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GROUND WATER QUALITY MONITORING AND EVALUATION IN DISTRICT JAMMU (J & K)

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PREFACE

In recent years, an increasing threat of ground water pollution due to human activities has become of great importance. The adverse effects on ground water quality are the results of man's activity at ground surface, unintentionally by agriculture, domestic and industrial wastes, unexpectedly by sub-surface or surface disposal of sewage and industrial waste and by solid dumps. Therefore, determination of ground water quality is important from the point of view to see the suitability of water for a particular use, e.g., public water supply, irrigation, industrial applications, fish culture and power generation etc.

In view of aggravation of ground water pollution problems in the country, it was envisaged to study the quality of ground water of Jammu district in J & K state.

Under the project area interaction with regional centres, Environmental Hydrology Division at the Head Quarter at Roorkee proposed to take up the study on "Ground water Quality Monitoring and Evaluation in District Jammu (J & K)". The study has been carried out jointly by Environmental Hydrology Division, NIH, Roorkee and Western Himalayan Regional Centre, Jammu.

The report has been prepared by Dr. C. K. Jain, Sc. 'C', Sri Omkar, Sc. 'B' and Sri. M. K. Sharma, SPA under the work programme of 1994-95.

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ABSTRACT

The detailed investigations of the chemical quality of ground water in district Jammu (J & K) has been carried out to see 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 forty seven water samples collected from open wells covering district Jammu. Various parameters, viz., pH, conductance, total dissolved solids, 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 different uses. The higher values of certain parameters at certain locations indicate the contamination in ground water and make the water unsuitable for specific applications. The values of sodium adsorption ratio indicate that majority of samples falls under the category of low to sodium hazards.

The ground water of the area 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 medium SAR). It is recommended that any water source must be thoroughly analysed and studied before being used for domestic applications and proper water management strategies should be adopted for agricultural and other developmental activities.

1.0 INTRODUCTION

1.1 General

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 large number of villages in our country, where we do not have adequate and safe drinking water supply inspite of spectacular advances made in various scientific and technological fields. It has been estimated that out of the average annual precipitation of 400 million hectare meter in the country, about 215 million hectare meter is soaked into the ground which eventually joins the aquifers. The use of ground water is 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.

On the other hand, the excessive use of fertilizers, pesticides and insecticides in agriculture activities adversely affect ground water quality. Constant pressure on the agriculture land and conversion of vegetative land to fertile land 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.

1.2 Status of Ground Water Pollution

As a result of rapid urbanisation and industrialisation in several parts of the country, there has been several fold increase in generation of wastewater. For most of the cities and towns, domestic sewage is being discharged without proper treatment into the rivers or land for irrigation. In case of industrial units, effluents without adequate treatment are discharged on land near the factories in many cases or through unlined channels to low lying depressions resulting in percolation and eventually pollution of ground water. In India, ground water pollution of all the three categories, viz., point, line and diffuse, is taking place. Wastes from municipal sources such as sewage effluents and sludge cause point, line and diffuse pollution whereas industrial effluent cause point pollution mostly and when discharged on land may also cause line and diffuse pollution of ground water. Agricultural activities such as irrigation return flow, excessive use of fertilizers and soil amendments, pesticides and herbicides are conducive to diffuse pollution of ground water.

Municipal Wastes of most of the cities and towns without proper treatment are discharged into the nearest available water course. In case water course is not available, sewage effluents are discharged on waste land or these sewage effluents are passed through unlined channels to nearby fields where farmers use it for irrigation purposes. In either case, sewage effluents find their way into ground water system which eventually results in ground water pollution.

Ground water pollution from discharge of untreated or inadequately treated industrial effluents has reached alarming proportion in several parts of the country. Most of the industries pass the effluents without proper treatment into unlined channels resulting in accumulation of wastewater near the factories or depressions leading to percolation of industrial wastes into the ground water system. Some of the cases where ground water has been severally effected due to industrial pollution include, i) High levels of cyanide to the extent of 2.0 mg/L have been found in ground water in several areas of Ludhiana town in Punjab, ii) High concentrations of chromium have been found in Ground water from Ludhiana (Punjab), Faridabad (Haryana), Kanpur (U.P.), Varanasi (U.P.), iii) Ground water in Pali (Rajasthan) and Jetpur (Gujarat) has become highly colored due to seepage of effluents from textile dye industries, iv) The colored water is obtained through pumping near a distillery site in Jalandhar (Punjab) due to percolation of effluent into the saturated zone, v) High levels of nickel and zinc have been found in ground water near Khetri mines (Rajasthan) and in part of Udaipur (Rajasthan) respectively, vi) Cadmium concentration at some places in Kanpur and Delhi have been observed to be in high concentration, vii) Ground water pollution in Warangal (A.P.) have been reported by Naram (1981) due to discharge of untreated tannery and textile wastes, viii) Tanneries located along the palar river in Tamil Nadu discharge their untreated effluents containing both organic and inorganic matter, resulting pollution of ground water (Krishnaswamy, 1981), ix) Neutral to slightly alkaline nature of ground water have been found in parts of upper catchment of Betwa river basin in central India (Das and Kidwai, 1981), x) The waste discharge from the big and small industries of Kota (Rajasthan) is resulting in increasing pollution of Chambal river which is further manifested in the deteriorating quality of the well waters on either flank of the river. The extensive use of fertilizers and pesticides in the Commond Area of Chambal irrigation system has caused further deterioration of the chemical quality of the adjoining ground water due to leaching and return flows (Kachwaha, 1981).

Fertilizers are applied for almost all crops and vary with crop type, soil conditions and irrigation practices. The use of nitrogen, phosphate and potassium fertilizers has increased from 45, 19, 8 thousand tones in 1950-51 to 4734, 1356, 754 thousand tones in 1981-82 respectively. This is further going to increase with projected values of 9883 and 2558 thousand tones in 1990 for nitrogen and phosphate respectively. Studies conducted by Central Ground Water Board and other agencies have revealed that there are high levels of nitrate in ground water to the extent of several hundred mg/L in parts of southern Punjab, Southern Haryana, Rajasthan, U.P., Maharastra, A.P. and several other states. In southern and south-western Haryana, nitrate levels exceeding 500 mg/L at shallow depths have been observed at several places (Kakar, 1981). High levels of potassium and phosphate have also been reported in ground water from several places in Punjab, Haryana and Uttar Pradesh.

Apart from ground water 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. Ground water is moderately to highly saline in several parts of Rajasthan, Gujarat, Punjab, Haryana, Delhi and many other areas. Fluoride concentrations in ground water are high in several parts of the country particularly in semiarid and arid tracts. In parts of Rajasthan, Southern Punjab, Haryana, U.P., Gujarat, 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 Gujarat, the fluoride concentration has been found to be 19 mg/L (Raghava Rao, 1977). High concentrations of iron in ground water have been reported from several areas, particularly West Bengal, North Eastern states and Kerala.

1.3 Scope of the Study

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 farm fields, or it can be caused by point source such as septic tanks, garbage disposal sites, oil spills or other accidental entry of pollutants into the under ground environment. A third possibility is contamination by line sources of poor quality water, like seepage from polluted streams.

Ground water quality problems can be understood only by regular monitoring of quality of water. Therefore, it has been proposed to take up monitoring work in district Jammu (J & K). Samples from 47 wells were collected during August 1994, December 1994 and March 1995 and analysed for various physical and chemical parameters.

The study was aimed at (i) to evaluate the suitability of ground water for various uses, (ii) to monitor seasonal variation in the ground water quality, (iii) to delineate the contaminated zones for irrigation and drinking purposes, if any and (iv) possible sources of pollution.

2.0 SOURCES OF GROUND WATER CONTAMINATION

There are many sources that contribute contaminants to the ground water. The major sources include -

a) Land disposal of solid wastes,
b) Sewage disposal on land,
c) Agricultural activities,
d) Petroleum leakage and spills,
e) Deep well disposal of liquid wastes, and
f) Urban runoff and polluted surface water.

The brief description of these sources are as follows:

2.1 Land Disposal of Solid Wastes

Solid waste is generally disposed in land fills where it decomposes and produces a leachate that can contaminate underlying ground water. Landfill range from unmanaged dumps where refuse is piled up with little or no regard for environmental effects, to carefully designed and operated "Sanitary" landfills.

The amount of leachate produced in a landfill depends on the amount and distribution of rainfall, hydraulic conductivity of soil, evaporation from cover soil and freezing and thawing. If the soil below the fill is relatively impermeable, percolation of leachate to underlying ground water is retarded. The chemical composition of landfill leachate depends on the nature of the refuse, on the leaching rate and on the age of the fill.

The hardness of leachate and contaminated ground water is mainly due to the dissolution of calcium and magnesium compounds by CO_2 (which forms carbonic acid) produced by the decomposition of the refuse. The type of leachate produced depends upon the type of refuse.

2.2 Sewage Disposal on Land

Sewage enters the ground intentionally from septic tanks, cesspools and systems where sewage is applied to land for crop irrigation, ground water recharge or simple disposal. Unintentional entry of sewage into the underground environment include leakage from sewers, sewage lagoons and from streams or dry washes in which sewage effluent is discharged.

The capability of soil to remove suspended and dissolved constituents from sewage is utilized in land treatment systems, where sewage is applied to land with sprinklers, irrigation furrows or borders or infiltration basins.

2.3 Agricultural Activities

Modern agriculture is based on extensive use of fertilizers and pesticides to obtain high crop yield. Some of the chemicals applied to farm land, however, move down with the deep percolating water from the root zone and can contaminate underlying ground water. Manure piles, feedlots and similar concentrations of animal waste are other possible sources of ground water contamination. Deep percolation water from irrigation fields in arid region tends to have high salt content, which adversely affects underlying ground water. In humid areas the major contaminant is nitrate, whereas TDS and NO_3 are of most concern in arid irrigated areas.

2.4 Petroleum Leakage and Spills

Gasoline and other petroleum products can enter soils and aquifers from leaking pipelines or storage tanks and from accidents involving tank trucks or rail road cars. Most ground water contamination cases are caused by underground tanks from gasoline stations. The main problem of petroleum contamination of ground water is taste.

2.5 Deep Well Disposal of Liquid Wastes

Injection of liquid wastes, mainly of industrial origin, has been widely adopted as a waste disposal practice. The purpose of this procedure is to isolate hazardous substances from the biosphere. As the discharge of pollutants to rivers and lakes has become increasingly objectionable, and as legislation for protection of surface water resources have become more stringent, the use of deep permeable zones for liquid waste disposal has become an increasingly attractive waste management option for many industries.

Deep injection of liquid wastes causes a point source of ground water pollution and contaminate the deeper aquifers, otherwise safe from pollution. Due to deep injection, the pollutants traverse in relatively thin column of soil and also the time lag between the pollution discharge and arrival of pollutants to ground water is reduced.

2.6 Urban Runoff and Polluted Surface Water

Many streams receive municipal and industrial waste water. Seepage of such water into underlying ground water may adversely affect ground water quality. Urban runoff may infiltrate directly into the ground through pavements after it has reached a stream, or via recharge pits or "dry wells" constructed for disposal of storm runoff.

3.0 STUDY AREA

The present study has been carried out for Jammu district in J & K state, India. The geographical area of the district is 3233.8 Sq. Km. Jammu is the district head quarter as well as capital of the state during winter season. The district is divided into four tehsils, viz., Jammu, Samba, Ranbir Singh Pura (R. S. Pura) and Akhnoor. The water sampling was done from 47 wells covering district Jammu (Fig. 1).

Jammu has always been an important place since ancient time. It is the gateway of J & K state as it lies on the nearest rail head. Jammu is also connected with National Highway from Pathankot to Uri. It is also the important place for pilgrims and tourists. There are large number of different kinds of industries in the state.

3.1 Physiography, Relief and Drainage

The area comprises of flat land to small hills. The tehsils of Jammu, Samba and Akhnoor are adjourned to the lower Siwaliks and varies from flat to partly hilly. The land of R. S. Pura tehsil is mostly flat in topography. The altitudes in the area varies considerably from one well to another. The reduced levels (R.L.) of open wells above msl at measuring point in Jammu (Satwari), R. S. Pura, Samba and Akhnoor are 291.15, 273.68, 356.80 and 314.78 m respectively.

The major natural drainage systems in the area are Chenab, Tawi, Basantar and Aik rivers/nalla. The Chenab river is a perennial and snow fed originating from a vast watershed of Himachal Pradesh which leaves the Himalayas at Akhnoor (J & K), 290 km below Kishtwar and 640 km from the source. The river Tawi flows through middle of Jammu city. The river tawi falls into chenab about 16 km to the west of Jammu city.

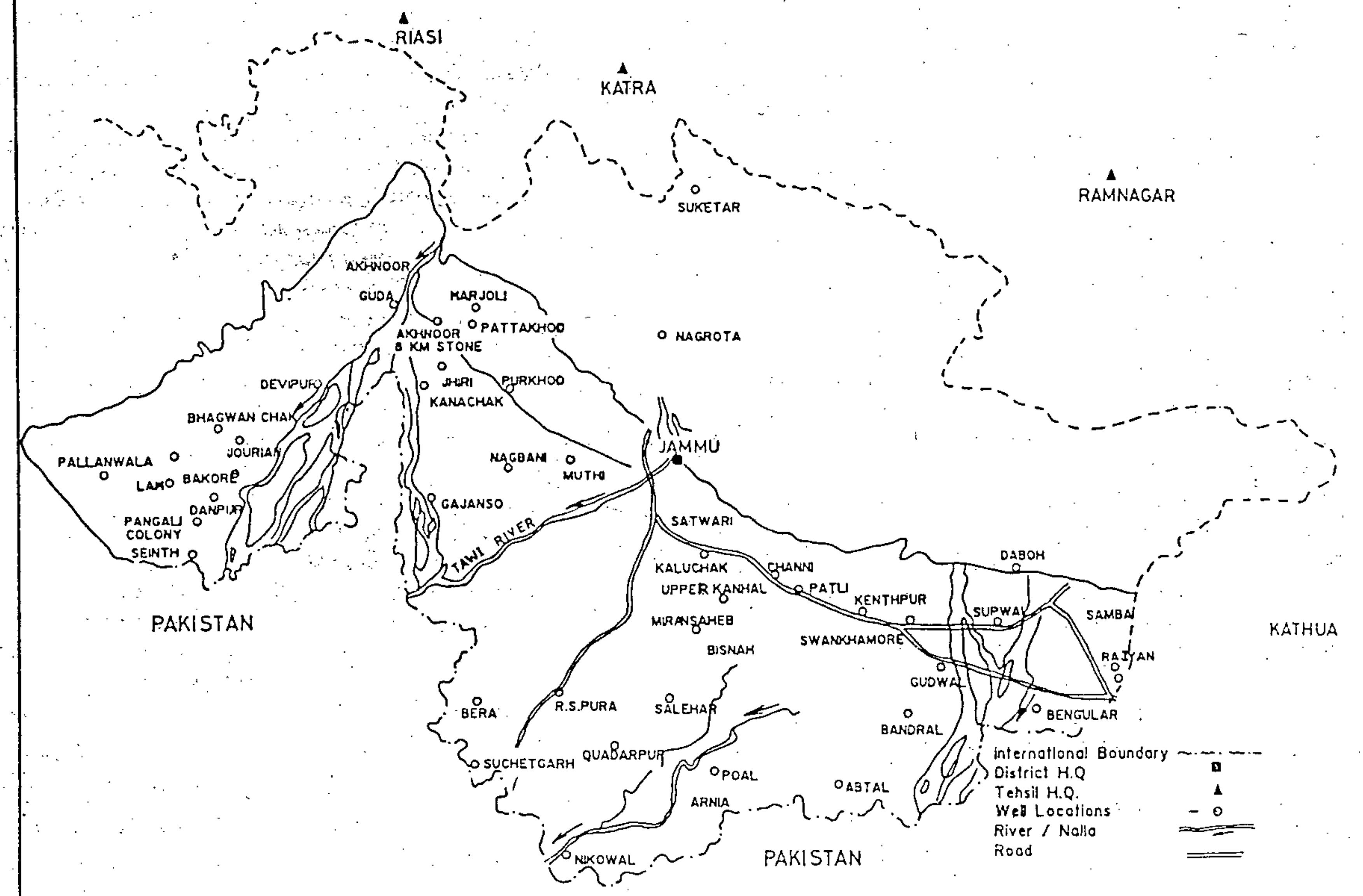

Fig. 1 Map of Ground Water Sampling Sites In Jammu Distt.

3.2 Climate and Rainfall

The climate of the area is of subtropical type, characterised by three well defined seasons, viz., winter, summer and Monsoon. The monsoon sets in by the beginning of July and continues till September. The normal rainfall recorded at Jammu Meteorological station is 108.94 cm. 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 minimum temperature was recorded to be 2.4° C during 1984.

3.3 Geology

The Karewa (alluvial) and tertiary groups of geological structures are present in the area. The major portion of the study area is dominated by Karewa (alluvial) group and is present all along the foot of the mountains. This is chiefly formed of alluvial of lacustrine materials. They belong to pre-historic and pleistocene age. However, the area adjacent to the Siwalik zone is composed of tertiary sand stones and shales known as Siwalik group. It consist of mostly lime stone, compact quartzite, calcareous slate or shale. These are believed to be of carboniferous age.

3.4 Soils

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. The plains of Jammu district are of alluvial nature. The soil survey organisation, Department of Agriculture, Jammu has classified soils of R. S. Pura tehsil as: a) Langotian soil, b) Bansultan soil and (c) Kotli soil.

The soils of langotian series are deep to very deep soils varying in colour from light yellow to dark brown and grayish brown. Soils are having silty loam to silty clay loam texture in the lower layers, the texture varies between silty clay loam to silty clay. The main characteristics of these soils are that iron concentrations are found in the lower layers and calcium carbonate is totally absent. The permeability within the profile is slow.

The soils of Bansultan series are deep to very deep soils with dark brown to dark yellowish brown colour. The texture of the soil varies between sandy loam to silt loam. These are well drained soils with moderate permeability. The soil do not have any concretions of lime or iron and there is no effervescence with dilute hydrochloric acid in any layer in the sub soil and showing that calcium in diffused form is absent.

The soils of Kotli series are very deep, medium to heavy textured having impeded drainage permeability within the profile is moderately slow to moderate. The texture varies from silty clay loam to silty clay. These soils are derived from old and recent alluvium and are characterised by the presence of concretes of lime and give violent effervescence with dilute hydrochloric acid.

4.0 METHODOLOGY

4.1 Sampling and Preservation

In the present study 47 ground water samples were collected from open wells covering Jammu district in J & K state for evaluating the quality of the ground water of the area. Sampling was carried out in the months of August 1994, December 1994 and March 1995. 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 conductance 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 Water Quality Parameters

During the present study the chemical properties and the constituents of water analysed are pH, conductance, alkalinity, hardness, chloride, sulphate, sodium, potassium, calcium and magnesium. The significance of these parameters have been described earlier by Jain and Bhatia (1987).

4.3 Analytical Methods

Physico-chemical analysis of water samples 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 kits.

Chloride was determined by argentometric method in the form of silver chloride. Alkalinity was determined by titrimetric method using phenolphthalein and methyl orange indicators. Sulphate was determined by gravimetric method. Nitrogen in the form of nitrate was determined by using UV-VIS spectrophotometer.

The total hardness and calcium hardness was determined by EDTA titrimetric method while magnesium hardness determined by deducting calcium hardness from total hardness. Sodium and potassium were determined by flame emission method using flame photometer.

The summary of analytical methods and equipment used for various parameters is given in Table 1.

Table 1. Summary of Analytical Methods and Equipment Used

Parameter	Analytical method	Equipment used
pH	Electrometric	Portable pH meter
Conductivity	Whetstone bridge	Portable kit
TDS	-	Portable kit
Alkalinity	Titrimetric	-
Hardness	Titrimetric	-
Chloride	Silver nitrate	-
Sulphate	Gravimetric	-
Sodium	Flame emission	Flame Photometer
Potassium	Flame emission	Flame Photometer
Calcium	Titrimetric	-
Magnesium	Titrimetric	-

5.0 RESULTS AND DISCUSSION

In the present study, ground water quality variation at different places (Fig. 1), covering Jammu district in J & K state, have been evaluated during 1994-95 with reference to the suitability of water for various uses. Sampling was carried in the months of August 1994, December 1994 and March 1995. Forty seven samples were collected from different open wells, which are uniformly distributed all over the study area. The samples were analysed for major ions like sodium, potassium, calcium, magnesium, chloride, sulphate, alkalinity, total dissolved solids, pH and conductance. The mean and range of concentrations of chemical constituents of ground water samples are presented in Tables 2-4.

5.1 Water Quality Evaluation for Domestic Purpose

On the domestic front, water is required for drinking, cooking, washing and bathing. The toxicity is due to excessive total dissolved solids, chloride, sulfate, nitrate, sodium, potassium, calcium and magnesium etc. The level of concentration and the toxicity caused by these constituent is discussed below.

pH : 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 lies in the range 6.3 to 8.6 (Tables 2-4), which is well within the limits prescribed by WHO and BIS for domestic applications. The pH value of most of the ground water samples in the study area indicate alkaline nature of the ground water.

Conductance : 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 400 to 1435 μS/cm during August 1994 (Table 2), 455 to 4481 μS/cm during December 1994 (Table 3) and 467 to 3159 μS/cm during March 1995 (Table 4) with wide range of fluctuations at different locations.

Alkalinity : The presence of carbonates, bicarbonates and hydroxides is the most common cause of alkalinity in natural waters. 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 92 to 334 mg/L during August 1994 (Table 2), 152 to 808 mg/L during December 1994 (Table 4) and 136 to 672 mg/L during March 1995 (Table 4).

Total Dissolved Solids : Total dissolved solids (TDS) indicate the general nature of water quality or salinity. Water containing more than 500 mg/L of TDS in not considered desirable for drinking water supplies, though more highly mineralised water is also used where better water in not available. For this reason, 500 mg/L as the desirable limit and 1500 mg/L as the maximum permissible limit has been suggested for drinking water. The TDS value in the ground water of Jammu district ranges from 258 to 911 mg/L during August 1994 (Table 2), 295 to 2875 mg/L during December 1994 (Table 3) and 290 to 2035 during March 1995 (Table 4), with most of the samples having TDS values within the prescribed limit for domestic applications. The higher values of TDS (> 1500 mg/L) observed at village Suchetgarh and Arnia make the water unsuitable for a number of domestic applications.

Sodium : Sodium concentration more than 50 mg/L makes the water unsuitable for domestic use. The sodium concentration in the ground water from Jammu region varies between 4 to 110 mg/L during August 1994 (Table 2), 3 to 350 during December 1994 (Table 3) and between 6 to 275 during March 1995 (Table 4). The high value of sodium than the prescribed limit of 50 mg/L is observed at village Patli, Bangular, Suchetgarh, R. S. Pura, Nikawal, Arnia, Kalachak and Gajansoo, making the water unsuitable for domestic applications. The maximum value of sodium was observed at village Bengular.

Calcium, Magnesium and Total Hardness : Calcium, magnesium and total hardness in the water are inter-related and hence combined in the description. The upper limits for calcium and magnesium for drinking water and domestic use are 75 and 30 mg/L respectively (BIS, 1983). In ground water of the area under study, calcium and magnesium ranges from 39 to 297 and from 1 to 87 mg/L respectively during August 1994 (Table 2), 37 to 279 and 1 to 102 mg/L respectively during December 1994 (Table 3) and 10 to 359 and 1 to 78 during March 1995. Toxicity due to these ions are shown at many places in the study area, particularly at village Swankhamore, Samba, Daboh, Satwari, Bera, Suchetgarh, R.S. Pura, Quadarpur, Salehar, Arnia, Poal, Nagrota, Kanachak, Jhiri, Pattakhoo, Guda, Devipur and Jourian.

Calcium and magnesium along with their carbonates, sulfates and chlorides makes the water hard, both temporarily and permanent. A limit of 300 mg/L has been recommended for potable waters (BIS, 1983). The ground water in the area contains these ions in quite high concentrations. The total hardness as $CaCO_3$ ranges between 154 to 740 mg/L during August 1994 (Table 2), 168 to 916 during December 1994 (Table 3) and between 152 to 980 mg/L during March 1995 (Table 4). From the hardness point of view, the ground water at village Abtal, Bengular, Suchetgarh, R.S. Pura, Salehar, Arnia, Bisnah, Nagrota, Gajansoo, Kalachak, Guda, Devipur and Seinth shows higher values and not suitable for domestic applications. The maximum value of hardness was observed at village Arnia.

Chloride : Limits to chloride content have been laid down primarily from taste considerations. A limit of 250 mg/L chloride has been recommended for drinking water supplies (BIS, 1983; WHO, 1984). However, no adverse health effects on humans have been reported from intake of waters containing even higher content of chloride. A concentration of more than 250 mg/L of chloride makes the water unsuitable for a number of domestic applications. The chloride content in the study area ranges from 4 to 340 mg/L during

August 1994 (Table 2), 1 to 520 mg/L during December 1994 (Table 3) and from 1 to 448 mg/L during March 1995 (Table 4). The maximum value of chloride concentration were observed at village Suchetgarh and Arnia.

Sulfate : A limit of 150 mg/L has been suggested for drinking water supplies (BIS, 1983). Sulfate content more than 150 mg/L is objectionable for many domestic purposes. Water containing more than 500 ppm sulfate tastes bitter and beyond 1000 ppm, it has purgative effect. The sulfate content in the water of Jammu region lies well below the permissible limits for domestic applications except at village Suchetgarh, Arnia and Gajansoo.

5.2 Water Quality Evaluation for Irrigation Purpose

Irrigation water quality refers to its suitability for agricultural use. A good quality water has the potential to cause maximum yield under good soil and water management practices. However, the quality of irrigation water depends primarily on its silt and salt content. The usefulness of water for irrigation is mainly evaluated based on the following criteria :

Total Concentration of Soluble Salts (TDS) : Water used for irrigation always contains measurable quantities of dissolved substances which, as a general collective term, are called salts. They include relatively small but important amounts of dissolved solids originating from dissolution or weathering of the rocks and soils and dissolving of lime, gypsum and other salt sources as water passes over or percolates through them. The salts present in the water, besides affecting the growth of the plants directly, also affect the soil structure, permeability and aeration, which indirectly affect the plant growth. The total concentration of soluble salts in irrigation water can thus be expressed for the purpose of classification of irrigation water as follows:

Zone	TDS (mg/L)	E.C. (μS/cm)
Low Salinity Zone	< 200	< 250
Medium Salinity Zone	200-500	250-750
High Salinity Zone	500-1500	750-2250
Very High Salinity Zone	1500-3000	2250-5000

In the study area the TDS value varies from 258 to 911 mg/L during August 1994 (Table 2), 295 to 2875 mg/L during December 1994 (Table 3) and from 290 to 2035 mg/L during March 1995 (Table 4). Majority of the samples of the study area falls under medium to high salinity zone. Water falling under high salinity zone should not be used on soils with restricted drainage. Special management for salinity control may be required and plants with good salt tolerance should be selected. Few samples of the study area also falls under very high salinity zone, such waters are not suitable for irrigation under ordinary conditions.

Relative Proportion of Sodium to Other Cations (SAR):

While a high salt concentration in water leads to formation of a saline soil, a high sodium leads to development of an alkali soil. The sodium or alkali hazard in the use of a water for irrigation is determined by the absolute and relative concentration 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. There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil. 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 water 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. A low SAR (2 to 10) indicate little danger from sodium; medium hazards are between 7 and 18, high hazards between 11 and 26, and very high hazards above that. The lower the ionic strength of the solution, the greater the sodium hazard for a given SAR.

The value of SAR in the ground water samples of the study area ranges from 0.130 to 2.258 during August 1994, 0.187 to 6.146 during December 1994 and from 0.182 to 5.871 during March 1995 (Table 5). As evident from Table 5, the ground water of the study area falls under the category of low sodium hazards, which reveals that water can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. Medium sodium water presents an appreciable sodium hazard in fine textured soils having good cation exchange capacity, especially under low leaching conditions. This water may be used on coarse-textural or organic soils with good permeability. High sodium water may produce harmful levels of exchangeable sodium in most soils and will require special soil management like good drainage, high leaching and organic matter additions.

5.3 Classification of Waters

In classification of irrigation waters, it is assumed that the water will be used under average conditions with respect to soil texture, infiltration rate, drainage, quantity of water used, climate and salt tolerance of crop. Different accepted and widely used graphical methods such as Stiff diagram, Piper trilinear diagram and Wilcox diagram are being used for classification of water. In the present investigations the ground water of the study area has been classified using Piper classification (1953) and U.S Salinity Laboratory Classification (Wilcox, 1955).

Piper classification (1953) is used to express similarity and dissimilarity in the chemistry of different water samples based on the dominant cations and anions. U.S Salinity Laboratory Classification (Wilcox, 1955) is used to study the suitability of ground water for irrigation purposes. The results of all the aforesaid classifications are discussed in the following pages and compiled in Tables 6 - 8.

Piper Trilinear Classification : Piper (1953) developed a form of trilinear diagram which is an effective tool in segregating analysis data with respect to sources of the dissolved constituents in ground water, modifications in the character of a water as it passes through an area, and related geochemical problems. For the Piper trilinear diagram, ground water is treated substantially as though it contained three cation constituents (Mg, Na+K and Ca) and three anion constituents (Cl, SO_4 and HCO_3). The diagram presents graphically a group of analysis on the same plot.

The diagram combines three distinct fields of plotting two triangular fields at the lower left and lower right respectively and an intervening diamond-shaped field. All three fields have scales reading in 100 parts. In the triangular field at the lower left, the percentage reacting values of the three cation groups (Ca, Mg, Na) are plotted as a single point according to conventional trilinear coordinates. The three anion groups (HCO_3, SO_4, Cl) are plotted likewise in the triangular field at the lower right. Thus, two points on the diagram, one in each of the two triangular fields, indicate the relative concentrations of the several dissolved constituents of a ground water. The central diamond-shaped field is used to show the overall chemical character of the water by a third single-point plotting, which is at the intersection of rays projected from the plottings of cations and anions. The position of this plotting indicates the relative composition of a ground water in terms of the cation-anion pairs that correspond to the four vertices of the field. The three trilinear plottings will show the essential chemical character of a ground water according to the relative concentrations of its constituents.

The chemical analysis data of all the forty seven samples have been plotted on trilinear diagram for the three sets of data (Fig. 2 - 4) and results are summarized in Table 6 - 8. The cation plots in the diagram reveals that, majority of the samples falls in calcium type followed by no dominant type. The anion plots in the diagram indicate that the samples fall in bicarbonate type followed by no dominant type. These two trilinear plots indicate that the ground water of the study area are of calcium, bicarbonate and no dominant types.

The Piper trilinear diagram combines three different areas for plotting, two triangle areas (cation and anion) and an intervening diamond shaped area (combined field). Using this diagram waters can be classified into four different hydrochemical facies. Majority of the samples of the study area falls in Ca - Mg - CO_3 - HCO_3 facies.

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 absorption ratio (SAR).

A diagram for use in studying the suitability of ground water for irrigation purposes, named after Wilcox (1955), is based on the sodium adsorption ratio (SAR) and conductivity of water expressed in $\mu S/cm$.

The chemical analysis data of all the forty seven samples have been plotted on Wilcox diagram for the three sets of data (Fig. 5 - 7) and the results of the same have been summarized in Table 6 - 8. It is evident from Table 6 that during August 1994, out of the forty seven samples analysed, thirty one samples were found to be of C2-S1 type (medium salinity and low SAR) which is suitable for irrigation purposes, sixteen samples were found to be of C3-S1 type (high salinity and low SAR), which is also fit for irrigation purpose in general, but may cause some problem where the soil permeability is very poor.

During December survey, majority of samples fall under C1-S1 type (low salinity and low SAR) followed by C2-S1 type (medium salinity and low SAR). Few samples also fall under C3-S1 (high salinity and low SAR), C4-S1 type (very high salinity and low SAR) and C4-S2 type (very high salinity and medium SAR).

Dring March 1995, majority of samples fall under C3-S1 type (low salinity and low SAR) followed by C2-S1 type (medium salinity and low SAR). Few samples also fall under C3-S2 (high salinity and medium SAR), C4-S1 type (very high salinity and low SAR).

Table 2. Chemical Characterstics of Ground Water Samples (August 1994)

Parameter	Max.	Min.	Mean
pH	8.6	6.3	7.1
Conductance, µS/cm	1435	400	797
TDS, mg/L	911	258	494
Alkalinity, mg/L	334	92	210
Hardness, mg/L	740	154	325
Chloride, mg/L	340	4	66
Sulphate, mg/L	384	5	48
Sodium, mg/L	110	4	23
Potassium, mg/L	152	1	29
Calcium, mg/L	297	39	86
Magnesium, mg/L	87	1	23

Table 3. Chemical Characterstics of Ground Water Samples (December 1994)

S.No. Parameter	Max.	Min.	Mean
pH	8.1	6.7	7.3
Conductance, $\mu S/cm$	4481	455	1224
TDS, mg/L	2875	295	801
Alkalinity, mg/L	808	152	367
Hardness, mg/L	916	168	415
Chloride, mg/L	520	1	82
Sulphate, mg/L	590	20	91
Sodium, mg/L	350	3	65
Potassium, mg/L	282	1	34
Calcium, mg/L	279	37	116
Magnesium, mg/L	102	1	29

Table 4. Chemical Characteristics of Ground Water Samples (March 1995)

S.No. Parameter	Max.	Min.	Mean
pH	8.0	6.6	7.3
Conductance, $\mu S/cm$	3159	467	1087
TDS, mg/L	2035	290	699
Alkalinity, mg/L	672	136	329
Hardness, mg/L	980	152	332
Chloride, mg/L	448	1	70
Sulphate, mg/L	477	8	77
Sodium, mg/L	275	6	48
Potassium, mg/L	400	1	44
Calcium, mg/L	359	10	85
Magnesium, mg/L	78	1	30

Table 5. Values of Sodium Adsorption Ratio

S.No.	Location	Aug. 94	Dec. 94	Mar. 95
1.	Chhanni	0.614	0.471	0.685
2.	Patli	3.639	3.990	6.738
3.	Kenthpur	0.302	0.336	1.167
4.	Swankhamore	0.364	0.570	0.809
5.	Abtal	1.229	1.758	1.767
6.	Bandral	1.022	4.444	1.612
7.	Gudwal	0.442	0.598	1.378
8.	Supwal	0.336	0.630	1.162
9.	Bengular	2.258	6.146	5.871
10.	Raiyam	0.348	0.495	0.795
11.	Samba	0.450	0.994	0.872
12.	Daboh	0.310	0.390	0.619
13.	Satwari	0.353	0.410	0.997
14.	Miransaheb	0.889	1.220	0.967
15.	Bera	0.226	0.263	0.313
16.	Suchetgarh	0.254	5.028	0.560
17.	R.S. Pura	0.559	3.765	0.649
18.	Nikowal	0.886	3.374	1.945
19.	Quadarpur	0.483	0.815	0.729
20.	Salehar	0.475	0.914	0.914
21.	Arnia	0.767	2.008	1.331
22.	Poal	0.375	1.348	0.388
23.	Bisnah	0.324	1.202	0.943
24.	Upper Kanhal	1.250	2.141	1.853
25.	Kaluchak	0.884	2.087	1.779
26.	Nagrota	0.489	0.889	1.176
27.	Suketar	0.711	1.599	1.391
28.	Muthi	0.266	0.764	0.818
29.	Nagbani	0.423	1.560	1.922
30.	Gajansoo	2.121	1.854	1.869
31.	Kanachak	0.184	0.259	0.269
32.	Jhiri	0.190	0.187	0.282
33.	Akhnoor	0.238	0.196	0.257
34.	Marjoli	0.207	0.323	0.278
35.	Pattakhoo	0.418	0.654	0.635
36.	Purkhoo	0.689	1.202	0.891
37.	Guda	0.260	0.788	0.593
38.	Devipur	0.171	0.291	0.287
39.	Jourian	0.798	1.421	1.526
40.	Bakore	0.226	0.285	0.290
41.	Bhagwanchak	0.301	0.307	0.788
42.	Danpur	0.130	0.084	0.182
43.	Khour	0.202	0.519	0.388
44.	Pallanwala	0.238	0.368	0.455
45.	Lam	0.386	0.620	0.680
46.	Pangali Colony	0.207	0.214	0.422
47.	Seinth	0.486	0.760	1.825

Table 6. Results of Water Classification (August 1994)

S.No.	Location	Piper Trilinear Classification	U.S. Salinity Lab. Classification
1.	Chhanni	Ca-Mg-Cl-SO4	C2-S1
2.	Patli	Na-K-Cl-SO4	C3-S1
3.	Kenthpur	Ca-Mg-CO3-HCO3	C2-S1
4.	Swankhamore	Ca-Mg-Cl-SO4	C3-S1
5.	Abtal	Ca-Mg-Cl-SO4	C3-S1
6.	Bandral	Ca-Mg-Cl-SO4	C3-S1
7.	Gudwal	Ca-Mg-CO3-HCO3	C2-S1
8.	Supwal	Ca-Mg-CO3-HCO3	C2-S1
9.	Bengular	Ca-Mg-Cl-SO4	C3-S1
10.	Raiyam	Ca-Mg-CO3-HCO3	C2-S1
11.	Samba	Ca-Mg-Cl-SO4	C2-S1
12.	Daboh	Ca-Mg-CO3-HCO3	C2-S1
13.	Satwari	Ca-Mg-CO3-HCO3	C3-S1
14.	Miransaheb	Ca-Mg-CO3-HCO3	C2-S1
15.	Bera	Ca-Mg-CO3-HCO3	C2-S1
16.	Suchetgarh	Ca-Mg-Cl-SO4	C2-S1
17.	R.S. Pura	Ca-Mg-Cl-SO4	C3-S1
18.	Nikowal	Ca-Mg-CO3-HCO3	C2-S1
19.	Quadarpur	Ca-Mg-CO3-HCO3	C2-S1
20.	Salehar	Ca-Mg-CO3-HCO3	C2-S1
21.	Arnia	Ca-Mg-Cl-SO4	C3-S1
22.	Poal	Ca-Mg-CO3-HCO3	C2-S1
23.	Bisnah	Ca-Mg-CO3-HCO3	C3-S1
24.	Upper Kanhal	Ca-Mg-CO3-HCO3	C2-S1
25.	Kaluchak	Ca-Mg-Cl-SO4	C3-S1
26.	Nagrota	Ca-Mg-CO3-HCO3	C3-S1
27.	Suketar	Ca-Mg-CO3-HCO3	C2-S1
28.	Muthi	Ca-Mg-CO3-HCO3	C2-S1
29.	Nagbani	Ca-Mg-CO3-HCO3	C2-S1
30.	Gajansoo	Na-K-Cl-SO4	C3-S1
31.	Kanachak	Ca-Mg-CO3-HCO3	C3-S1
32.	Jhiri	Ca-Mg-CO3-HCO3	C2-S1
33.	Akhnoor	Ca-Mg-CO3-HCO3	C2-S1
34.	Marjoli	Ca-Mg-CO3-HCO3	C2-S1
35.	Pattakhoo	Ca-Mg-CO3-HCO3	C3-S1
36.	Purkhoo	Ca-Mg-Cl-SO4	C2-S1
37.	Guda	Ca-Mg-CO3-HCO3	C2-S1
38.	Devipur	Ca-Mg-CO3-HCO3	C3-S1
39.	Jourian	Ca-Mg-CO3-HCO3	C3-S1
40.	Bakore	Ca-Mg-CO3-HCO3	C2-S1
41.	Bhagwanchak	Ca-Mg-Cl-SO4	C2-S1
42.	Danpur	Ca-Mg-CO3-HCO3	C2-S1
43.	Khour	Ca-Mg-CO3-HCO3	C2-S1
44.	Pallanwala	Ca-Mg-CO3-HCO3	C2-S1
45.	Lam	Ca-Mg-CO3-HCO3	C2-S1
46.	Pangali Colony	Ca-Mg-CO3-HCO3	C2-S1
47.	Seinth	Ca-Mg-Cl-SO4	C2-S1

Table 7. Results of Water Classification (December 1994)

S.No.	Location	Piper Trilinear Classification	U.S. Salinity Lab. Classification
1.	Chhanni	Ca-Mg-CO3-HCO3	C2-S1
2.	Patli	Na-K-CO3-HCO3	C3-S1
3.	Kenthpur	Ca-Mg-CO3-HCO3	C2-S1
4.	Swankhamore	Ca-Mg-CO3-HCO3	C2-S1
5.	Abtal	Ca-Mg-CO3-HCO3	C2-S1
6.	Bandral	Ca-Mg-Cl-SO4	C4-S2
7.	Gudwal	Ca-Mg-CO3-HCO3	C3-S1
8.	Supwal	Ca-Mg-CO3-HCO3	C2-S1
9.	Bengular	Na-K-CO3-HCO3	C3-S2
10.	Raiyam	Ca-Mg-CO3-HCO3	C1-S1
11.	Samba	Ca-Mg-CO3-HCO3	C3-S1
12.	Daboh	Ca-Mg-CO3-HCO3	C3-S1
13.	Satwari	Ca-Mg-CO3-HCO3	C2-S1
14.	Miransaheb	Ca-Mg-CO3-HCO3	C3-S1
15.	Bera	Ca-Mg-CO3-HCO3	C2-S1
16.	Suchetgarh	Na-K-Cl-SO4	C4-S2
17.	R.S. Pura	Ca-Mg-CO3-HCO3	C3-S1
18.	Nikowal	Ca-Mg-CO3-HCO3	C3-S1
19.	Quadarpur	Ca-Mg-CO3-HCO3	C3-S1
20.	Salehar	Ca-Mg-CO3-HCO3	C3-S1
21.	Arnia	Ca-Mg-Cl-SO4	C4-S1
22.	Poal	Ca-Mg-CO3-HCO3	C2-S1
23.	Bisnah	Ca-Mg-CO3-HCO3	C3-S1
24.	Upper Kanhal	Ca-Mg-CO3-HCO3	C3-S1
25.	Kaluchak	Ca-Mg-CO3-HCO3	C3-S1
26.	Nagrota	Ca-Mg-CO3-HCO3	C3-S1
27.	Suketar	Ca-Mg-CO3-HCO3	C3-S1
28.	Muthi	Ca-Mg-CO3-HCO3	C3-S1
29.	Nagbani	Ca-Mg-CO3-HCO3	C3-S1
30.	Gajansoo	Ca-Mg-CO3-HCO3	C3-S1
31.	Kanachak	Ca-Mg-CO3-HCO3	C2-S1
32.	Jhiri	Ca-Mg-CO3-HCO3	C2-S1
33.	Akhnoor	Ca-Mg-CO3-HCO3	C3-S1
34.	Marjoli	Ca-Mg-CO3-HCO3	C2-S1
35.	Pattakhoo	Ca-Mg-Cl-SO4	C3-S1
36.	Purkhoo	Ca-Mg-CO3-HCO3	C3-S1
37.	Guda	Ca-Mg-Cl-SO4	C3-S1
38.	Devipur	Ca-Mg-CO3-HCO3	C3-S1
39.	Jourian	Ca-Mg-CO3-HCO3	C3-S1
40.	Bakore	Ca-Mg-CO3-HCO3	C2-S1
41.	Bhagwanchak	Ca-Mg-CO3-HCO3	C2-S1
42.	Danpur	Ca-Mg-CO3-HCO3	C3-S1
43.	Khour	Ca-Mg-CO3-HCO3	C3-S1
44.	Pallanwala	Ca-Mg-CO3-HCO3	C2-S1
45.	Lam	Ca-Mg-CO3-HCO3	C3-S1
46.	Pangali Colony	Ca-Mg-CO3-HCO3	C2-S1
47.	Seinth	Ca-Mg-CO3-HCO3	C3-S1

Table 8. Results of Water Classification (March 1995)

S.No.	Location	Piper Trilinear Classification	U.S. Salinity Lab. Classification
1.	Chhanni	Ca-Mg-CO3-HCO3	C3-S1
2.	Patli	Na-K-CO3-HCO3	C3-S2
3.	Kenthpur	Ca-Mg-CO3-HCO3	C2-S1
4.	Swankhamore	Ca-Mg-CO3-HCO3	C2-S1
5.	Abtal	Ca-Mg-CO3-HCO3	C3-S1
6.	Bandral	Ca-Mg-CO3-HCO3	C2-S1
7.	Gudwal	Ca-Mg-CO3-HCO3	C3-S1
8.	Supwal	Ca-Mg-CO3-HCO3	C3-S1
9.	Bengular	Na-K-CO3-HCO3	C3-S2
10.	Raiyam	Ca-Mg-CO3-HCO3	C2-S1
11.	Samba	Ca-Mg-CO3-HCO3	C3-S1
12.	Daboh	Ca-Mg-CO3-HCO3	C2-S1
13.	Satwari	Ca-Mg-CO3-HCO3	C2-S1
14.	Miransaheb	Ca-Mg-CO3-HCO3	C2-S1
15.	Bera	Ca-Mg-CO3-HCO3	C2-S1
16.	Suchetgarh	Ca-Mg-Cl-SO4	C4-S1
17.	R.S. Pura	Ca-Mg-CO3-HCO3	C3-S1
18.	Nikowal	Ca-Mg-Cl-SO4	C3-S1
19.	Quadarpur	Ca-Mg-CO3-HCO3	C3-S1
20.	Salehar	Ca-Mg-CO3-HCO3	C3-S1
21.	Arnia	Ca-Mg-Cl-SO4	C4-S1
22.	Poal	Ca-Mg-CO3-HCO3	C2-S1
23.	Bisnah	Ca-Mg-CO3-HCO3	C3-S1
24.	Upper Kanhal	Ca-Mg-CO3-HCO3	C3-S1
25.	Kaluchak	Ca-Mg-CO3-HCO3	C3-S1
26.	Nagrota	Ca-Mg-CO3-HCO3	C3-S1
27.	Suketar	Ca-Mg-CO3-HCO3	C2-S1
28.	Muthi	Ca-Mg-CO3-HCO3	C3-S1
29.	Nagbani	Ca-Mg-CO3-HCO3	C3-S1
30.	Gajansoo	Na-K-CO3-HCO3	C4-S1
31.	Kanachak	Ca-Mg-CO3-HCO3	C2-S1
32.	Jhiri	Ca-Mg-CO3-HCO3	C2-S1
33.	Akhnoor	Ca-Mg-CO3-HCO3	C2-S1
34.	Marjoli	Ca-Mg-CO3-HCO3	C2-S1
35.	Pattakhoo	Ca-Mg-CO3-HCO3	C2-S1
36.	Purkhoo	Ca-Mg-CO3-HCO3	C3-S1
37.	Guda	Ca-Mg-CO3-HCO3	C3-S1
38.	Devipur	Ca-Mg-CO3-HCO3	C3-S1
39.	Jourian	Ca-Mg-Cl-SO4	C3-S1
40.	Bakore	Ca-Mg-Cl-SO4	C2-S1
41.	Bhagwanchak	Ca-Mg-CO3-HCO3	C3-S1
42.	Danpur	Ca-Mg-CO3-HCO3	C2-S1
43.	Khour	Ca-Mg-CO3-HCO3	C3-S1
44.	Pallanwala	Ca-Mg-CO3-HCO3	C3-S1
45.	Lam	Ca-Mg-CO3-HCO3	C3-S1
46.	Pangali Colony	Ca-Mg-CO3-HCO3	C3-S1
47.	Seinth	Ca-Mg-CO3-HCO3	C3-S1

Table 9. Sample Identification for Piper Trilinear and Wilcox Diagrams

Label	Seq. No.	Sample Identification
1	1.	Chhanni
2	2.	Patli
3	3.	Kenthpur
4	4.	Swankhamore
5	5.	Abtal
6	6.	Bandral
7	7.	Gudwal
8	8.	Supwal
9	9.	Bengular
A	10.	Raiyam
B	11.	Samba
C	12.	Daboh
D	13.	Satwari
E	14.	Miransaheb
F	15.	Bera
G	16.	Suchetgarh
H	17.	R.S. Pura
I	18.	Nikowal
J	19.	Quadarpur
K	20.	Salehar
L	21.	Arnia
M	22.	Poal
N	23.	Bisnah
P	24.	Upper Kanhal
Q	25.	Kaluchak
R	26.	Nagrota
S	27.	Suketar
T	28.	Muthi
U	29.	Nagbani
V	30.	Gajansoo
W	31.	Kanachak
X	32.	Jhiri
Y	33.	Akhnoor
Z	34.	Marjoli
a	35.	Pattakhoo
b	36.	Purkhoo
c	37.	Guda
d	38.	Devipur
e	39.	Jourian
f	40.	Bakore
g	41.	Bhagwanchak
h	42.	Danpur
i	43.	Khour
j	44.	Pallanwala
k	45.	Lam
l	46.	Pangali Colony
m	47.	Seinth

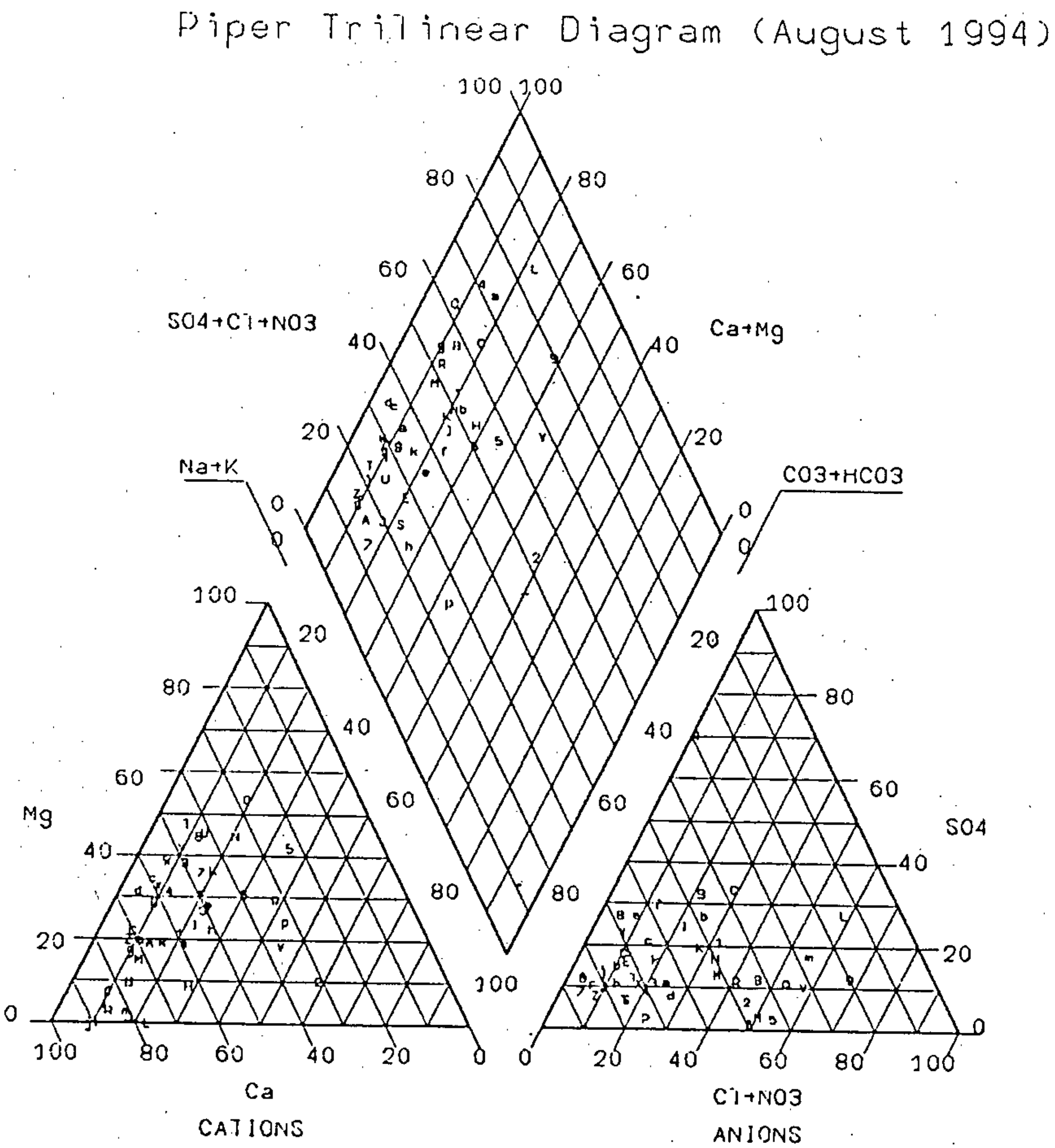

Fig. 2. Piper Trilinear Diagram (August 1994)

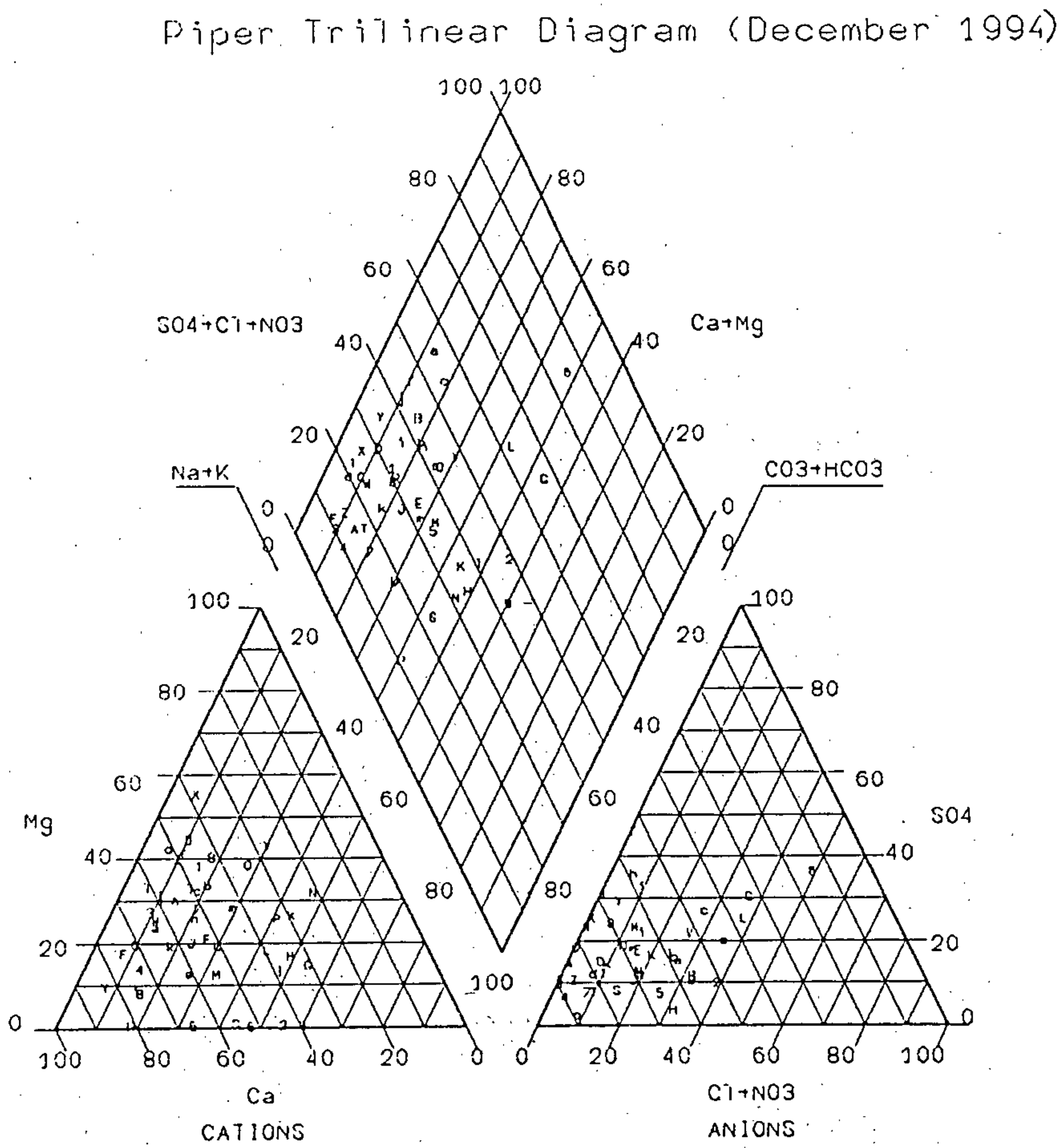

Fig. 3. Piper Trilinear Diagram (December 1994)

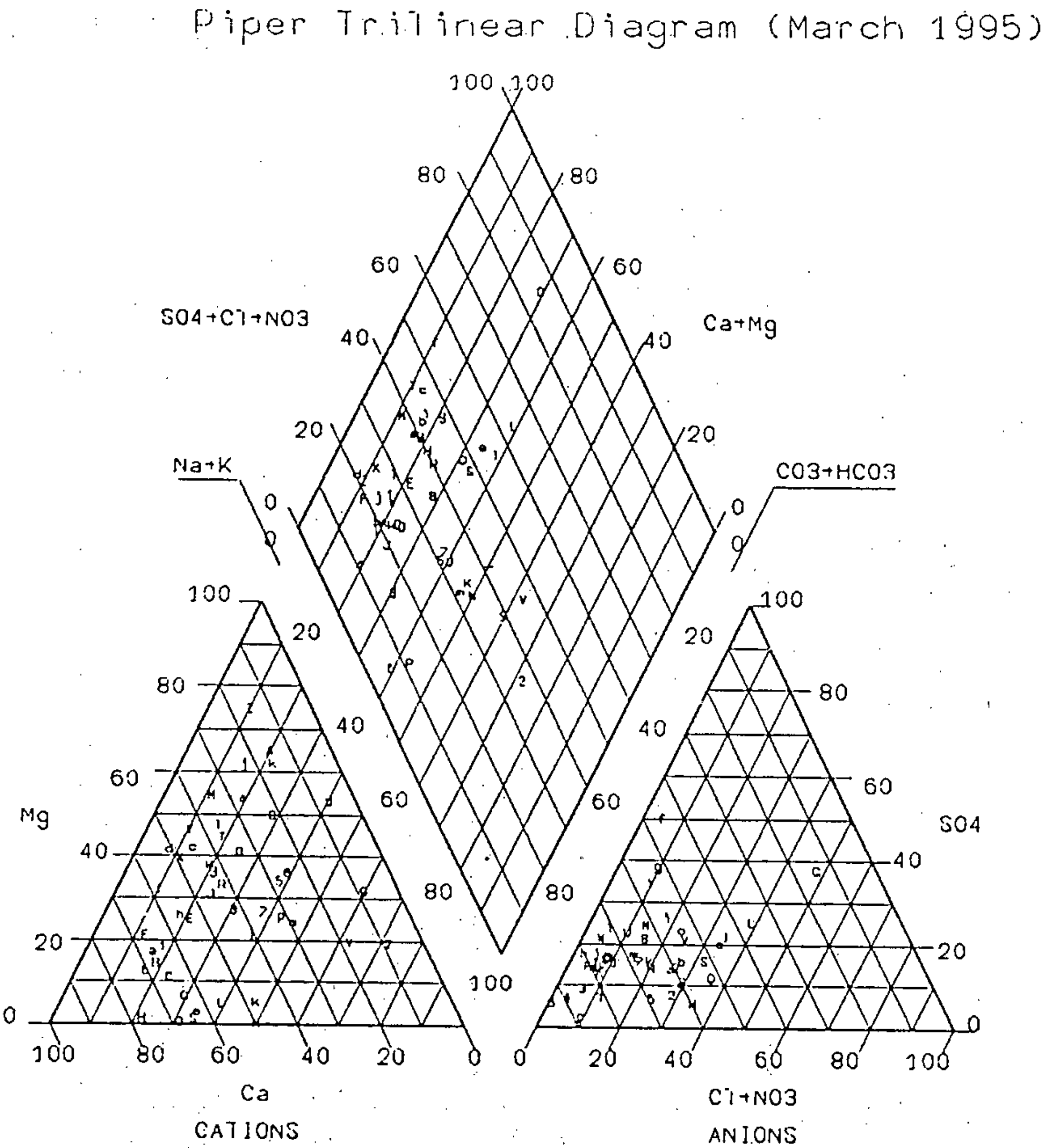

Fig. 4. Piper Trilinear Diagram (March 1995)

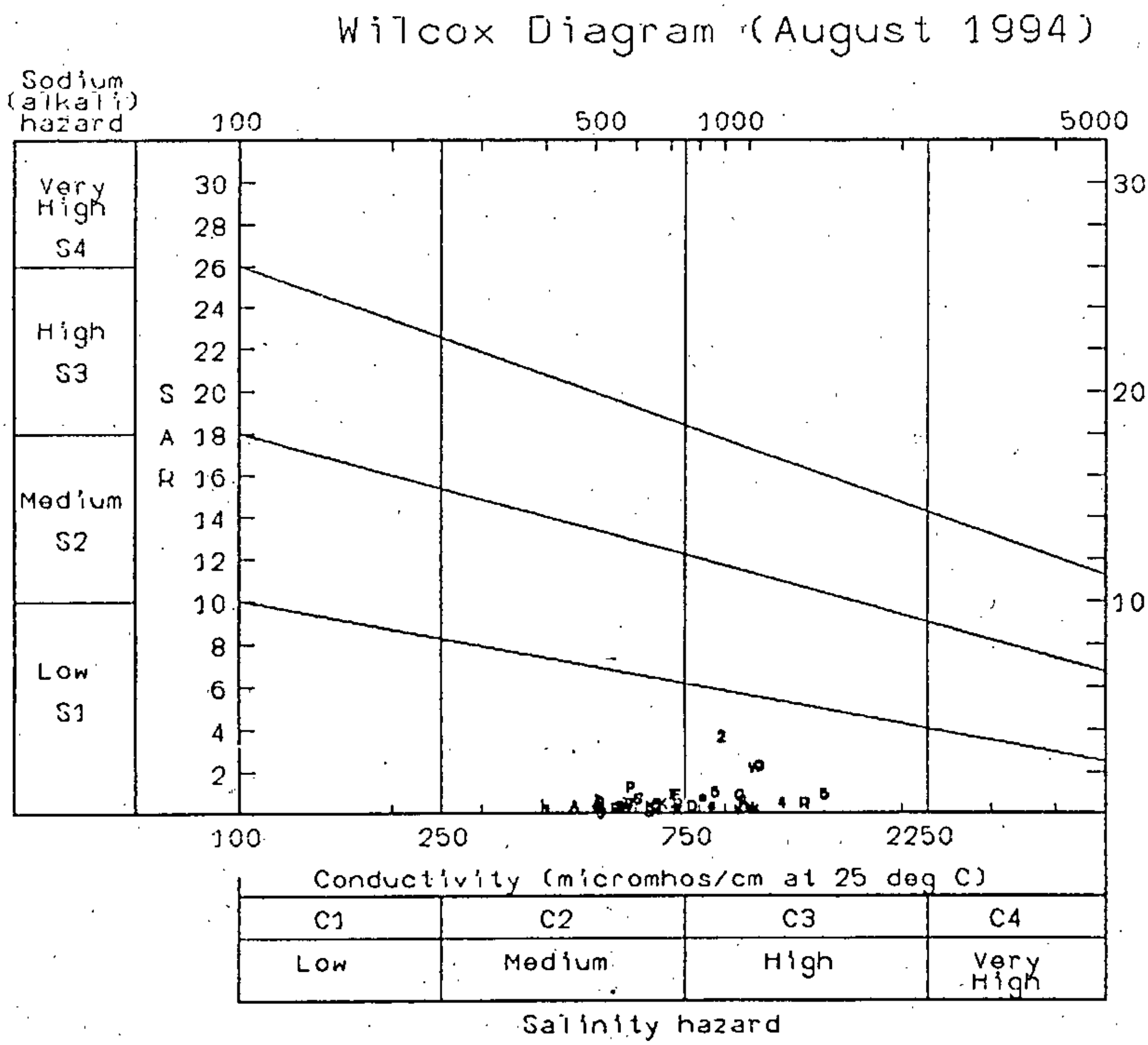

Fig. 5. U.S. Salinity Laboratory Classification (August 1994)

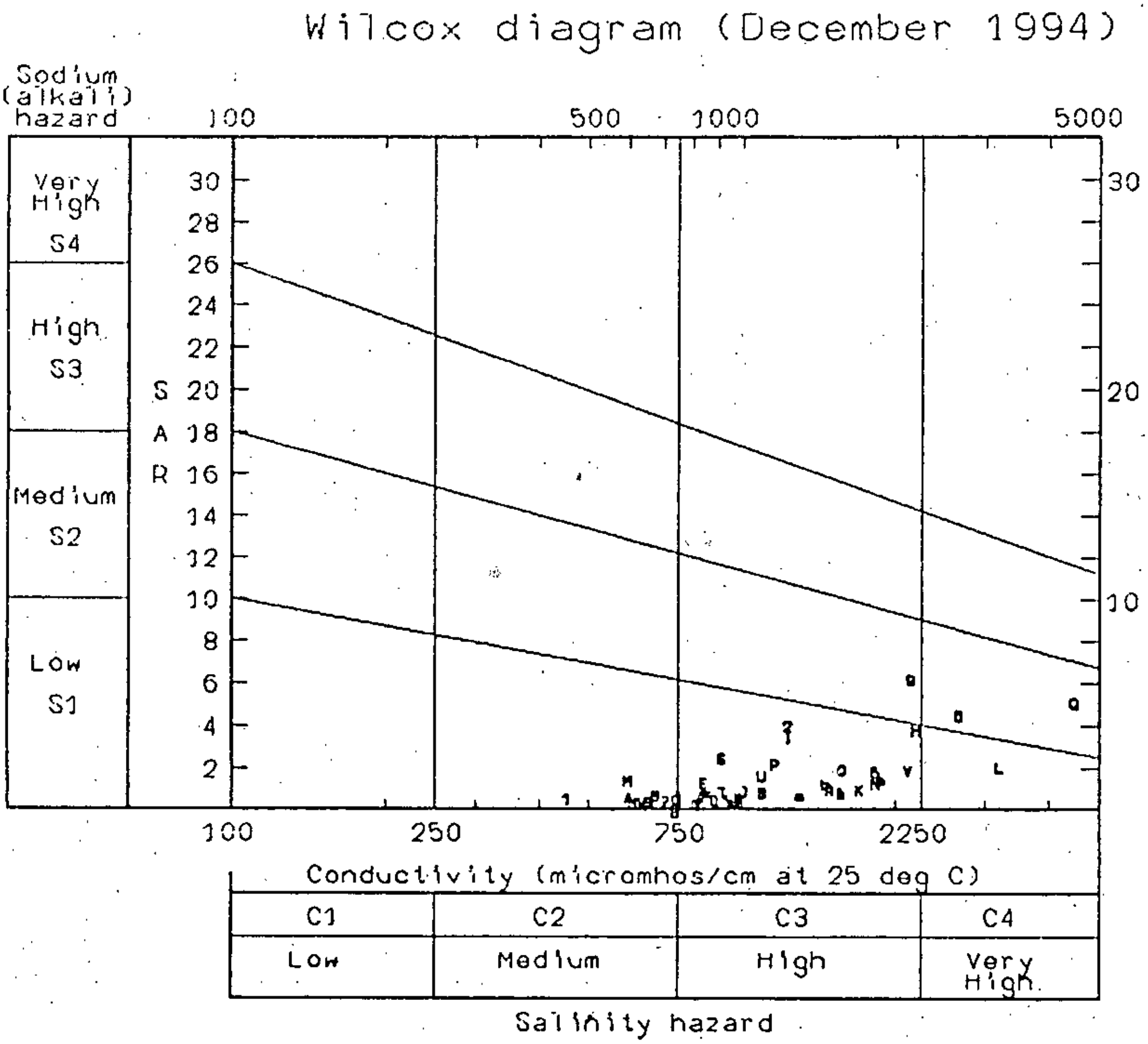

Fig. 6: U.S. Salinity Laboratory Classification (December 1994)

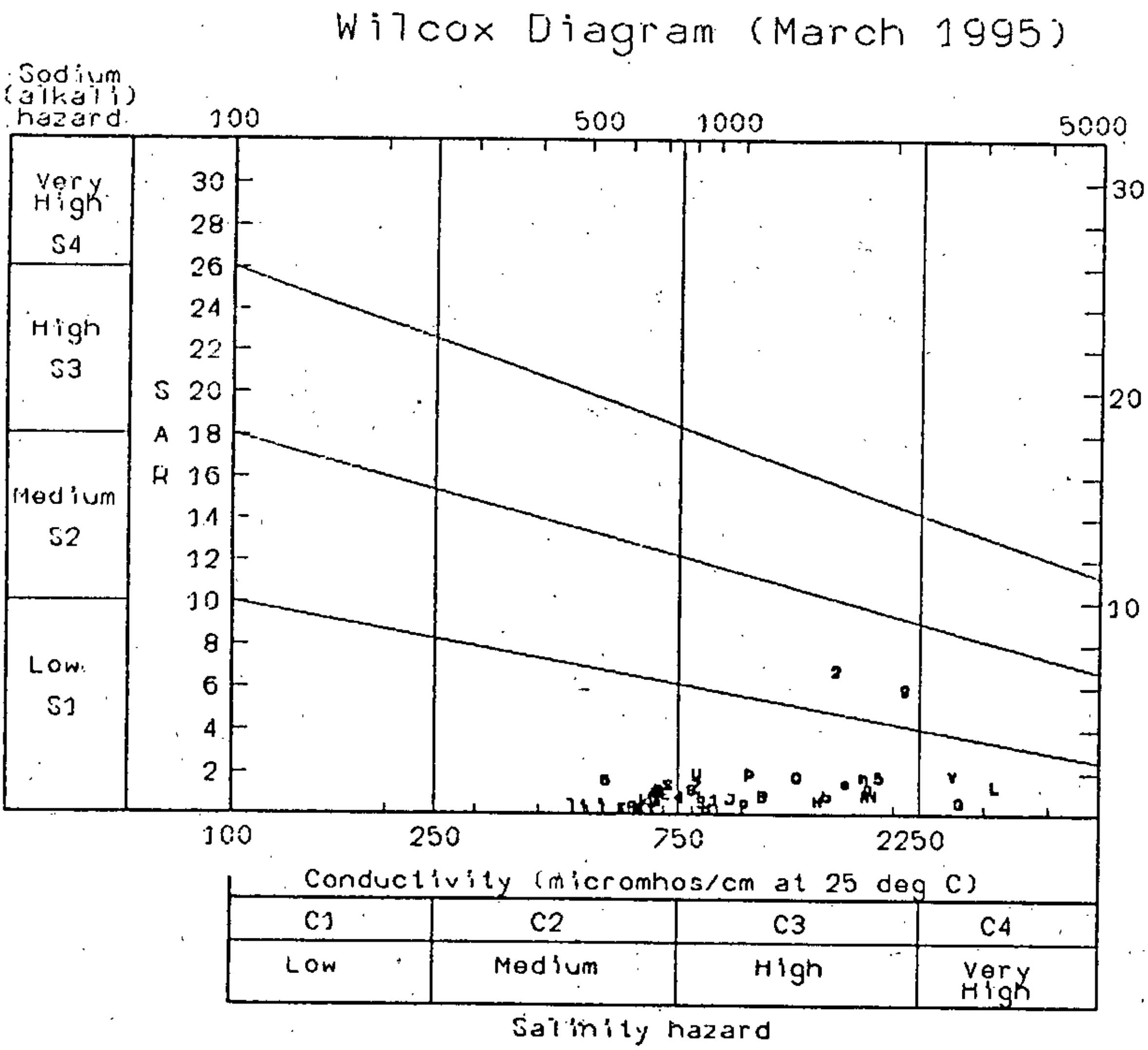

Fig. 7. U.S. Salinity Laboratory Classification (March 1995)

6.0 CONCLUSIONS

The chemical characteristics of ground water of Jammu district has been studied on the basis of chemical characteristics of water samples collected from forty seven open wells. From the results of the study it is concluded that the quality of ground water varies from place to place.

Higher values of certain constituents at certain locations indicate that the water is not suitable for domestic applications. Hence it is recommended that any water source must be thoroughly analysed and studied before being used for domestic applications. On the basis of SAR values it can be concluded that the water of the study area can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium.

An attempt has also been made in this study to classify the hydrochemical characteristics of ground water of the study area based on the classification schemes of Piper trilinear and U.S. Salinity Laboratory classification. The Piper trilinear diagram indicate that majority of samples fall under Ca - Mg - CO_3 - HCO_3 hydrochemical facies.

The U.S. Salinity Laboratory classification of irrigation water indicate that ground water at village Suchetgarh, Arnia and Gajansoo falls under very high salinity zone and should not be used for irrigation purpose. At these place proper water management strategies need to be adopted for agricultural activities.

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