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RESEARCH ARTICLE

Physico-chemical Parameters of Groundwater of Bishnah, District Jammu, Jammu and Kashmir, India

Pragya Khanna

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Abstract The present study aims to assess the physico-chemical parameters (pH, electrical conductivity, carbonate, bicarbonate, chloride, sulphate, nitrate, fluoride, calcium, magnesium, sodium, potassium, iron and total hardness) of the underground water in tehsil Bishnah, district Jammu, Jammu and Kashmir, India. The water samples were collected from tube wells and hand pumps in 26 chosen sites during the pre-monsoon period (May, June 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, nitrate, total hardness, calcium, magnesium, sodium and iron as determined from the groundwater samples of tehsil Bishnah were above the limits set by IS: 10500, WHO and BIS at certain places. To analyse the data with statistical point of view the statistical parameters like mean, range, standard deviation, coefficient of variation, correlation coefficient, 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.

Keywords Physico-chemical parameters · Water quality standards · Groundwater · Statistical analysis

P. Khanna (✉)
Government College for Women, Parade Ground, Jammu 180 001, Jammu and Kashmir, India
e-mail: pragyajmu2002@yahoo.co.in

Introduction

Water plays a fundamental role in human life. Water supplies available for drinking and other domestic purposes must hold high degree of cleanliness. It should be free from chemical contamination and microorganisms [1–3]. Although groundwater is thought to be relatively clean and free from pollution than the surface water, however, the scientific research conducted globally during the last couple of decades has established that the ground water is also getting polluted radically because of increased human activities [4, 5]. Consequently, a number of cases of water borne diseases have been witnessed from time to time leading to health hazards [6, 7]. Therefore, basic monitoring on water quality is essential to observe the demand and pollution level of ground water.

For the present study, various samples of groundwater were collected from the different locations of tehsil Bishnah, dist. Jammu, Jammu and Kashmir, India and analysed for their physico-chemical parameters. The results were compared with drinking water specifications of WHO [8].

Material and Methods

Study Area (Fig. 1)

District Jammu is located between 74°24′–75°18′ east longitude and 32°50′–33°30′ north latitude. Administratively the district has been divided into four tehsils, viz. Jammu, R. S. Pura, Akhnoor and Bishnah. Bishnah consist of 39 villages and 39 panchayats. Its coordinates are 32°37′0″N and 74°52′0″E in DMS (Degrees Minutes Seconds). It is located at an elevation of 294 m above sea level and its population amounts to 11,645.

Geography

In the area under investigation, the climate is typically monsoonal, though the region sufficiently harvests average 40–50 mm (1.6–2 in.) of rain per month between January and March. In the summer season, Bishnah is very hot and can reach up to 40 °C (104 °F) whilst in July and August, very heavy though erratic rainfall occurs with monthly extremes of up to 650 mm (25.5 in.). In September, rainfall declines, and by October conditions are hot but extremely dry, with minimal rainfall and temperature of around 29 °C (84 °F).

Sample Collection

The ground water samples were collected from tube wells and hand pumps from 26 chosen sites during the pre-monsoon period (May, June 2013).

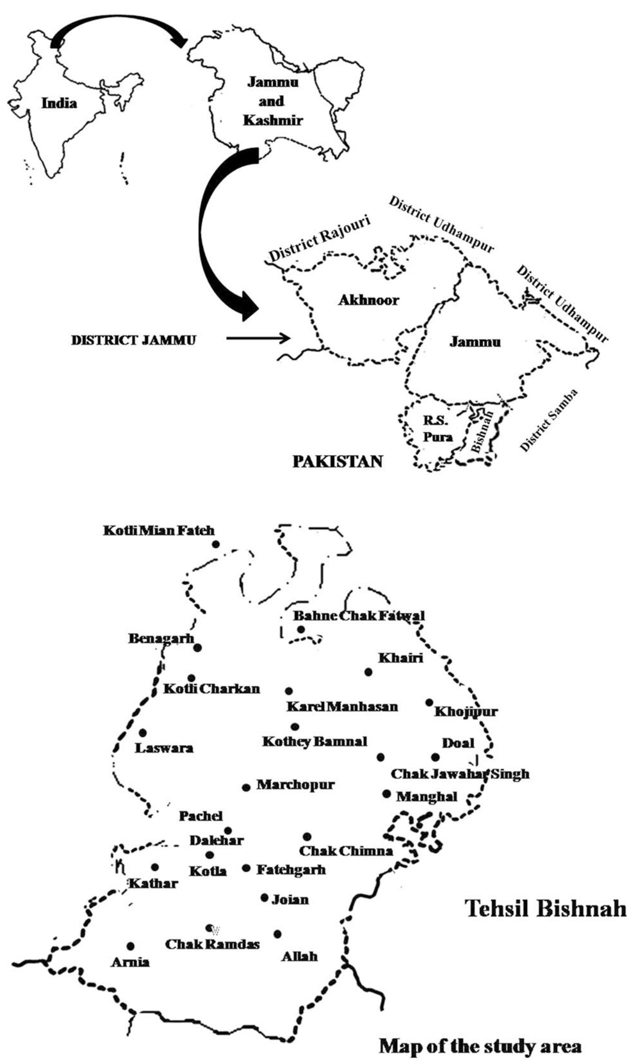

Fig. 1 Map of the study area

Preparation of Water Samples

The samples were collected in precleaned, sterilized polyethylene bottles of one litre capacity without any air bubble as per standard procedure. Each sample bottle was clearly labelled and relevant details were recorded. The samples were kept in refrigerator, maintained at 4 °C and were analyzed within 12–24 h after collection.

Physico-chemical Analysis

Physico-chemical analysis was 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 [5] (Table 1).

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

Statistical Analysis

To analyse the data with statistical point of view the statistical parameters like mean, range, standard deviation, coefficient of variation, correlation coefficient, kurtosis, skewness were systematically calculated for each parameter.

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

$$\text{Mean } \mu = \frac{\sum x}{n}$$

where x is the value of observation, n the no. of observations

$$\text{Standard deviation } \sigma = \frac{\sum (\bar{x} - x)^2}{n - 1}$$

where x is the value of parameter, n the no. of observations

$$\text{Variance cv} = \frac{\sigma}{\mu}$$

Correlation coefficient

$$r = \frac{n(\sum xy) - (\sum xy)(\sum y)}{\sqrt{\left[n \sum x^2 - (\sum x)^2\right]\left[n \sum y^2 - (\sum y)^2\right]}}$$

where x, y are values of array 1 and array 2 respectively, n is no. of observations.

Also, Single factor Anova tables, Piper diagram and Schoeller graph were prepared to signify the major results.

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),

Table 1 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-})	Gravimetric method
Nitrate (NO_3^-)	Colorimetric method
Fluoride (F^-)	Ultraviolet spectrophotometric method
Total Hardness (TH)	Titrimetric method
Calcium (Ca^{2+}), Magnesium (Mg^{2+})	EDTA titrimetric method
Sodium (Na^+)	Flame photometric method
Potassium (K^+)	Flame photometric method
Iron (Fe)	Digestion followed by atomic absorption spectrophotometry (AAS)

sylvite (KCl), carbonate ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), anhydrite ($CaSO_4$), permanent hardness, temporary hardness and alkalinity.

Dissolved minerals for the present water samples were calculated using the software.

Results and Discussion

The experimental values for all the physico-chemical parameters are presented in Table 2 and were compared with standards as prescribed by different agencies [4, 8]. The interpretation of data has been made with the help of statistical tools.

pH

pH serves as an index to denote the extent of pollution by acidic and alkaline waste and represents hydrogen ion activity in water. It affects equilibrium between most chemical species in water. The permissible range for pH is 6.5–8.5 [4] for potable drinking water. pH of the underground water tested (in 90 % samples) is in the range of 7.0–8.45 which is within the permissible limit.

Electrical Conductivity (EC)

It is a measure of the ability of an aqueous solution to carry an electric current. It depends on the presence of ions, on their total concentration, mobility and temperature of measurement. Higher value of conductivity shows higher concentration of dissolved ions [8]. Conductivity of water sample was found in the range of 470–1630 micromhos/cm^2, which is quite high in some areas (Allah, Chak Chimna, Chak Jawahar Singh, Chak Ramdas, Doal, Fatehgarh, Karel Manhasan, Kathar, Khairi, Khojipur, Kotli Charkan, Pandhori Brahmna and Upper Kanhal) as compared to the WHO standards (0–800). Electrical conductivity is considered to be a rapid and good indicator of dissolved solids.

Carbonate (CO_3^{2-}) and Bicarbonate (HCO_3^-)

The stoichiometric or chemical equilibrium equation between bicarbonate and carbonate is $HCO_3^- = CO_3^{2-} + H^+$. Because bicarbonate and carbonate are on opposite sides of the equilibrium equation, they are not often detected in the same groundwater sample. However, they can occur simultaneously at defined temperature, pressure, and hydrogen ion concentrations (pH).

The carbonate concentration is zero at all places except at Doal, Joian and Khairi. Bicarbonate ranges from 134 to 775 mg/L in 98 % of the samples studied. The acceptable limit of carbonate (CO_3^{2-}) and bicarbonate HCO_3^- is 75 mg/L and 30–400 mg/L, respectively. The presence of high concentrations of HCO_3^- can cause nutritional disturbances, such as reducing the availability of calcium and the uptake of iron.

Chloride (Cl^-)

Chloride is an anion found in variable amount in groundwater. Chloride may be present naturally in groundwater and may also originate from diverse sources such as weathering and leaching of sedimentary rocks. The maximum permissible limit of chloride in potable water is 250 mg/L. In the analyzed water samples, the concentration of chloride varied from 7.1 to 82 mg/L which is well within the permissible limit.

Sulphate (SO_4^{2-})

Aquifers with a naturally occurring sulphate source, such as gypsum, have very high concentrations of sulphate as compared to other aquifers. Sulphate in groundwater may enter through weathering of sulphide bearing deposits. The acceptable limit of sulphate is 200 mg/L. The sulphate content in all the analyzed water samples varied from 0 to 125 mg/L.

Nitrate (NO_3^-)

Natural nitrate levels in groundwater are generally very low (typically less than 10 mg/L), but nitrate

Table 2 Result of physico-chemical analysis of samples of ground water from tube wells and hand pumps of tehsil Bishnah, dist. Jammu, Jammu and Kashmir

S. no.	Location	Source	Latitude	Longitude	pH	EC	CO_3^{2-} mg/L	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	F^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	Fe	TH	Type of water
1.	Allah	TW	32.5172	74.8386	7.55	1,000	0	470	43	38	33	0.33	52	41	64	64	1.15	300	Mg–Na–Ca-HCO_3
2.	Arnia	HP	32.5219	74.7992	7.40	710	0	342	25	54	11	0.43	98	23	20	3.5	1.11	340	Ca–Mg-HCO_3
3.	Bahne Chak Fatwal	TW	32.605	74.8803	7.95	730	0	464	21	nd	9.79	0.32	72	43	28	3.1	1.20	355	Ca–Mg-HCO_3
4.	Bishnah Samadhiyan	TW	32.6131	74.86417	7.57	620	0	415	7.1	nd	nd	0.60	70	33	21	2	nd	310	Ca–Mg-HCO_3
5.	Chak Chimna	TW	32.5361	74.8991	7.00	1,140	0	574	43	15	11	0.49	82	26	52	108	0.78	310	Ca–K-Na-HCO_3
6.	Chak Jawahar Singh	HP	32.5589	74.9017	7.95	1,200	0	580	57	125	4.36	0.50	108	45	112	3.4	0.04	455	Ca–Na–Mg-HCO_3
7.	Chak Ramdas	TW	32.5188	74.8155	7.30	960	0	421	43	65	4.11	0.63	100	29	55	1.0	0.15	370	Ca–Na–Mg-HCO_3
8.	Chorli	HP	32.5997	74.86639	7.47	660	0	452	11	nd	nd	0.40	46	49	32	1.7	2.42	315	Mg–Ca-HCO_3
9.	Daleher	HP	32.54	74.8514	7.50	620	0	354	11	25	1.2	0.77	50	34	33	2.3	1.06	265	Mg–Ca–Na-HCO_3
10.	Doal	HP	32.5633	74.925	8.35	1,150	36	534	53	14	38	0.57	64	57	114	30.0	0.05	395	Na–Mg–Ca-HCO_3
11.	Fatehgarh	TW	32.5338	74.8461	7.25	970	0	360	53	120	28	0.20	120	35	32	14.0	nd	445	Ca–Mg-HCO_3–SO_4
12.	Joian	TW	32.5225	74.8708	8.45	850	66	360	25	18	25	0.39	110	17	36	48.0	0.07	345	Ca-HCO_3–CO_3
13.	Karel Manhasan	TW	32.5658	74.8708	7.60	1,630	0	769	78	115	45	0.36	148	52	94	95	nd	585	Ca–Mg–Na-HCO_3
14.	Kathar	HP	32.5125	74.8622	7.55	1,280	0	775	46	nd	0	0.90	152	36	50	52.0	0.10	530	Ca–Mg-HCO_3
15.	Khairi	TW	32.585	74.9075	8.45	1,300	42	720	28	50	3.24	0.39	66	43	107	166	0.20	340	Na–K–Mg–Ca-HCO_3
16.	Khojipur	TW	32.5775	74.9233	8.25	920	0	543	35	29	13	0.14	62	26	130	2.2	0.08	260	Na–Ca-HCO_3
17.	Kothey Bamnal	TW	32.5428	74.8703	7.80	620	0	293	18	38	23	0.46	58	27	34	0.8	0.9	255	Ca–Mg–Na-HCO_3
18.	Kotla	TW	32.5244	74.8531	7.75	500	0	299	11	19	2.18	0.93	48	21	38	2.6	0.45	205	Ca–Mg–Na-HCO_3
19.	Kotli Charkan	HP	32.6003	74.8353	7.80	1,210	0	561	64	110	14	0.38	110	56	64	36.0	nd	505	Ca–Mg–Na-HCO_3
20.	Laswara	TW	32.5853	74.8375	7.60	550	0	220	39	48	4.72	nd	84	17	6.5	2.7	0.12	280	Ca–Mg-HCO_3
21.	Manghal	HP	32.5525	74.9033	8.10	660	0	458	14	nd	1.6	0.31	62	36	45	3.0	nd	305	Ca–Mg–Na-HCO_3
22.	Marchopur	HP	32.5508	74.8539	7.25	580	0	134	82	65	6.12	0.07	86	15	16	1.1	2.06	275	Ca–Mg–Cl-HCO_3–SO_4
23.	Marol	TW	32.5311	74.8269	7.30	470	0	220	7.1	55	6.5	0.33	52	21	5.6	26	1.88	215	Ca–Mg-HCO_3–SO_4
24.	Pachel	HP	32.545	74.8261	7.25	750	0	458	14	40	1.0	0.49	130	23	11	0.9	5.32	420	Ca–Mg-HCO_3
25.	Pandhori Brahmna	TW	32.53	74.8531	8.00	1,000	0	665	28	35	20	0.48	140	43	30	41.0	nd	525	Ca–Mg-HCO_3
26.	Upper Kanhal	TW	32.6339	74.79443	7.58	1,270	0	641	67	32	14	0.27	158	26	78	2.6	0.49	500	Ca–Na-HCO_3

concentrations grow due to human activities, such as agriculture, industry, domestic effluents and emissions from combustion engines.

Nitrates generally move relatively slow in soil and groundwater: there is a time lag of approximately 20 years between the pollution activity and the detection of the pollutant in groundwater. For this reason, it is predicted that current polluting activities will continue to affect nitrate concentrations for several decades. However, if the pressure in the aquifer is high, transport can be very rapid within the saturation zone [9].

The nitrate content in the study area varied in the range 0–45 mg/L which is higher than prescribed limit of 40 mg/L at selected places like Karel Manhasan.

Fluoride (F^-)

Small concentration of fluoride in drinking water has beneficial effect on human health for preventing dental caries. Higher concentration of fluoride than that of 1.5 mg/L carries an increased risk of dental fluorosis and even higher concentration could lead to skeletal fluorosis [10].

Fluoride content of 95 % of the groundwater samples of the study area ranges from 0.0 to 0.93 mg/L which is well within the permissible limit.

Total Hardness (TH)

When water passes through or deposits over limestone the levels of Ca^{2+}, Mg^{2+} and HCO_3^- ions present in the water can greatly increase and cause the water to be classified as hard water. High levels of hard-water ions can cause scaly deposits in plumbing, appliances, and boilers. These two ions also combine chemically with soap molecules, resulting in decreased cleansing action. In the present study the total hardness values ranged from 205 to 585 mg/L. The moderately hard water has the range of 60–120 mg/L.

The high values of total hardness have an effect on the soil nature like lack of aeration and permeability of earth surface and it may indirectly affect the growth of plants and the general health of human society.

Calcium (Ca^{2+})

Calcium salts and calcium ions occur most commonly in nature. They may result from the leaching of soil and other natural sources or may come from man-made sources such as sewage and some industrial wastes. Calcium is usually one of the most important contributors to hardness. Human body requires approximately 0.7–2.0 g of calcium per day as a food element; excessive amounts can lead to the formation of kidney or gallbladder stones [11]. The desirable limit of calcium is 75 mg/L while in the present

Table 3 Statistical evaluation of different parameters in the groundwater samples

	pH	EC	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	F^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	Fe	TH
Min.	7.0	470.00	0.00	134.00	7.100	0.00	0.00	0.00	46.00	15.00	5.60	0.800	0.00	205.00
Max.	8.45	1630.00	66.00	775.00	82.00	125.00	45.00	0.93	158.00	57.00	130.00	166.00	5.3200	585.00
Mean	7.69308	898.0769	25.53846	464.692	135.507	42.6923	12.3007	0.42846	89.53846	33.6153	50.3115	27.4192	0.755	361.730
Range	1.45	1160.00	66.00	641.00	74.90	125.00	45.00	0.93	112.00	42.00	124.400	165.200	5.3200	380.00
St. dev.	0.39714	304.5917	816.2707	168.601	22.20551	38.1919	12.679	0.22141	35.20594	12.27380	35.4689	41.2963	1.16958	104.287
Coefficient of variation	0.05162	0.33916	2.93778	0.36282	0.62537	0.89459	1.03075	0.51675	0.39319	0.36512	0.70499	1.50611	1.54911	0.28830
Skewness	0.44729	0.48041	2.78281	0.10198	0.49617	0.91999	1.10225	0.44300	0.53697	0.31992	0.83854	1.92581	2.51697	0.54851
Kurtosis	−0.67383	−0.63429	6.50483	−0.60527	−0.77928	−0.09203	0.23773	0.29505	−0.95605	−0.93871	−0.37691	3.29882	7.00499	−0.72889

Table 4 Anova tables: single factor Anova

	SS	*df*	MS	F	*p* value
Between subjects[a–c]					
Factor	22,740,865.607	13	1,749,297.354	176.428	0.00
Error	3,470,270.373	350	9,915.058		
Total	26,211,135.980	363			
Within subjects[a–d]					
Factor	22,740,865.607	13	1,749,297.354	210.777	0.00
Within	3,470,270.373	350	9,915.058		
Error	2,697,266.087	325	8,299.280		
Total	26,211,135.980	688			

[a] Each group has a normal distribution of observations

[b] The variances of each observation are equal across groups (homogeneity of variance)

[c] The observations are statistically independent

[d] The variances of each station are equal across groups (homogeneity of covariance)

Table 5 Correlation coefficient (concentrations in mg/L)

	pH	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	F^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	Fe
pH	1.0	0.526	0.378	−8.9E−2	−0.147	0.116	−9.4E−2	−0.143	0.348	0.589	0.357	−0.508
CO_3^{2-}		1.0	−0.734	−0.615	−0.542	8.7E−2	−0.526	0.985	−0.982	−0.992	−0.297	−0.296
HCO_3^-			1.0	0.29	0.173	0.267	7.1E−2	0.461	0.631	0.68	0.618	−0.285
Cl^-				1.0	0.531	0.464	−0.381	0.567	0.206	0.408	0.155	−0.292
SO_4^{2-}					1.0	0.197	−0.341	0.398	0.425	0.151	−2.0E−3	2.8E−2
NO_3^-						1.0	−0.264	0.309	0.406	0.265	0.159	−0.238
F^-							1.0	−8.0E−2	4.2E−2	−0.138	−7.4E−2	−0.16
Ca^{2+}								1.0	3.5E−2	4.7E−2	4.2E−2	4.4E−2
Mg^{2+}									1.0	0.522	0.325	−0.175
Na^+										1.0	0.475	−0.534
K^+											1.0	−0.265
Fe												1.0

samples it ranged from 46 to 158 mg/L. Thus it was found higher than the desirable limit at many places like Arnia, Chak Chimna, Chak Jawahar Singh, Chak Ramdas, Fatehgarh, Joian, Karel Manhasan, Kathar, Kotli Charkan, Laswara, Marchopur, Pachel, Pandhori Brahmna and Upper Kanhal.

Magnesium (Mg^{2+})

The magnesium content in the study area varied in the range from 15 to 57 mg/L while the range prescribed by WHO is 30 mg/L as desirable limit to 100 mg/L as permissible limit in the absence of alternate source.

A major hypothesis that has emerged from studies in recent years is that magnesium, which together with calcium is the main determinant of water hardness, protects against death from ischemic heart disease [18]. There are a number of facts to support the hypothesis that magnesium deficiency can induce artery spasm, as has been shown in animal experiments [12, 13].

Epidemiological studies in the United States [14], Canada [15, 16], South Africa [17], Finland [18, 19], and Sweden [20] have shown an inverse correlation between magnesium in drinking water and mortality from ischemic heart disease.

It has been suggested that the incidence of sudden death from ischemic heart disease is higher when water magnesium level is lower, owing to an increased tendency to vasoconstriction [13, 14] or arrhythmias [17, 21–24].

Though it has also been suggested that at very high concentrations, magnesium salts have a laxative effect particularly when present as magnesium sulphate [25].

Table 6 Analysis of physico-chemical parameters of samples of ground water from tube wells and hand pumps of tehsil Bishnah, Dist. Jammu, Jammu and Kashmir

S. no.	Location	Sum of anions (meq/L)	Sum of cations (meq/L)	Balance (%)	Cal. TDS (mg/L)	Dissolved minerals (mg/L)					Permanent hardness (mg/L $CaCO_3$)	Temporary hardness (mg/L $CaCO_3$)	Alkalinity (mg/L $CaCO_3$)
						Halite (NaCl)	Sylvite (KCl)	Carbonate ($CaCO_3$)	Dolomite (($CaMg(CO)_2$)	Anhydrite ($CaSO_4$)			
1.	Allah	10.2575	10.4297	0.83	491.8	162.853	70.953	–	166.022	53.881	0.0	298.4	385.2
2.	Arnia	7.6354	7.7817	0.95	578.0	36.015	6.673	93.776	174.179	76.568	58.8	280.3	280.3
3.	Bahne Chak Fatwal	8.3726	8.4706	0.58	392.3	30.013	5.911	2.762	325.64	–	0.0	356.5	380.3
4.	Bishnah Samadhiyan	7.0342	7.1725	0.97	319.9	8.723	3.813	38.943	249.91	–	0.0	310.4	340.1
5.	Chak Chimna	11.1370	11.2828	0.65	515.8	132.318	70.953	82.105	196.898	21.269	0.0	311.5	470.4
6.	Chak Jawahar Singh	13.8140	14.0515	0.85	650.0	88.967	6.483	–	256.504	177.24	0.0	454.6	475.3
7.	Chak Ramdas	9.5664	9.7992	1.20	478.6	69.457	1.907	62.602	219.617	92.165	23.8	345.0	345.0
8.	Chorli	9.0936	7.8487	−7.35	356.7	15.607	3.241	–	86.714	92.165	0.0	316.3	370.4
9.	Daleher	6.6932	6.8244	0.97	301.5	14.71	4.385	–	181.751	35.448	0.0	264.6	290.1
10.	Doal	12.6111	13.6108	3.81	602.5	42.569	57.2	–	246.057	35.448	0.0	394.2	497.6
11.	Fatehgarh	10.3564	10.6175	1.24	762.2	66.508	26.693	30.531	265.056	170.151	148.3	295.0	295.0
12.	Joian	9.6042	9.6837	0.41	474.8	91.605	41.252	185.968	128.741	25.523	0.0	344.4	405.0
13.	Karel Manhasan	17.9441	18.1817	0.66	905.4	239.191	128.706	35.672	393.797	163.061	0.0	583.2	630.2
14.	Kathar	14.0481	14.0549	0.02	653.4	127.229	75.903	231.385	272.629	–	0.0	527.3	635.2
15.	Khairi	15.1052	15.7379	2.05	637.5	272.271	46.202	–	207.329	70.896	0.0	341.6	660.1
16.	Khojipur	10.7085	10.9466	1.10	436.3	54.461	4.195	17.566	196.898	41.12	0.0	261.6	445.0
17.	Kothey Bamnal	6.4967	6.6471	1.14	329.9	28.504	1.525	–	193.582	53.881	15.6	240.1	240.1
18.	Kotla	5.6910	5.8584	1.45	255.0	14.261	4.957	13.61	159.033	26.941	0.0	206.1	245.0
19.	Kotli Charkan	13.5368	13.8007	0.97	688.6	51.743	68.64	–	294.44	155.972	45.0	459.8	459.8
20.	Laswara	5.7817	5.9463	1.40	422.0	16.54	5.148	89.77	128.741	68.06	99.2	180.3	180.3
21.	Manghal	7.9442	8.0897	0.91	343.6	18.613	5.72	6.61	272.629	–	0.0	302.8	375.4
22.	Marchopur	5.9651	6.3233	2.92	407.3	40.713	2.097	85.284	113.595	92.165	166.5	109.8	109.8
23.	Marol	5.0737	5.2984	2.17	270.7	14.25	11.716	–	133.44	77.986	35.8	180.3	180.3
24.	Pachel	8.7769	9.0713	1.65	683.6	21.754	1.716	188.286	174.179	56.717	43.6	375.4	375.4
25.	Pandhori Brahmna	12.7665	12.8772	0.43	631.3	76.338	46.202	136.118	325.64	49.627	0.0	526.2	545.0
26.	Upper Kanhal	13.3029	13.5001	0.74	659.1	106.665	4.957	254.2	196.898	45.374	0.0	501.2	525.3

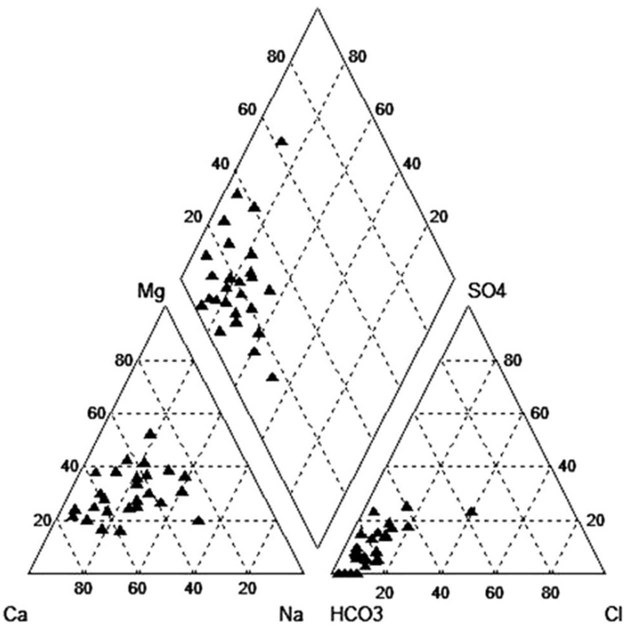

Fig. 2 Piper trilinear diagram for anion and cation composition of water samples

Sodium (Na^{+})

The sodium content of all groundwater samples of the study area ranged from 5.6 to 130 mg/L while the permissible limit is 50 mg/L as prescribed by BIS. At room temperature, the average permissible limit of sodium is about 200 mg/L according to WHO. Sodium is a principal chemical in body fluids, and it is not considered harmful at normal levels of intake from combined food and drinking water sources. However, increased intake of sodium in drinking water may be problematic for people with hypertension, heart disease or kidney problems that require them to follow a low sodium diet besides it also affects the palatability of water [26]. Higher content of sodium in irrigation water may cause salinity problems.

Potassium (K^{+})

Potassium, an important fertilizer, is strongly held by clay particles in soil. Therefore, leaching of potassium through the soil profile into ground water is important only on coarse-textured soils. Potassium is common in many rocks. Many of these rocks are relatively soluble and potassium concentrations in ground water increase with time [27].

Potassium is weakly hazardous in water, but it does spread rapidly, because of its relatively high mobility and low transformation potential.

Vital functions of potassium include its role in nerve stimulus, muscle contractions, blood pressure regulation and protein dissolution. It protects the heart and arteries, and may even prevent cardiovascular disease. The intake of a number of potassium compounds may be particularly harmful at high doses [28].

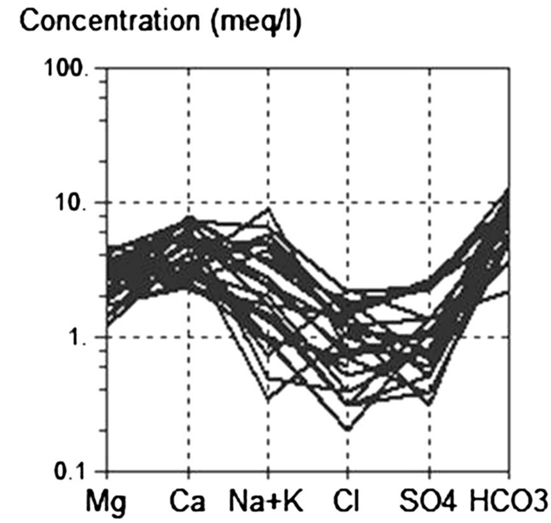

Fig. 3 Schoeller graph showing the groundwater types

In the present samples the range of potassium varied in between 0.8 and 166 mg/L.

Iron (Fe)

Iron in rural groundwater supplies is a common problem: its concentration level ranges from 0 to 50 mg/L, while WHO recommended level is <0.3 mg/L. Iron and manganese occur naturally in water, especially groundwater. Neither of the elements causes adverse health effects; they are, in fact, essential to the human diet. However, water containing excessive amounts of iron and manganese can stain clothes, discolour plumbing fixtures, and sometimes add a "rusty" taste and look to the water. In the present samples the concentration ranges from 0 to 5.32 mg/L which is higher to the desirable limit at certain places.

Long term consumption of drinking water with high concentration of iron may lead to liver diseases [29].

Statistical Analysis

The statistical results related to mean, standard deviation and coefficient of variation are given in Table 3, Anova tests are depicted in Table 4 and correlation coefficient is shown in Table 5.

An account has been prepared (Table 6) to analyze the factors like sum of anions (meq/L), sum of cations (meq/L) and ion balance.

Also, the major ionic species obtained from the physicochemical analysis are projected graphically on the modified

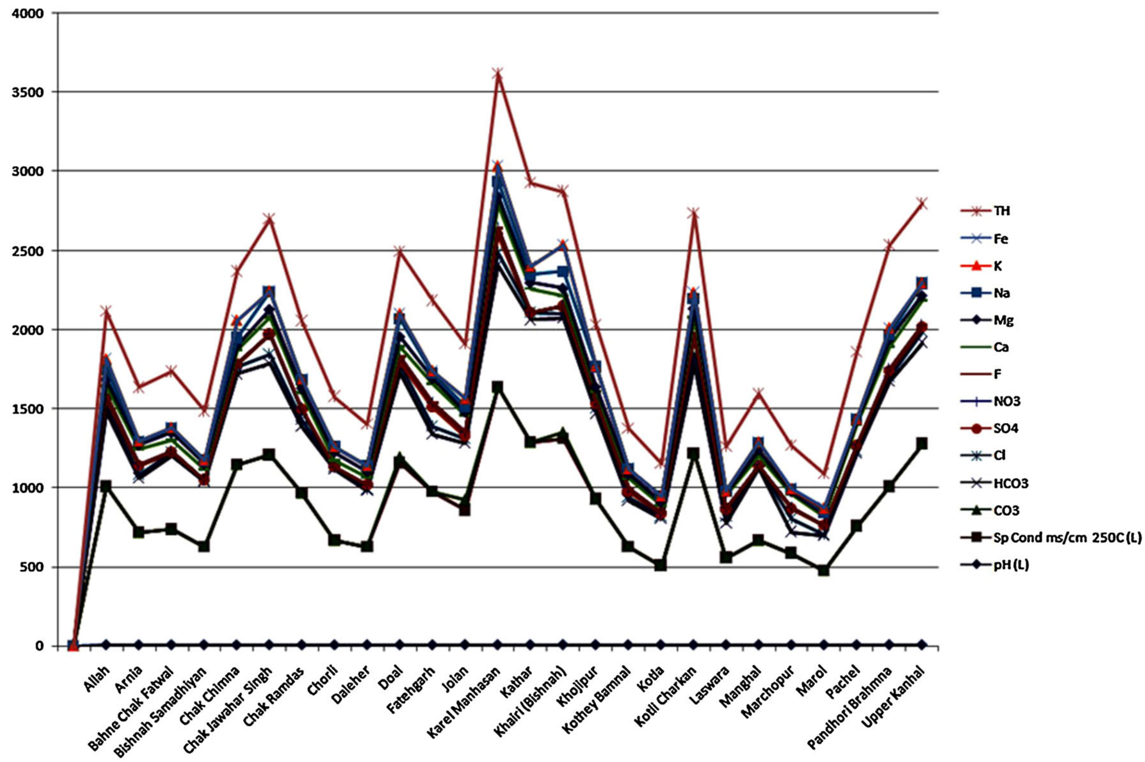

Fig. 4 Line graph showing variation in different parameters at 26 stations

Trilinear Piper diagram (Fig 2). The water-types interpreted from Trilinear Piper diagrams are summarized in Table 2.

Figure 3 represents the groundwater types in the Schoeller diagram. The Schoeller diagram [30] is used to study the comparative changes in the concentrations and ratios of water quality parameters for different samples.

Figure 4 represents the variation in different parameters at 26 stations.

Conclusion

In the present study it was observed that some physico-chemical parameters like electrical conductivity, bicarbonate, nitrate, total hardness, calcium, magnesium, sodium and iron as determined from the groundwater samples of tehsil Bishnah were above the limits set by IS: 10500, WHO and BIS at certain places. The people residing in these areas are therefore at high impending threat of contracting ailments/diseases related to higher level of such contaminants present in water.

In conclusion, it is essential to apply tough preventive measures in the area concerned to save groundwater from further deterioration and regular supervision and assessment of the groundwater should be done periodically. The present paper forms a part of a major project, the studies undertaken during the post-monsoon period reveal that a better water quality was found in the post-monsoon season than that of pre-monsoon season, because of water recharging due to rains.

Since, agriculture is the main source of economy of people in the area under study, it is evident that except for water lost through evapotranspiration, agricultural water is recycled back to surface water and/or groundwater. However, agriculture is both source 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.

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