Hydrogeochemical Evaluation of Groundwater Quality in Auchi and Its Environs

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Abstract

The quality of groundwater is determined by its physical, chemical, bacteriological and radiological characteristics. The hydrogeochemical evaluation of groundwater quality in Auchi and its environs is conducted to ascertain its potability and facies types. Geologic mapping of the area revealed that the area is dominated by ferruginized sandstone. Thirty (30) groundwater samples were collected from the study area and sent to the laboratory analysis for chemical and microbial analyses. Prior to the laboratory analyses, physical parameters were determined insitu using a multi-meter. The It was observed that the hydrochemical parameters of the groundwater falls within the permissible limits of the NSDWQ of 2007 and WHO standard of

2004, with the exception of pH and iron concentration. The pH of the groundwater is 5.75±0.0707 indicating acidic water, and the iron concentration has a value of 0.375±0.1061 mg/l, which is beyond the permissible limits.

The concentration sequence of the major cations of the groundwater in the study area is Ca^{2+}> Na^{+}>Mg^{2+}>K^{+}, with Na^{+} value of 1.07±0.2121 mg/l, K^{+} 0.1950±0.0778 mg/l, Ca^{2+} 2.5750 ±1.2516 mg/l and Mg^{2+} 0.7750± 0.2756 mg/l. The concentration sequence of the major anions of the groundwater in the study area is Cl^{-}> HCO_3^{-}>NO_3^{-}>SO_4^{2-}, with Cl^{-} value of 28.6500±4.4548 mg/l, HCO_3^{-} 21.4000±8.6267 mg/l, SO_4^{2-} 0.3550±0.1485 mg/l and NO_3^{-} 1.2500±0.9051 mg/l. The electrical conductivity (EC) of groundwater in the study area ranges from 49.10 to 580.40 µS/cm. It falls within the permissible limits for NSDWQ and WHO. The total dissolved solids (TDS) in the groundwater of the study area have an average value of 42.95 mg/l, indicating fresh water. Stiff plots of the groundwater in the study area reveals that they are from the same aquiferous formation, and has a Calcium Bicarbonate (Ca-HCO_3) hydrochemical facies.

Keywords: Hydrochemical facies, Groundwater quality, Auchi, Cations, Anions.

1. Introduction

Water is essential for human existence, many people in developing countries do not have access to potable water. In achieving sustainable development goal, adequate supply of safe and clean water is one of the most important factors (Ibrahim *et al.*, 2012), and groundwater which is the water present in the subsurface of the earth at the zone of saturation more safe for consumption than surface water and it serves as a major source of potable water supply (Amadi *et al.*, 2012). The quality of groundwater is pertinent to its suitability for domestics and purposes. Thus, there is need to evaluates the hydrogeochemical evaluation of the groundwater in Auchi and its environs in ascertaining its potability, hydrochemicalfacies and and the groundwater trend in the area.

2. Materials and Methods

Study Area Description

The study area lies in the south-south geo-political zone of Nigeria, and situated between latitude latitude N 7º00′00″ to N 7º10′00″ and longitude E 6º10′00″ to E 6º20′00″.and it can be accessed through the Auchi-Benin express road.

Geomorphology

The study area is characterized by two distinct seasons; the dry and rainy seasons. The dry seasons which occurs between November-April and it is associated with hamattan that comes up between late November and February which is characterized by dust knew winds as a result of the North East or trade wind. The rainy season spans from April-November, with an average of about 100cm-15cm, the south west trade wind brings the rain for wet season. The vegetation of the area falls within the guinea savannah which is characterized with few grasses, shrubs and few scattered moderate height trees of about 6m tall. The vegetation is dense during the rainy season and less dense during the dry season, and it is always altered during dry season due to degradation by fire, animal grazing and farming activities, thus enhancing erosion in the area (Matthew, 2002). The topography of the area is undulating with a ruggy relief. Figure 1 shows the topographic map of the study area.

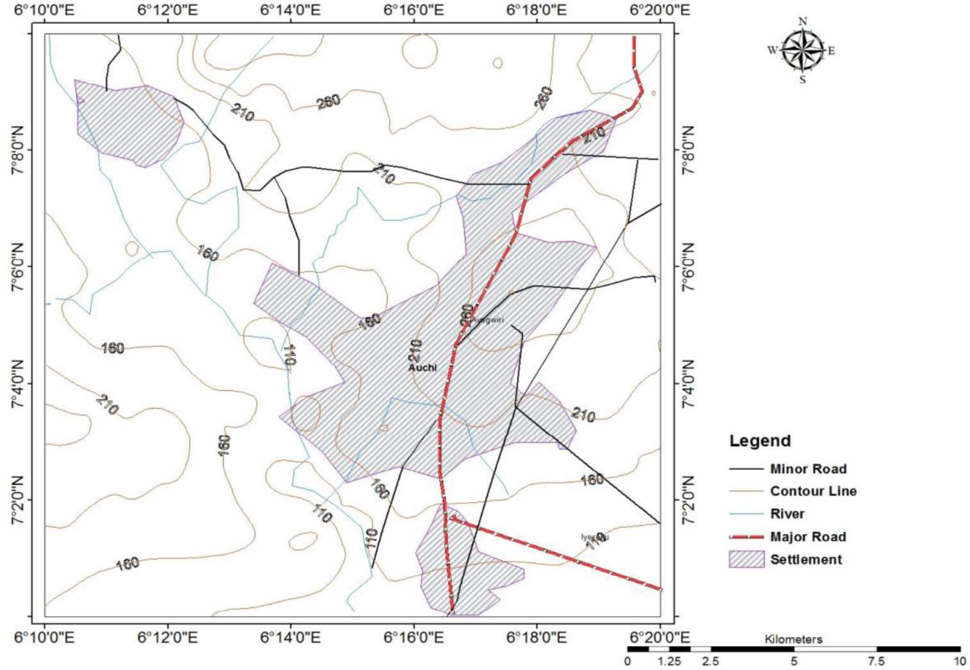

Figure 1: Topographic map of the study area (Office of Surveyor General of the Federation, 2009)

Geology and Hydrogeolgy of the Study Area

The study area lies within the Anambra basin, which is one of the sedimentary basins in Nigeria, and it's distinctively belonging exclusively to Nigeria (Okogbue, 2005). It is a structural depression located at the south-western of the Benue Trough. The basin is the Upper Senonian – Maastrichtian and Paleocene basin at the end of the Benue Trough in which Nkporo Shales and younger sediments accumulated, and which extended towards the southwest as the

Niger Delta basin (Reyment, 1965), with a lithological units of Nsukka, Ajali, Mamu and Nkporo Formation.

The area is widely covered by ferruginized sandstone, sandstone and clayey sand and it is drained by River Orle and River Niger (Sule *et al.,* 2014) and poses a detrital drainage system. The aquifer of the basin is the Ajali sandstone within the false-bedded Sandstone formation which is about 457m thick (Macaulay, 2008). Figure 2 shows the geology map of Nigeria.

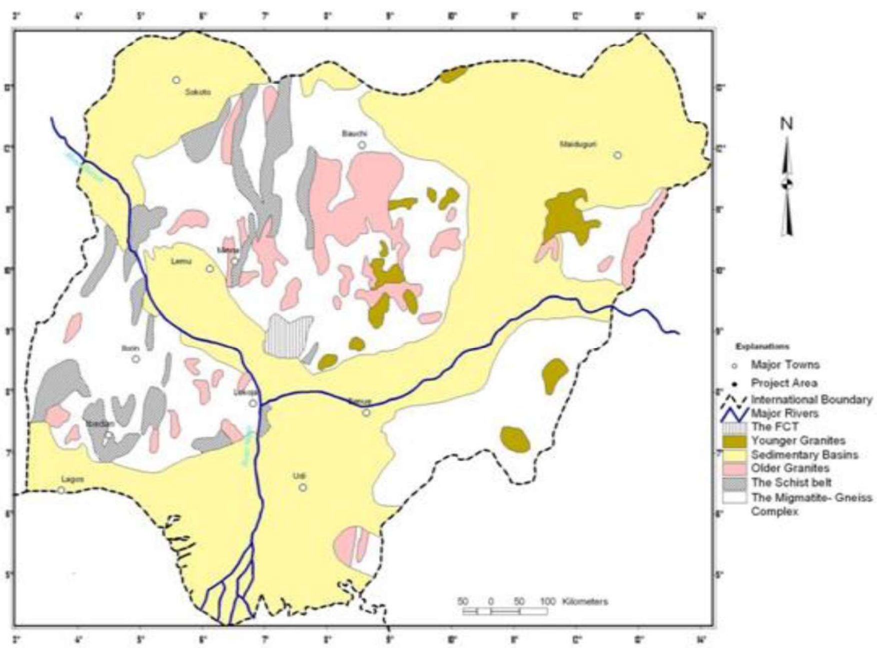

Figure 2: Geology map of Nigeria (Ajibade, 1983)

3.0 Methodology

Sample Collection and Laboratory Analysis

Groundwater samples were collected in two sets of one litre containers for both cation (which was stabilized with dilute hydrochloric acid) and anion analysis. An insitu testing was done to determine the physical parameter of the groundwater by the use of a Model PHS-3B pH Meter

Uniscope to measure the temperature, pH and electrical conductivity of the groundwater samples. The laboratory analysis of the groundwater samples was done with the aid of an Atomic Absorption Spectrophotometer (AAS), Spectronic 20D+ spectrophotometer, oven, incubator and titration apparatus. The groundwater physico-chemical parameters is compared with World Health Organization (WHO) standard of 2004 and Nigerian Standard for Drinking Water Quality (NSDWQ) of 2007. Figure 3 shows the groundwater samples location in the study area.

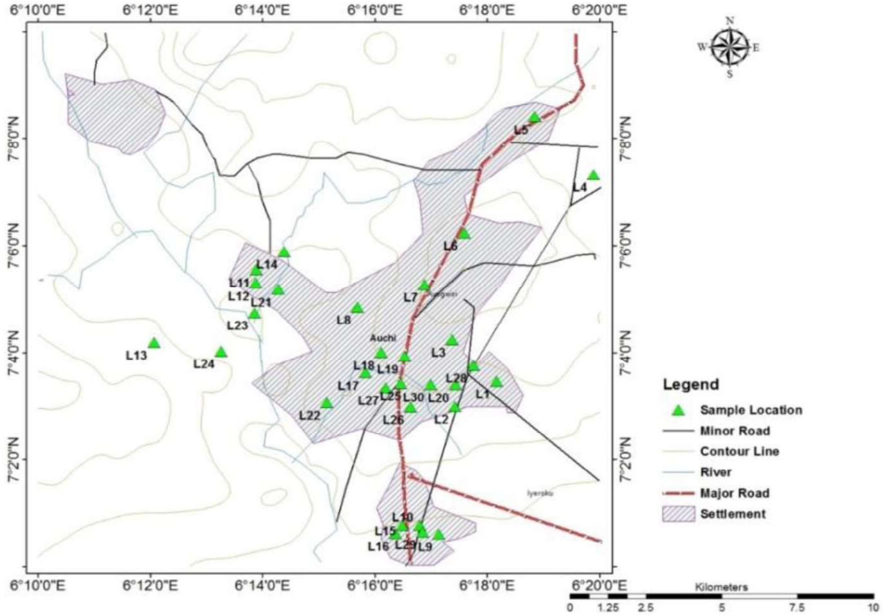

Figure 3: Groundwater sample location in the study area

4.0 Results and Discussion

The geostatistical result of the groundwater physico-chemical analysis is shown in table 1.

Table 1: Geostatistical results of the groundwater physico-chemical parameters in the study area

Descriptive Statistics						
	N	**Minimum**	**Maximum**	**Mean**	**Median**	**Std. Deviation**
Na	30	0.760	7.530	1.7450	1.0700	1.6318
K	30	0.120	1.100	0.2767	0.1950	0.2368
Ca	30	1.450	13.800	3.6190	2.5750	2.9789
Mg	30	0.500	4.730	1.1450	0.7750	1.0195
Cl	30	15.200	145.100	38.1667	28.6500	30.4629
HCO_3	30	10.200	96.700	27.1067	21.4000	20.2481
SO_4	30	0.140	1.410	0.6093	0.3550	0.3277
pH	30	4.3	7.0	5.8367	5.7500	0.6955
EC	30	49.100	580.400	1.3395	85.6500	125.7812
TDS	30	24.800	290.300	67.1500	42.9500	62.8647
Fe	30	3.820	0.170	3.9900	0.8130	0.3750
Mn	30	0.183	0.000	0.1830	0.0395	0.0265
Zn	30	0.700	0.052	0.7500	0.2226	0.1285
Cu	30	0.082	0.000	0.0820	0.0153	0.0000
Cr	30	0.034	0.000	0.0340	0.0038	0.0000
Cd	30	0.031	0.000	0.0310	0.0037	0.0000
Ni	30	0.000	0.000	0.0000	0.0000	0.0000
Pb	30	0.024	0.000	0.0240	0.0025	0.0000
V	30	0.000	0.000	0.000	0.0000	0.0000
THC	30	0.120	0.000	0.120	0.0150	0.0000
P	30	3.520	0.110	3.630	0.7710	0.4550

NH4N	30	0.155	0.004	0.159	0.04500	0.0265
NO_2	30	0.229	0.000	0.229	0.03640	0.0140
NO_3	30	7.480	0.200	7.680	2.0140	1.2500
COD	30	30.100	2.400	32.500	11.8700	9.6500
BOD5	30	4.000	0.000	4.000	1.5000	0.0000
Sal	30	0.240	0.022	0.262	0.06047	0.0390
Col	30	11.200	0.000	11.200	0.9867	0.0000
Turb	30	9.600	0.000	9.600	0.7933	0.0000
TSS	30	15.900	0.000	15.900	1.3067	0.0000
DO	30	2.300	4.900	7.200	6.1867	5.9500

Figure 4 shows the major cations and anions concentration (mg/l) in the groundwater samples of the study.

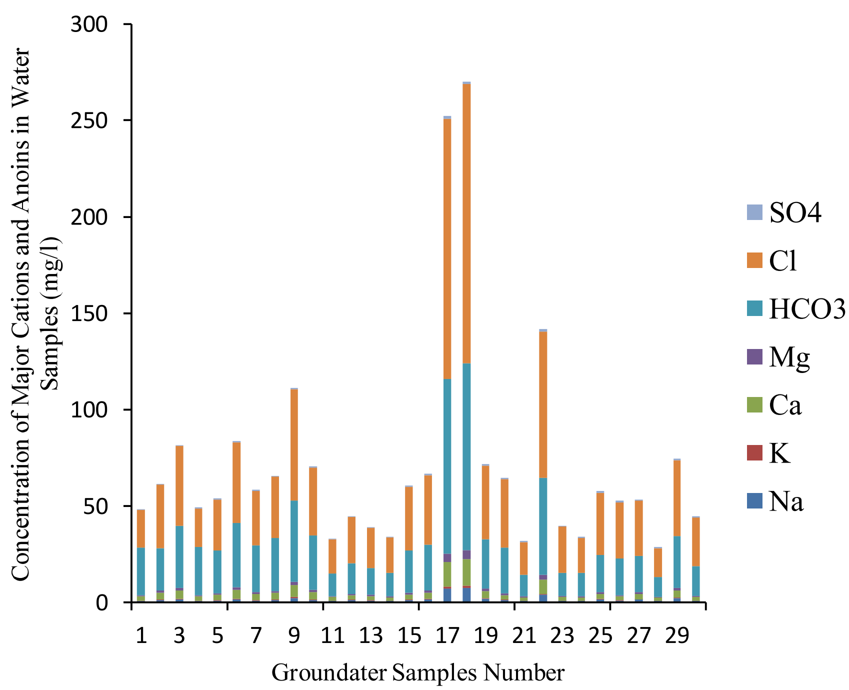

Figure 4: Major cations and anions concentration (mg/l) in the groundwater of the study area

The cation Na^{+} has a value of 1.07±0.2121 mg/l, K^{+} 0.1950±0.0778 mg/l, Ca^{2+} 2.5750 ±1.2516 mg/l and Mg^{2+} 0.7750± 0.2756 mg/l. The concentration sequence of the major cations of the groundwater in the study area is Ca^{2+}> Na^{+}>Mg^{2+}>K^{+}. The anoin Cl^{-} has a value of 28.6500±4.4548 mg/l, HCO_3^{-} 21.4000±8.6267 mg/l, SO_4^{2-} 0.3550±0.1485 mg/l and NO_3^{-} 1.2500±0.9051 mg/l. The concentration sequence of the major anions of the groundwater in the study area is Cl^{-}> HCO_3^{-}>NO_3^{-}>SO_4^{2-}.

The electrical conductivity (EC) of groundwater in the study area ranges from 49.10 to 580.40 µS/cm. It falls within the permissible limits for NSDWQ and WHO.

The total dissolved solids (TDS) in the groundwater of the study area have an average value of 42.95 mg/l. Table 2 shows the classification of groundwater based on total dissolved solids content (after Freeze and Cherry, 1979).

Table 2: Classification of Groundwater Based on TDS Content (Freeze and Cherry, 1979)

Groundwater	TDS (mg/l)
Freshwater	0 – 1, 000
Brackish water	1, 000–10, 000

Saline water (seawater)	10, 000–100, 000 (35, 000)
Brine water	> 100, 000

*TDS > 2, 000 – 3, 000 mg/l is too salty to drink

The TDS of the groundwater in the study area falls within the range of 0 to 1000 mg/l, thus it is classified as fresh water.

The hydrochemical parameters of the groundwater lie within the permissible limits of the NSDWQ of 2007 and WHO standard of 2004. However, the pH of the water samples has a range of 4.30 to 7.00 and an average value of 5.75 (5.75±0.0707). The iron concentration has a range of 0.17 to 3.99 mg/l and an average value of 0.375 (0.375±0.1061 mg/l). Figure 5 shows the iron concentration map of the study area.

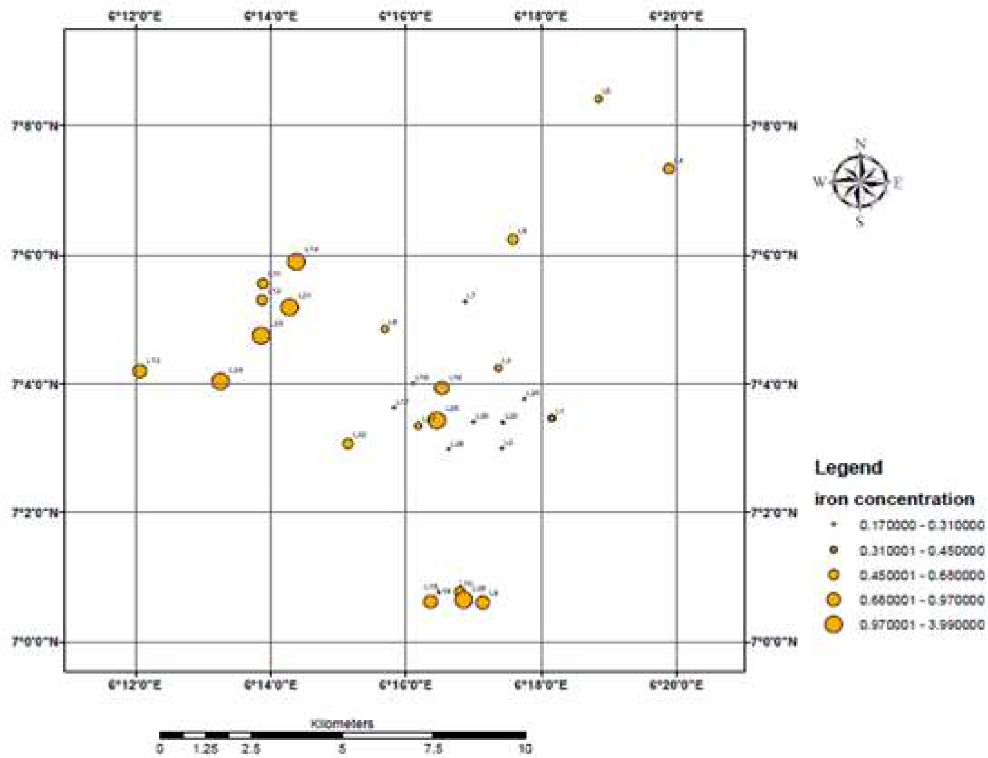

Figure 5: Iron concentration distribution map of the groundwater in the study area

Groundwater hydrogeochemical characterization

The groundwater hydrogeochemical characterization of the study area was done using Stiff (1951) diagram, Schoeller (1962) plot, Gibbs (1970) plot, Piper (1944) diagram and correlation analysis of the physico-chemical parameters of the groundwater.

Stiff diagram shows the composition of water with respect to its major cations and anions in a polygonal shape made from four horizontal axes with zero at the center mark. The cations are plotted on the left-half from the zero mark and anions on the right-half side from the zero mark of the plot. This represents the hydrochemical pattern and signatures of each groundwater samples. The hydrochemical pattern and signatures are alike with same water chemistry and it shows that the groundwater is from the same aquifer formation. Figure 6 shows the Stiff diagrams of the groundwater samples in the study area.

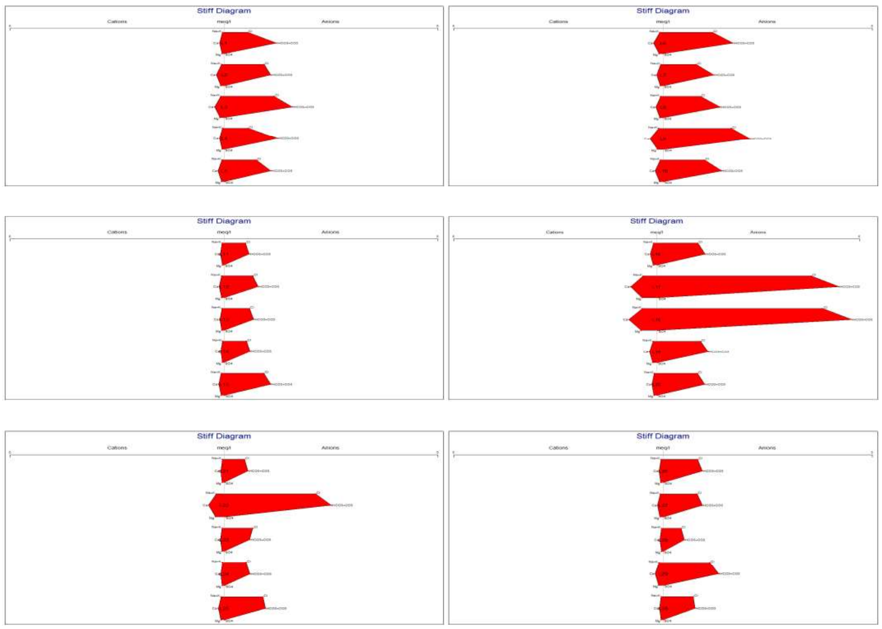

Figure 6: Stiff diagrams of the groundwater samples in the study area

Correlation analysis of the some physico-chemical parameters in the groundwater samples shows that the concentration of cations and anions has a positive relationship with the temperature, pH and electrical conductivity of the water samples. It has a negative relationship with the dissolved oxygen in the water samples. The dissolved oxygen has a positive relationship with the HCO_3^-concentration. It also reveals that the concentration of heavy metals in the groundwater in the study area has a negative relationship with the electrical conductivity, dissolve oxygen, total dissolve solids, temperature, cations and anions concentration. The heavy metals have a positive relationship with the colour, pH, NO_2 and NO_3 concentration of the groundwater. Table 3 shows correlation of the physico-chemical parameter of the water samples in the study area.

Table 3: Correlation of some physico-chemical parameter of the groundwater in the study area

	TDS	DO	Col.	Temp	pH	EC	Na^+	K^+	Ca^{2+}	Mg^{2+}	HCO_3^-	Cl^-	SO_4^{2-}	NO_2	NO_3	Fe	Mn	Zn	Cu
TDS	1																		
DO	-0.053	1																	
Col.	-0.131	-0.456	1																
Temp	0.439	0.023	-0.076	1															
pH	0.236	-0.233	0.174	0.048	1														
EC	1.000	-0.055	-0.129	0.439	0.238	1													
Na^+	0.992	-0.063	-0.136	0.471	0.190	0.992	1												
K^+	0.970	-0.038	-0.172	0.472	0.106	0.969	0.990	1											
Ca^{2+}	0.949	-0.019	-0.191	0.471	0.056	0.948	0.976	0.997	1										
Mg^{2+}	0.981	-0.043	-0.160	0.472	0.133	0.981	0.996	0.998	0.991	1									
HCO_3^-	0.944	0.043	-0.224	0.500	0.034	0.943	0.965	0.986	0.990	0.981	1								
Cl^-	0.980	-0.018	-0.168	0.447	0.117	0.979	0.990	0.995	0.990	0.996	0.984	1							
SO_4^{2-}	0.806	-0.182	0.091	0.305	0.211	0.807	0.781	0.743	0.714	0.758	0.715	0.762	1						
NO_2	-0.241	-0.312	0.809	-0.335	0.240	-0.239	-0.247	-0.281	-0.298	-0.267	-0.333	-0.281	-0.132	1					
NO_3	-0.040	-0.566	0.675	-0.195	0.038	-0.038	-0.045	-0.079	-0.097	-0.068	-0.150	-0.070	0.129	0.606	1				
Fe	-0.222	-0.455	0.720	-0.413	0.206	-0.220	-0.220	-0.256	-0.275	-0.242	-0.318	-0.273	-0.072	0.884	0.559	1			
Mn	-0.141	-0.377	0.661	-0.366	0.197	-0.139	-0.143	-0.183	-0.205	-0.167	-0.247	-0.185	-0.032	0.752	0.711	0.809	1		
Zn	-0.161	-0.383	0.745	-0.349	0.308	-0.159	-0.176	-0.231	-0.259	-0.209	-0.304	-0.233	-0.029	0.884	0.706	0.877	0.888	1	
Cu	-0.196	-0.455	0.678	-0.367	0.251	-0.195	-0.204	-0.237	-0.255	-0.225	-0.287	-0.237	-0.043	0.822	0.760	0.842	0.877	0.872	1

Schoeller plot is a semi-logarithm diagram representing the water chemistry and concentration in meq/l of major ion in the water. A Schoeller plot of the groundwater shown in Figure 7 reveals that the predominate cations in the groundwater in the study area is Ca^+ and Na^+ while the predominate anion are Cl^- and HCO_3^-.

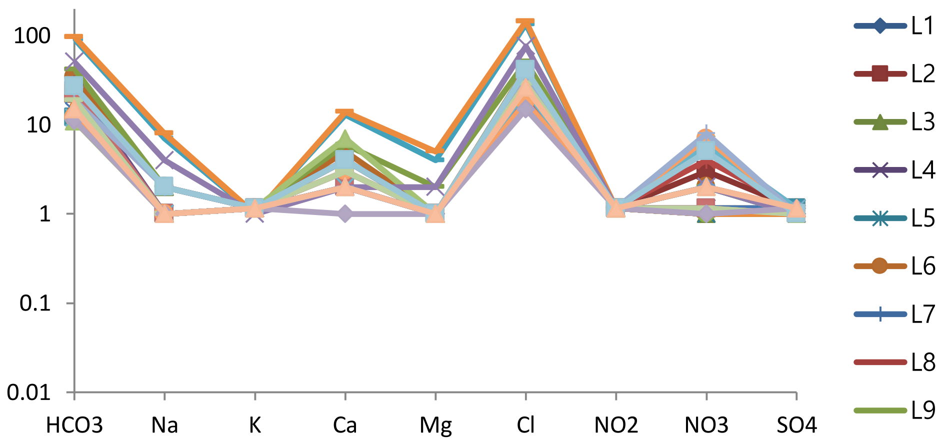

Figure 7: Schoeller plot of groundwater sample in the study area

Gibbs plot reveals the major natural mechanism controlling the water chemistry. It is a plot of TDS versus the weight ratio of $(Na^{+} + K^{+})/(Na^{+} + K^{+} + Ca^{+})$. The Gibbs plot of the groundwater is shown in Figure 8. It reveals that the major natural mechanism controlling the groundwater chemistry in the study area is rock-water interaction, with little influence of precipitation on the groundwater chemistry.

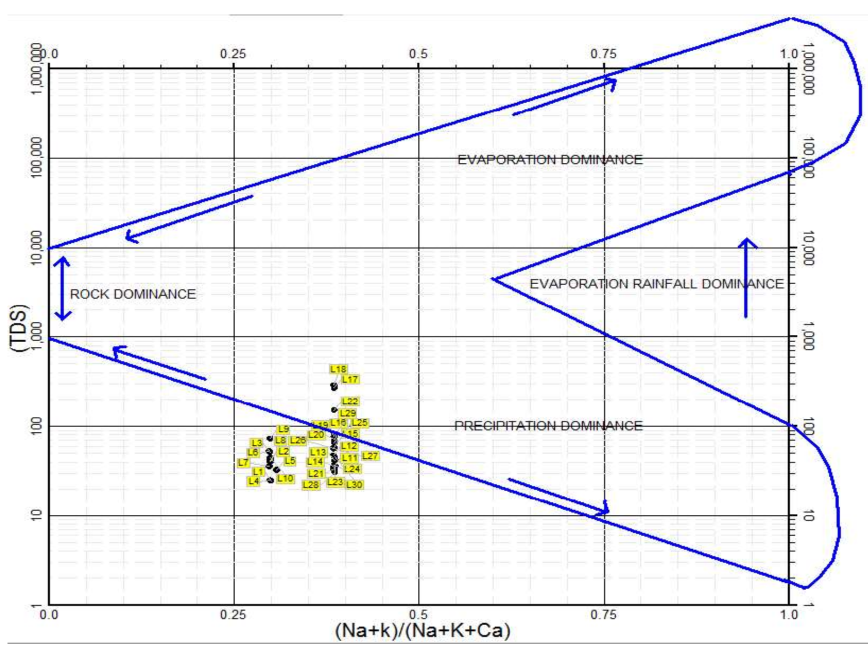

Figure 8: Gibbs plot of groundwater sample in the study area

Piper diagram is a graphical representation of two trilinear diagrams representing the major ion cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) and anions (Cl^-, CO_3^{2-}, HCO_3^- and SO_4^{2-}) in water and a centered diamond shaped diagram. The plots represent percentages of the total cation and/or anion concentrations, such that the water with very different total ionic concentrations can occupy the same position in the diagrams. The trilinear plots requires three paramters each, therefore the cations are reduced from four to three by grouping Na^+ and K^+, while the anions are reduced by grouping CO_3^{2-} and HCO_3^-. The plot on the diagram is projected on a straight line within the central diamond field, to represent mixing of groundwaters between two end-member solutions. This identify the hydrochemical facies of the groundwater. Figure 9 shows a Piper diagram of the groundwater in the study area. This indicates that the groundwater in the study area is of calcium bicarbonate (Ca-HCO_3) hydrochemical facies.

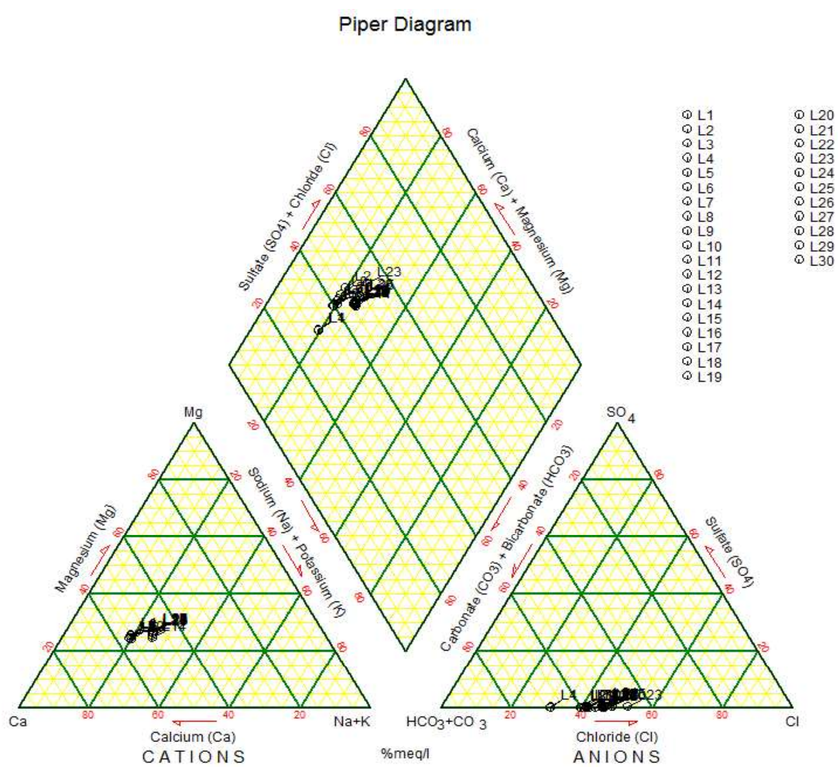

Figure 9: Piper diagram classifying the water samples in the study area

5. Conclusion and Recommendations

Conclusion

The area is widely covered by ferruginized sandstone, sandstone and clayey sand, with the Ajali Sandstone as the aquifer formation. The hydrochemical parameters of the groundwater in the study area falls within the permissible limits of the NSDWQ of 2007 and WHO standard of 2004, with the exception of pH and iron concentration. The groundwater in the study area has a pH value of 5.75±0.0707 indicating acidic water. The iron concentration has a value of 0.375±0.1061 mg/l, which is above the permissible limit. The high concentration of iron in the groundwater has a secondary health hazard to human. It is probably responsible for the high cases of health challenges that comprises of skin wrinkles, damage of health skin cells, water borne diseases, fatigue, joints pain and weight loss. The ferruginized sandstone in the study area is suggested to be responsible for observed colour of groundwater in some location. Also, the groundwater in the study area is from the same aquiferous formation as shown by the Stiff plot, and has a Calcium Bicarbonate ($Ca\text{-}HCO_3$) hydrochemical facies of the groundwater.

Recommendations

A periodic evaluation and assessment of the groundwater in the study area should be carried out, for effective monitoring and management of its quality. Also the host communities should be sensitized on the health challenges of low pH value and high iron concentration of the groundwater in the study area and the need for water treatment before consumption.

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