AJES
ASIAN JOURNAL OF ENVIRONMENTAL SCIENCE ■ VOLUME 9 | ISSUE 1 | JUNE, 2014 | 54-61
| e ISSN-0976-8947 | Open Access : *www.researchjournal.co.in*

A CASE STUDY

Hydro chemical appraisal of ground water in R.S. Pura tehsil and adjoining areas of district Jammu (J&K)

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Article Chronicle :
***Received* :**
03.04.2014;
***Accepted* :**
29.05.2014

SUMMARY : The present study aims to assess the physico-chemical parameters (pH, Electrical conductivity (EC), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), chloride (Cl^-), sulphate (SO_4^{-2}), nitrate (NO_3^-), fluoride (F^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), iron (Fe), total hardness (TH)) of the underground water in tehsil R.S. Pura, district of Jammu, J&K, India. The water samples were collected from tube wells and hand pumps in 30 chosen sites during the pre-monsoon period (Mar. 2013 to May 2013). The results were compared with standard values of drinking water prescribed by IS:10500, BIS and WHO. It was observed that certain parameters like electrical conductivity, bicarbonate, total hardness, calcium, sulphate, nitrate and iron as determined from the groundwater samples of tehsil R.S. Pura were above the limits set by IS:10500 and BIS at certain places. To analyse the data with statistical point of view, the statistical parameters like mean, range, standard deviation, co-efficient of variation, correlation co-efficient, kurtosis, skewness were systematically calculated for each parameter. Also, single factor Anova tables, piper diagram and schoeller graph were prepared to signify the major results. Also, an account has been prepared to analyze the factors like sum of anions (meq/l), sum of cations (meq/l), calculated TDS (mg/l), dissolved minerals (mg/l) like halite (NaCl), sylvite (KCl), carbonate ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), anhydrite ($CaSO_4$), permanent hardness, temporary hardness and alkalinity.

Key Words : Groundwater, Physico-chemical parameters, Water quality standards

HOW TO CITE THIS ARTICLE : Khanna, Pragya and Kanwar, Priya (2014). Hydro chemical appraisal of ground water in R.S. Pura tehsil and adjoining areas, district Jammu, J&K. *Asian J. Environ. Sci.*, **9**(1): 54-61.

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Much of the current concern with regards to environmental quality is focused on water because of its importance in maintaining the human health and health of the ecosystem. Ground water is a finite resource, essential for agriculture, industry and even human existence and plays a key role in meeting the water needs of various user-sectors in India. There is an extensive literature, which stresses deterioration of quality of both surface and ground water (Tiwari, and Ali, 1987; Reddy and Venkateswar, 1987; Khulab, 1989). The addition of various kinds of pollutants and nutrients through the agencies like sewage, industrial effluents, agricultural runoff etc. into the water bodies bring about a series of changes that affect the environmental quality and animal and human health. The changes in the physico-chemical characteristics of water have been the subject of several investigations (Milway, 1969; Olimax and Sikorska, 1975; Vollenweidre, 1986; Moore *et al*., 1998; Mahananda *et al*., 2005).

When ground water becomes contaminated, it is always a difficult and expensive affair to clean up (Sirkar *et al*., 1996, WHO, 1999, Muller *et al*., 2001, Kelkar *et al*., 2001). In most of the instances the extraction of excessive quantities of ground water has resulted in drying up of wells, damaged ecosystems, land subsidence, salt-water intrusion and depletion of the resource. The problem of ground water pollution in several parts of the country has become so acute that unless urgent steps for detailed identification and abatement are taken, extensive ground water resources may be damaged (Muhammad *et al*., 2007).

For the present study, various samples of groundwater were collected from the different locations of Tehsil R.S. Pura dist. Jammu (J&K), India and analysed for their physico-chemical parameters. The results were compared with drinking water specifications of BIS and IS:10500, 1991(reaffirmed in 1993).

Study area:

District Jammu is located at 74°24' and 75°18' East longitude and 32°50' and 33°30' North latitude (Fig. A). Administratively the district has been divided into 5 tehsils, *viz.*, Jammu, Samba, R.S. Pura, Akhnoor and Bishnah, R.S. Pura is located on the Indo-Pak border at 32°38' N 74°44' E / 32.63°N 74.73°E. It is 22 km towards South from district head quarters Jammu and consists of 59 villages and 59 Panchayats. It has an average elevation of 270 metres above mean sea level.

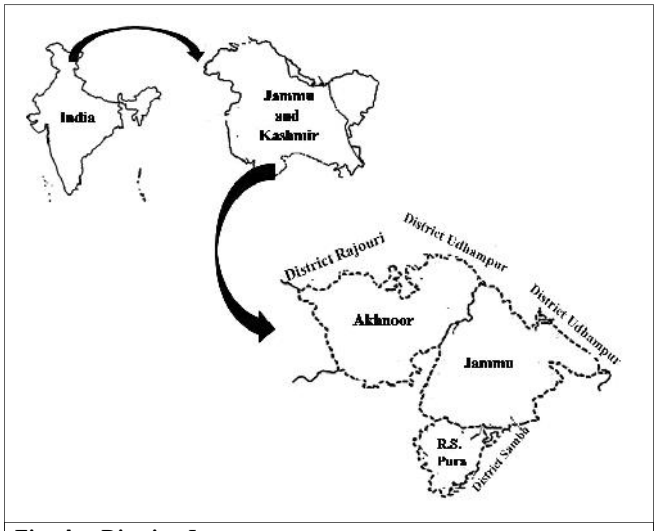

Fig. A : District Jammu

The total average rainfall is 1276 mm, the bulk of the rainfall occurs from June to September. Geologically the study area is a part of Sirowal belt which is equivalent of Tarai belt of Indo-Gangetic plains and comprised of finer sediments. The ground water levels are quite shallower in the study area.

EXPERIMENTAL METHODOLOGY

Sample collection:

The ground water samples were collected from tube wells and hand pumps from 28 locations during the pre-monsoon period (Mar. 2013 to May 2013).

Preparation of water samples:

The samples were collected in pre-cleaned, sterilized polyethylene bottles of one litre capacity without any air bubbles as per standard procedure. Each sample bottle was clearly labelled and relevant details were recorded. The samples were kept in refrigerator maintained at 4^0C and were analyzed within 12 to 24 hrs after collection.

Physico-chemical analysis:

Physico-chemical analysis were carried out for various water quality parameters such as pH, Electrical conductivity (EC), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), chloride (Cl^-), sulphate (SO_4^{-2}), nitrate (NO_3^-), fluoride (F^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), iron (Fe), total hardness (TH) as per standard methods (APHA, 1989).

High purity certified analytical grade reagents; double distilled de-ionized water and borosil glassware was used.

Statistics:

To analyse the data with statistical point of view the statistical parameters like mean, range, standard deviation, co-efficient of variation, correlation co-efficient, kurtosis, skewness were systematically calculated for each parameter. Also, single factor Anova tables, Piper diagram and schoeller graph were prepared to signify the major results.

Table A: Analytical methodology for various parameters analysed

Parameters	Analytical methods
pH	Electro-metric method (pH meter)
Conductivity (EC)	Electrical conductivity meter (EC meter)
Carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), chloride(Cl^-)	Titrimetric method
Sulphate (SO_4^{-2})	Argenoto metric method
Nitrate (NO_3^-)	Turbidity method
Fluoride (F^-)	Ultraviolet spectrophotometric method
Total Hardness (TH)	SPADNS method
Calcium (Ca^{2+}), Magnesium (Mg^{2+})	EDTA Titrimetric method
Sodium (Na^+)	By difference
Potassium (K^+)	Flame photometric method
Iron (Fe)	Digestion followed by Atomic Absorption spectrophotometry (AAS)

Also, an account has been prepared to analyze the factors like sum of anions (meq/l), sum of cations (meq/l), calculated TDS (mg/l), dissolved minerals (mg/L) like halite (NaCl), sylvite (KCl), carbonate ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), anhydrite ($CaSO_4$), permanent hardness, temporary hardness and alkalinity.

EXPERIMENTAL FINDINGS AND DISCUSSION

The results obtained from the present investigation as

well as relevant discussion have been summarized under following heads :

Ground water quality

The ground water quality is a very important and dynamic parameter that keeps on changing with time. The change in the quality is the resultant of all the processes and reactions that have acted on the water. The chemical analysis of ground water samples collected from shallow aquifer includes 14 handpumps and deep aquifer includes 14 tubewells from Sirowal formation of Jammu district. The experimental values for all the physico-chemical parameters are tabulated in Table 1 and were compared with standards as prescribed by Bureau of Indian Standards (BIS). The interpretation of data has been made with the help of statistical tools.

The minimum and maximum values obtained from the analytical results of chemical parameters of shallow and deeper aquifers were compared with the most desirable limits and maximum allowable standard guideline values of various parameters as recommended by the BIS for drinking and public health purposes (Table 1).

The analysis of Table 2 is interpreted for shallow and deep aquifers as under:

Shallow aquifers:

pH:

pH may be defined as negative logarithmic of hydrogen ion concentration. The pH of ground water in shallow aquifers was observed in the range of 7.25 to 8.4 and was well within the limits prescribed by BIS.

EC:

The measurement of electrical conductivity is directly related to the concentration of ionized substance in water and may also be related to problems of excessive hardness and/or other mineral contamination. In the study area, EC ranges from 400 to 1260 μS/cm in shallow aquifers.

Cations:

The Ca^{2+}, Na^{+}, K^{+} ions were well within the permissible limit. The Mg^{2+} concentration in 6 water samples were more than desirable limit of 30 mg/l but all the 15 samples were having Mg^{2+} well within the permissible limits. The Fe^{2+} ions were found in 9 samples, of which 7 samples were having Fe^{2+} more than desirable limit and in two samples its concentration was more than permissible limit (1.0 mg/l).

Anions:

All the anions HCO_3^{2-}, SO_4^{2-}, Cl^{-}, NO_3^{2-} and F^{-} were well within the permissible limits as prescribed by BIS.

Preferential order:

The preferential order of the major ions was calculated and the order was $Ca^{2+}>Mg^{2+}>Na^{+}>K^{+}$ and $HCO_3^{2-}>SO_4^{2-}>Cl^{-}>NO_3^{2-}$. Calcium and magnesium were the dominant cations and bicarbonate was the dominant anion in this region.

Table 1: Analytical results of chemical parameters of shallow and deep aquifers

Parameters	BIS limits		Handpumps		Tubewells	
	Desirable limit	Permissible limit	Min	Max	Min	Max
pH	6.5-8.5	No relaxation	7.25	8.4	6.95	8.4
EC μmhos/cm at 25°C	500	2000	400	1260	510	2200
CO_3^{2-} (mg/l)	-	-	0	0	0	0
HCO_3^{-} (mg/l)	-	-	226	622	262	812
Cl^{-} (mg/l)	250	1000	7.1	53	7.1	110
NO_3^{-} (mg/l)	45	100	1	45	2	55
F^{-} (mg/l)	1.0	1.5	0.08	0.72	0.15	0.72
SO_4^{2-} (mg/l)	200	400	8	120	12	450
Ca^{2+} (mg/l)	75	200	54	164	50	253
Mg^{2+} (mg/l)	30	100	11	61	15	63
Na^{+} (mg/l)	-	-	9.1	90	6.1	116
K^{+} (mg/l)	-	-	0.5	80	1.3	160
Fe (mg/l)	0.3	1.0	0.12	5.32	0.12	2.95
Alkalinity	200	600	185	509	214.7	665.5
TH as $CaCO_3$ (mg/l)	300	600	230	610	265	891

Alkalinity:

Shallow ground water of the area is alkaline in nature. The alkalinity ranges from 185 to 509 and was within the permissible limit of BIS.

Hardness:

As per the classification of hardness, ground water of shallow aquifer fell in very hard category. All the samples were found to have total hardness values as calcium carbonate, more than 180 mg/l (Table 2).

Deeper aquifers:

pH:

The pH of ground water samples from deeper aquifers was observed in the range of 6.95 to 8.4. The pH values for all the samples were well within the limits prescribed by BIS.

EC:

In deeper aquifers, EC ranged from 510 to 2200 μS/cm which was within the permissible limits of BIS.

Cations:

The Mg^{2+}, Na^{+}, K^{+} ions were well within the permissible limit. The Ca^{2+} concentration in one water sample was more than permissible limit of 200 mg/l. The Fe^{2+} ions were found in 9 samples, of which 7 samples were having Fe^{2+} more than desirable limit and in two samples its concentration was more than permissible limit (1.0 mg/l).

Anions:

All the anions HCO_3^{2-}, Cl^{-} and F^{-} are well within the permissible limits as prescribed by BIS except NO_3^{2-} and SO_4^{2}. The NO_3^{2-} concentrations were above desirable limits in two water samples and one sample has SO_4^{2-} concentrations above permissible limit.

Preferential order:

The preferential order of the major ions was calculated and the order was $Ca^{2+}>Mg^{2+}>Na^{+}>K^{+}$ and $HCO_3^{2-}>SO_4^{2-}>Cl^{-}>NO_3^{2-}$. Calcium and magnesium were the dominant cations and bicarbonate was the dominant anion in this region.

Alkalinity:

Deep ground water of the area is alkaline in nature. The alkalinity ranges from 214 to 665 and was within the permissible limit of BIS except for one sample having alkalinity value above permissible limit of 600 mg/l.

Hardness:

As per the classification of hardness, ground water of shallow aquifer falls in very hard category. All the samples were found to have total hardness values as calcium carbonate, more than 180 mg/l (Table 3).

Type of ground water:

The Hill Piper Trilinear diagram (Fig. 1), shows that the alkaline earth metals (Ca and Mg) were dominant over alkali metals (Na) in the ground water of the study area. All samples of the study area collected from shallow as well as deeper aquifers were of mixed type water. About 80 per cent of samples were of Ca-Mg-HCO_3 type. Some were having Mg-Ca-HCO_3 type or Ca-HCO_3, In deeper aquifers some, samples have Na-Ca-Mg HCO_3 and Ca-Na-Mg-HCO_3 type of water.

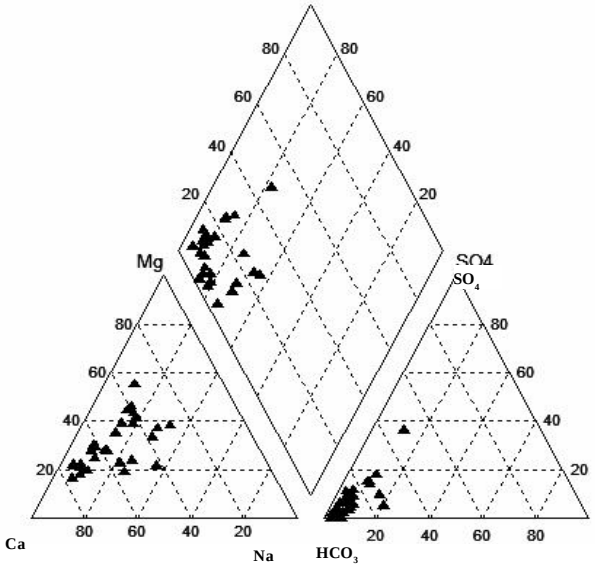

Fig. 1 : Piper trilinear diagram for anion and cation composition of water samples

Fig. 2 represents the groundwater types in the schoeller diagram. The schoeller (1965) diagram is used to study the comparative changes in the concentrations and ratios of water

Table 2 : Classification of hardness (shallow ground water)

Number of samples	Soft 0-60 mg/l TH	Moderate 61-120 mg/l TH	Hard 121-180 mg/l TH	Very hard more than 180 mg/l TH
15	00	00	00	15 (100%)

Table 3 : Classification of hardness (deep ground water)

Number of samples	Soft 0-60 mg/l TH	Moderate 61-120 mg/l TH	Hard 121-180 mg/l TH	Very Hard more than 180 mg/l TH
15	00	00	00	15

quality parameters for different samples.

Fig. 3 represents the variation in different parameters at 30 stations.

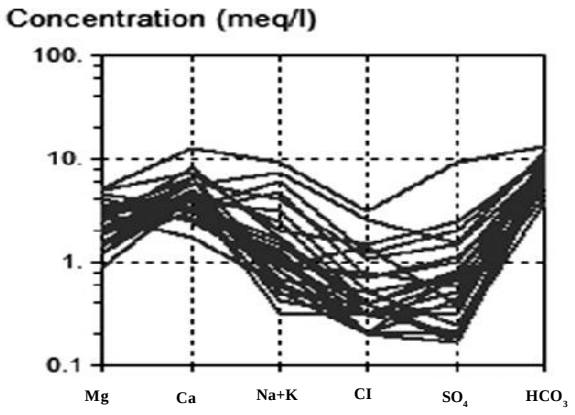

Fig. 2 : Schoeller graph showing the groundwater types

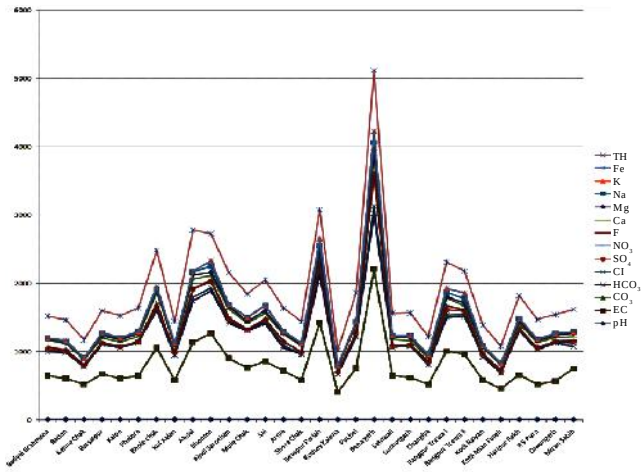

Fig. 3 : Schoeller graph showing the groundwater types

Statistical analysis:

The standard formulae were used in the calculation for statistical analysis as follows:

$$\textbf{Mean } \mu = \frac{\Sigma x}{N}$$

where,

x= Value of observation

N= No. of observations.

$$\textbf{Standard deviation } \sigma = \sqrt{\frac{\Sigma(\overline{X} - X)^2}{n-1}}$$

where,

x= Value of parameter

n= No. of observations.

$$\textbf{Co-efficient of variation } cv = \frac{\sigma}{\mu}$$

Table 4 : Statistical evaluation of different parameters in the groundwater samples

	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	Ca	Mg	Na	K	Fe	TH
Min.	5.95	400	0	226	7.1	0	0	0.08	50	11	6.1	0.5	0	230
Max.	8.4	2200	0	812	110	450	55	0.72	253	63	116	160	5.32	891
Mean	7.57067	780.16667	0.00	453.86667	23.02667	42.33333	11.80233	0.43667	93.43333	32.33333	34.24000	19.30333	0.66667	366.53333
Range	1.45	1800	0.00	586	102.9	450	55	0.64	203	52	109.9	159.5	5.32	661
St. Dev.	0.36424	361.51139	0.00	139.06306	24.62439	82.30194	15.13929	0.17562	40.99127	13.99939	29.43063	38.22790	1.11149	127.8341
Co-efficient of variation	0.04748	0.46338	0.00	0.29979	1.06939	1.89928	1.28265	0.40219	0.43875	0.43019	0.85954	1.98038	1.67173	0.34877
Skewness	0.34864	2.29861	0.00	0.35403	2.24813	4.22729	1.66264	-0.18661	2.15472	0.51011	1.53177	2.35472	2.95298	2.63006
Kurtosis	-0.11565	6.12632	0.00	-0.22655	4.60638	18.32040	1.85604	-0.87877	5.81804	-0.52930	1.42272	4.84305	8.81766	7.82280

Table 5: ANOVA

	SS	Df	MS	F	p-value
Factor	0.000	14	0.000	0.000	1.00000
Error	5167297.369	405	12758.759		
Total	5167297.369	419			

Single factor ANOVA

Between subjects : Each group has a normal distribution of observations, The variances of each observation are equal across groups (homogeneity of variance), The observations are statistically independent

Table 6: Correlation co-efficient (Concentrations in mg/1)

	pH	CO_3	HCO_3	C1	SO_4	NO_3	F	Ca	Mg	Na	K	Fe
pH	1.0	0.0	-0.181	-7.9E-2	5.8E-2	-2.1E-2	-2.0E-2	6.3E-2	-0.17	-0.17	5.8E-2	-0.237
CO_3		1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HCO_3			1.0	0.591	0.59	0.296	0.171	0.475	0.679	0.809	0.641	6.4E-2
C1				1.0	0.804	0.37	-8.2E-2	0.632	0.565	0.793	0.824	-0.144
SO_4					1.0	0.429	9.5E-2	0.773	0.581	0.687	0.79	-4.0E-2
NO_3						1.0	-7.9E-2	0.58	7.1E-2	0.261	0.456	-7.6E-2
F							1.0	0.193	0.296	0.105	-8.1E-2	0.175
Ca								1.0	0.209	0.42	0.558	0.266
Mg									1.0	0.612	0.447	-0.18
Na										1.0	0.849	-0.129
K											1.0	-0.129
Fe												1.0

Table 7: Analysis of physico-chemical parameters of samples of ground water

Sampling location	Dissolved minerals				
	Halite (NaCl)	Sylvite (KCl)	Carbonate ($CaCO_3$)	Dolomite ($CaMg(CO_3)_2$	Anhydrite ($CaSO_4$)
Badyal Brahmana	20.724	11.44	154.015	143.887	17.015
Ratian	3.651	24.787	174.654	113.595	11.343
Kahne Chak	15.009	4.004	143.031	113.595	-
Barsalpur	14.124	11.44	-	267.536	12.761
Kaloe	6.928	6.101	26.59	272.629	-
Phalora	7.526	5.339	-	312.345	-
Bhole chak	58.525	23.101	249.588	227.19	49.627
Kul Kalan	9.322	3.051	86.352	181.752	53.881
Abdal	84.312	4.004	-	431.446	170.151
Bhoome	229.013	70.953	-	124.519	138.956
Pindi Sarochan	43.06	4.004	134.031	287.775	39.702
Mule Chak	20.857	2.86	123.589	204.471	-
Sai	23.417	8.008	-	300.384	49.627
Arnia	36.015	6.673	93.776	174.179	76.568
Shera Chak	10.219	1.907	152.871	128.741	29.776
Beaspur Parlah	279.904	146.856	57.445	265.056	106.344
Kothey Kalena	9.92	2.288	58.844	136.314	29.776
Pachel	21.754	1.716	188.286	174.179	56.717
Bena garh	295.172	181.508	-	299.643	638.065
Satowali	10.967	0.953	104.385	196.898	11.343
Suchetgarh	7.825	4.957	-	284.785	-
Changiya	16.206	2.479	-	94.842	45.374
Rangpur Trewa	152.675	64.353	110.861	181.752	102.09
Rangpur Trewa II	152.675	41.252	-	192.789	68.06
Kotli Raiyan	12.465	7.245	133.718	128.741	35.448
Haripur Rakh	14.111	5.148	-	287.033	25.523
R.S. Pura	15.607	3.241	84.468	174.179	21.269
Diwangarh	8.274	4.385	-	228.873	14.179

$$\text{Correlation co - efficient } r = \sqrt{\frac{n(pxy) - (px)(py)}{[npx^2 - (px)^2][npy^2 - (py)^2]}}$$

where,

x, y = values of array 1 and array 2, respectively

n= No. of observations.

$$\text{Skewness} = \frac{\Sigma^N_{i=1}(Y_i - \Sigma)^3}{(N-1)s^3}$$

where,

Σ is the mean, s is the standard deviation and N is the number of data points.

$$\text{Kurtosis} = \frac{\Sigma^N_{i=1}(Y_i - \Sigma)^4}{(N-1)s^4}$$

where,

Σ is the mean, s is the standard deviation and N is the number of data points.

The statistical results mean, standard deviation and co-efficient of variation are given in Table 4, Anova tests are depicted in Table 5 and correlation co-efficient is shown in Table 6.

Dissolved minerals:

The common dissolved minerals in the ground water of the study area were Halite, Sylvite, Dolomite, Carbonate and Anhydrite. Of these minerals Halite, Sylvite and Anhydrite are major constituents of evaporates (sedimentary rocks) and Calcite and dolomite are the predominant component of carbonate sedimentary rocks (limestone, dolomite). Carbonates break down with increasing temperature by decarbonation reactions to give CO_2-free Ca (-Mg etc.) minerals. Carbonates are also fairly soluble in mildly acid solutions such as rain water. The concentration of these minerals in the water samples of the study area is given in Table 7.

Conclusion:

In the present study, it was observed that some physico-chemical parameters like electrical conductivity, bicarbonate, total hardness, calcium, sulphate, nitrate and iron as determined from the analysis of groundwater samples of tehsil R.S. Pura were above the limits set by IS:10500 and BIS at certain places.

The people residing in these areas are, therefore, at high potential risk of contracting ailments/diseases related to higher level of such contaminants present in water.

In conclusion, it is crucial to apply strong preventive measures in the area concerned to save groundwater from further deterioration and regular monitoring and assessment of the groundwater should be done.

Since, agriculture is the main source of livelihood in the area under study; it is obvious that except for water lost through evapo-transpiration, agricultural water is recycled back to surface water and/or groundwater. However, agriculture is both cause and victim of water pollution. Therefore, appropriate steps must be taken to ensure that agricultural activities do not adversely affect the water quality in the area so that subsequent use of water for different purposes is not impaired.

Acknowledgement:

The first author is grateful to the J&K State Council for Science and Technology for providing financial assistance for the present study. The second author acknowledges the Central Ground Water Board, Jammu, J&K for the necessary help in carrying out the present work.

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