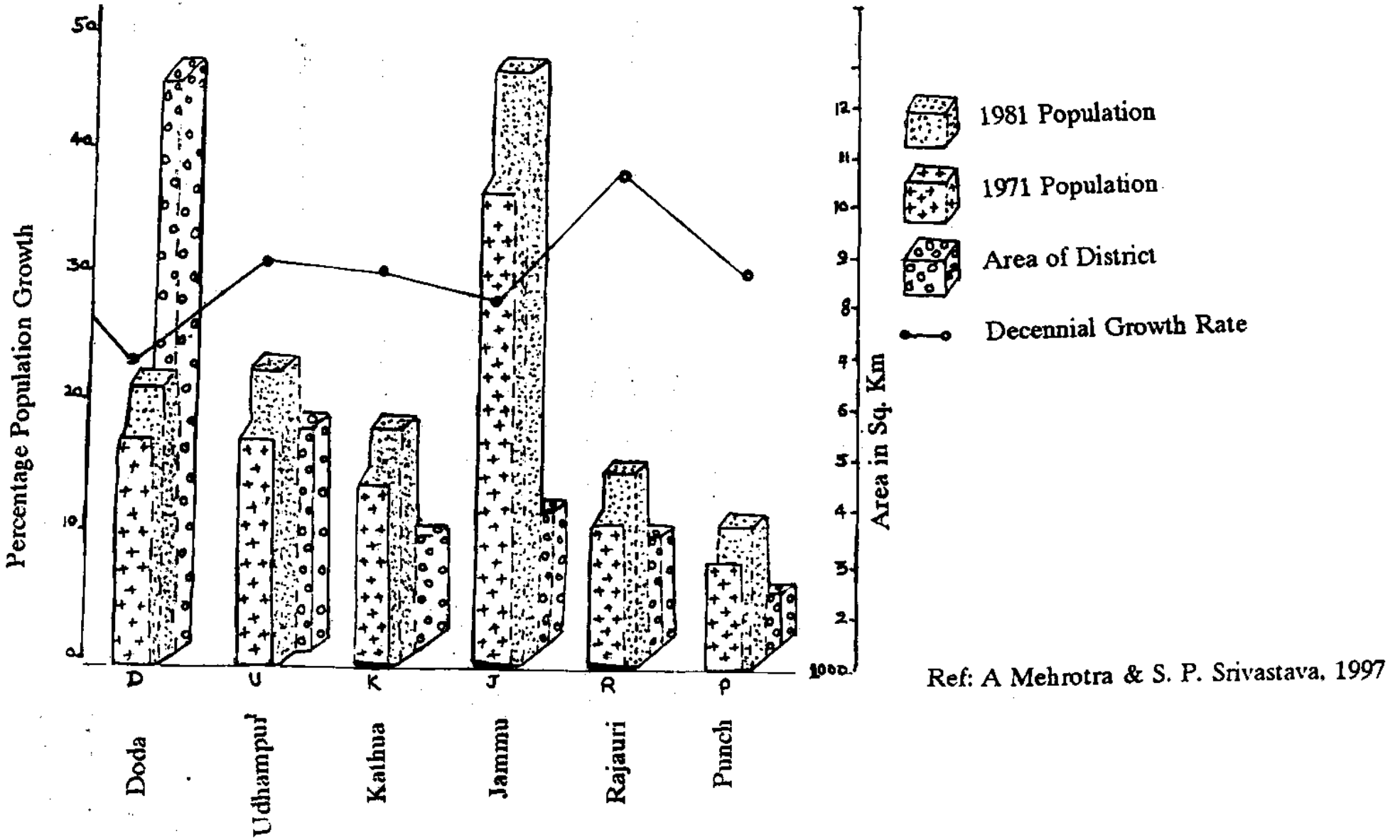
3.6 Infiltration Characteristics

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).

3.7 Population Density

The population plays an important role in changing the scenario of environment because of pressure exerted by it on the available resources. Thus, higher the population density, greater the environmental degradation. Jammu region is inhabited by 27, 17,242 people (as per 1981 census) living in 29 townships and in nearly 3500 villages. The average density of the region is 103 persons per sq km. Since, the Jammu district fulfills many requirements which govern the growth of population which is 305 persons per sq km. The expansion of Jammu and Kathua cities are taking place in a haphazard way which is real cause of environmental degradation. A map showing variation in population in relation to geographical area of Jammu region is given in Fig. 3.



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

Fig 3. Map showing Variation of Population in Jammu Region.

4.0 MATERIALS AND METHODS

4.1 Sampling and Preservation

Sampling is one of the most important and foremost step in collection of representative water samples for water quality studies. In the present study 53 samples were collected from open wells and one spring in Jammu and Kathua district. View of sampling at two locations has been shown in Fig. 4 & 5 respectively.

The samples were collected in clean plastic bottles fitted with screw caps. The depth of the water in the respective wells was also measured during sampling using graduated steel tape. The 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 performed following standard methods (APHA, 1985; Jain and Bhatia, 1987). The parameters analysed in this study are: pH, electrical conductivity, total dissolved solids, sodium, potassium, calcium, magnesium, chloride, sulphate, bicarbonate, nitrate, phosphate and fluoride.

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 0.401 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.

Fig 4. View of Water sampling & Preservation at Mandli.

Fig 5. View of Water sampling & Preservation at Hiranagar.

5.0 RESULTS AND DISCUSSION

5.1 Ground Water Quality Variation in Jammu District

The pH value of water is very important indication of acidic and alkaline nature of water. It influences to a great extent the growth of both plant and soil micro-organisms since it affects the suitability of water for irrigation. The presence of considerable amount of CaCO3 increase the ph value of water, making it alkaline. The water quality parameters obtained for different periods are given in Table-2 and in Fig. 6-8. The average pH values range from 7.13 to 7.32 in the study area. The pH values are within the permissible limits (6.5 to 8.5) for drinking purposes (BIS, 1983).

The electrical conductivity is an useful parameter of water quality for indicating salinity hazards. In general, water with conductivity values below 750 micro mhos/cm are satisfactory for irrigation except for salt sensitive crops that may be adversely affected by the use of irrigation waters having conductivity values in the range 250-750 micro mhos/cm. However, waters in the range 750-2250 micro mhos/cm are widely used and satisfactory crop growth is obtained under good management and favourable drainage conditions. The EC values vary from 400 to 1435 micro mhos/cm (August, 1994), 455 to 4481 micro mhos/ cm (Dec. 1994), 467 to 3159 micro mhos/cm (March, (1995), 700 to 2100 micro mhos/cm (June, 1995) and 270 to 1520 micro mhos/cm (Nov., 1995) respectively under the present investigation in Jammu district. The results have shown that the EC values of most wells in the district are within 2250 micro mhos/cm except the wells located in Suchetgarh (Dec., 1994; Mar., 1995), Gajansoo and Arnia (Mar., 1995).

The TDS values of ground water ranges from 258 to 911 mg/l (Aug, 1994), 295 to 2875 mg/l (Dec., 1994), 290 to 2035 mg/l (Mar.,1995), 300 to 1180 mg/l (June, 1995) and 180 to 1030 mg/l (Nov., 1995) for periods as mentioned. For many wells in the district the TDS values exceeded the general acceptability limit of TDS (500 mg/l, BIS-1983). However, the wells in the District for which TDS exceeded the desirable limit (1500 mg/l, WHO) were Bandral (Dec., 1995), Suchetgarh (Dec., 1995; Mar., 1995), Arnia (Dec., 1995; Mar., 1995) and

Gajansoo(Mar., 1995).

The study have shown that the calcium content is relatively higher in the study area. However, the wells in the District as identified under exceeding allowable limit of calcium for drinking (200 mg/l, WHO 1984) were at Arnia (Aug., 1994; Dec., 1994; Mar., 1995), Suchetgarh (Mar., 1995), Abtal (Mar., 1995), Bandral (Dec., 1994), Nagrota (Dec., 1994), Jourian (Dec., 1994), and Purkhoo (Nov., 1995) during the period under this study.

The magnesium content was found well within the limit (50 mg/l) prescribed for drinking purpose (WHO, 1984) at most of the places in the study area. However, the wells which have gone out of this limit were Abtal (Aug.,1994; Mar.,1995), Kaluchak (Aug.,1994; Dec., 1994), Arnia (Dec., 1994), Bishnah (Aug., 1994; Dec., 1994; Nov., 1995), Salehar (Dec., 1994), Gajansoo (Dec., 1994; Nov, 1995), Purkhoo (Dec., 1994), Devipur (Dec., 1994; June, 1995), Bengular (Mar., 1995), Raiyan (Mar., 1995), Nagrota (Mar, 1995; June, 1995), Guda (Mar., 1995), Patakhoo (June, 1995) and Jourian (Nov., 1995).

In the present study five anions e.g., bicarbonate, chloride, sulphate, phosphate and nitrate were determined. Among them bicarbonate was dominant in the district. Mandel and Shiftan (1961) stated that more than 60 mg/l of bicarbonate content in the water is necessarily attributed from the biological activities of plant roots, from the oxidation of organic matter included in the soil and in the rock and from various chemical reactions. According to Foster (1950) the occurrence of concentrations of more than 450 mg/l of bicarbonate is attributed to the presence of carbonaceous material.

In the present study the bicarbonates ranges from 92 to 334 mg/l (Aug.,1994), 152 to 808 mg/l (Dec..1994), 136 to 672 mg/l (Mar.,1995), 160 to 540 mg/l (June,1995) and 144 to 430 mg/l (Nov.,1995) under the present study. The average values of bicarbonates in the area varies from 209 to 367 mg/l.

The average values of chloride varies from 28 to 82 mg/l in the district. The wells under the

category of exceeding limit (200 mg/l, WHO 1984) for drinking purposes were observed at Abtal (Aug.,1994), Bengular (Aug., & Dec.,1994), Salehar (Aug.,1994), Bandral (Dec.,1994), Suchetgarh (Dec.,1994 & Mar.,1995), Arnia (Dec.,1994 & Mar.,1995) and Patli (Nov.,1995).

The average sulphate values range from 48 to 90 mg/l in the district. On an individual, the sulphate values in the district vary from 4.3 to 590 mg/l. The wells beyond the category of tolerance limit (400 mg/l, BSI 1983, Class A Drinking Water) in district were located at Suchetgarh (Mar.,1995 & Dec.,1994) and Bandral (Dec.,1994) respectively.

The limited data on nitrate in this study has shown that most wells in the area fall within limit of general acceptability (45 mg/l, WHO, 1984) for drinking purposes except at Pallanwala and Seinth (Nov.,1995). However, the quantity of nitrate at few pockets in the area more than 10 mg/l may be assumed to be attributed from agricultural pollution caused due to fertilizers application.

Table-2 Values of Water Quality Parameters in Jammu District

Parameters	Aug.,94			Dec.,94			Mar.,95			June, 95			Nov, 95		
	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
pH	6.34	8.55	7.13	6.73	8.12	7.32	6.66	8.0	7.2	6.3	8.0	7.28	6.9	7.8	7.25
EC, μ m/cm	400	1435	796	455	4481	1224	467	3159	1087	700	2100	1180	270	1520	755
TDS, mg/l	258	911	493	295	2875	801	290	2035	699	300	1180	588	180	1030	453
HCO3, mg/l	92	334	209	152	808	367	136	672	329	160	540	302	144	430	268
Hardness, mg/l	151	740	325	168	916	415	152	980	331	128	484	246	160	600	323
Cl, mg/l	4	340	66	0	520	82	0	448	70	0	108	27	0	268	57
SO4, mg/l	5.0	384	48	20	590	91	8.0	476	76	4.0	121	48	6.0	174	48
PO4, mg,l	0.06	2.15	0.3	-	-	.21	0	2.64	.24	0.1	.64	0.18	0.1	1.24	0.24
NO3, mg/l	-	-	-	-	-	-	-	-	-	0	24	6	0	48	12
Ca, mg/l	38.5	296	85	37	279	116	5	359	84	5	174	47	40	234	93
Mg, mg/l	0	87	22	0	102	29	0	79	29	8	59	31	0	69	22
Na, mg/l	4	110	23	3	350	65	6	275	47	8	207	45	3	200	38
K, mg/l	0.39	151	29	0.08	282	34	1.1	400	43	1.2	150	18	1.2	224	25

The average phosphate values in the district were in the range of 0.18 to 0.33 mg/l under the study of two years data. The phosphate values on an individual basis for the wells in the area range from 0.0 to 2.64 mg/l under the same period.

The values of Sodium Adsorption Ratio (SAR) were calculated using the following formula:

$$\text{Sodium Adsorption Ratio} = \frac{Na^+}{[Ca^{2+}+Mg^{2+}/2]^{0.5}} \quad \text{(i)}$$

The minimum, maximum and mean values of sodium adsorption ratios obtained during 1994-95 in Jammu district are given in Table-3. The variation of SAR values obtained during different periods is given in Fig. 9. The results indicate that SAR values in the district were below the limit of excellent water for irrigation (USDA, 1954).

Table-3 Variation of SAR Values During Different Periods in Jammu District

Sampling Period	Sodium Adsorption Ratios		
	Minimum	Maximum	Average
Aug.,94	0.130	3.639	0.60
Dec.,94	0.187	6.146	1.309
Mar.,95	0.182	6.738	1.15
June,95	0.212	7.21	1.35
Nov.,95	0.113	6.03	0.90

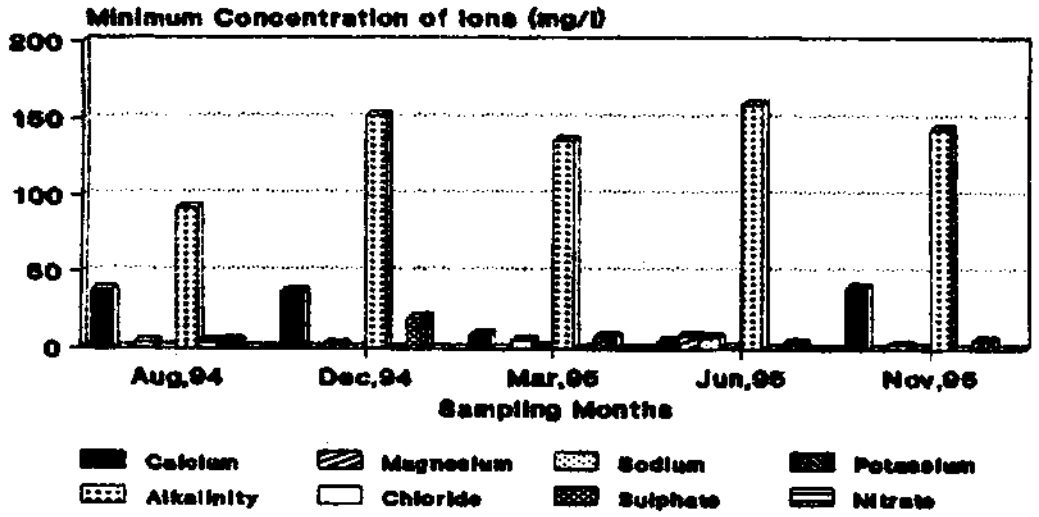


Fig 6. Minimum Values Variation of Ion Concentration in Jammu District.

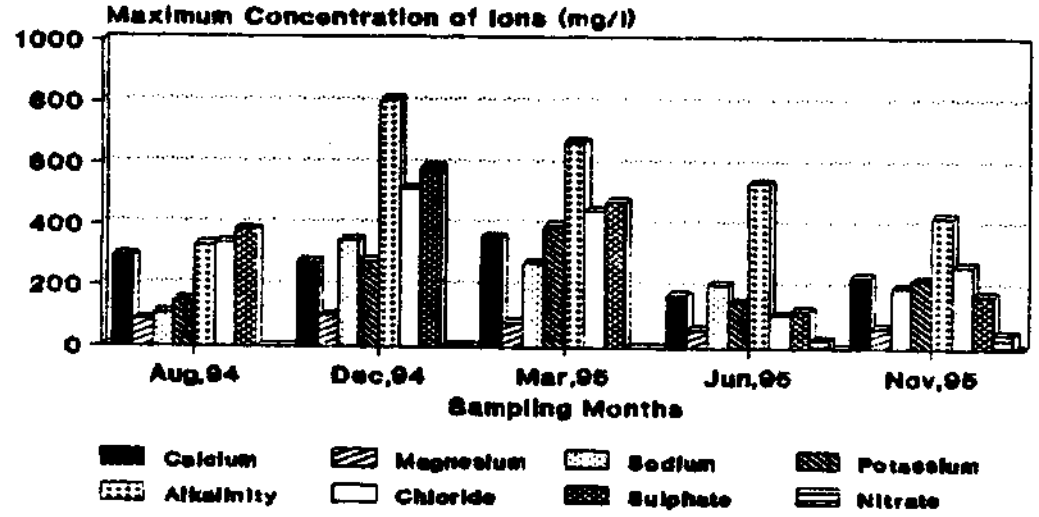


Fig 7. Maximum Values Variation of Ion Concentration in Jammu District.

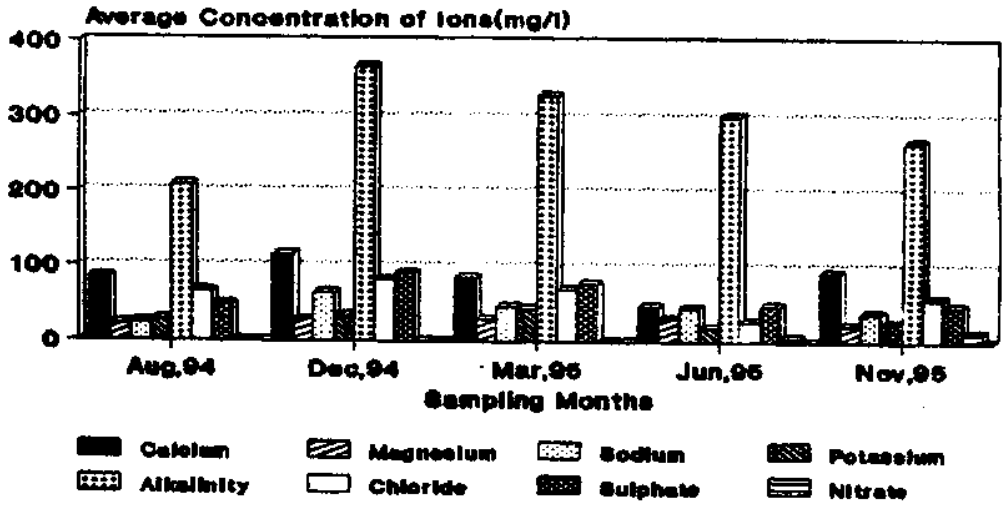


Fig 8. Mean Values Variation of Ion Concentration in Jammu District.

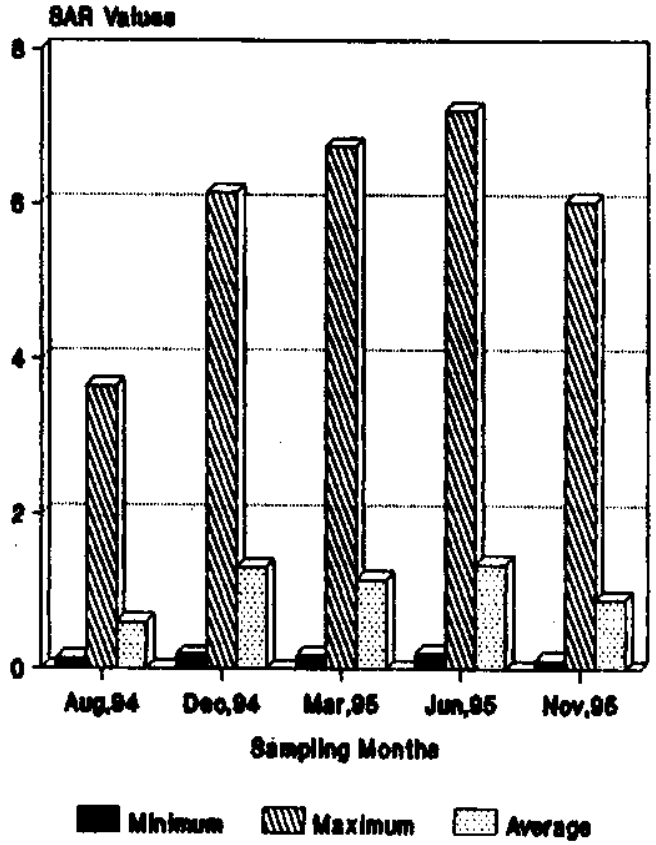


Fig 9. Variation of SAR values in Jammu District.

5.2 Ground Water Quality Variation in Kathua District

Ground water quality samples from 27 open wells in the district were collected during June and November, 1995. The analysed results are given in Table-4 and Fig. 10-12. The average pH values in the district were in the range 7.1 to 7.5. The average EC values range from 827 - 1138 μ mhos/cm. The average TDS values range from 408 to 571 mg/l. The TDS values were exceeding at few places in the district in view of the of drinking purpose under class-A (500 mg/l, BIS 1983).

The EC values greater than 750 μ mhos/cm were obtained at many places. Therefore, it may be emphasized that good land and water management practices should be adopted while irrigating the fields to prevent any consequent effects of salinity in the district.

The calcium content in the district was within limit of general acceptability (75 mg/l, WHO 1984) except at Naran, Madun, Londi (June,1995) and Madun, Khukhial, Ramkot, Nagrota Gujru, Billawar, and Londi (Nov.,1995) .

The magnesium content at few wells was beyond the limit of general acceptability for drinking purpose (50 mg/l, WHO 1984). The wells in this category were located at Jandi (June,95) and Naran, Madum, Jandi (Nov,95) under the present study.

The average concentration of bicarbonate varies from 238-257 mg/l in the district . The average concentration of chloride varies from 37.26-47.59 mg/l. The chloride concentration in the district was well within the prescribed limit for drinking water (200 mg/l, WHO) except a few wells at Madun, Nagrota Gujru and Londi during November, 95. The average sulphate values in the district vary from 37.83 to 44.91 mg/l .

The average concentration of phosphate values vary from 0.07 to 0.08 mg/l in the district. The average concentration of nitrate values vary from 5.84- 11.93 mg/l. The wells beyond acceptable limit of nitrate (45 mg/l, WHO) for drinking purpose were located at Madun

(June,1995; Nov.,1995) and Londi (Nov.,1995).

Table-4 Variation of Water Quality Parameters in Kathua District.

Parameters	Concentrations					
	(June, 95)			(Nov., 95)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
pH	6.5	8.3	7.5	6.5	7.6	7.1
Temp., °C	20.3	28.3	24.7	20	27	23
EC, μ m/cm	600	2900	1138	300	2580	827
TDS, mg/l	230	1760	571	210	1490	408
Alkalinity, mg/l	100	720	257	100	544	238
Hardness, mg/l	96	640	209	148	768	268
Chloride, mg/l	0	188	37	0	309	47
Sulphate, mg/l	5.9	280	44	4	261	37
Phosphate, mg/l	0.025	0.5	0.08	0	0.21	0.066
Nitrate, mg/l	0	57	5.84	0	64	11
Fluoride, mg/l	0	0.9	0.3	0	1.3	0.362
Calcium, mg/l	6.4	224	43	4	236	60
Magnesium, mg/l	0	54	22	0.5	118	29
Sodium, mg/l	8	280	43	3	400	42
Potassium, mg/l	1.6	144	13	1.0	160	13

The average fluoride concentration in the district varies from 0.28 to 0.36 mg/l. However, its maximum concentration were obtained 0.86 and 1.5 mg/l at Madun and Khanpur during June and Nov.,95 respectively. The study has shown that the fluoride concentration in the district was within limit (1.0 -1.7 mg/l, European Drinking Water Standards, 1970, Cited from Raghunath, H.M., 1987).

The average SAR values in the district vary from 0.965-1.125 . Whereas, in general variation in SAR values was observed 0.204 to 4.93 during June, 1995 and 0.1 to 6.75 during Nov., 1995 respectively in the district (Fig. 13). The results have shown that SAR values in the district were below the limit (10.0, USDA, 1954) for excellent quality of irrigation water.

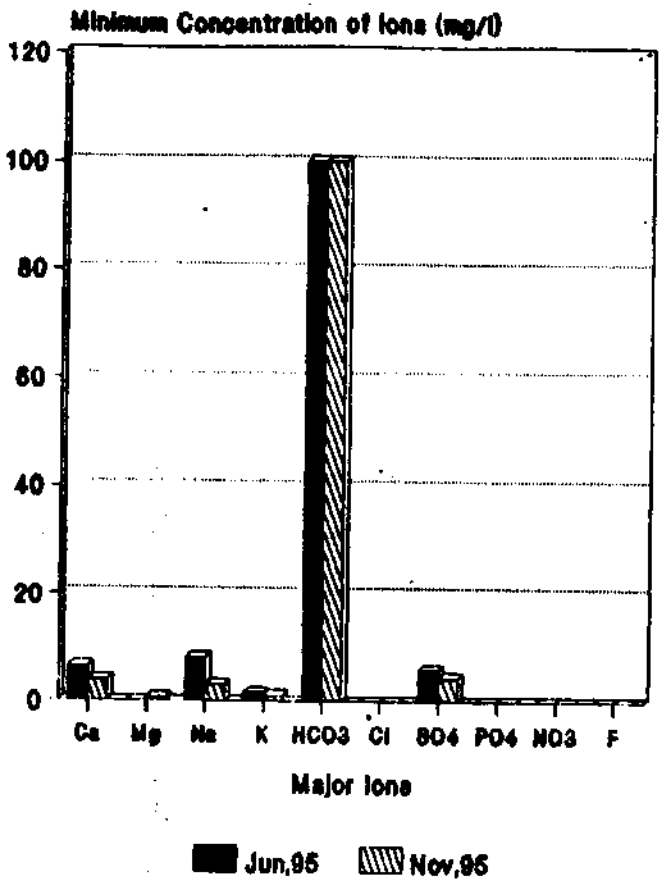


Fig 10. Minimum Values Variation of Ion Concentration in Kathua District.

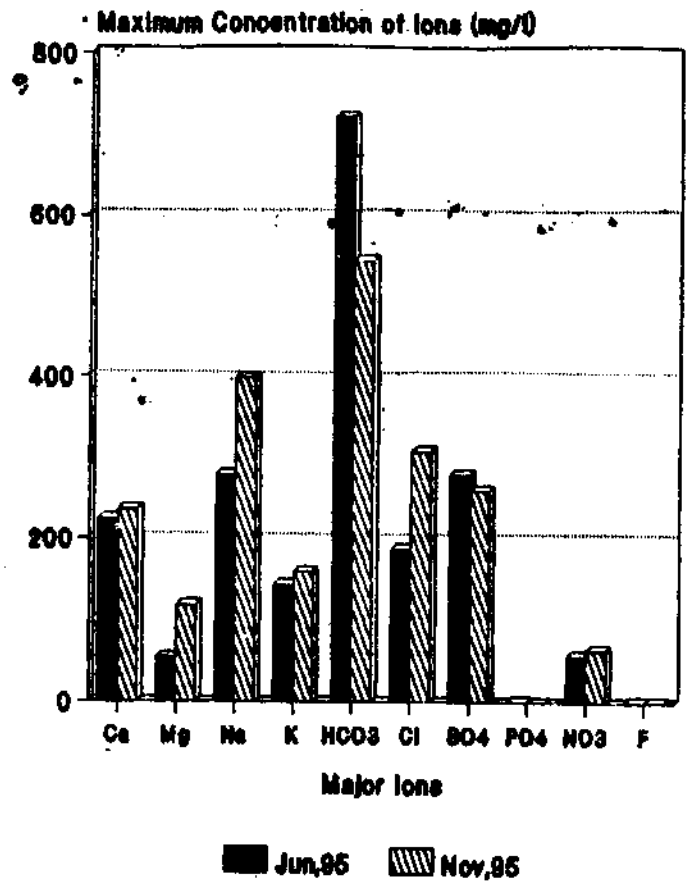


Fig 11. Maximum Values Variation of Ion Concentration in Kathua District.

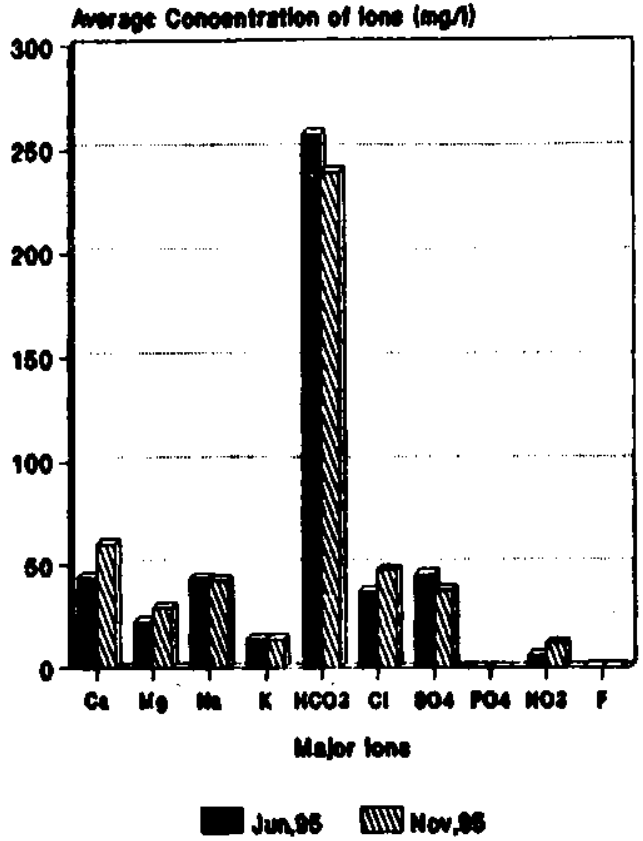


Fig 12. Mean Values Variation of Ion Concentration in Kathua District.

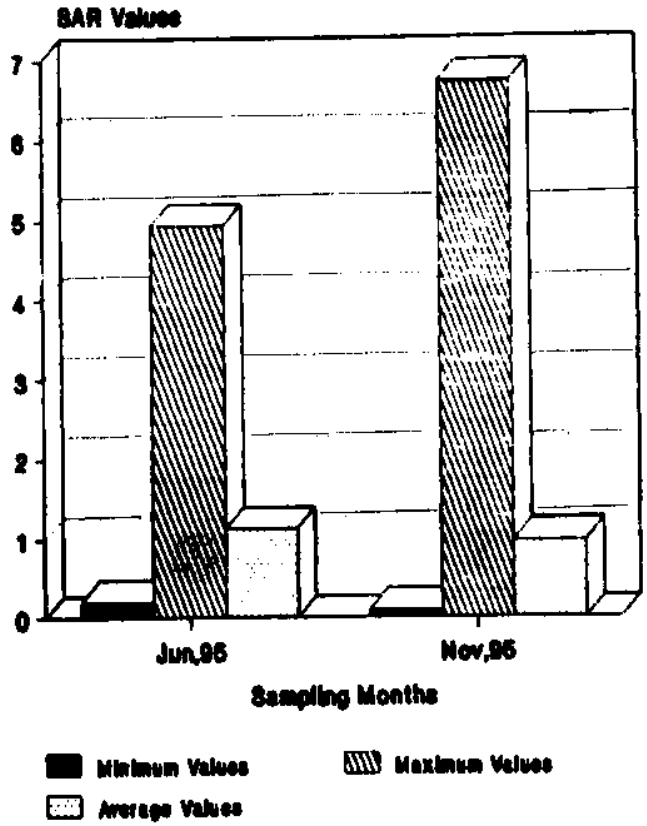


Fig 13. Variation of SAR values in Kathua District.

5.3 Classification of Water

Water in the study area comprising of Jammu and Kathua district was classified based on Piper Trilinear classification (Piper, 1944; 1953) and U.S. Salinity Laboratory classification (Wilcox, 1955).

5.3.1 Piper Trilinear Classification:

Piper's Trillinear classification (1953) is used to express similarity and dissimilarity in the chemistry of different water samples based on dominant cations and anions. The piper trilinear diagram combines three distinct fields for plotting, two triangular fields at the lower left and lower right respectively, and an intervening diamond shaped field. 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.

Hydrochemical facies can be classified on the basis of the dominant ions in the facies by means of the trilinear 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 results of trilinear diagrams have shown that 47 wells are falling under Ca-Mg-CO_3 - HCO_3, 3 wells under Ca-Mg-Cl-SO_4 , 2 wells under Na-K-CO_3 - HCO_3 and 1 well under Na-K- Cl-SO_4 hydrochemical facies during pre-monsoon period (June, 1995). However, during post monsoon period (Nov., 1995) 43 wells are falling under Ca-Mg-CO_3 - HCO_3, 9 wells under Ca-Mg-Cl-SO_4 and 1 well under Na-K- Cl-SO_4 hydrochemical facies. The results are given in Table-5 and Fig. 14-15.

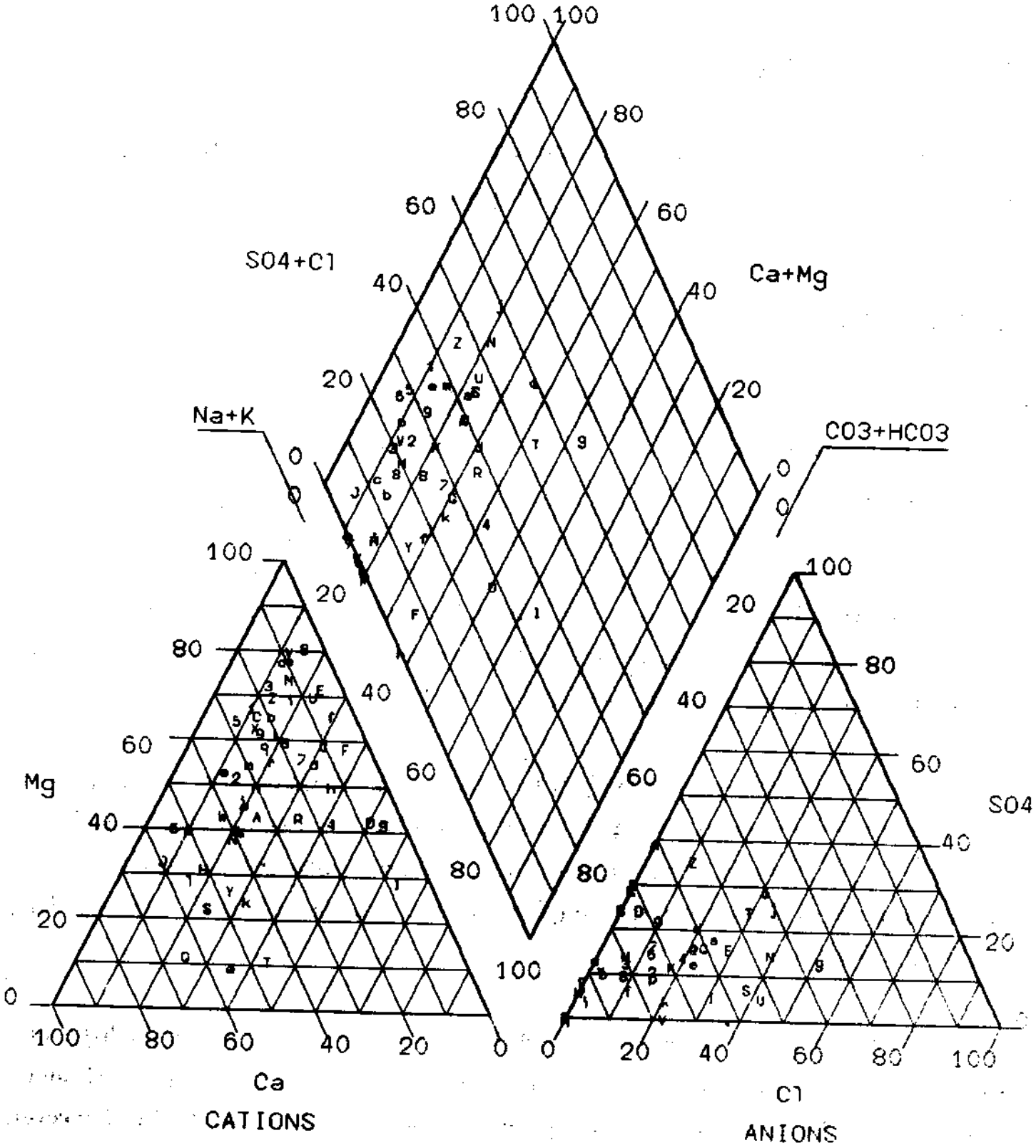


Fig 14. Piper's Trillinear Diagram for Jammu and Kathua Districts (June, 1995)

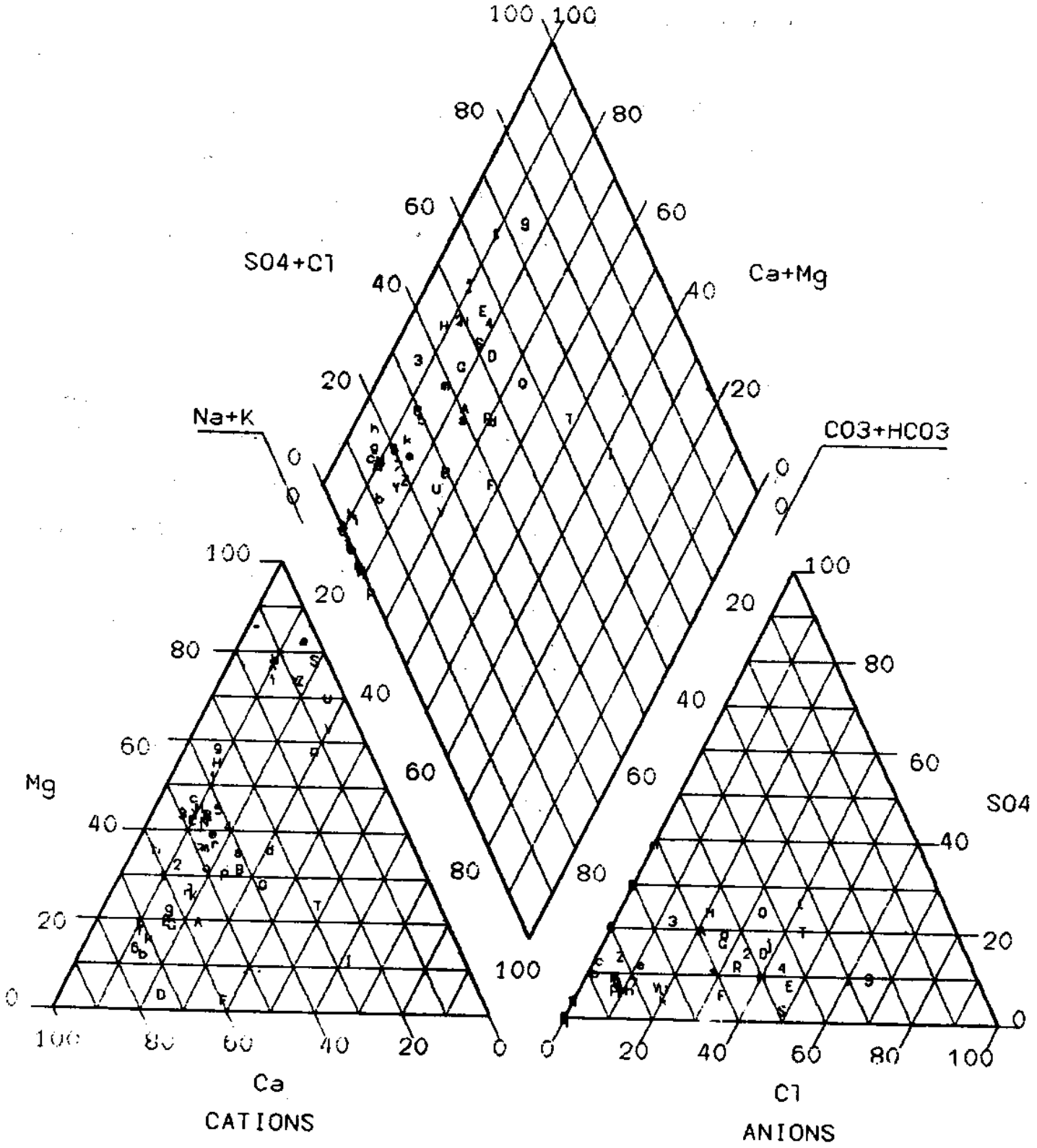


Fig 15. Piper's Trillinear Diagram for Jammu and Kathua Districts (Nov., 1995)

5.3.2 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). A diagram for evaluating suitability of ground water for irrigation purposes, named after Wilcox (1955), is based on Sodium Adsorption Ratio (SAR) and Conductivity of water expressed in micro mhos/cm.

The chemical analysis data were plotted on Wilcox diagram. The results have shown that 43 water samples lie under C3-S1 (high salinity- low SAR), 8 samples under C2-S1 (medium salinity- low SAR) and two samples under C4-S1 (very high salinity- low SAR) during June, 1995. Whereas, results of post monsoon sampling(Nov., 1995) have indicated that 18 water samples lie under C3-S1 (high salinity- low SAR), 33 samples under C2-S1 (medium salinity- low SAR) and one each samples under C4-S1 (very high salinity- low SAR) and C1-S1 (low salinity - low SAR) category on the Wilcox diagram. The results are given in Table-6 & Fig. 16-17.

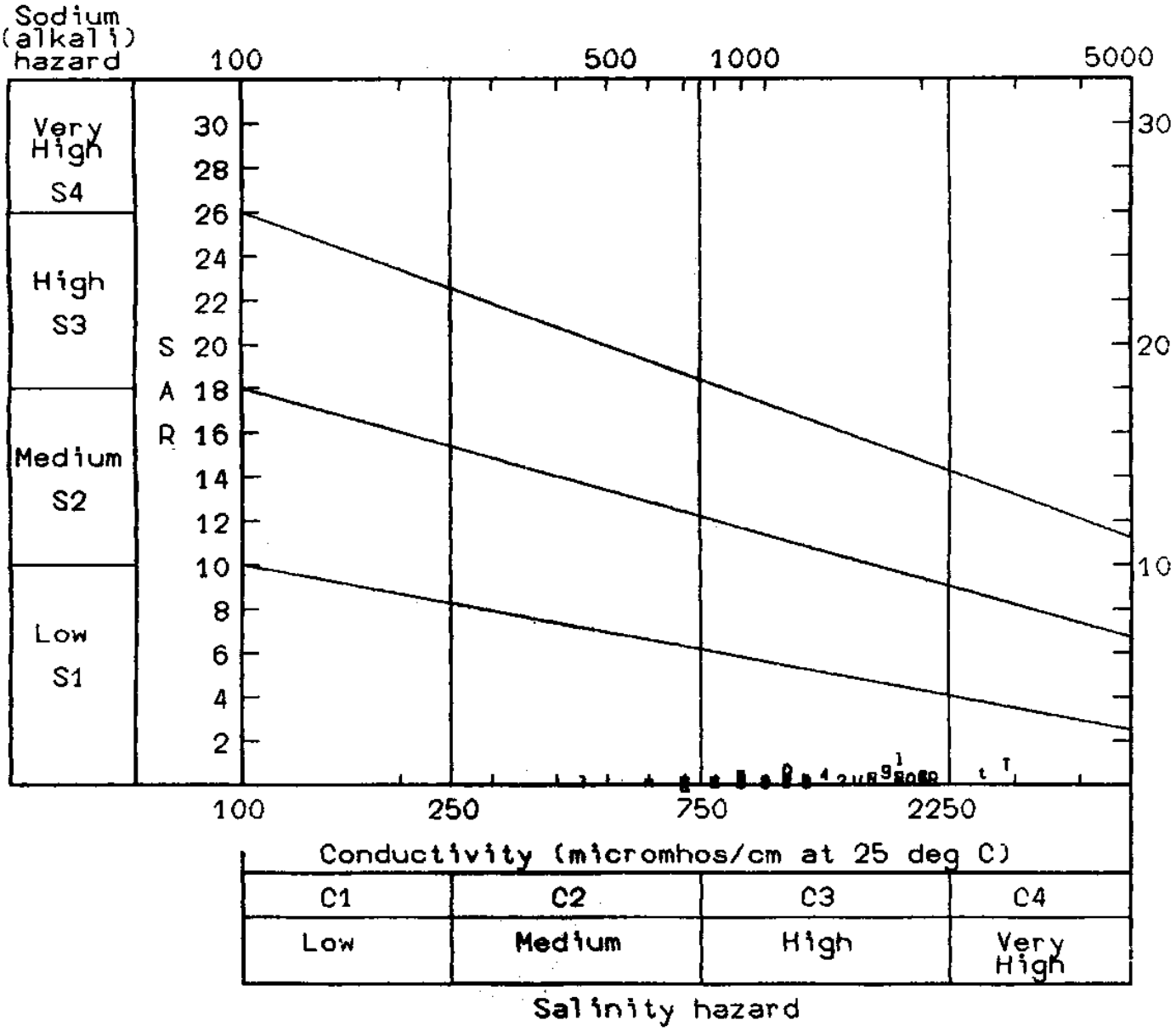


Fig 16. U.S. Salinity Laboratory Classification for Jammu and Kathua Districts (June, 1995)

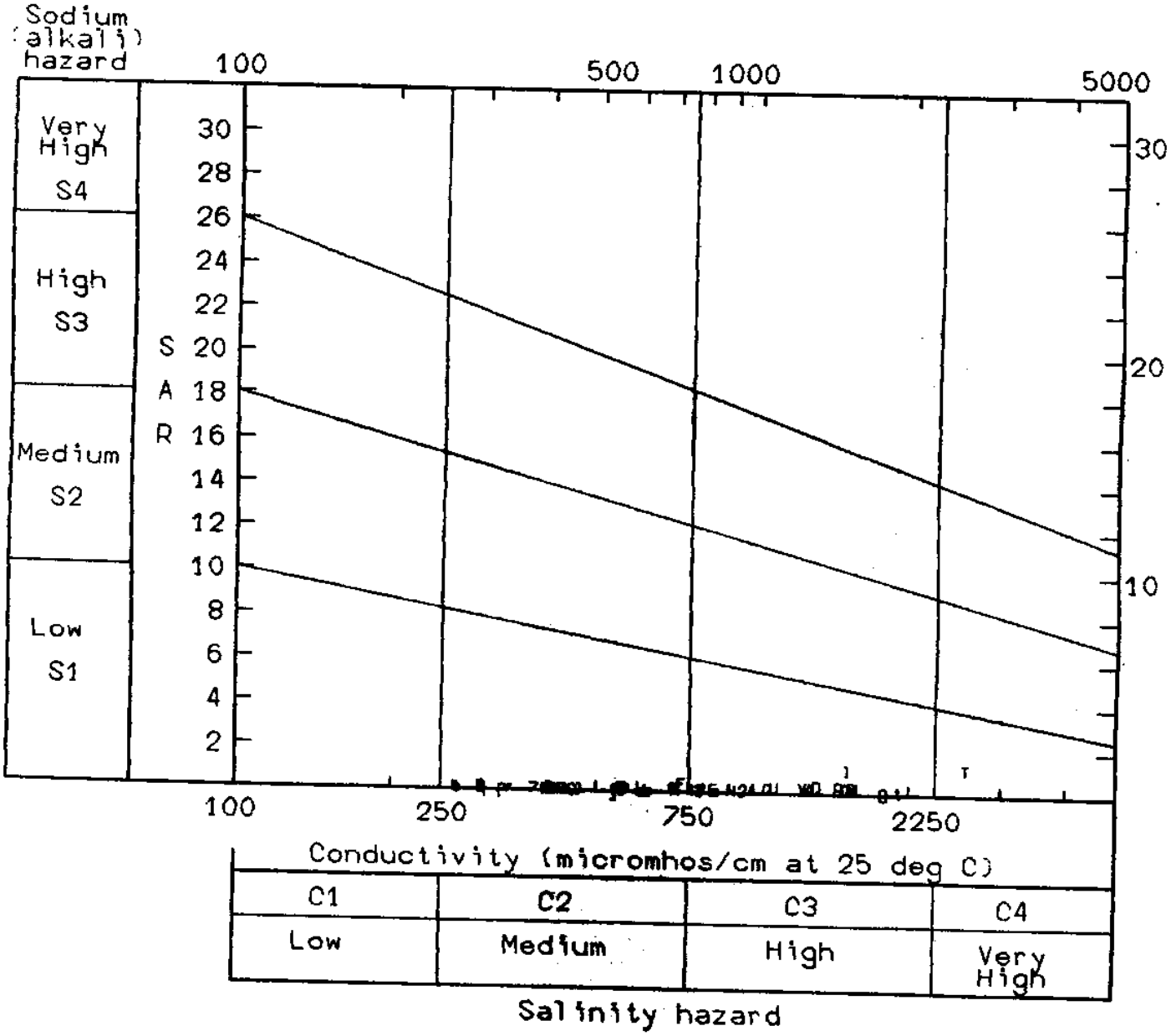


Fig 17. U.S. Salinity Laboratory Classification for Jammu and Kathua Districts (Nov., 1995)

Table 5. Summary of Hydrochemical Facies for Jammu and Kathua Districts (Piper's classification)

Sl. No.	Location	June, 1995	Nov., 1995
1.	Akhnoor	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
2.	Guda	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
3.	Devipur	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
4.	Jourian	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-Cl-SO_4$
5.	Bakore	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
6.	Khour	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
7.	Lam	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
8.	Pangali Colony	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
9.	Palanwalla	$Na-K-Cl-SO_4$	Ca-Mg-Cl-SO4
10.	Seinth	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
11.	Danpur	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
12.	Marjoli	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
13.	Purkhoo	$Na-K-CO_3 - HCO_3$	$Ca-Mg-Cl-SO_4$
14.	Patakhoo	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-Cl-SO_4$
15.	Sugetar	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
16.	Nagrota	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
17.	Chhauni	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
18.	Parli	$Na-K-CO_3 - HCO_3$	$Ca-Mg-Cl-SO_4$
19.	Keinth Pur	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
20.	Bandral	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
21.	Gudwal	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
22.	Raiyan	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
23.	Samba	$Ca-Mg-Cl-SO_4$	$Ca-Mg-CO_3 - HCO_3$
24.	Daboh	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
25.	Salehar	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-Cl-SO_4$
26.	Bishnah	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
27.	Naran	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-Cl-SO_4$
28.	Madun	$Ca-Mg-Cl-SO_4$	$Ca-Mg-Cl-SO_4$
29.	Jandi	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
30.	Hiranagar	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
31.	Khanpur	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
32.	Hariyachak	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
33.	Mukandpur	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
34.	Maharajpur	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
35.	Mahichak	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
36.	Jamral	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
37.	Nagri Parol	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
38.	Khakial	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
39.	Kathua	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
40.	Ramkot	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
41.	Nagrota Gujroo	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
42.	Lakri	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
43.	Mandli	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-Cl-SO_4$
44.	Phinter	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
45.	Billawar	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
46.	Parnala	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
47.	Kootah	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
48.	Nichlah	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
49.	Chanranga	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
50.	Bhogwal	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
51.	Gadiyal	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
52.	Chakra	$Ca-Mg-CO_3 - HCO_3$	$Ca-Mg-CO_3 - HCO_3$
53.	Londi	$Ca-Mg-Cl-SO_4$	$Ca-Mg-Cl-SO_4$

Table 6. U.S. Salinity Laboratory Classification for Jammu & Kathua Districts

Sl. No.	Location	June, 1995	Nov., 1995
1.	Akhnoor	C3-S1	C2-S1
2.	Guda	C3-S1	C3-S1
3.	Devipur	C3-S1	C2-S1
4.	Jourian	C3-S1	C3-S1
5.	Bakore	C3-S1	C2-S1
6.	Khour	C3-S1	C1-S1
7.	Lam	C3-S1	C2-S1
8.	Pangali Colony	C3-S1	C2-S1
9.	Palanwalla	C3-S1	C2-S1
10.	Seinth	C3-S1	C3-S1
11.	Danpur	C3-S1	C2-S1
12.	Marjoli	C3-S1	C2-S1
13.	Purkhoo	C3-S1	C3-S1
14.	Patakhoo	C3-S1	C3-S1
15.	Sugetar	C3-S1	C2-S1
16.	Nagrota	C3-S1	C2-S1
17.	Chhanni	C2-S1	C2-S1
18.	Patli	C3-S1	C3-S1
19.	Keinth Pur	C3-S1	C2-S1
20.	Bandral	C3-S1	C2-S1
21.	Gudwal	C3-S1	C2-S1
22.	Raiyan	C3-S1	C2-S1
23.	Samba	C3-S1	C3-S1
24.	Daboh	C3-S1	C2-S1
25.	Salehar	C3-S1	C3-S1
26.	Bishnah	C3-S1	C3-S1
27.	Naran	C3-S1	C3-S1
28.	Madun	C4-S1	C4-S1
29.	Jandi	C3-S1	C3-S1
30.	Hiranagar	C3-S1	C3-S1
31.	Khanpur	C3-S1	C2-S1
32.	Hariyachak	C3-S1	C2-S1
33.	Mukandpur	C3-S1	C2-S1
34.	Maharajpur	C3-S1	C2-S1
35.	Mahichak	C3-S1	C3-S1
36.	Jamrai	C3-S1	C2-S1
37.	Nagri Parol	C3-S1	C2-S1
38.	Khakial	C3-S1	C3-S1
39.	Kathua	C3-S1	C2-S1
40.	Rankot	C3-S1	C3-S1
41.	Nagrota Gujroo	C3-S1	C3-S1
42.	Lakri	C3-S1	C2-S1
43.	Mandli	C3-S1	C3-S1
44.	Phinter	C2-S1	C2-S1
45.	Billawar	C3-S1	C2-S1
46.	Parnala	C2-S1	C2-S1
47.	Kootah	C3-S1	C2-S1
48.	Nichlah	C2-S1	C2-S1
49.	Chanranga	C2-S1	C2-S1
50.	Bhogwal	C2-S1	C2-S1
51.	Gadiyal	C2-S1	C2-S1
52.	Chakra	C3-S1	C2-S1
53.	Londi	C4-S1	C3-S1

Table 7. Sample Identification for Piper and Wilcox Diagrams for Jammu and Kathua Districts

Label	Seq. No.	Sample Identification
1	1.	Akhnoor
2	2.	Guda
3	3.	Devipur
4	4.	Jourian
5	5.	Bakore
6	6.	Khour
7	7.	Lam
8	8.	Pangali Colony
9	9.	Palanwalla
A	10.	Seinth
B	11.	Danpur
C	12.	Marjoli
D	13.	Purkhoo
E	14.	Patakhoo
F	15.	Sugetar
G	16.	Nagrota
H	17.	Chhanni
I	18.	Patli
J	19.	Keinth Pur
K	20.	Bandral
L	21.	Gudwal
M	22.	Raiyan
N	23.	Samba
P	24.	Daboh
Q	25.	Salehar
R	26.	Bishnah
S	27.	Naran
T	28.	Madun
U	29.	Jandi
V	30.	Hiranagar
W	31.	Khanpur
X	32.	Hariyachak
Y	33.	Mukandpur
Z	34.	Maharajpur
a	35.	Mahichak
b	36.	Jamral
c	37.	Nagri Parol
d	38.	Khakial
e	39.	Kathua
f	40.	Ramkot
g	41.	Nagrota Gujroo
h	42.	Lakri
i	43.	Mandli
j	44.	Phinter
k	45.	Billawar
l	46.	Patnala
m	47.	Kootah
n	48.	Nichlah
p	49.	Chanranga
q	50.	Bhogwal
r	51.	Gadiyal
s	52.	Chakra
t	53.	Londi

5.4 Principal Component Analysis

The principal component analysis (PCA) may be used to find inter-relationship between different variables of the water quality (Melloul and Collin, 1992). In present study an attempt is made to employ principal component analysis (PCA) technique for the ground water quality data obtained during June-July, 1995 for Jammu district.

The statistical analysis was carried out using SYSTAT. The factor analysis includes eight water quality variables (v = 8) obtained from 26 open well locations numbered as 1, 3, 5... (n = 26) during June/July, 1995 in Jammu District. These variables are: calcium, magnesium, sodium, potassium, bicarbonate, sulphate, chloride and nitrate. Once a complete set of data has been collected for all the variables (v) and well sampling sites (n), this can be represented by a data matrix [X] of dimension v*n. At this point, factor analysis is used to transform the data matrix [X] in to a new set of composite variables or principal components. This is done by the resolution of the data matrix [X] . where j = 1, . . . v, represents the columns of the matrix, involving such variables as major ions. Furthermore, I = 1, . . . n represents the rows of the matrix, involving the number of well sampling sites. The output given by this program includes statistical data such as minimum, maximum, mean, median, variance, standard deviation, eigen values and Principal component factors.

The principal components analysis of data can help to find out the influence of specific variables upon the patterns of water quality. The statistical results (minimum, maximum, mean, variance, standard deviation and median) of variables are given in Table-7. The co-variance matrix and results of principal component analysis are given in Tables- 8 & 9 respectively. The results show that first eigen value is 3.698 and explains 46.22 % of the total variance. Whereas, the second and third eigen values are 1.419 and 1.079 that explain 17.733 % and 13.483 % of the total variance respectively. Hence, it may be observed that the first three components contribute 77.436 % of the total variance of the data. The component loading of all eight factors is given in Table-10. It may be observed that the first principal component has high loading on almost all water quality parameters. However, the remaining components have shown decreasing trends of the loading effect.

Table 8 : Statistical Values of Ground Water Quality Variables in Jammu District (June/July, 1995)

	Minimum	Maxium	Mean	Variance	Std Deviation	Median
Ca	0.240	8.720	2.148	3.985	1.996	1.520
Mg	0.720	4.880	2.578	1.033	1.016	2.400
Na	0.350	3.780	1.261	1.008	1.004	0.845
K	0.030	3.840	0.436	0.654	0.808	0.150
HCO_3	0.000	8.850	4.658	5.218	2.284	4.390
SO_4	0.080	2.520	1.050	0.431	0.656	1.020
Cl	0.000	3.050	0.777	0.851	0.923	0.450
NO_3	0.000	0.400	0.097	0.012	0.109	0.060

Table 9: Covariance Matrix of Ground Water Quality Variables in Jammu District (June/July, 1995).

	Ca	Cl	HCO_3	K	Mg	Na	NO_3	SO_4
Ca	3.985							
Cl	0.835	0.851						
HCO_3	1.669	1.500	5.218					
K	0.578	0.322	0.673	0.654				
Mg	-0.447	0.156	0.352	0.026	1.033			
Na	0.760	0.492	0.270	0.395	0.374	1.008		
NO_3	0.104	0.061	0.043	0.047	0.031	0.088	0.012	
SO_4	0.268	0.186	0.185	0.262	0.210	0.345	0.037	0.431

Table 10 : Latent Roots (Eigen Values) and Principal Components of Ground Water Quality Variables in Jammu District (June/ July, 1995).

Factor	Latent roots (eigenvalues)	%of Variation explained	Cumulative % of variation explained
1	3.698	46.220	46.220
2	1.419	17.733	63.953
3	1.079	13.483	77.436
4	0.710	8.870	86.306
5	0.459	5.733	92.039
6	0.355	4.437	96.476
7	0.188	2.356	98.832
8	0.093	1.168	100.00

Table 11 : Component Loadings under Factor Analysis for Ground Water Quality Variables in Jammu District (June/ July, 1995).

Variable	Factors							
	1	2	3	4	5	6	7	8
NO_3	0.858	-0.191	0.219	0.252	-0.123	-0.062	0.288	-0.122
Cl	0.799	0.314	-0.323	0.151	-0.101	-0.306	0.014	0.179
SO_4	0.651	-0.403	0.142	-0.420	0.414	-0.214	-0.013	-0.006
HCO_3	0.525	0.536	-0.613	-0.154	0.067	0.042	-0.045	-0.172
K	0.715	0.088	0.189	-0.529	-0.326	0.231	0.020	0.064
Na	0.816	-0.329	0.178	0.263	-0.147	-0.003	-0.316	-0.061
Mg	0.314	-0.667	-0.587	0.121	0.094	0.284	0.055	0.073
Ca	0.590	0.523	0.344	0.244	0.347	0.275	0.000	0.063

6.0 CONCLUSIONS

The following conclusions were drawn from the present investigations:

(1) The pH values were well within the prescribed limit for drinking purpose (6.5-8.5, Indian Standards).

(2) The EC values at a number of places in Jammu & Kathua districts vary from 750-2250 micro mhos/cm and therefore, the irrigator should ensure good drainage conditions in the study area while irrigating the fields with the present quality of water.

(3) The TDS values exceeded the allowable limit of total solids (1500 mg/l, WHO) for drinking purposes at few places in Jammu district. However, the TDS values for Kathua district were within allowable limit.

(4) The concentration of calcium was relatively higher in the study area. The concentration of bicarbonate was also much higher than other anions in the study area.

(5) The concentration of calcium exceeded the acceptable limit at many places in Jammu district. However, the magnesium concentration was within the acceptable limit for drinking water at a maximum number of wells in this district.

(6) The concentration of calcium and magnesium was within acceptable limit at many places in Kathua district except at few wells.

(7) The chloride concentration exceeded the acceptable limit (200 mg/l, WHO) at few wells in the study area (Jammu & Kathua). However, for none of the wells the concentration was beyond the allowable limit (600 mg/l, WHO).

(8) The concentration of sulphate values was within acceptable limits (400 mg/l, Indian Standards Class-A Water) in the study area except at few wells.

(9) The concentration of nitrate exceeded the acceptable limit (45 mg/l, WHO) in the study area at Pallanwala, Seinth, Londi (Nov.,1995) and Madun (June,1995; Nov.,1995).

(10) The average concentration of phosphate values range from 0.18 to 0.33 mg/l and 0.07 to 0.08 mg/l respectively in the study area under the present investigation.

(11) The concentration. of fluoride was within acceptable limit (1.0-1.7 mg/l, European Drinking Water Standards) in Kathua district. The maximum value of fluoride was 1.5 mg/l in the present investigations.

(12) The average SAR values range from 0.90 to 1.35 and 0.965 to 1.125 for Jammu and Kathua district, respectively under the present investigation. The SAR values were found well within the limit of excellent water in the study area.

(13) The results of Trilinear diagrams have shown that 47 wells are falling under Ca-Mg-CO_3 - HCO_3, 3 wells under Ca-Mg-Cl-SO_4, 2 wells under Na-K-CO_3 - HCO_3 and 1 well under Na-K- Cl-SO_4 hydrochemical facies during pre-monsoon period (June/ July, 1995). However, during post monsoon period (Nov., 1995) 43 wells are falling under Ca-Mg-CO_3 - HCO_3, 9 wells under Ca-Mg-Cl-SO_4 and 1 well under Na-K- Cl-SO_4 hydrochemical facies.

(14) The results of Wilcox diagram have shown that 43 water samples lie under C3-S1 (high salinity- low SAR), 8 samples under C2-S1 (medium salinity- low SAR) and two samples under C4-S1 (very high salinity- low SAR) during June/July, 1995. Whereas, results of post monsoon sampling(Nov., 1995) have indicated that 18 water samples lie under C3-S1 (high salinity- low SAR), 33 samples under C2-S1 (medium salinity- low SAR) and one each samples under C4-S1 (very high salinity- low SAR) and C1-S1 (low salinity - low SAR) category on the Wilcox diagram.

(15) From the factor analysis, it could be concluded that first three components contribute more than 77 % of the total variance of the data. It may be observed that the first principal component has high loading on almost all water quality parameters. However, the remaining components have shown decreasing trends of the loading effect.

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