



Research Paper

Groundwater quality assessment: Physico-chemical and statistical analysis of selected groundwater samples in district Samba, Jammu, Jammu and Kashmir, India

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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 District Samba, Jammu, J&K, India. The water samples were collected from tube wells, dug wells and hand pumps in 15 chosen sites during the pre-monsoon period (Mar to May, 2018).

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 and nitrate as determined from the groundwater samples of Dist. Samba 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 ($\text{CaMg}(\text{CO}_3)_2$), Anhydrite (CaSO_4), permanent hardness, temporary hardness and alkalinity.

Keywords: Physicochemical parameters, water quality standards, Groundwater, Statistical analysis.

INTRODUCTION:

The importance of water quality in human health has recently attracted a great deal of interest. In developing countries like India, around 80 % of all diseases are directly related to poor drinking water quality and unhygienic conditions (Olajire and Imeokparia, 2001; David et al., 2011; Khadri et al., 2013).

There is an extensive literature, which stresses on deterioration of quality of both surface and ground water (Tiwari, and Mishra, 1986; 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. in to the water bodies brings about a series

of changes that affects the environmental quality and animal and human health. The changes in the physicochemical characteristics of water have been the subject of several investigations over time. (Milway, 1969; Olimax and Sikorska, 1975; Vollenweidre, 1986; Moore et al., 1998; Mahananda et al., 2005, PriyaKanwar and Pragya Khanna, 2015).

In the present scenario, water demand is increasing all over the world due to rapid growth in population and more than half of the world depends on groundwater for survival (UNESCO, 1992). In Asia alone, about 1 billion people are directly relying on groundwater source (Foster, 1995). According to World Health Organization, about 80% of all the diseases in human beings are caused by poor quality of water (Al-Hadithi, 2012). Usually the groundwater is considered less polluted as compared to the surface water due to less exposure to the external environment (Iqbal and Gupta, 2009). However, the modern civilization, industrialization, urbanization, increase in population and improper waste management are agents of degradation of groundwater quality (Agarwal, 2009).

A couple of decades back the ground water quality of different villages of Samba district was good and was successfully used for different domestic purposes but unfortunately due to setup of Small Scale Industries Development Corporation (SIDCO) on the bank of river Basantar the ground water quality got badly deteriorated. Ground water is generally considered to be pure and fit for drinking purposes but in Samba during the past couple of decades it was observed that the ground water was getting contaminated. In this study an attempt was to check suitability of groundwater for agricultural, municipal, industrial and domestic uses by evaluating physico-chemical parameters.

For the present study, various samples of groundwater were collected from the different locations of Samba Dist., Jammu, J&K, India and analysed for their

physicochemical parameters like H, Electrical conductivity, Carbonate, Bicarbonate, Chloride, Sulphate, Nitrate, Fluoride, Calcium, Magnesium, Sodium, Potassium, Iron and Total hardness. The results were compared with drinking water specifications of WHO, 1999; IS:10500, 1991 and BIS, 2004.

STUDY AREA

Samba is located between latitude 32°26'25" and 32°48'12" N and longitudes between 74°52'04" and 75°10'56"E. It has an average elevation of 384 metres (1259 feet). Samba town is situated on range of Shivalik hills alongside the National Highway 1-A / on the bank of river Basantar at a distance of forty km from Jammu city. District Samba is bounded by District Udampur in the North, District Kathua in the East, Tehsils Jammu and Bishnah of District Jammu in the west, while on the southern side it has International Border with Pakistan. The perennial Basantar River drains the study area. (Map 1)

The drainage pattern is dendritic to sub-dendritic. In the study area, an industrial estate lies on the bank of Basantar River, due to which natural and anthropogenic condition prevails that are in turn reflected in the hydrological and ground water quality conditions of the area. The study area is in general an agriculture based area and the source of recharge in the area is rainfall.

MATERIALS AND METHODS:

Sample collection

The ground water samples were collected from shallow aquifer based hand pumps and dug wells in 15 chosen sites during the pre-monsoon period (Mar. 2018 to May 2018).

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°C 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 (CO₃), Bicarbonate (HCO₃), Chloride (Cl), Sulphate (SO₄), Nitrate (NO₃), Fluoride (F), Calcium (Ca), Magnesium (Mg), 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.

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)	Argenoto metric method
Nitrate (NO ₃)	Turbidity method
Fluoride (F)	Ultraviolet spectrophotometric method
Total Hardness (TH)	SPADNS method
Calcium (Ca), Magnesium (Mg)	EDTA Titrimetric method
Sodium (Na)	By difference
Potassium (K)	Flame photometric method
Iron (Fe)	Digestion followed by Atomic Absorption Spectrophotometry (AAS)

RESULTS AND DISCUSSION:

The experimental values for all the physico-chemical parameters are tabulated in table 2 and were compared with standards as prescribed by different agencies (IS:10500, 1991 WHO, 1999 and BIS, 2004).

pH

The permissible range for pH is 6.5-8.5 as per IS:10500 for potable drinking water. pH represents hydrogen ion activity in water. It affects equilibrium between most chemical species in water. The underground water tested here has a pH range of 6.92-8.22 which is within the permissible limit.

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 (Wightman et al., 2003). Conductivity of water sample was found in the range of 290-1290micromhos per cm², which is quite high in some areas as compared to the WHO standards (0-800). Electrical conductivity is considered to be a rapid and good measure of dissolved solids.

Carbonate (CO₃²⁻) and Bicarbonate (HCO₃⁻)

The carbonate concentration is zero throughout the Dist. Samba. Bicarbonate ranges from 220 to 660 mg/l. The acceptable limit of Carbonate (CO₃²⁻) and Bicarbonate (HCO₃⁻) is 75 mg/l and 30 to 400 mg/l respectively. The presence of high concentrations of HCO₃⁻ 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, 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 10-180 mg/l which is well within the permissible limit.

Sulphate (SO₄)

Sulphate in groundwater may enter through weathering of sulphide bearing deposits. The acceptable limit of sulphate is 200 mg/l. The sulphate content in analyzed water samples varied from 6 to 33.1 mg/l. All samples were within the permissible limit.

Nitrate (NO₃)

Nitrate contamination occurs when there is more nitrate in the soil than plants can use and when water can move easily through the soil and underlying rock. The excess nitrate is carried through the soil into groundwater supplies by irrigation, rainwater, and snowmelt. This occurs particularly where the soil is sandy, gravelly, or shallow over porous limestone bedrock (Spalding and Exner, 1993)

The nitrate content in the study area varied in the range 2.45 to 81 mg/l which is higher than the maximum prescribed limit of 45 mg/l.

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 carry an increased risk of dental fluorosis and even higher concentration could lead to skeletal fluorosis (Vyas and Sawant, 2008).

Fluoride content of groundwater samples of the study area ranges from 0.01 to 0.62 mg/l which is well within the permissible limit.

Total Hardness (TH)

High concentration of carbonates and bicarbonates of calcium and magnesium in groundwater causes hardness. In the present study the total hardness values ranged from

230-560 mg/l. The desirable limit of hardness as fixed by WHO is 300 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)

Calcium is usually one of the most important contributors to hardness. Human body requires approximately 0.7 to 2.0 grams of calcium per day as a food element; excessive amounts can lead to the formation of kidney or gallbladder stones. The desirable limit of calcium is 75 mg/l while in the present samples it ranged from 40 to 160 mg/l and it was found higher than the desirable limit in 07 locations out of 14 studied.

Magnesium (Mg)

The magnesium content in the study area varied in the range from 7 to 39 mg/l while the range prescribed by WHO is 30 mg/l (desirable limit) to 100 mg/l (permissible limit in the absence of alternate source).

Sodium (Na)

The sodium content of groundwater samples of the study area ranges from 17 to 190 mg/l. At room temperature, the average permissible limit of sodium is about 200 mg/l according to WHO. Higher concentration of Na⁺ ion in drinking water may cause heart problems besides affecting the palatability of water (Chandetrik and Sharma, 2011).

Potassium (K)

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

The intake of a number of potassium compounds may be particularly harmful at high doses (IOM, 2004). In the present samples the range of potassium varied in between 1.1 to 8.6 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. In the present samples the concentration ranges from 0.01 to 1.65 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 (Gyamfiet *et al.*, 2012).

STATISTICAL ANALYSIS

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

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

Where x= Value of observation
 N= No. of observations

Standard deviation σ =

$$\sqrt{\frac{\sum (\bar{X} - X)^2}{n-1}}$$

Where x= Value of parameter
 n= No. of observations

Coefficient of variation $cv = \frac{\sigma}{\mu}$

Correlation coefficient

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

Where
 x,y = values of array 1 and array 2 respectively
 n= No. of observations

The statistical results 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.

Also, the major ionic species obtained from the physico-chemical analysis are projected graphically on the modified Trilinear Piper diagram (Graph 1). This shows the percentage composition of different ions. By grouping Na^+ and K^+ together, the major cations were displayed on the trilinear diagram. Likewise, CO_3^{-2} and HCO_3^- are grouped resulting in three groups of the major anions. The cations and anions were plotted in left and right triangles as a single point. These points have been projected into the central diamond-shaped area parallel to the upper edges of the central area. All these points in the diamond-shaped area represent the total ionic distribution. For each water sample, a single point was obtained in the diamond-shaped area, which represents the total ionic distribution. The water-types interpreted from Trilinear Piper diagrams are summarized in Table 2.

Graph 2 represents the variation in different parameters at 14 stations.

Calculated values for Sum of anions, cations, major ion composition, calculated TDS, total hardness (permanent and temporary) and alkalinity of all the water samples in all the 14 stations are represented in table 6.

CONCLUSION:

In the present study it was observed that some physico-chemical parameters like electrical conductivity, bicarbonate, total hardness, calcium and nitrate as determined from the groundwater samples of Dist. Samba were above the limits set by WHO 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 imperative 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 periodically.

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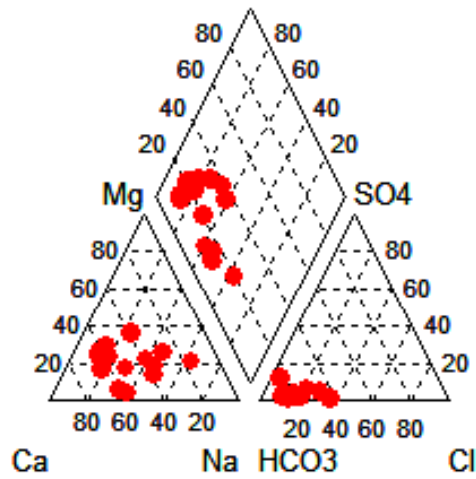
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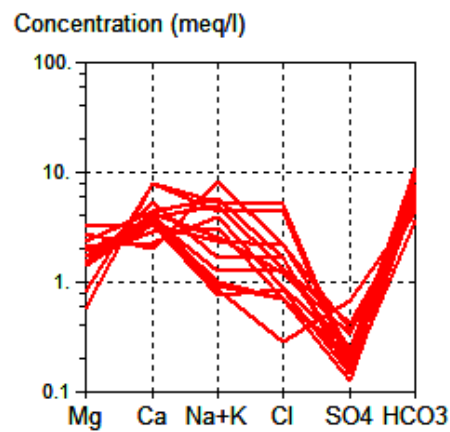
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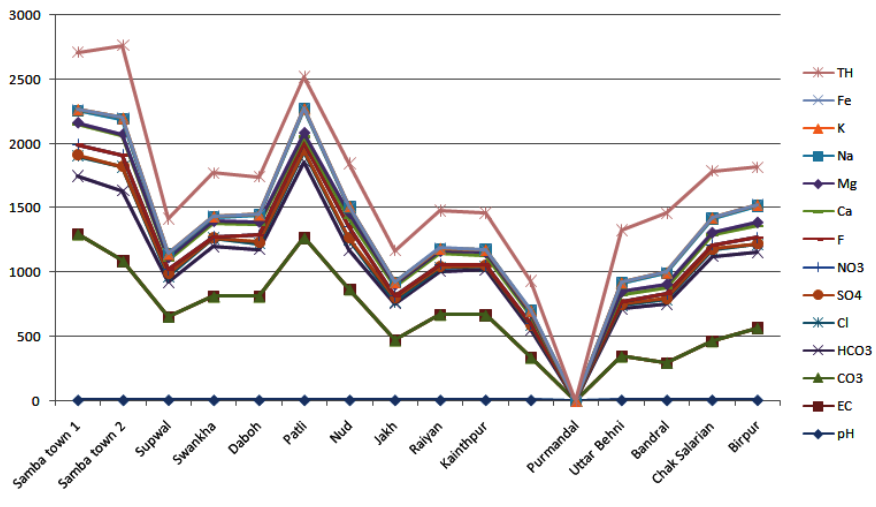
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Graph 1: Piper trilinear diagram for anion and cation composition of water samples



Graph 2: Schoeller graph showing the groundwater types.



Graph 3: Line Graph showing variation in different parameters at 15 stations.

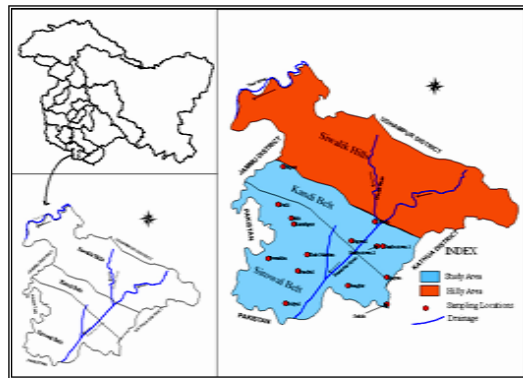


Figure 1: Location of Study area and Sampling sites.

Table 2: Result of Physico-chemical analysis of samples of Ground water from Tube wells of Dist. Samba, J&K.

S. No.	Location	Latitude	Longitude	pH	EC	mg/L												TYPE OF WATER
						CO ₃	HCO ₃	Cl	SO ₄	NO ₃	F	Ca	Mg	Na	K	Fe	TH	
1.	Samba town 1	32.72	74.85	7.48	1290	0	451	156	8	78	0.09	160	10	98	7.4	0.03	440	Ca-Na-HCO ₃ -Cl
2.	Samba town 2	32.55	75.11	7.9	1080	0	550	180	9	80	0.07	158	7	120	7.8	0.01	560	Ca-Na-HCO ₃ -Cl
3.	Supwal	32.52	75.04	8.22	648	0	268	46	20	29	0.11	76	19	28	1.6	0.18	270	Ca-Mg-HCO ₃
4.	Swankha	32.50	74.88	7.35	805	0	390	60	8	2.76	0.06	106	17	36	3	1.44	335	Ca-HCO ₃ -Cl
5.	Daboh	32.55	75.07	7.4	805	0	366	43	16	49	0.01	86	18	58	1.4	0.25	290	Ca-Na-HCO ₃
6.	Patli	32.77	74.80	7.42	1260	0	592	78	12	58	0.62	40	34	190	2	0.16	240	Na-Mg-HCO ₃
7.	Nud	32.62	75.14	7.6	862	0	305	78	18	81	0.03	68	39	49	7.2	0.05	330	Ca-Mg-Na-HCO ₃ -C
8.	Jakh	32.65	74.93	6.92	465	0	287	10	33.1	14	0.14	70	17	18	2.3	-	245	Ca-Mg-HCO ₃
9.	Raiyan	32.52	75.09	7.46	665	0	336	25	10	17	0.07	82	21	20	1.9	1.65	290	Ca-Mg-HCO ₃
10.	Kainthpur	32.58	74.61	7.52	660	0	354	25	6	2.45	0.13	74	24	22	1.2	0.23	285	Ca-Mg-HCO ₃
11.	Purmandal	32.68	75.00	7.3	330	0	220	30	7	3.2	0.12	68	19	17	1.1	0.16	230	Ca-Mg-HCO ₃
12.	Uttar Behni	32.68	75.00	7.4	340	0	370	25	9	18	0.01	58	21	68	3.4	0.14	405	Na-Ca-Mg-HCO ₃
13.	Bandral	32.91	74.68	7.22	290	0	458	32	12	35	0.05	46	26	87	5.4	0.12	458	Na-Ca-Mg-HCO ₃
14.	ChakSalarian	32.49	74.89	7.8	458	0	660	46	11	29	0.16	78	17	110	7.2	0.05	360	Na-Ca-HCO ₃
15.	Birpur	32.63	74.91	7.7	560	0	590	58	7	46	0.12	89	29	130	8.6	0.8	290	Na-Ca-HCO ₃

Table 3: 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.	6.92	290.00	0.0	220.00	10.00	6.00	2.45	0.01	40.00	7.00	17.00	1.1	0.0	230.00
MAX.	8.22	1290.00	0.0	660.00	180.00	33.10	81.00	0.62	160.00	39.00	190.00	8.6	1.65	560.00
MEAN	7.512	701.20	0.0	413.133	59.466	12.406	36.1606	0.1193	83.9333	21.20	70.066	4.1	0.3513	335.20
RANGE	1.30	1000.00	0.0	440.00	170.00	27.10	78.55	0.61	120.00	32.00	173.00	7.5	1.65	330.00
ST. DEV.	0.3073	319.362	0.0	132.672	48.405	7.0697	28.0967	0.1461	34.5718	8.3341	51.407	2.8142	0.5226	93.8381
Coefficient of Variation	0.0409	0.4554	0.0	0.3211	0.814	0.5698	0.777	1.2244	0.4119	0.3931	0.7337	0.6864	1.4874	0.2799
SKEWNESS	0.4890	0.5468	0.0	0.4626	1.5409	1.8150	0.4170	2.8783	1.2310	0.4852	0.8179	0.4159	1.7385	1.009
KURTOSIS	0.5596	-0.7134	0.0	-0.9364	1.3188	2.8910	-1.1247	7.6172	0.7630	-0.0017	-0.1417	-1.5326	1.4675	0.1916

Table 4: ANOVA TABLE

**Single Factor Anova:
 Between subjects**

1. Each group has a normal distribution of observations.
2. The variances of each observation are equal across groups (homogeneity of variance).
3. The observations are statistically independent.

	SS	Df	MS	F	p-value
Factor	8620947.662	13	663149.820	68.518	0.0
Error	1896972.540	196	9678.431		
Total	10517920.203	209			

Single Factor Anova:

Within subjects

1. Each group has a normal distribution of observations.
2. The variances of each observation are equal across groups (homogeneity of variance).
3. The observations are statistically independent.

	SS	Df	MS	F	p-value
Factor	8620947.662	13	663149.820	75.157	0.0
Within	1896972.540	196	9678.431		
Error	1605875.768	182	8823.493		
Total	10517920.203	391			

Table 5: Correlation coefficient matrix: Concentrations in mg/l

pH	CO3	HCO3	Cl	SO4	NO3	F	Ca	Mg	Na	K	Fe	
pH	1.0	0.0	0.258	0.387	-0.227	0.327	-3.5E-2	0.298	-9.5E-2	0.204	0.309	-0.199
CO3		1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HCO3			1.0	0.417	-0.355	0.406	0.411	0.184	-4.2E-3	0.879	0.619	-0.121
Cl				1.0	-0.273	0.791	6.2E-2	0.803	-0.362	0.511	0.605	-0.287
SO4					1.0	1.7E-2	1.4E-2	-0.251	6.4E-2	-0.278	-0.204	-0.251
NO3						1.0	0.106	0.435	8.6E-2	0.599	0.655	-0.441
F							1.0	-0.325	0.349	0.608	-0.186	-0.126
Ca								1.0	-0.713	8.3E-2	0.468	3.4E-2
Mg									1.0	0.168	-2.3E-2	2.9E-3
Na										1.0	0.521	-0.311
K											1.0	-0.221
Fe												1.0

Table 6: Analysis of Physico-chemical parameters of samples of Ground water from tube wells, dug wells and hand pumps of Dist. Samba, Jammu, J&K.

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 ₃) ₂)	Anhydrite (CaSO ₄)			
1.	Samba town 1	13.2218	13.2598	0.14%	968.5	246.34	14.109	350.087	75.73	11.343	70.7	70.7	70.7
2.	Samba town 2	15.5735	13.8796	-5.75%	810.1	285.343	14.872	356.403	53.011	12.761	0.0	423.0	450.8
3.	Supwal	6.5802	6.6208	0.31%	487.9	71.248	3.051	90.733	143.887	28.358	48.1	219.6	219.6
4.	Swankha	8.2992	8.3822	0.50%	624.2	91.605	5.72	186.399	128.741	11.343	14.8	319.6	319.6
5.	Daboh	8.3359	8.3399	0.02%	434.8	68.858	2.669	123.994	136.314	22.687	0.0	288.6	300.0
6.	Patli	13.1216	13.1146	-0.03%	551.1	125.713	3.813	-	160.733	17.015	0.0	239.7	485.2
7.	Nud	8.8820	8.9191	0.21%	645.2	117.933	13.728	-	277.847	25.523	80.1	250.0	250.0
8.	Jakh	5.9087	5.7334	-1.51%	290.6	13.06	4.385	70.332	128.741	46.933	9.4	235.2	235.2
9.	Raiyan	6.6987	6.7971	0.73%	514.6	38.409	3.623	107.904	159.033	14.179	15.6	275.4	275.4
10.	Kainthpur	6.6790	6.6630	-0.12%	321.3	39.456	39.456	79.739	181.752	8.508	0.0	283.4	290.1
11.	Purmandal	4.6559	5.7297	10.34%	365.6	43.258	2.097	84.3	143.887	9.925	67.5	180.3	180.3
12.	Uttar Behni	7.2481	7.6717	2.84%	335.6	36.165	6.483	49.006	159.033	12.761	0.0	231.1	303.2
13.	Bandral	9.2267	8.3611	-4.92%	369.1	44.723	10.296	-	188.293	17.015	0.0	221.7	375.4
14.	ChakSalarian	12.8209	10.2614	-11.09%	450.3	65.131	13.728	113.342	128.741	15.597	0.0	264.5	540.9
15.	Birpur	12.2007	12.7302	2.12%	569.0	82.837	16.397	95.571	219.617	9.925	0.0	341.3	483.5