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GROUND WATER QUALITY MONITORING AND EVALUATION IN JAMMU AND KATHUA DISTRICTS, J.&K. (1997-98)

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ABSTRACT

In the present report, chemical characteristics of ground water of Jammu and Kathua Districts have been studied on the basis of 30 water samples collected from open wells during July and December, 1997. The water quality has been evaluated for drinking and irrigation purposes. The suitability of water for drinking purposes has been compared with the standards norms i.e. BIS, 1983 and WHO, 1984. The suitability of water for irrigation purposes has been evaluated on the basis of salinity levels, SAR and RSC. The water has also been classified on the basis of Piper's diagram for determining hydrochemical facies and U.S. Salinity diagram for irrigation purposes using Ground Water Software (version-1, 1989). The behaviour of water levels fluctuation has been studied on the basis of water levels data for January, May, July and December, 1997.

The average values of pH have indicated alkaline nature of ground water in the study area the except at the few wells. The high values of calcium, magnesium and sodium than the prescribed limits for drinking purposes were obtained at certain number of wells in the study area. The concentration of chloride at all wells was within the prescribed limits for drinking purposes under the present sampling program. The water samples have shown that the sulphate at almost all wells was within the limit (150 mg/l) for drinking purposes except at 2 wells during July and one well during December, 1997 respectively. The nitrate concentration was within the limit for drinking purposes except at Londi (79 and 78 mg/l). The concentration of fluoride was below desirable limit (0.6-1.2 mg/l) at about 83% of wells under the present study and therefore, suitable public health measures should be taken.

The majority of wells lie under high salinity zone. However, remaining few wells are under medium salinity and very high salinity zones. Whereas, SAR values have shown that all samples lie below 10 and may be classified under excellent category of water for irrigation. The results obtained through Piper's diagram have shown that, all wells are falling under Ca^{2+}, Mg^{2+}, HCO_3^- hydrochemical facies during both sampling programs except at 3 well locations. The U. S. Salinity diagrams have shown that majority of water samples (26 and 20 number of wells) were falling under C3-S1 (high salinity- low SAR) category during July and December, 1997 respectively. The water levels data from 30 wells in the present study have shown that about 26% wells during January, about 13% during May, about 20% during July and about 23% of wells during December, 1997 were found within 2.0 m depth below ground level.

1.0 INTRODUCTION

The ground water is main source of water supply for domestic purposes in rural as well as in urban areas of the country. The role of ground water is equally important for agriculture, industries and various other uses. Ground water is regarded as the largest source of fresh water on the planet excluding the polar icecaps and glaciers.

Till some time ago, the quality of ground water was considered to be relatively very good in comparison to surface water. Now, the problem of ground water quality deterioration is well recognised over world wide. Further, the advancement of science and technology has enabled us to properly identify various harmful effects of bad quality water for different designated uses.

Therefore, the ground water pollution became a major issue in the management of the vital natural resource and protection of environment about a decade ago. As nearly one-fifth of all the water used in the world is obtained from ground water resources and in many areas ground water is only fresh source available, protection of ground water quality has become a high priority management goal.

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.

Ground water quality problems can be understood by systematic and regular monitoring of water quality of the region. A very few ground water quality studies have been reported in the state of Jammu and Kashmir so far. The field investigation in the area of ground water quality and monitoring of water levels in the state was initiated about a decade ago by the Central Ground Water Board, Jammu. The Various Regional Co-Ordination Committee's of National Institute of Hydrology, Western Himalayan Regional Centre, Jammu have recommended to undertake water quality studies in the region. The monitoring and evaluation of ground water quality is one major issue to save the ground water from pollution. In the beginning years the ground water monitoring program was confined to Jammu District only. In subsequent years, the Kathua District was also been included in the program. Therefore, the present study has been continued to assess use of ground water for drinking and irrigation purposes in Jammu & Kathua districts in the J. & K State.

The main objectives of this study are:

1. Ground water quality monitoring and evaluation for drinking and irrigation purposes.

2. Classification of ground water and study of water table fluctuation.

2.0 REVIEW

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. The problem of pollution in ground water is much less than that of surface water, even though this problem is nowadays becoming a severe threat to public health (Pitchaiah, 1995).

In 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).

The ground water pollution of all the three categories, viz., point, line and diffuse is taking place in India. Wastes from municipal sources such as sewage effluent and sludge cause point, line and diffuse pollution whereas industrial effluent cause point pollution mostly and when discharged on land may also cause line and diffuse pollution of ground water. Agricultural activities such as irrigation return flow, excessive use of fertilizers and soil amendments, pesticides and herbicides are conducive to diffuse pollution of ground water (Jain et. al, 1995).

Municipal wastes are discharged without proper treatment into nearest available water course (s) in most of the cities and towns in our country. The sewage effluent are also discharged on waste lands or passed through unlined channels to nearby fields where farmers use it for irrigation purposes. In either case, sewage effluent find their way into ground water system which finally results in ground water pollution.

The studies conducted in our countries have shown that ground water pollution from discharge of untreated or inadequately treated industrial effluent has reached alarming proportion in several parts of the country. Various researchers have found in their case studies that ground water has been severely affected due to industrial pollution in India (Naram, 1981; Krishnaswamy, 1981; Das and Kidwai, 1981; Kachwaha, 1981). The studies have shown that most industries produce waste products also (gaseous, liquid and solid) as by-products, which can harm the environment, unless treated properly and conform to specified standards laid down by health authorities (CGWB, 1991b, Handa, 1978b, 1986, 1988b,c, 1992; Joshi et al., 1982; Moitra, 1991; Singh, 1986).

The study conducted by Olania and Saxena (1977) for 25 wells near to the open refuse dumps at Jaipur during 1969 to 1971 in order to assess the extent of pollution by leachate. They found that the pollution by total dissolved solids, chloride and iron salts has reached considerably upto a distance of about 450. The increase in hardness and COD are also perceptible upto about the same distance.

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

A very high concentration of nitrate was found in ground water around North Railway City Station in Lucknow. The main source of this nitrate pollution was septic tanks which are located in the study area (Singh, et al., 1991).

Kakar (1981) has carried out geohydrological investigation in North and South- West Haryana and observed the localised rise in nitrate concentration from 43 mg/l at Singhani to 1920 mg/l in natural groundwater. This nitrate pollution is likely to be caused by sewage and agricultural waste because due to absence of any geological source of nitrate in the area and non uniform distribution of nitrate along the direction of groundwater movement.

Kakar and Bhatnagar (1981) have conducted field studies in Ludhiana (Punjab) and observed that ground water 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 ground water in different concentrations, although below the permisible limits for drinking water.

National Institute of Hydrology, Roorkee has carried out study to work out groundwater quality variations in Saharanpur District (U.P.) for shallow wells which are generally used for agriculture and domestic purposes. Therefore, suitability of water for irrigation and drinking purpose has been tested. 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. The temporal variation of ground water quality have also been marked. There is not much variation in the quality of water pre-monsoon and post monsoon seasons due to less rainfall during the year (Kumar, et al., 1988).

Seth and Singhal (1994) have carried out studies in order to assess status of ground water quality of upper Hindon Basin, Saharanpur (UP) due to large scale industrial and agricultural activities. The results indicate that the ground water of the area is marginally affected comparing the chemical results of water as per World Health Organization and Indian Standards norms. In their investigation, the concentration of toxic metals (lead, cadmium and total chromium) was high, however its erratic concentration at few localities was also obtained.

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

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

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

The ground water quality studies in the Jammu & Kashmir State are hardly reported. The Central Ground Water Board (CGWB), Jammu is doing field investigations to measure the condition and trends of ground water quality and quantity in the State. This organisation 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 in J & K. The explorartion & ground water sampling works have also been undertaken by CGWB in the State.

The National Institute of Hydrology, Western Himalayan Regional Centre located at Jammu has conducted ground water quality monitoring and evaluation study in Jammu district during 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. The Centre has extended it water quality monitoring & evaluation program from Jammu District to Kathua District in the Jammu & Kashmir State and study was continued to subsequent years (Jain et al., 1995, Omkar et al., 1996, 1997).

3.0 STUDY AREA

3.1 General Description

The study area of Jammu and Kathua districts falls in Jammu Division of J. & K. State, India (Fig.1). In general, the study area comprises of flat with gentle slope and little undualted land to smaller hills with varying topography. The Central Ground Water Board, Jammu, has determined the Latitudes, longitudes and Reduced Levels (R.L.) of various open wells in Jammu & Kashmir State a long ago for the purpose of carrying out field investigations (Table-1).

3.2 Drainage System

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

3.3 Climate and Rainfall

The climate of the area is of subtropical type, characterized by three well defined seasons viz; winter, summer and Monsoon . The monsoon sets in by the beginning of July and continues till September. Winter starts in November and continues till April , when summer season sets in May and June are the hottest months and the maximum day temperature of 41.8 °C has been recorded during June, 1983. January is the coldest month when days minimum temperature was found to be 2.4 C during 1984. The average temperature in the Jammu region varies from 4 to 40 Celsius. India Meteorological Department (IMD) has observed the normal annual rainfall about 1055 mm and 1177 mm at Jammu and Kathua stations respectively. The normal rainfall (mm) observed by IMD for few places in the study area is given in Table-2.

3.4 General Geology

The general geology of the study 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). According to this Map, the general geology of the study area is categorized into two groups e.g., Recent/ Sub-recent and Shivalik groups.

Table-1 Weli Locations and Altitudes in Jammu & Kathua Districts.
(Source: CGWB, Jammu)

No.	Well Place	Latitude '	Longitude	R.L. amsl, m, at M.P.	Ht. of M.P.
1	Guda	32° 53' 00"	74° 42' 20"	314.12	0.92
2	Jourian	32 50 00	74 34 30	284.34	0.29
3	Marjoli	32 51 00	74 46 00	326.72	0.13
4	Seinth	32 46 26	74 30 30	273.47	0.46
5	Palanwala	32 51 00	74 27 15	271.27	0.52
6	Nagrota	32 47 50	74 54 54	360.1	0.57
7	Bera	32 37 08	74 40 33	-	0.51
8	Suchetarh	32 34 40	74 40 10	263.8	0.39
9	Suchetgarh BSF-1	32 34 40	74 40 10	-	-
10	Suhetgarh BSF-2	32 34 40	74 40 10	-	-
11	Nikowal	32 30 30	74 42 20	261.48	0.53
12	Bishnah	32 36 46	74 51 50	292.07	0.21
13	Chhanni	32 37 35	74 55 10	325.94	0.56
14	Keinthpur	32 35 15	74 58 30	319.39	1.05
15	Daboh	32 35 12	75 06 45	347.68	0.39
16	Samba	32 33 27	74 07 09	356.8	0.8
17	Naran	32 30 15	75 9 15	334.72	0.53
18	Nichla	32 33 35	75 15 15	422.17	0.6
19	Hiranagar	32 22 0	75 17 10	326.85	0.8
20	Londi	32 25 30	75 12 45	295.15	0.63
21	Jamral	32 22 15	75 24 45	300.53	0.46
22	Nagriparol	32 21 0	75 26 0	287.2	1.1
23	Khakial	32 21 0	75 28 0	290.9	0.44
24	Kathua	32 21 50	75 31 45	315.66	0.26
25	Lakhanpur	32 23 00	75 35 40	347.52	0.46
26	Ramkot	32 38 30	75 20 10	650.76	0.4
27	Nagrotagujru	32 38 47	75 23 38	771.16	0.7
28	Lakri	-	-	-	-
29	Mandli	32 38 8	75 30 30	693.01	0.65
30	Phinter	-	-	629.99	0.7

Table-2 Details of Normal Rainfall (mm) in the Study Area
(Source: India Meteorological Department)

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

3.5 Hydrogeology / Lithology:

The Central Ground Water Board, Jammu has carried out detailed investigation of various exploratory sites in Jammu & Kashmir State. As per their investigation, the lithology of the study area is generally non homogeneous and varies significantly from hilly areas to non hilly areas. The general lithostratigraphic sequence in Kandi belt varies from clay to conglomerates with boulders, Pebbles, gravels at many places. The general lithostratigraphic sequence in Plain areas of Jammu District (R.S. Pura/ Samba) was found as multi coloured Clay with little sand/ Silt and occasional Clay hard plastic with gravels. The lithostratigraphic sequence of two sites representing the Kandi belt in Jammu and Kathua Districts is given in Tables- 3 & 4 respectively.

Table-3 Lithostratigraphic Details for the Well at Akhnoor in Jammu District.
(Source : CGWB, Jammu)

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

Table-4 Lithostratigraphic Details for the Well at Naran in Kathua District

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

3.6 Ground Water Resources in J. & K. State

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

3.6.1 Piedmont Deposits of Outer Plains of Jammu

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

(a) Ground Water in Recent River Terraces and Present Day Flood Plains.
(b) Ground Water in the Kandi (Bhaber) zone.
(c) Ground Water in Sirowal (Terai) Zone.
(d) Ground Water in the Transitional Zone between Kandi and Sirowals.

(a) Ground Water in Recent River Terraces and Present Day Flood Plains: The limited quantities of ground water are available in aquifers of limited thickness and areal extent in the recent river terraces and flood plains which can suffice the water supply requirements of few hutments in and around the ground water structures there. The ground water in this zone is found under perched water table conditions. These terraces are deposited over the Siwaliks and because of limited thickness and areal extent of these overlying deposits, the composition of Siwalik formations, the rugged topography, steep gradient resulting in major runoff and many other negative factors for ground water replenishment of these flood plains and terraces and also the underlying Siwaliks are not feasible for large scale ground water development.

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

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

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

3.6.2 Dun Belt in the Outer Himalaya

The Dun belt occurs as a series of terraces across the outer most hills of Jammu and are enclosed within the Lesser Himalayas. This belt extends from Basoli (Kathua district) in the east to Reasi in the west. The sediments are a few meters to few tens meters thick occurring in the form of isolated sub recent to recent valley fill deposits. They comprise of coarse clastic nature of the boulders, cobbles, and pebbles interbedded with lenticular bodies of clays and silt, sand and gravels.

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

3.7 Classification of 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 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).

3.8 Infiltration Characteristics

Infiltration rates vary under different land uses and soil types in different hydroclimatic environments. The National Institute of Hydrology, Regional Centre, Jammu carried out infiltration studies 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., 1993 ; Patwary et al., 1997).

3.9 Classification of Land Use/ Land Cover

The land use/ land cover map of Jammu region prepared by Geological Survey of India (Ref: 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.

4.0 METHODOLOGY

4.1 Collection of Samples and Preservation:

Sampling is one of the most important and foremost step in collection of representative water samples for water quality studies. To achieve the objectives in present study, 30 ground water samples were collected from open wells including one spring (Mandli) in Jammu and Kathua Districts, Jammu & Kashmir State. The ground water sampling was carried out during July and December, 1997. All water samples were collected in clean plastic bottles fitted with screw caps. The depth of the water table from measuring point in the respective wells was measured during sampling programs. The samples were preserved by adding appropriate reagents (Jain and Bhatia, 1987) and brought to the laboratory for detailed chemical analysis.

4.2 Methods of Analysis and Equipment Used:

All chemical used in the study were of analytical reagent grade (Merck). Aqueous solutions were prepared from the respective salts. Double distilled water was used throughout the study. All glassware and other containers were thoroughly cleaned by soaking in detergent and finally rinsed with double distilled water several times prior to use.

The physio-chemical analysis was performed by adopting standard methods (APHA, 1985; Jain and Bhatia, 1987). The water samples were analysed for pH, electrical conductivity, sodium, potassium, calcium, magnesium, chloride, sulphate, bicarbonate, nitrate, phosphate and fluoride. A few water quality parameters e.g., temperature, pH and EC were determined in field during sampling programs using portable thermometer, pH meter and portable water testing kit (Naina model NPC - 361 D).

The total hardness and calcium hardness was determined by EDTA titrimetric method and magnesium hardness was determined by deducting calcium hardness from total hardness. Calcium (as Ca^{2+}) was calculated by multiplying calcium hardness with o.401 and Magnesium (as Mg^{2+}) by multiplying magnesium hardness with 0.243.

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

Phosphate, nitrate sulphate and fluoride concentrations were determined using UV-VIS Spectrophotometer (Chemito 2000).

5.0 RESULTS AND DISCUSSION

A sampling program was carried out to assess ground water quality in Jammu and Kathua Districts, J. & K. State. In the present study, 30 water samples were collected from open wells and one spring (Mandli) during July and December, 1997. The samples were analysed for sodium, potassium, calcium, magnesium, chloride, sulphate, alkalinity, nitrate, phosphate, fluoride, pH and electrical conductivity.

To achieve the objectives, the water quality parameters were compared with the water quality standards for drinking and irrigation purpose. The classification of ground water was done on the basis of Piper's and U.S. Salinity Laboratory Classifications. The average and range of concentrations of chemical constituents of ground water samples of the study area are given in Table -5. The report also describes the water table fluctuation behaviour in the wells during January, May, July and December, 1997. For this purpose, the water table fluctuation data for January & May, 1997 is included from the report of Central Ground Water Board, Jammu (Srivastava and Singh, 1997). The results have been summarized and presented in the following sections:

5.1 Water Quality Evaluation for Drinking Purposes: The various physio-chemical parameters of water quality were compared with the Indian Standards (BIS, 1983) or WHO (1984) Norms for drinking purposes (Table-6). The level of concentration and toxicity caused by these constituents is discussed below:

5.1.1 pH of Water : The pH is a measure of the intensity of acidity or alkalinity and measures the concentration of hydrogen ion in water. It has no direct adverse affect on health, however, a low value below 4.0 will produce sour taste, and higher value above 8.5 and alkaline taste. A pH range of 6.5 to 8.5 is normally acceptable as per guidelines suggested by WHO (1984) and BIS (1983). In this study, pH values vary from 6.35 to 7.89 (average, 7.17) during July, 1997 and 7.02 to 7.81 (average, 7.27) during, Dec., 1997. The average values of pH variation in the study area indicate that ground water in general is of alkaline nature except at few wells (Nikowal, Daboh, Samba, Mandli, Phinter) during July, 1997. The variation of pH in the study area is shown in Fig. 3.

5.1.2 Electrical Conductivity (EC): The electrical conductivity is the measure of capacity of a substance or solution to conduct electrical current. It is the reciprocal of the resistance, in ohms, of a conductor, metallic or electrolyte, which is one cm long and has a cross sectional area of 1 sq cm. As most of the salts in water are present in the ionic forms and capable of conducting current, conductivity is a good and rapid measure of the total dissolved solids.

The conductivity value is used for expressing the total concentration of soluble salts in water. The electrical conductivity values in the study area ranges from 450 to 4400 micro mho/cm at 25 ^{0} C (average, 1397) during July, 1997 and 470 to 3765 micro mho/cm at 25 ^{0} C (average, 1157) during Dec., 1997 with wide range of fluctuations at different locations. The variation in EC is shown in Fig. 4 in Jammu & Kathua Districts, J. & K State.

5.1.3 Alkalinity: The alkalinity of water is a measure of its capacity to neutralize acids. Alkalinity values provide guidance in applying proper doses of chemicals in water and waste water treatment processes particularly in coagulation, softening and operational control of anaerobic digestion. The alkalinity in natural water is caused by bicarbonates, carbonates and hydroxides which may be ranked in order of their association with high pH values. However, Bicarbonates represent the major form since they are formed in considerable amounts from the action of carbonates upon the basic materials in the soil.

The bicarbonate content more than 60 mg/l in the water is necessarily attributed from the biological activities of plant roots, from the oxidation of organic matter included in the soils and in the rock, and from various chemical reactions (Mandel and Shiftan, 1961).The alkalinity values in the study area ranges from 108 to 588 mg/l (average, 293) during July, 1997 and 112 to 570 mg/l (average, 286) during December, 1997.

5.1.4 Sodium : The concentration of sodium more than 50 mg/l makes the water unsuitable for domestic use. In the present study, the concentration of sodium varies from 8 to 381 mg/l (average, 54) during July, 1997 and 9 to 378 mg/l (average, 54) during December, 1997. The high values of sodium than the prescribed limit of 50 mg/l is observed at Jourian (80.29 mg/l), Marjoli (61.29 mg/l), Nagrota (70.29 mg/l), Suchetgarh (381.45 mg/l), Naran (79.29

mg/l), Londi (301.16 mg/l), Khakhial (55.29 mg/l), Nagrotagujru (66.29 mg/l) during July, 1997 and Jourian (81.68 mg/l), Marjoli (60.88 mg/l), Nagrota (71.24 mg/l), Suchetgarh (378.14 mg/l), Samba (55.68 mg/l), Naran (86.17 mg/l), Hiranagar (51.06), Londi (267.87 mg/l), Khakhial (57.12) and Nagrotagujru (68.74) during December, 1997.

5.1.5 Calcium, Magnesium and Total Hardness: The upper limits for calcium and magnesium for drinking water are 75 and 30 mg/l respectively (BIS, 1983). In the present study, the concentration of calcium in the ground water ranges from 5 to 353 mg/l (average, 77) and 30 to 363 mg/l (average, 97) during July and December, 1997 respectively. The concentration of magnesium varies from 8 to 56 mg/l (average, 29) and 13 to 68 mg/l (average, 28)respectively in the present study.

The excess concentration of calcium was obtained at Guda (110.7 mg/l), Nagrota (186.7 mg/l), Suchetgarh (352.9 mg/l), Daboh (94.6 mg/l), Naran (113.9 mg/l), Londi (328.8 mg/l), Ramkot (93 mg/l), Nagrotagujru (166.8 mg/l) during July, 1997 and Guda (111.5 mg/l), Seinth (75.4 mg/l), Nagrota (167.6 mg/l), Bera (91.4 mg/l), Suchetgarh (363.3 mg/l), Suchetgarh BSF Camp-2 (89.8 mg/l), Daboh (89 mg/l), Samba (94.6 mg/l), Naran (129.9 mg/l), Hiranagar (91.4 mg/l), Londi (267.9 mg/l), Jamral (87.4 mg/l), Khakial (81 mg/l), Ramkot (101.9 mg/l), Nagrotagujru (157.9 mg/l) during December, 1997.

The excess concentration of magnesium (more than 30 mg/l) was obtained at Marjoli (35 mg/l), Seinth (55.9 mg/l), Palanwala (53.5 mg/l), Bera (52.4 mg/l), Suchetgarh BSF Camp-1 & 2 (42.3 mg/l & 48.6 mg/l), Nikowal (49 mg/l), Samba (33.5 mg/l), Naran (31.1 mg/l), Hiranagar (44.22 mg/l), Jamral (49 mg/l), Nagrotagujru (30.6 mg/l) during July, 1997 and Nagrota (45.2 mg/l), Bera (31.1 mg/l), Suchetgarh (40.3 mg/l), Suchetgarh BSF Camp-1 & 2 (56.4 mg/l & 31.6 mg/l), Daboh (30.6 mg/l), Naran (39.9 mg/l), Hiranagar (31.1 mg/l), Londi (68 mg/l), Ramkot (34 mg/l), Nagrotagujru (44.3 mg/l) during December, 1997.

The hardness of water was originally defined in terms of its ability to precipitate soap. It is the property attributable to the presence of alkaline earths (Brown et al., 1970). Calcium and magnesium along with their carbonates, sulphates and chlorides makes the water hard, both temporarily and permanent. A limit of 300 mg/l has been recommended for potable waters (BIS, 1983). In this study, total hardness as $CaCO_3$ varies from 150 to 968 mg/l (average, 312) during July, 1997 and 168 to 1080 mg/l (average, 356) during December, 1997. The excess concentration of hardness as $CaCO_3$ was observed at Guda (390 mg/l), Nagrota (548 mg/l), Suchetgarh (968 mg/l), Suchetgarh BSF Camp-1 & 2 (324 mg/l & 306 mg/l), Daboh (330 mg/l), Naran (412 mg/l), Londi (860 mg/l), Ramkot (354 mg/l), Nagrotagujru (542 mg/l) during July, 1997 and Guda (388 mg/l), Nagrota (604 mg/l), Bera (356 mg/l), Suchetgarh (1080 mg/l), Suchetgarh BSF Camp-1 & 2 (396 mg/l & 356 mg/l), Daboh (348 mg/l), Samba (324 mg/l), Naran (488 mg/l), Hiranagar (356 mg/l), Londi (948 mg/l), Jamral (302 mg/l), Ramkot (394 mg/l), Nagrotagujru (576 mg/l) during December, 1997.

5.1.6 Chloride: The chloride occurs naturally almost in all types of waters. The most important source of chlorides in water is the discharge of domestic sewage. A limit of 250 mg/l has been recommended for drinking purposes (BIS, 1983; WHO, 1984). In this study, the concentration of chloride varies from 8 to 190 mg/l (average 47) during July, 1997 and 10 to 178 mg/l (average, 46) during December, 1997. The results have shown that all wells in the study area were within the prescribed limits for drinking purposes under the present sampling program.

5.1.7 Sulphate: The sulphate is also a naturally occurring anion in all kind of natural waters. It is an important constituents of hardness with calcium and magnesium. A limit of 150 mg/l has been suggested for drinking purposes (BIS, 1983). However, Sulphate produces an objectional taste at 300-400 mg/l and above 500 mg/l bitter taste is produced in the water. It is laxative at concentrations around 1000 mg/l in water. The concentration of sulphate varies from 7 to 345 mg/l (average, 48) during July, 1997 and 4 to 204 mg/l (average, 40) during December, 1997. The present analysis of water samples have shown that almost all wells were within the limits (150 mg/l) for drinking purposes except at Suchetgarh (345 mg/l), Londi during July, 1997. The concentration of sulphate during December, 1997 was also exceeding the prescribed limits at Suchetgarh (204 mg/l).

5.1.8 Nitrate: The nitrate is present in soils, in most waters, and in plants, including vegetables in the substantial quantities (WHO, 1978). The water supplies containing high levels of nitrate have been responsible for cases of infantile methemoglobinemia and death (USEPA, 1977). However, this problem does not arises in adults. The limit of general acceptability of nitrate for drinking water is 45 mg/l (BIS, 1983). The values of nitrate in the study area ranges from 0.1 to 79 mg/l (average, 8) during July, 1997 and 0.4 to 78 mg/l (average, 8) during December, 1997. It is evident that almost all wells were within the limit for drinking purposes except at Londi (79 and 78 mg/l) under the present study.

The concentration of nitrate at few places was observed more than 10 mg/l and it may be assumed to be attributed from agricultural pollution caused due to fertilizers application. These wells were located at Guda (10.06 & 12.1 mg/l), Bishnah (24.32 & 18.8 mg/l), Samba (13.79 & 12.8 mg/l), Nagrotagujru (29.4 & 26.2 mg/l), Phinter (10.15 & 10.32 mg/l) and Londi during July and December, 1997 respectively.

5.1.9 Fluoride: Fluoride is an essential element for some animal species (Underwood, 1977). The desirable range of fluoride for drinking water is 0.6 to 1.2 mg/l (BIS, 1983). Low fluoride levels are linked with dental carries and above 1.5 mg/l may cause fluorosis. If the limit is below 0.6 mg/l, the water source should be rejected but suitable public health measures should be taken (Pitchaiah, P.S., 1995). In the present study, the concentration of fluoride varies from 0.14 to 0.94 mg/l (average, 0.42) during July, 1997 and 0.1 to 0.86 mg/l (average, 0.38) during December, 1997. The results have shown that, the average values of fluoride concentration are much below the desirable limit (0.6 to 1.2 mg/l) during both sampling programs. The fluoride concentration is below desirable limit for drinking purposes at many places except at Suchetgarh (0.62 mg/l), Bishnah (0.94 mg/l), Hiranagar (0.6 mg/l), Londi (0.7 mg/l), Ramkot (0.62 mg/l) during July, 1997 and Jourian (0.6 mg/l), Bishnah (0.86 mg/l), Hiranagar (0.67 mg/l), Jamral (0.81 mg/l), Nagriparol (0.76 mg/l) during December, 1997.

5.2 Water Quality Evaluation for Irrigation Purposes:

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

5.2.1 Total Concentration of Soluble Salts:

Total salt concentration of soluble salts in irrigation water can be adequately expressed for the purpose of diagnosis and classification of irrigation water in terms of electrical conductivity. The results depicted in the Table-7 have shown that the majority of wells lie under high salinity zone. Remaining few wells are under medium salinity and very high salinity zones. The wells under medium salinity were observed at Palanwala, Channi during July, 1997 and Jourian, Palanwala, Bera, Suchetgarh (BSF Camp 1 & 2), Nikowal, Channi, Keinthpur during December, 1997. The ground water samples under very high salinity zone were obtained at Suchetgarh and Londi during both sampling programs.

According to US Salinity Laboratory Staff (1954), water with conductivity values below 750 micromhos/cm at 25 ^{0} C are satisfactory for irrigation in so far salt content is concerned, although salt sensitive crops may be adversely affected by use of irrigation water having conductivity values in the range of 250-750 micro-mhos/cm. Water in the range of 750-2250 micro-mhos/cm at 25 ^{0} C are widely used, a satisfactory crop growth is obtained under good management and favourable drainage conditions, but saline conditions will develop if leaching and drainage facilities are inadequate. The use of water with conductivity values above 2250 micro mhos/cm at 25 ^{0} C is exception and in this case more salt tolerant crops can be grown only if sub-soil drainage is good.

5.2.2 Sodium Adsorption Ratio (SAR)

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

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

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

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

In calculation of SAR and SSP, all ionic concentrations are expressed in milliequivalent per liter. The U.S. Salinity Laboratory, Department of Agriculture, USA has recommended the SAR as basis for classification of water for agriculture uses as given in the Table- 8 & 9. SAR values vary from 0.29 to 5.33 during July, 1997 and from 0.22 to 5.0 during December, 1997 respectively. The result has shown that, SAR values of all samples in the study area lie below 10 and may be classified under excellent category of water for irrigation. The values of soluble sodium percentage (SSP) or Na% vary from 7.41 to 52.1 during July, 1997 and from 5.73 to 49.11 during December, 1997 respectively.

5.2.3 Residual Sodium Carbonate:

The quality of water for irrigation can also be assessed by the quantity, Residual Sodium Carbonate (RSC) and it is considered an additional criterion for determining the suitability of irrigation water. United States Salinity Laboratory Staff (1954) observed that the water containing more than 2.5 meq/l of RSC is generally not suitable for irrigation. Water containing 1.25 to 2.5 meq/l RSC is marginal and that contains less than 1.25 meq/l is absolutely safe (Chandu, S.N. et al., 1995). The quantity of Bicarbonate concentration of water play a significant role in RSC. If water contains high concentration of bicarbonate ion, there is a tendency for calcium ions to precipitate as carbonates. As a consequence, the relative proportion of sodium ion increases and gets fixed in the soil by the process of base exchange thereby decreasing the soil permeability. The RSC is calculated using the following equation:

$$RSC = [CO_3^{2-} + HCO_3^-] - [Ca^{2+} + Mg^{2+}]$$

The classification of water on the basis of residual sodium carbonate values was also carried and their results are in Table-10. The study shows that, the number of suitable wells for the purpose of irrigation were 17 and 11, marginal 9 and 10, unsuitable 4 and 9 during July and December, 1997 respectively.

5.3. Classification of Waters

In the present study, the ground water has been classified on the basis of widely used graphical methods e.g., Piper's diagram and U.S. Salinity Laboratory Classification. The graphical presentation of water quality data has been done based on the Ground Water Software (version-1, 1989), Figures 7-10. The results have been summarized and are given in Table-11 & 12.

5.3.1 Piper's Classification:

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

The results obtained through Piper's diagram have shown that, all wells are falling under Ca^{2+}, Mg^{2+}, HCO_3^- hydrochemical facies during both sampling programs except 3 wells which represent individually under 3 different hydrochemical facies i.e., Na^+, K^+, HCO_3^- ; Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} and Na^+, K^+, Cl^-, SO_4^{2-} respectively during July, 1997.

5.3.2 U.S. Salinity Laboratory Classification

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

(SAR). The diagram has distinction to classify the irrigation water into 16 categories.

The U. S. Salinity diagrams have shown that majority of water samples (26 and 20 number of wells) are lying under C3-S1 (high salinity- low SAR) category during July and December, 1997 respectively. The wells at Suchetgarh and Londi were under the category of C4-S2 (very high salinity- medium SAR) during both investigations. The remaining few wells were under C2-S1 (medium salinity- low SAR) during July, 1997 (Palanwala, Chhanni) and December, 1997 (Jourian, Palanwala, Bera, Suchetgarh including BSF-1 & 2, Chhanni, Keinthpur) under the present study.

5.4 Behaviour of Ground Water Levels in Jammu & Kathua Districts

The ground water level fluctuations have been described on the basis of ground water levels monitoring for 30 wells in the Jammu and Kathua Districts during months of January, May, July and December, 1997. Srivastava and Singh (1998) have determined the behaviour of ground water levels for different Districts in Jammu & Kashmir and found that the majority of the wells are in the range of 10 to 20 m below ground level. The Gound Water Year Book- 1997 has also shown that about 20% of the stations in Jammu District and about 25 % in Kathua District were under waterlogged conditions under their investigation.

The results of water level fluctuations on the basis of water levels data of 30 open wells in the Jammu and Kathua Districts are given in Table-13. The graphical representation of water levels fluctuation is given in Figure-11. The minimum, maximum and average values of water levels were found 1.16, 24.01, 4.72 m bgl during January; 1.57, 26.07, 5.5 m bgl during May; 1.3, 25.95, 5.72 m bgl during July; 1.2, 23.83, 4.15 m bgl during December, 1997. The results have shown that water levels at about 26% wells during January, 13% during May, 20% during July and about 23% of wells during December, 1997 were found within 2.0 m bgl under the present investigations.

Table 5. Chemical Characteristics of Ground Water Samples in the Study Area.

Parameters	June, 1997			December, 1997		
	Max	Min	Average	Max	Min	Average
pH	7.89	6.35	7.17	7.81	7.02	7.27
EC, μ mhos/cm at 25^0 C	4400	450	1397	3765	470	1157
Alkalinity, mg/l	588	108	293	570	112	286
Total Hardness as $CaCO_3$ mg/l	968	150	312	1080	168	356
Chloride, mg/l	190	8	47	178	10	46
Sulphate, mg/l	345	7	48	204	4	40
Phosphate, mg/l	0.59	-	0.10	0.5	-	0.12
Nitrate, mg/l	79	0.1	8	78	0.4	8
Calcium, mg/l	353	5	77	363	30	97
Magnesium, mg/l	56	8	29	68	13	28
Sodium, mg/l	381	8	54	378	9	54
Potassium, mg/l	175	0.22	17	172	1.02	16
Flouride, mg/l	0.94	0.14	0.42	0.86	0.1	0.38

Table-6 Summary of Drinking Water Quality in Jammu & Kathua Districts during 1997.

Parameter	Limits (BIS-1983)	Wells Exceeding the Limits	
		July, 1997	December, 1997
pH	6.5 - 8.5	-	-
Sodium	50 mg/l	2, 3, 6, 8, 17, 20, 23, 27	2, 3, 6, 9, 16, 17, 19, 20, 23, 27
Calcium	75 mg/l	1, 6, 8, 15, 17, 20, 26, 27	1, 4, 6, 7, 8, 10, 15, 16, 17, 19, 20, 23, 26, 27
Magnesium	30 mg/l	3, 4, 5, 7, 9-11, 16, 17, 19, 21, 27	6-10, 15, 17, 19, 20, 26, 27
Total Hardness as CaCO3	300 mg/l	1, 6, 8-10, 15, 17, 20, 26, 27	1, 6-10, 15-17, 19-21, 26, 27
Chloride	250 mg/l	-	-
Sulphate	150 mg/l	8, 20	8
Nitrate	45 mg/l	20	20
Fluoride	>1.5 mg/l (unsuitable)	-	-
	0.6-1.2 mg/l (desirable limit)	8, 12, 19, 20, 26	2, 12, 19, 21, 22
	< 0.6 mg/l (unsuitable)	1-7, 9-11, 13-18, 21-25, 27-30 (83% Wells)	1, 3-11, 13-18, 20, 23-30 (83 % Wells)

Table-7 Classification of Water on the basis of Salinity Levels.

Zone	E.C. (micro mhos/cm at 25 ^{0} C)	No. of Wells in Jammu and Kathua Districts	
		July, 1997	December, 1997
Low Salinity Zone	< 250	nil	nil
Medium Salinity Zone	250-750	2	8
High Salinity Zone	750-2250	26	20
Very High Salinity Zone	2250-5000	2	2

Table- 8. Sodium Adsorption Ratio (SAR) & % Na for Jammu & Kathua Districts

Sl. No.	Well	SAR Values		% Na	
		July, 1997	Dec., 1997	July, 1997	Dec., 1997
1.	Guda	0.54	0.56	12.42	13.07
2.	Jourian	2.36	2.11	50.7	44.50
3.	Marjoli	2.07	1.84	45.1	39.42
4.	Seinth	0.92	0.9	35.17	33.21
5.	Palanwala	0.44	0.41	13.11	11.35
6.	Nagrota	1.30	1.26	23.91	22.49
7.	Bera	0.25	0.22	7.41	5.73
8.	Suchetgarh	5.33	5.0	52.1	49.11
9.	Suchetgarh, BSF-1	0.70	0.65	17.0	14.70
10.	Suchetgarh, BSF-2	0.71	0.70	17.49	16.48
11.	Nikowal	0.66	0.70	17.12	17.48
12.	Bishnah	0.69	0.75	21.03	23.07
13.	Channi	0.31	0.31	14.88	12.87
14.	Keinthpur	0.52	0.48	14.99	13.86
15.	Daboh	0.63	0.66	15.24	15.46
16.	Samba	1.46	1.34	31.27	28.47
17.	Naran	1.7	1.7	30.48	28.68
18.	Nichla	0.29	0.31	11.21	10.47
19.	Hiranagar	1.25	1.18	31.44	28.06
20.	Londi	4.46	4.02	43.36	39.70
21.	Jamral	0.62	0.59	19.33	17.58
22.	Nagriparol	0.38	0.37	13.07	11.93
23.	Khakial	1.49	1.44	49.52	44.91
24.	Kathua	0.55	0.55	21.96	20.32
25.	Lakhanpur	0.32	0.33	12.03	11.39
26.	Ramkot	0.73	0.73	20.57	19.71
27.	Nagrotagujru	1.24	1.25	21.68	21.34
28.	Lakri	0.57	0.58	18.18	17.16
29.	Mandli	1.0	0.9	28.10	24.33
30.	Phinter	0.9	0.85	26.91	24.01

Table-9 Classification of Irrigation Water on the Basis of SAR Values (USDA, 1954).

Sodium Adsorption Ratios (SAR)	Water Class	No. of Wells in Jammu & Kathua Districts	
		July, 1997	Dec., 1997
< 10	Excellent	30	30
10-18	Good	-	-
18-26	Fair	-	-
>26	Poor	-	-

Table- 10 Classification of Irrigation Water on the Basis of RSC.

Category	RSC (meq/l)	No. of the wells in the different Category	
		July, 1997	Dec., 1997
Safe	< 1.25	17	11
Marginal	1.25-2.5	9	10
Unsuitable	>2.5	4	9

Table-11 Summarized Results of Water Classification

Piper Classification (Hydrochemical facies)	Well Nos. in Jammu and Kathua Districts	
	July, 1997	Dec., 1997
Ca^{2+}, Mg^{2+}, HCO_3^-	1, 3-7, 9-26, 28-30	1- 30
Na^+, K^+, HCO_3^-	2	-
Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}	27	-
Na^+, K^+, Cl^-, SO_4^{2-}	8	-
U.S. Salinity Laboratory Classification (U.S. Salinity Laboratory Staff, 1954)		
C2-S1	5, 13	2, 5, 7, 9, 10, 11, 13, 14
C3-S1	1-4, 6, 7, 9-12, 14-19, 21-30	1, 3, 4, 6, 12, 15-19, 21-30
C4-S2	8, 20	8, 20

Table-12 Sample Identification Levels for Piper and U.S. Salinity Diagrams

Well No.	Well Location	Sample Identification Levels
1	Guda	1
2	Jourian	2
3	Marjoli	3
4	Seinth	4
5	Palanwala	5
6	Nagrota	6
7	Bera	7
8	Suchetgarh	8
9	Suchetgarh BSF1	9
10	Suchetgarh BSF2	A
11	Nikowal	B
12	Bishnah	C
13	Chhanni	D
14	Keinthpur	E
15	Daboh	F
16	Samba	G
17	Naran	H
18	Nichla	I
19	Hiranagar	J
20	Londi	K
21	Jamral	L
22	Nagriparol	M
23	Khakial	N
24	Kathua	P
25	Lakhanpur	Q
26	Ramkot	R
27	Nagrotagujru	S
28	Lakri	T
29	Mandli	U
30	Phinter	V

Table-13 Ground Water Levels in Jammu & Kathua Districts (# Source: CGWB, Jammu)

Well No.	Well Location	January 97*	May 97*	July 97	Dec.97
1	Guda	9.63	9.98	11.35	10.00
2	Jourian	2.23	3.76	3.4	1.60
3	Marjoli	24.07	26.07	25.95	23.83
4	Seinth	2.76	3.46	4.00	2.50
5	Palanwala	1.68	1.83	1.90	1.95
6	Nagrota	3.31	4.11	4.50	3.25
7	Bera	3.39	3.09	3.50	2.5
8	Suchetgarh	1.95	2.58	3.45	3.70
9	Suchetgarh BSF1	4.8	6.10	5.95	1.90
10	Suchetgarh BSF2	4.80	6.10	5.95	1.90
11	Nikowal	2.79	4.02	4.30	3.20
12	Bishnah	2.06	2.44	2.55	1.95
13	Chhanni	5.34	6.49	7.20	5.00
14	Keinthpur	1.95	2.63	3.35	2.70
15	Daboh	2.07	2.59	3.40	2.50
16	Samba	10.8	11.7	12.60	10.40
17	Naran	5.87	8.87	10.10	5.90
18	Nichla	7.55	8.8	9.90	5.80
19	Hiranagar	2.2	3.20	2.40	1.95
20	Londi	5.32	6.02	6.70	3.95
21	Jamral	4.64	4.79	4.90	2.40
22	Nagriparol	1.35	1.70	1.50	2.50
23	Khakial	1.86	2.01	1.60	2.20
24	Kathua	1.16	2.23	1.30	1.20
25	Lakhanpur	1.54	1.57	1.60	1.95
26	Ramkot	5.51	6.51	6.75	5.26
27	Nagrotagujru	8.43	9.72	10.05	4.20
28	Lakri	3.98	4.93	2.40	2.40
29	Mandli	1.85	1.89	1.70	1.20
30	Phinter	6.62	6.82	7.40	4.60

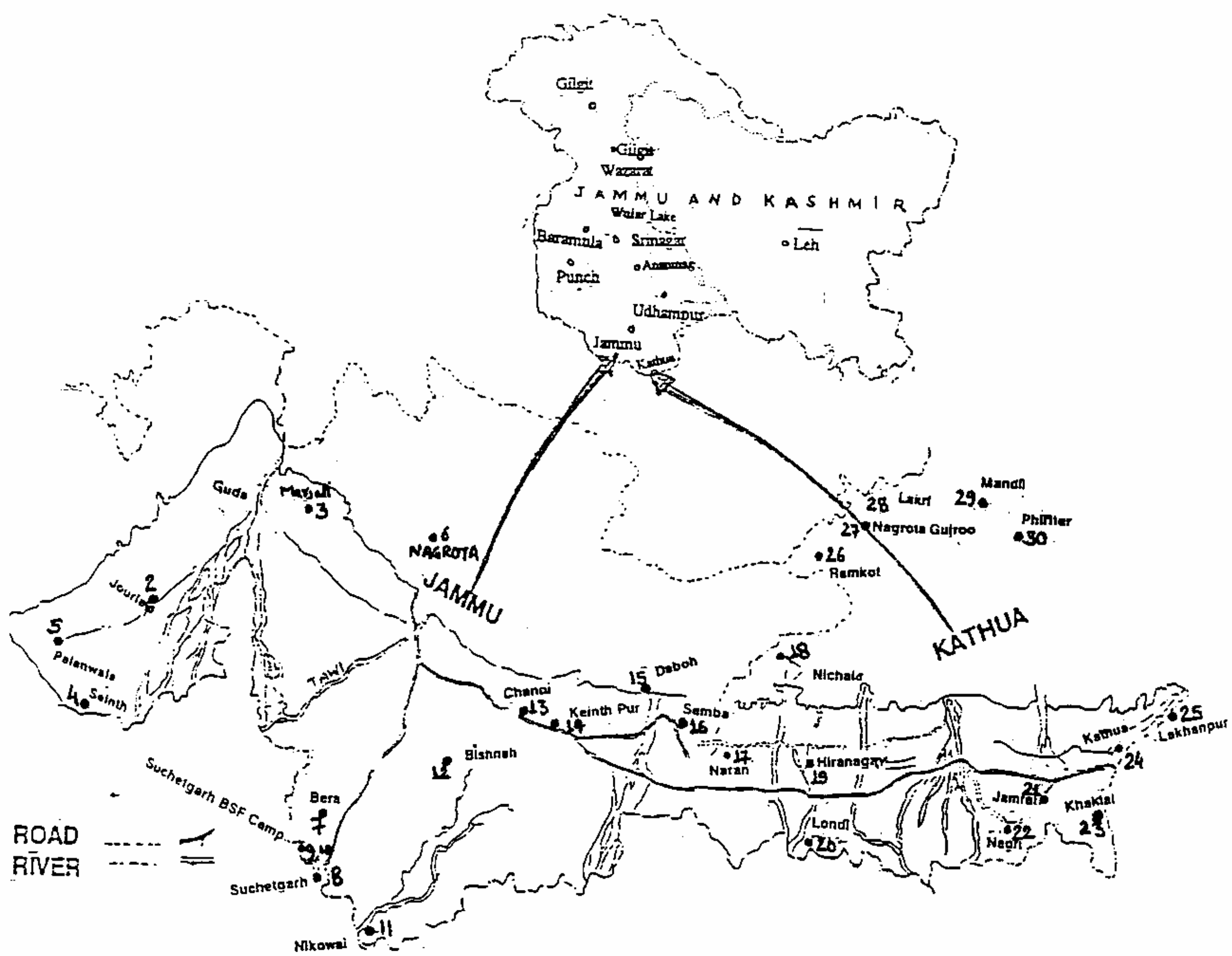


Figure-1. Location Map of Wells in Jammu & Kathua Districts, J & K.

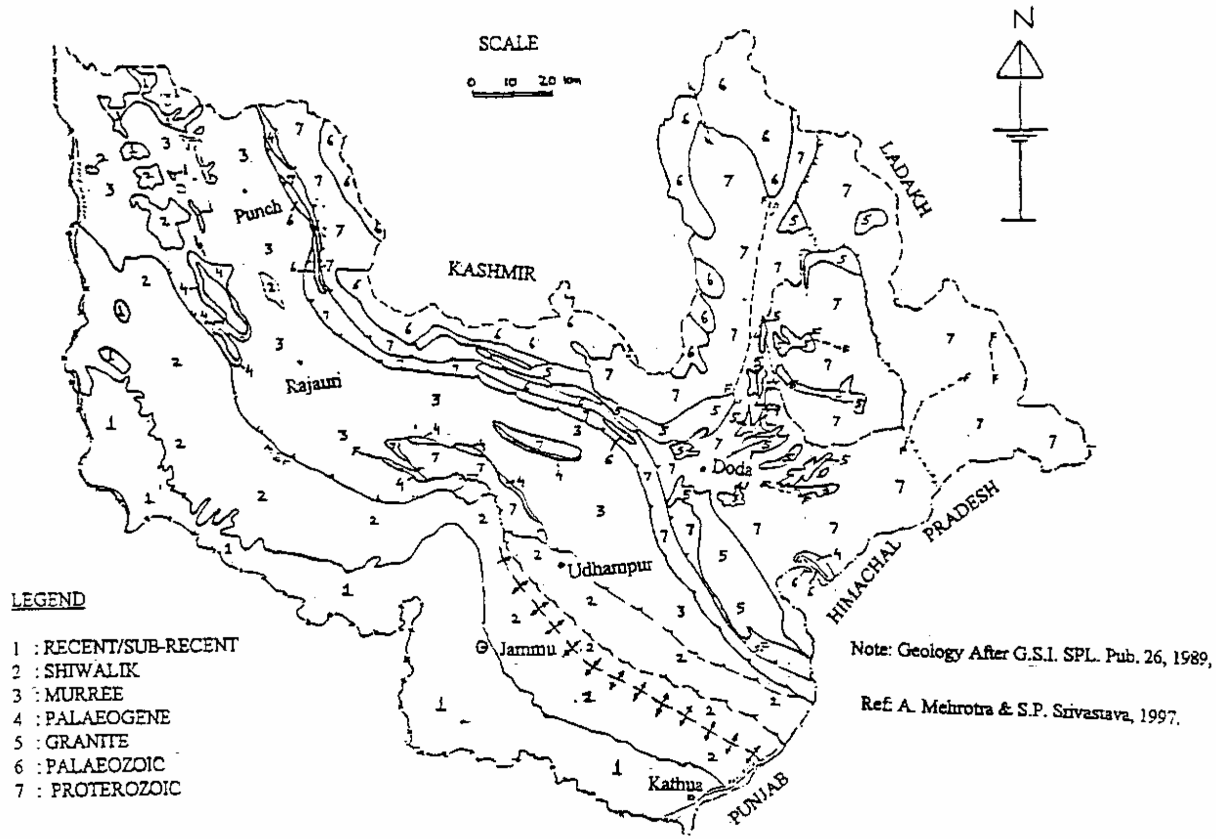


Fig. 2 Generalised Geological Map of Jammu Region.

Fig. 3 Variation of pH in Jammu & Kathua Districts during 1997

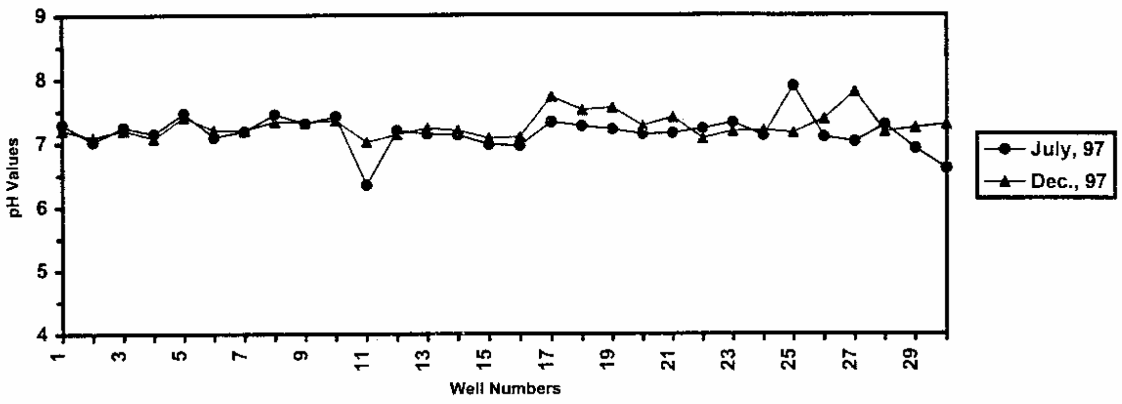


Fig. 4 Variation of EC in Jammu & Kathua Districts during 1997.

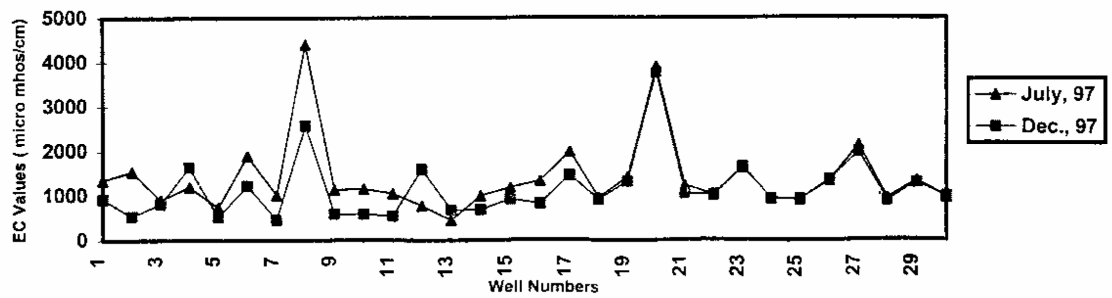


Fig. 5a Concentration of Cation in Jammu & Kathua Districts during 1997.

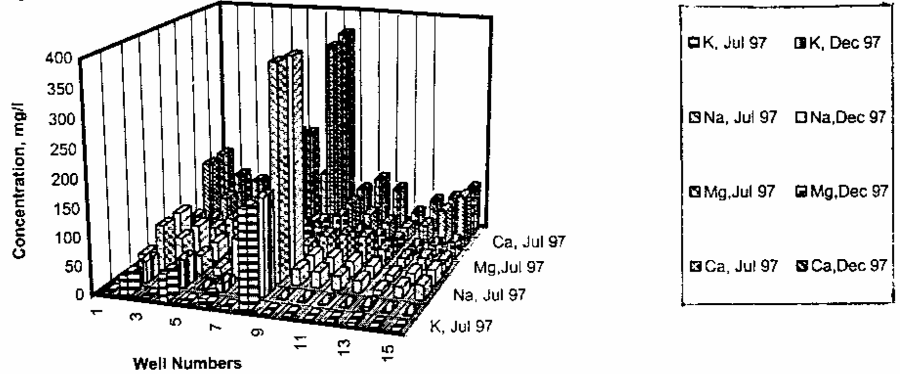


Fig. 5b Concentration of Cation in Jammu & Kathua Districts during 1997.

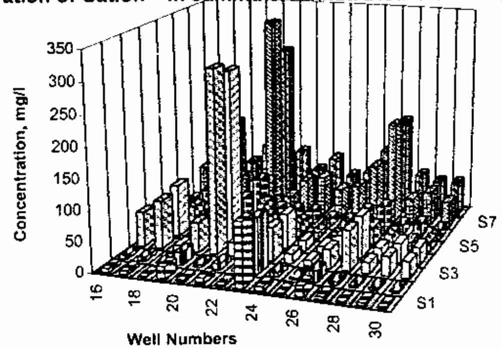


Fig. 6a Concentration of Anion in Jammu & Kathua Districts during 1997.

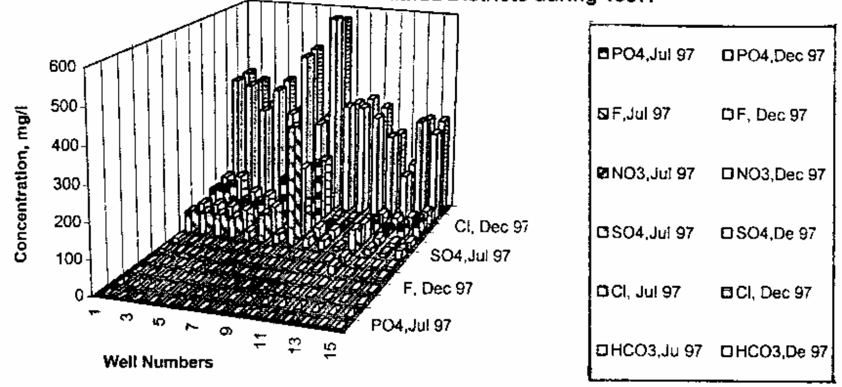
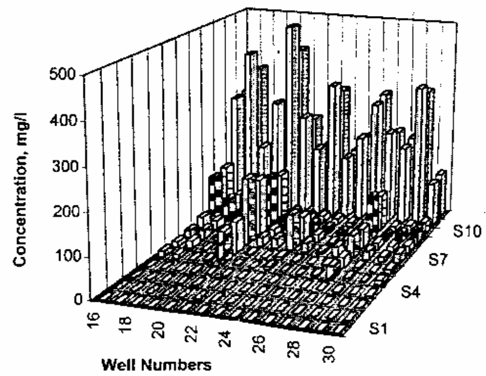


Fig. 6b Concentration of Anion in Jammu & Kathua Districts during 1997.



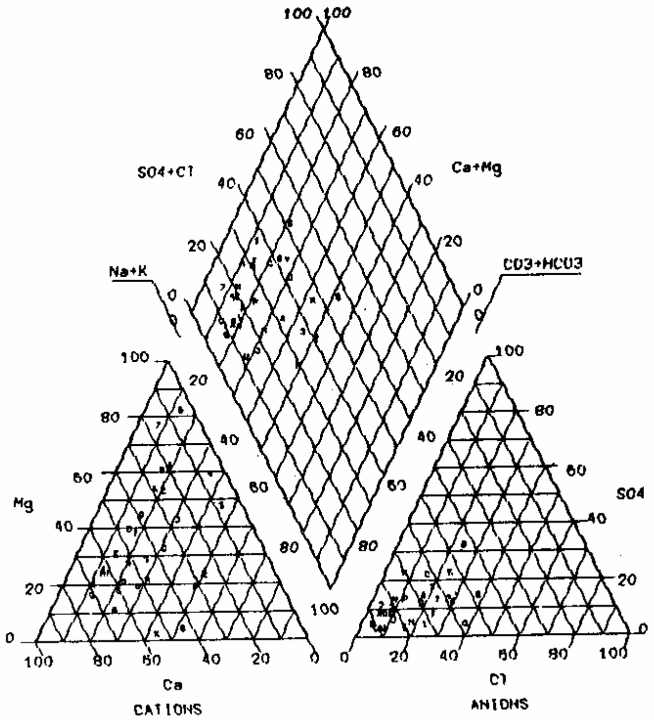


Figure-7. Piper's Diagram for Jammu & Kathua Districts, July, 1997.

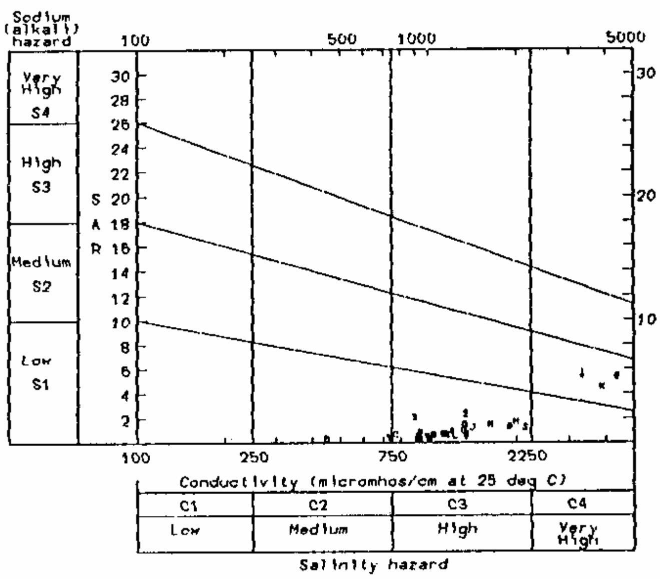


Figure-8. U.S. Salinity Diagram for Jammu & Kathua Districts, July, 1997.

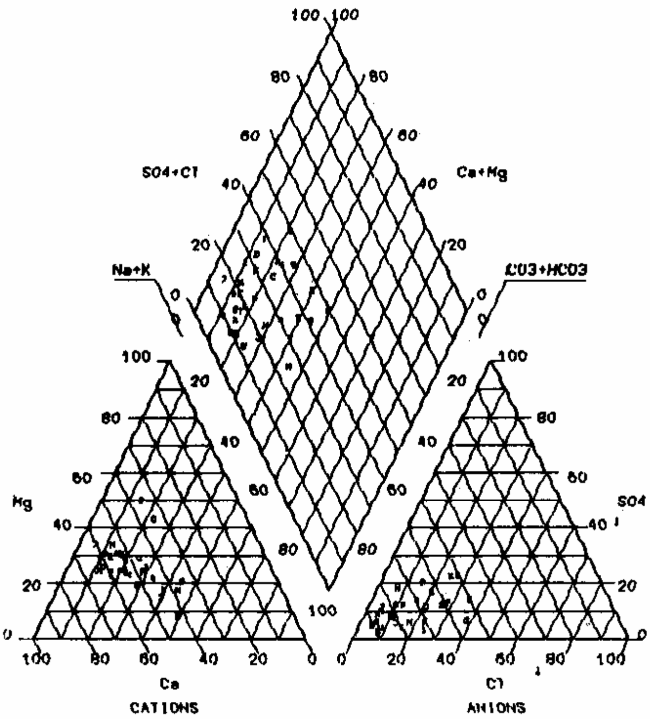


Figure-9. Piper's Diagram for Jammu & Kathua Districts, December, 1997.

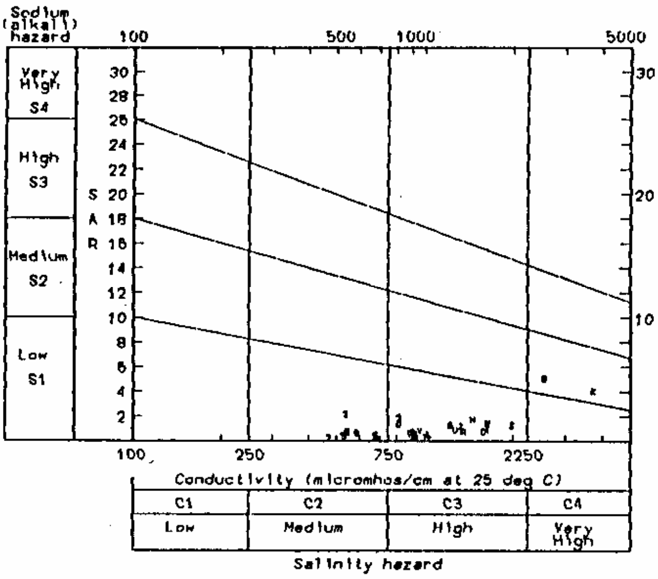
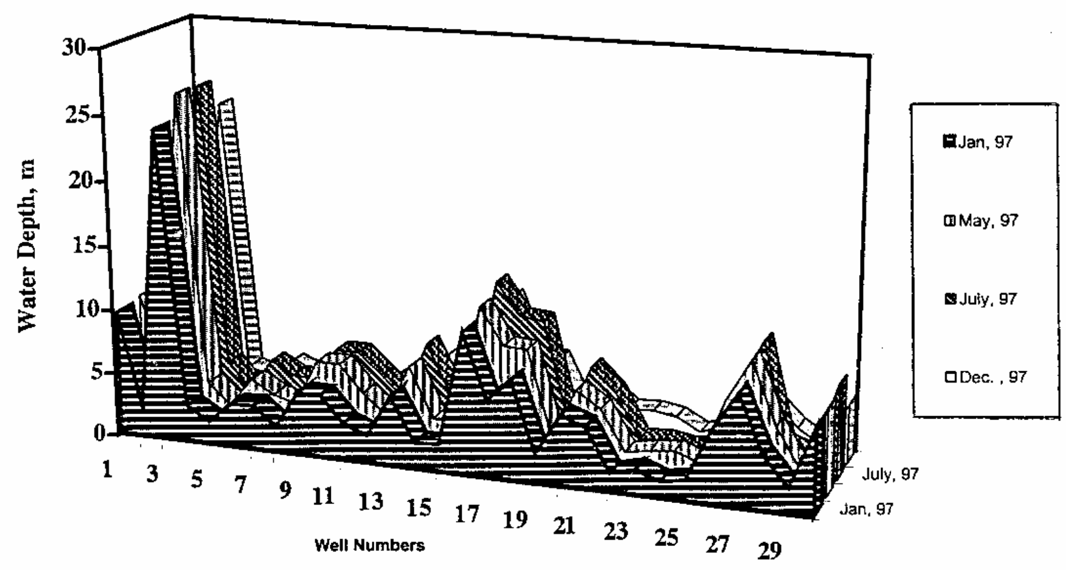


Figure-10. U.S. Salinity Diagram for Jammu & Kathua Districts, December, 1997.

Fig. 11 Variation of Water Levels in Jammu and Kathua Districts during 1997



6.0 CONCLUSIONS

In the present report, chemical characteristics of ground water of Jammu and Kathua Districts have been studied. Thirty water samples were collected from open wells during July and December, 1997. The water quality has been evaluated for drinking and irrigation purposes. The suitability of water for drinking purposes has been compared with the standards norms i.e. BIS, 1983 and WHO, 1984. The suitability of water for irrigation purposes has been evaluated on the basis of salinity levels, SAR and RSC. The water has also been classified on the basis of Piper's diagram for determining hydrochemical facies and U.S. Salinity diagram for irrigation purposes using Ground Water Software (version-1, 1989). The behaviour of water levels fluctuation has been studied on the basis of water levels data for January, May, July and December, 1997.

The average values of pH in the study area indicate that ground water in general is of alkaline nature except at few wells (Nikowal, Daboh, Samba, Mandli, Phinter) during July, 1997. The electrical conductivity values in the study area ranges from 450 to 4400 micro mho/cm at 25 ^{0} C (average, 1397) during July, 1997 and 470 to 3765 micro mho/cm at 25 ^{0} C (average, 1157) during Dec., 1997 with wide range of fluctuations at different locations. The alkalinity values in the study area ranges from 108 to 588 mg/l (average, 293) during July, 1997 and 112 to 570 mg/l (average, 286) during December, 1997.

The concentration of sodium varies from 8 to 381 mg/l (average, 54) during July, 1997 and 9 to 378 mg/l (average, 54) during December, 1997. The high values of sodium than the prescribed limit of 50 mg/l is observed at 8 wells during July, 1997 and 10 wells during December, 1997. The concentration of calcium in the ground water ranges from 5 to 353 mg/l (average, 77) and 30 to 363 mg/l (average, 97) during July and December, 1997 respectively. The concentration of magnesium varies from 8 to 56 mg/l (average, 29) and 13 to 68 mg/l (average, 28) respectively in the present study. The excess concentration of calcium was obtained at 8 wells during July, 1997 and at 14 during December, 1997. The excess concentration of magnesium (more than 30 mg/l) was obtained at 13 wells during July, 1997 and 12 wells during December, 1997. The excess concentration of hardness as $CaCO_3$ was observed at 10 wells during July, 1997 and at 14 wells during December, 1997.

The concentration of chloride varies from 8 to 190 mg/l (average 47) during July, 1997 and 10 to 178 mg/l (average, 46) during December, 1997. The results have shown that the concentration of chloride at all wells in the study area was within the prescribed limits for drinking purposes under the present sampling program. The concentration of sulphate varies from 7 to 345 mg/l (average, 48) during July, 1997 and 4 to 204 mg/l (average, 40) during December, 1997. The present analysis of water samples have shown that almost all wells were within the limits (150 mg/l) for drinking purposes except at 2 wells during July and one well during December, 1997 respectively. The values of nitrate in the study area ranges from 0.1 to 79 mg/l (average, 8) during July, 1997 and 0.4 to 78 mg/l (average, 8) during December, 1997. It is evident that the nitrate concentration was within the limit for drinking purposes except at Londi (79 and 78 mg/l) under the present study.

The study has shown that, the concentration of fluoride varies from 0.14 to 0.94 mg/l (average, 0.42) during July, 1997 and 0.1 to 0.86 mg/l (average, 0.38) during December, 1997. The average values of fluoride concentration were much below the desirable limit (0.6 to 1.2 mg/l) during both sampling programs. The fluoride concentration was below desirable limit for drinking purposes at about 83% of wells under both sampling programs.

The majority of wells lie under high salinity zone. However, remaining few wells are under medium salinity and very high salinity zones. The wells under medium salinity were identified at 2 places during July, 1997 and 8 places during December, 1997. The ground water samples under very high salinity zone were obtained at Suchetgarh and Londi during both sampling programs. Whereas, SAR values vary from 0.29 to 5.33 during July, 1997 and from 0.22 to 5.0 during December, 1997 respectively and it has shown that all samples lie below 10 and may be classified under excellent category of water for irrigation. The values of soluble sodium percentage (SSP) or Na% vary from 7.41 to 52.1 during July, 1997 and from 5.73 to 49.11 during December, 1997 respectively.

According to residual sodium carbonate values, the number of suitable wells for the purpose of irrigation were 17 and 11, marginal 9 and 10, unsuitable 4 and 9 during July and December, 1997 respectively.

The results obtained through Piper's diagram have shown that, all wells are falling under Ca^{2+}, Mg^{2+}, HCO_3^- hydrochemical facies during both sampling programs except 3 wells which represent individually under 3 different hydrochemical facies i.e., Na^+, K^+, HCO_3^- ; Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} and Na^+, K^+, Cl^-, SO_4^{2-} respectively during July, 1997. The U. S. Salinity diagrams have shown that majority of water samples (26 and 20 number of wells) were falling under C3-S1 (high salinity- low SAR) category during July and December, 1997 respectively. The wells at Suchetgarh and Londi were under the category of C4-S2 (very high salinity- medium SAR) during both investigations.

The water levels data from 30 wells in the present study have shown that about 26% wells during January, about 13% during May, about 20% during July and about 23% of wells during December, 1997 were found within 2.0 m depth below ground level.

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