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Appraisal of water quality and hydro-geochemistry of groundwater quality classification for drinking and irrigation

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Abstract
Declining in the groundwater quality and increasing in the anthropogenic activities at an alarming rate in parts of the Karnataka, especially in Channagiri Taluk, Davangere district. A limited work has been carried out on groundwater quality classification for drinking and irrigation in selected locations. In the current paper highlights the groundwater quality and compare its appropriateness for drinking and irrigation purpose in Channagiri Taluk, Davangere region. Fifteen different ground water samples selecting underground sources were collected and analyzed for almost all chief cations, anions and other hydro-chemical variables. Analytical results of hydro-chemical analysis indicated majority of the samples above the permissible limits of the Indian standards. Various irrigation water quality diagrams and variables such as sodium absorption ratio (SAR), sodium percentage (Na %), Residual sodium carbonate (RSC), Residual Sodium Bicarbonate (RSBC) and Kelley's ratio revealed that most of the water samples are suitable for irrigation. Langelier Saturation Index (LSI) values suggest that the water is slightly corrosive and non-scale forming in nature. Piper plot indicates the chemical composition of water, mainly controlled by termination and mixing of irrigation return flow. This work thus concludes that groundwater in the Channagiri Taluk, Davangere district is chemically unsuitable for domestic and agricultural uses. It is recommended to carry out a continuous water quality monitoring program and development of effective management practices for utilization of water resources.

Keywords: Channagiri, piper, irrigation, SAR, percentage of Na, magnesium ratio.

Introduction

Significance of groundwater for irrigation in India has been enhanced in the current years, especially due to the fact that groundwater proposes consistency and elasticity in contact to water that irrigation channel can play competition [18]. Water, one of the most vital resources, is essential to sustain life. Based on the fundamental quality, water is used in different sectors viz. domestic, agriculture, power and industry. Therefore, one should have some basic information on quantity and quality of water resources for its proper usage and management. In the surface of the Earth water covers about 70%, all the living organism are depending upon the resource for the natural a biotic resource. Water is the basis of life; it makes up to 75-95% of the total weight of any functioning living cell. However, due to rapid industrialization and increasing human population, the stress on natural resources is increasing and their conservation is one of the major challenges for mankind [14].

Water is a fundamental resource for most of the living things; epically ground water is for human community for both drinking and irrigation. The quality of groundwater is as important as its quantity because it is the major factor in determining its suitability for drinking, domestic, irrigation and industrial purposes. The concentration of chemical constituents which is greatly inclined by geological formations and anthropogenic activities determine the water quality. Both the agricultural and anthropogenic activities have resulted in deterioration of water quality rendering serious threats to human beings [13].

Once contamination of groundwater in aquifers occurs by means of industrial activities and urban development, it persists for hundreds of years because of very slow movement of water in them [3] and prompts investigations on their quality. The quality of groundwater cannot be restored once it is contaminated. Cations and anions occur naturally in groundwater and give the composition of minerals present in water. Especially, the urban aquifers are the only natural resource for drinking water supply, they are often professed as of minor relevance for the drinking water supply, leading to crisis in terms of drinking water scarcity, becoming increasingly polluted thereby decreasing their permissibility [16]. The knowledge of ionic (cations and anion) composition is important to understand the ground water quality in any region in which the ground water is used for both irrigation and drinking needs [11].

The quality of ground water depends on the nature of the soil and the rock masses present along the pathway of groundwater saturation zone [2]. Assessment of ground water quality determines the subsurface geological environment in which the water present also called ground water layer in earth crust. The conventional techniques such as trilinear plots, statistical techniques are widely accepted methods to determine the quality of water. In the present study, an attempt is made towards to evaluate the chemical and ionic composition characteristics of ground water quality and major parts of Channagiri Taluk, Davangere area, Davangere region with dense human activities like agricultural and mining activities. The analytical and interpreted results of the study will be useful in the sustainable management of groundwater resources in the region.

Materials and Methods

Study area

The present study is carried out at Channagiri taluk of Davangere district, Karnataka which is geographically bounded by latitude 13°59'53.34"N to 14°2'31.20"N and longitude 76° 0'23.62"Eto 76° 1'26.83"E covering an area of above 662 mm (Figure 1). Channagiri and its surrounding village's majority of the farmers in the taluk are cultivating areca, coconut, maize and ragi and most of the villages are depending upon the ground water for their daily needs. Channagiri Taluk has Soil colour of the pedons was measured both under dry and moist condition morphological properties were described as per Soil Survey manual. The horizons were identified and designated according to revisions in Soil Taxonomy in and around the taluka. The details longitude and latitude of the selected ground water locations are given in Table 1.

Methodology

To study the quality in and around the Channagiri region, total number of 50 groundwater samples were collected imperviously soaked in 10 % nitric acid (HNO_3) for 24 hands rinsed with rinsed with water, 5L colored polythene cans from different locations for the period of two years from March 2021 to February 2023. Before collecting the ground water samples, the ground water was pumped out from bore wells for about 10minutes to remove stagnant groundwater. All the ground water samples were transported to laboratory and kept for 5^0C until used for further analysis. The physicochemical variables have been analyzed by volumetric like total hardness, calcium and chloride [1]. Cation and anions are measured as per the methodology accessible in the literature and followed the guidelines and methodology.

Results and Discussion

Assessment of chemical and ionic characteristics of ground water is essential for the suitability of water for drinking, agricultural, industrial and household uses. The summary of the analytical results and the mathematical variables such as minimum, maximum, mean and standard deviation is given in Table 2 for March 2018 to February 2020. Standards have been laid down by various agencies (BIS, 1992) for drinking water quality and agricultural purposes. The results of the chemical and ionic variables of ground water samples are shown in table 2.

In the present study reveal that, the soil texture in the study area was principally calcareous which may be the possible reason of hardness in water. The occurrence the major cations and anions in winter, summer and rainy seasons is depicted in Figure 2. Kumar, et al., [5] worked on sodium as the most dominant cation in the Muktsar district of Punjab, India. In the present study, the average sodium content got third rank (9.4%) during winter season and in other two seasons summer (25.14%) and Rainy (21.13%) got second rank and was found to be 150.01mg/L, 106.3mg/L in summer and rainy seasons ground water samples which was more as compared to winter samples with an average value of 44.78 mg/L. Present study reveals that, the agricultural activities may be the key indication of increasing potassium content in groundwater [10].

Both sodium and potassium does not have any prescribed limits for drinking water but the high levels of sodium in drinking water makes it salty in nature. During summer and winter seasons, 96 % of ground water samples were found to exceed the permissible limit of Ca^{2+} for drinking water (200 mg/L). In rainy season, the average value of calcium ion was 333.6 mg/L with maximum value of 1024.0 mg/L observed in sample S18 (Alur). The average value of magnesium was 65.47 mg/L and 78.21 mg/L during summer season respectively, which were more as compared to the mean value (36.57 mg/L) in rainy. Average calcium cation found in our study were higher than those reported previously in Muktsar groundwater by Kumar et al. [6] while mean Mg concentration were found to be lower in this study (Figure 2).

Chloride content was above the permissible limits with some 46.04 % and 53.59% samples in winter and summer samples during summer and rainy season showed higher concentration of chloride than desirable limit (250 mg/L) set by BIS for drinking water which may be due to the use of inorganic fertilizers and irrigation drainage. Total alkalinity in water is mainly origin due to OH, CO_3, HCO_3 ions. Bicarbonate represents second dominant anion in the present study followed by sulfates. A similar result was also observed by Thakur, *et al.,* [15] in parts of Punjab which showed that HCO_3 as the dominant anion in the region (Figure 2).

The highest concentration of sulfates (255.66 mg/L) was observed in summer ground water sample (S47,) collected from Channagiri near Hirevuda Kakanuru, Dodderikatte area of Davangere district. High sulfate content may be due to breakdown of organic substances of weathered soils, anthropogenic activities, and use of fertilizers and sulfate leaching (Miller 1979). Maximum allowable limit of sulfate is 400 mg/L. It becomes unstable when this limit exceeds and leads to laxative effect on human system with excess of magnesium [12].

Water Quality for Irrigation

As the groundwater is being used for irrigation in Channagiri taluk, Davangere district, it is necessary to determine the parameters responsible for irrigation water quality. The important parameters to know the quality of ground water for irrigation purposes are sodium absorption ratio (SAR), sodium percentage (Na%) and magnesium ratio (MR) [17] are also calculated.

Sodium adsorption ratio (SAR)

SAR is a gives the hazards on crops by alkali/sodium [12]. Excessive amount of sodium relative to Ca and Mg in water reduces the soil permeability in the agricultural land [5]. The SAR values for each ground water sample were calculated as: $\text{SAR} = \frac{Na^{+}}{(Ca^{2+} + Mg^{2+})^{1/2}/2}$ (All concentrations presented in Meq/l) According to Richards (1954) classification SAR values ranges <10 Excellent, 10-18 are good, 18-26 are doubtful and >26 is unsuitable. From the present results it is concludes that except (Halemallapura) S19 (9.35 Meql) during summer season, all the collected ground water samples are found to be suitable for irrigation during the study period, and hence no alkali hazard is predictable to the crops in the study area [4].

Sodium percentage (%Na)

Sodium concentration is depending upon the soil permeability since sodium dissolves in the soil and reduces the permeability. Hence in the study quality of ground water classify for the purposes of irrigation [8]. The clay particles of the soil will adsorb the sodium content during the agricultural practices. Dispersion of sodium in the soil may changes the composition of Na^{+} and Mg^{2+} in water and replacing Ca from soil. The soil permeability decreases with poor internal drainage resulting in limited air and water circulation during wet conditions. When dry, such types of soils become hard [9] and [4]). The classification ground water for irrigation purposes based on the sodium percentage as per the author Wilcox (1955) and used the formulae to calculate sodium percentage is $\%Na = \frac{(Na^{+} + K^{+})x100}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}}$ (All ionic concentrations expressed in meq/l).

In the present study, according to Wilcox (1955) classification the percent sodium (%Na) ranges between < 20 is Excellent, 20 - 40 is good, 40 - 60 is Permissible and 60 – 80 is Doubtful. In the present study according to Wilcox that majority of the ground water samples were found to be good for irrigation (Table 2).

Seasonal observation during winter season (0.62%) of ground water samples are good category, during summer season (36.8%) falls under good category and (0.62%) fall under permissible category. During the rainy season (28%) of ground water falls under good category, (0.62%) of ground water falls permissible category but only one sample (Chikkabennur) showing under Doubtful category (0.24%), may be because of interpretation of agricultural activities. Overall, the analytical data illustrates that except few ground water samples; most of the groundwater samples fall in excellent and good categories and can be used for irrigation.

Magnesium ratio (MR)

Ground water can be classified for irrigation based on the magnesium ratio. if the magnesium ration is greater than 50% (Palliwal, 1972). It is expressed as: $\text{MG} = \frac{Mg^{2+}x\ 100}{Ca^{2+} + Mg^{2+}}$
Generally, Ca and Mg are present in equilibrium in most of the waters. The quality of soil is affected adversely when magnesium content is high in water, resulting in alkaline nature of the soil and thereby reducing the crop yield [5] and [4]. Based on MR, all most all the ground water samples and in the entire study samples were showing above the 50% magnesium ratio, hence samples were unsuitable for irrigation (Table 3).

Table 1: Physico-chemical parameters of bore well (BW) and hand pump (HP) of Channagiri taluk, Davangere district.

Code	Village	Code	Village
S1	Kattalagere	S26	Chikkabennur
S2	Rattenahalli	S27	Nagenahalli
S3	Halipura	S28	Kalenahalli
S4	Belalagere	S29	Siddanamata
S5	Miapura	S30	Yakkegondi
S6	Tyavanige	S31	Medikere
S7	Nallukudre	S32	Mallapura
S8	Iraganahalli	S33	Chakkali
S9	Ramanahalli	S34	Kulanuru
S10	Kulumenahalli	S35	Kakanuru
S11	Basavapura	S36	Dodderikatte
S12	Doddagatta	S37	Kondadhahalli
S13	Navilehalu	S38	Giriyapura
S14	Ramanahalli	S39	Karekatte
S15	Maradi	S40	Tannigere
S16	Belliganuru	S41	Mangenahalli
S17	Kodligere	S42	Doddabbigere
S18	Alur	S43	Nuggehalli
S19	Halemallapura	S44	Aralikatte
S20	Kashipura	S45	Ramagondanahalli
S21	Mallapura	S46	Devarahalli
S22	Somalapura	S47	Hirevuda
S23	Channapura	S48	Ittige
S24	Somanahalu	S49	Somalapura
S25	Santebennur	S50	Kagaturu

Piper Diagram

Piper diagram was made in such a way that the milli-equivalent percentages of the major cations and anions are plotted in a break up triangle. These plotted points in the triangular areas projected further into the central dia-mond area, which provides the overall character of the water. The triangular fields are plotted separately with ppm values of cations, (Ca, Mg) alkali earth, (Na+K) alkali, (HCO_3) weak acid and (SO_4 and Cl) strong acid. Krishna Kumar, et al., [7] diagram is useful for understanding of correspondences and differences in groundwater because it indicates the similar qualities as factions. Most of the deep-water samples fall under Na–Cl type indicating the dissolution and anthropogenic processes. Most of the samples predict the mixing types of cations and anions (Figure. 3).

Conclusion

The groundwater of the study area was very hard and the relative abundance of major cations and anions was $Ca^{2+}>Mg^{2+}>Na^{+}>K^{+}$ during winter season, $Ca^{2+}>Na^{+}>Mg^{2+}>K^{+}$ during summer and rainy seasons and $Cl^{-}>HCO_3>SO_4^{2-}$ during the entire study period respectively. The variables like sodium adsorption ratio (SAR), sodium percentage, and magnesium ratio were calculated from the chemical data. As per the results obtained, SAR and Na% revealed good quality of groundwater for irrigation purposes, whereas, MR values showed that this water is not suitable for agriculture and domestic use. Finally, it is concluded that there is lack of proper monitoring of ground water quality and a regular chemical analysis and monitoring of ionic composition is required to check the suitability of water for drinking and irrigation purpose. The irrigation water quality parameters indicated that the majority of the water samples are suitable for irrigation purposes, except less than 5 % of the samples.

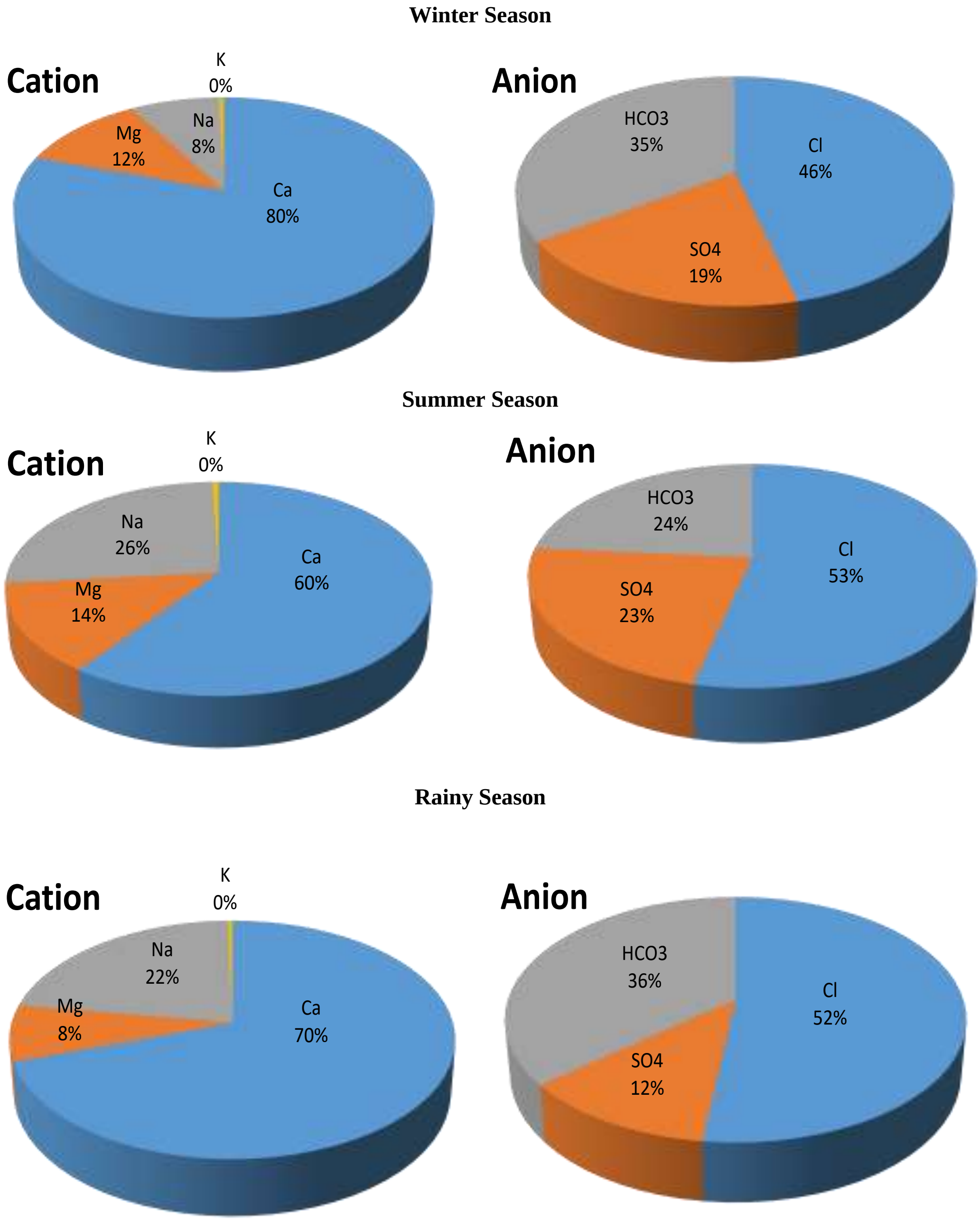

Fig. 2. Pie diagram of mean values of major ions during the study period.

Table 2: Seasonal variation in SAR, %Na and MR values during the study area.

Code	Winter			Summer			Rainy		
	SAR	**%Na**	**MR**	**SAR**	**%Na**	**MR**	**SAR**	**%Na**	**MR**
S1	0.58	4.08	138.17	1.94	13.28	126.42	1.42	12.21	126.12
S2	0.42	5.18	114.58	1.35	13.23	112.80	1.10	14.05	110.17
S3	0.53	6.40	112.82	1.67	17.73	111.18	1.44	18.30	109.07
S4	0.41	4.42	115.87	1.29	12.85	113.44	1.09	12.86	111.74
S5	0.57	4.67	128.06	2.00	15.73	122.64	1.56	13.83	120.35
S6	0.54	5.82	115.90	1.88	18.80	111.73	1.47	16.57	111.74
S7	0.40	4.13	120.34	1.38	12.93	114.72	1.11	11.95	114.87
S8	0.38	4.46	116.00	1.19	11.17	117.23	1.19	14.96	109.96
S9	0.34	2.55	131.55	1.09	8.49	125.12	0.86	7.48	124.19
S10	0.94	7.72	126.90	3.30	23.56	120.17	2.62	21.53	119.57
S11	0.46	4.39	123.61	1.59	13.65	118.87	1.29	12.72	117.22
S12	1.17	10.21	121.92	4.21	31.00	116.38	3.27	27.65	115.65
S13	0.41	4.28	117.78	1.31	12.24	116.44	1.16	13.37	112.25
S14	0.65	5.31	129.18	2.30	17.32	119.67	1.82	15.51	121.13
S15	1.20	8.40	135.77	4.48	27.90	123.91	3.34	23.32	125.83
S16	0.53	5.54	118.14	1.91	18.29	112.17	1.48	15.86	113.30
S17	0.36	2.85	136.54	1.53	13.12	122.52	0.95	7.56	129.88
S18	1.42	7.54	163.19	5.78	29.13	141.95	3.73	19.37	151.23
S19	2.34	20.54	117.03	9.36	55.61	109.02	6.47	45.77	112.52
S20	0.62	4.96	130.22	2.19	16.33	123.88	1.73	14.64	121.91
S21	0.77	6.30	127.05	2.65	19.55	120.76	2.16	18.63	119.07
S22	1.52	17.21	111.30	5.27	42.94	109.85	4.33	41.76	107.83
S23	0.63	8.89	109.28	2.29	27.61	107.82	1.72	23.20	107.04
S24	0.37	3.37	123.59	1.34	12.20	117.98	1.02	10.22	117.22
S25	0.64	3.81	153.68	2.56	16.31	133.53	1.71	10.89	141.75
S26	2.42	19.55	120.33	8.31	46.60	119.45	6.70	44.48	114.87
S27	0.47	5.06	117.00	1.84	19.66	108.24	1.30	14.58	112.52
S28	0.65	8.33	112.47	2.34	26.03	109.23	1.77	21.97	108.61
S29	0.60	7.22	111.54	2.33	26.12	108.59	1.64	19.87	109.39
S30	0.89	5.01	158.85	3.12	16.49	144.58	2.47	14.87	142.69
S31	0.44	4.02	125.81	1.56	13.35	120.91	1.31	11.73	118.78
S32	0.55	6.34	114.80	1.92	19.82	111.83	1.51	17.54	110.96
S33	0.59	6.97	114.69	2.15	22.73	110.30	1.63	19.17	110.17
S34	0.45	5.12	113.79	1.53	16.04	111.56	1.23	14.68	110.96
S35	1.10	8.77	126.91	3.91	27.03	121.56	3.05	24.14	119.57
S36	0.60	8.86	108.17	2.17	25.42	107.17	1.63	23.15	106.26
S37	1.02	11.35	113.68	3.79	34.72	109.53	2.79	28.92	110.17
S38	0.52	5.98	114.82	1.95	20.90	110.84	1.44	16.81	110.96
S39	0.68	8.52	110.77	1.86	17.57	115.26	4.28	61.28	101.56
S40	1.07	10.08	119.21	4.01	32.25	113.41	2.95	26.69	114.09
S41	0.75	10.29	109.20	3.00	35.42	106.24	2.03	26.22	107.04
S42	0.27	3.82	111.48	0.89	10.82	109.50	0.75	10.74	108.61
S43	0.33	3.26	121.55	1.04	9.03	117.67	1.02	11.72	112.81
S44	0.38	4.26	115.91	1.28	13.16	112.60	1.05	12.44	111.74
S45	0.52	5.21	128.21	1.80	17.24	114.41	1.43	15.02	114.09
S46	1.15	7.63	140.22	4.20	25.10	127.17	3.20	21.57	128.96
S47	0.96	8.61	122.19	3.39	25.95	117.15	2.86	26.00	114.23
S48	1.48	9.24	147.57	5.50	29.31	133.27	4.24	25.71	132.73
S49	0.96	8.84	122.48	3.54	28.02	115.32	2.66	23.50	116.43
S50	0.47	4.98	118.10	1.65	15.96	113.76	1.31	14.32	113.30

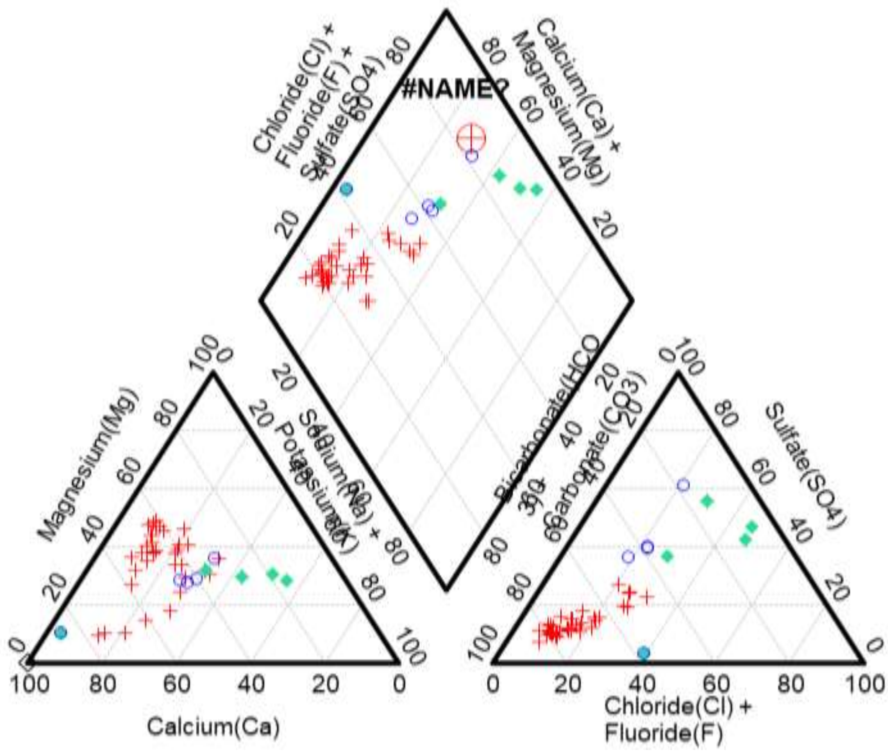

Fig. 3: Piper trilinear diagram showing hydro-chemical parameters of groundwater.

Conflict of Interest

The authors of this article declare that they have no conflict of interests.

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