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Geology and Chemical Characterisation of Groundwater in Kafin-Koro and its Environs, North Central Nigeria

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Abstract
Physico-chemical characteristics of groundwater within Kafin-Koro and environs, North central Nigeria were determined in order to ascertain the chemical quality of the resource. This was achieved by subjecting the 15 water samples to chemical analysis using the titration, flame photometric, electrometric, nephometric and colorimetric method. Statistical techniques were applied to the result of the groundwater analyses to determine the hydro-geochemical parameters in order to establish the relationship between the measured parameters and their sources. From various statistical analysis the cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (Cl^{-}, HCO_3^{-}, CO_3^{2-}, SO_4^{2-}, F^{-}, NO_3^{-}, NO_2^{-}, PO_4^{3-}) fell within WHO recommended standard as well as heavy metals like (Zn,Mn,Cu) with exception of Iron and manganese which are found higher than the acceptable limits in some locations. The dominant water type is $CaHCO_3$ representing 86.67% as well as mixed $CaNaHCO_3$ water type that accounts for 13.33%. Groundwater in the study area is found to be suitable for drinking, livestock feeding as recommended by WHO and NSWQD. The studied groundwater is also good for irrigation purposes as revealed by irrigation indices such as Sodium Absorption Ratio (SAR), % sodium (SSP), Magnesium ratio (MR) and Permeability index (PI). Gibbs plot, stoichiometric ratio and Chloro-Alkaline Indices (CAI) show rock weathering, cation exchange and carbonate weathering as major geochemical processes responsible for the water chemistry in the study area.

Keywords: *Groundwater, Irrigation, Physico-Chemical, Recommended*

Introduction

Groundwater is most reliable source of potable water in Nigeria as over 70% of the population depends mostly on it for domestic, agricultural and industrial. However, its reliability in terms of quality needs to be ascertain as it could pose a threat to humans.

Water quality is traceable to chemical composition of precipitation, mineral composition of aquifer and confining beds through which the water moves, anthropogenic activities as well as chemical reactions occuring on the land surface and in soil zones (Amin and Amadi, 2014). Hydrogeochemical processes are responsible for the seasonal, temporal and spatial variations of groundwater chemistry and consequently the quality (Nwankwola, and Udoh, 2013). Activities of Artisanal Miners have been observed in Kaffin-koro area in recent years, therefore the need to determine and monitor the chemical quality of groundwater in the area has become necessary for the safety of lives and proper management of the resources.

The study area is located within Paikoro Local Government Area of Niger State, north-central Nigeria. The area is an integral part of the topographical map of Bishini Sheet 165 South West and lies between latitude 09° 31" to 09° 37" N and longitude 07° 04" to 07° 16" 5´´ E. The study area is bounded in the north east by a thick forest which consists of plains and a long watershed that runs east and west. The geology of the study area consists of Pre-Cambrian Basement Complex rocks, made-up of granite, gneiss and migmatite group, (McCurry, 1976). The area is within the Migmatite-Gneiss-Quartzite Complex zones of Nigeria (Rahaman, 1988). The studied area is underlain by Granite Gneiss and granites. However, the rocks are weathered and highly fractured in most locations. The research is aimed at characterizing the ground water in the study area for domestic and agricultural purposes.

Materials and Methods

Fieldwork entailed geological and hydrochemical mapping. Geological mapping was conducted on a scale of 1:50,000 to delineate the rock types in the area. The geological information were represented on the base map using the geographical positioning system and samples were collected from the rock exposures for laboratory analysis.

Fifteen groundwater samples were collected in duplicates from Kafin-Koro and environs using sterilised sampling bottles. One set of the samples were acidified with few drops of nitric acid as preservation while the other set of water samples were stored in

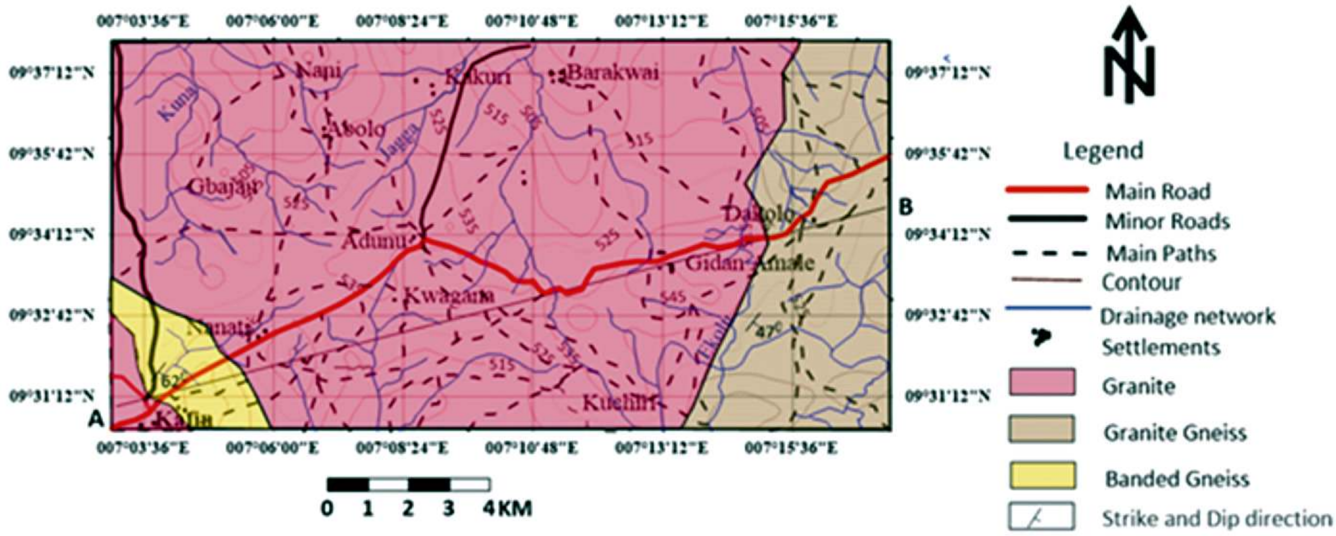


Fig. 1: Location Map of Kafin-Koro and its environs.

coolers at temperature of -4°C in line with APHA , 2005. Physical and chemical analyses of the samples were undertakenusing standard water analysis techniques at the Regional Water Quality Laboratory, Minna. Nephelometric method was employed for turbidity, electrometric for pH, and multipurpose meter (multi 3420) for electrical conductivity and temperature determination. Colorimetric method (Hach Colorimeter DR890) was used for determination of heavy metals, sulphate, nitrate and nitrite. Flame Photometric (APHA 3500D) for sodium and potassium while titration method was used to determine alkalinity and bicarbonate.

Results and Discussion

Result of the physico-chemical analysis is presented in Table 1.

Table 1: Physical parameters of groundwater in the study area

CODE	TURBIDITY	TEMP(^{0}C)	pH	EC (µS/cm)	TDS (mg/l)	TH (mg/l)	TA	TS	DO	TSS
A1	193	29.1	6.7	189	131	69.79	73.6	321	6.4	197
A2	2	29.2	7.1	213	148	70.56	98.4	132	6.7	7
A3	0	29.1	6.6	172	119	55.24	66.4	78.4	6.5	0
A4	7	29.3	6.55	185	129	47.83	68	123	6.58	0
A5	51	32	7.2	231	173	75.91	144	202	6.49	44
A6	7	29	6.9	175	120	51.31	81.6	97.8	6.83	0
A7	0	29.4	6.89	208	145	66.56	80	136	6.58	0
A8	0	29.1	6.45	128	89	39.41	45.6	55.6	6.63	4
A9	1	29.2	6.5	200	135	58.64	56	190	6.63	0
A10	7	29.2	6.4	112	76	34.69	37.6	70.6	6.6	17
A11	0	29.1	6.6	158	109	41.69	58.2	85.4	6.7	3
A12	0	29.3	6.47	141	98	36.59	44.8	98.1	6.72	15
A13	0	29.1	6.7	180	124	43.22	62.4	131	6.8	9
A14	3	29.2	6.58	165	113	51.58	52.8	87.4	6.88	3
A15	0	29.2	6.75	270	182	66.47	62.4	236	6.83	2

Table 2: Result of chemical parameters of the studied groundwater

	Cations (mg/l)				Anions (mg/l)							Trace elements (mg/l)					
Location	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}	NO_3^-	NO_2^-	PO_4^{3-}	F^-	Fe^{2+}	Cr	Cu	Mn	Zn	SiO_2
A1	6	3	23	3	11	75	9	3.48	0.07	0.45	0.2	0.32	0	0.06	0.08	0.4	1.5
A2	12	5	13.2	9.13	11	88.4	9	2.11	0.04	0.6	0.1	0.1	0	0.06	0.09	0.48	1.3
A3	8	4	18	2.5	13	67.4	5	1.88	0	0.38	0.3	0.11	0.1	0.03	0.07	0.35	0.62
A4	13	7	16.5	1.61	12	68	10	2.73	0.02	0.85	0.5	0.13	0.03	0.09	0.06	0.29	0.26
A5	12	5	19	6.92	6.6	111	12	5.17	0.03	1.83	0.6	0.38	0	0.1	0.18	0.78	0.6
A5	10	5	15.6	3	13	61.6	11	3.11	0.04	0.9	0.4	0.02	0.02	0.05	0.13	0.3	0.28
A7	11	4	17.8	5.37	12	80	15	4.05	0.06	0.88	0.6	0.01	0.03	0.15	0.2	0.41	2.9
A8	6	5	14	1.08	12	45.6	5	0.89	0	0.3	0.1	0.08	0	0.01	0	0.03	1.28
A9	14	4	22	0.9	21	56	17	6.11	0.04	0.35	0.6	0.16	0.03	0.2	0.25	0.53	3.9
A10	6	3	13	0.54	10	38	5	1.03	0	0.2	0.1	0.1	0	0	0	0	1.17
A11	12	4	13	2.24	13	59.2	5	1.87	0	0.34	0.3	0.01	0.01	0.03	0.06	0	1.35
A12	9	7	12	1.61	12	50	6	1.93	0	0.29	0.3	0.03	0.01	0.04	0.06	0	1.35
A13	15	5	12	3.22	12	68	9	2.69	0.05	0.4	0.4	0.02	0.02	0.09	0.08	0.67	0.27
A14	13	3	18	1.61	17	52.8	7	1.95	0.02	0.37	0.3	0.5	0.01	0.05	0.07	0	1.48
A15	27	6	16	6.44	34	70.4	21	13.4	0.13	0.39	0.8	0.08	0.05	0.35	0.34	1.03	15.5
MIN	6	3	12	0.54	6.6	38	5	0.89	0	0.2	0.1	0.01	0	0	0	0	0.26
MAX	27	7	23	9.13	34	111	21	13.4	0.13	1.83	0.8	0.5	0.1	0.35	0.34	1.03	15.5
MEAN	11.6	5	16.2	3.28	14	66.09	9.73	3.49	0.03	0.57	0.4	0.14	0.02	0.09	0.11	0.35	2.25
WHO (2004)	75	-	-	30	250	-	500	50	0.2	-	1.5	0.3	0.05	1	0.2		
NSDQW (2007)	200	N/A	N/A	20	100	N/A	100	50	0.2	-	1.5	0.3	0.05	1	0.2	3	-

Table 1 shows that the Total Dissolved Solids (TDS values ranges between 76 and 182 mg/l with mean concentration of 126.07 mg/L indicating a meteoric water with limited rock-water interaction. The EC values ranges from 112-270 mg/L which indicates the low enrichment of salts in the groundwater. The TDS, EC, values are way below the recommended WHO standards of 500 mg/L (TDS) and 1500**µS/cm (EC)** indicates that the groundwater in the study area are generally suitable for drinking purpose in line with the WHO (2004) and NSDWQ (2007). The recorded low temperatures (29-32°C) suggest quick infiltration and a shallow flow-path of groundwater further confirming the meteoric origin of the groundwater and it also negates any possibility of magmatic heating which increases temperature of groundwater in areas prone to volcanic activities (Rose et., 1996). Most of the groundwater revealed pH range of 6.4-7.2, suggestive of slightly acidic to mildly alkaline in nature. Most of pH condition in the study sites shows that the water is safe for consumption, except for sample A10 with pH of 6.40 which is below the recommended standard of 6.5 - 8.5 maximum permissible limits of WHO (2004) and NSDQW (2007)standards.

The Total hardness values in water samples range from 34.69 to 75.91 mg/L with the mean value of 53.97 mg/L. By implication, the groundwater in the area are within prescribed limits as the recommended limit of total hardness is 80 mg/L-100 mg/L CaCO3 (Mohsen, 2010). Groundwater exceeding the limit of 300 mg/L CaCO3 is considered to be very hard (Sawyer et al., 2003). Total Alkalinity (TA) in the groundwater of the study area could be caused by HCO_3 ion, as the pH is between 6.4 and 7.2. The threshold for Dissolve Oxygen (DO) is 5.0 mg/L for drinking water and values higher than 5 mg/L for agricultural and domestic purposes (Cruise and Miller, 1994). Very low DO may result in anaerobic conditions that cause bad odours. Table 1 indicates that the groundwater in the study area are generally suitable for agricultural purposes as high DO helps to prevent anaerobic conditions in drinking water. Total Suspended Solids (TSS) does not have a health based guideline; however it is recommended that it should be below 500 mg/L for effective disinfection (WHO, 2006)

The abundance of the major cations in the groundwater is in the following order: Ca > Na > Mg > K and contribute approximately 49 %, 29.1%, 14.6% and 7.3% respectively to the total cations (table 2). While, excessive sodium intake above 200mg/L may cause congenial heart diseases, hypertension, and kidney

Table 3: Pearson correlation matrix of groundwater in the study area

	pH	EC	TDS	TH	Ca^{2+}	Mg^{2+}	K^+	Na^+	HCO_3	SO_4^{2}	Cl^-	F^-	NO_3^-	NO_2^-	PO_4^{3-}	Fe	Cu	Cr	Mn	SiO_2	Zn
pH	1																				
EC	0.67	1																			
TDS	0.73	0.99	1																		
TH	0.78	0.84	0.87	1																	
Ca^{2+}	0.14	0.4	0.41	0.63	1																
Mg^{2+}	0.89	0.76	0.79	0.77	-0.01	1															
K^+	0.09	0.22	0.22	-0.12	-0.4	0.17	1														
Na^+	0.22	0.75	0.69	0.31	-0.02	0.42	0.36	1													
HCO_3^-	0.9	0.75	0.82	0.84	0.32	0.83	0.13	0.24	1												
SO_4^{2-}	0.37	0.84	0.8	0.61	0.42	0.44	0.21	0.75	0.385	1											
Cl^-	-0.18	0.5	0.4	0.15	0.14	0.07	0.14	0.82	-0.18	0.66	1										
F^-	0.3	0.75	0.75	0.46	0.39	0.27	0.3	0.73	0.42	0.85	0.53	1									
NO_3^-	0.26	0.82	0.77	0.52	0.31	0.42	0.24	0.85	0.31	0.9	0.82	0.8	1								
NO_2^-	0.4	0.82	0.76	0.62	0.32	0.54	0.09	0.72	0.391	0.84	0.65	0.61	0.85	1							
PO_4^-	0.77	0.48	0.58	0.58	0.27	0.52	0.22	0.05	0.805	0.29	-0.35	0.46	0.15	0.12	1						
Fe	0.15	0.15	0.2	0.4	0.59	0.02	-0.4	-0.05	0.258	-0.02	-0.05	0.07	0.02	0.02	0.29	1					
Cu	0.21	0.82	0.76	0.5	0.3	0.39	0.25	0.87	0.279	0.95	0.82	0.83	0.96	0.85	0.1	-0.05	1				
Cr	-0.12	0.26	0.21	0.1	0.19	-0.03	0.09	0.28	0.015	0.21	0.39	0.37	0.29	0.13	-0.13	-0.22	0.32	1			
Mn	0.4	0.86	0.82	0.63	0.42	0.48	0.15	0.77	0.419	0.96	0.7	0.87	0.92	0.79	0.29	0.01	0.94	0.31	1		
SiO_2	0.02	0.62	0.54	0.3	0.1	0.31	0.18	0.81	0.029	0.73	0.92	0.57	0.91	0.77	-0.18	-0.1	0.88	0.29	0.76	1	
Zn	0.59	0.9	0.89	0.71	0.3	0.66	0.22	0.69	0.675	0.79	0.44	0.71	0.8	0.8	0.42	0.03	0.78	0.29	0.79	0.57	1

problems (Singh et al. 2008), it is noteworthy that all the cations are within the permissible limits recommended byWHO, 2007 and NSDWQ, 2007. The sources of these anions could be ascribed to the dissolution of mineral like apatite, amphibolites, feldspar and pyroxene.

However, the relative abundance of the major anions in the groundwater is in the following order: $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^-$ and contributes approximately 64.7 %, 23.7%, and 11.6% respectively to the total anions (table2). Chloride concentration is between 6.58 and 34.30 mg/L and the mean concentration was 12.0 mg/L with these values within the range of maximum permissible limit of 150mg/l (WHO, 2006). The low concentrations recorded in the study area indicate the paucity of low soluble salt in the area. The concentration of carbonate in all samples are 0 mg/L which is below the detection limit and lowerthan that of WHO standard of highest desirable level of 200mg/l and maximum permissible level for domestic purpose is 500mg/l respectively. Bicarbonate concentration falls between 38.00 and 111.00 mg/L with mean concentration of 66.09 mg/Land it is the dominant ion in the groundwater of the study area, suggesting possible influence of recent meteoric recharge which also corroborates the result of the physico-chemical parameters like EC and TDS. Sulphate concentrations in these groundwater samples ranged from 5 to 21mg/L with mean values of 9.73 mg/L which is below the maximum allowable limit of the WHO, therefore possess no groundwater problem. Furthermore, nitrate concentrations in the samples are below allowable limit of 50 mg/L (WHO, 2004) and (NSDWQ, 2007) which is attributable to limitedinfluence of anthropogenic pollutants in the area. Nitrite (NO_2^-) concentrations ranged from 0 to 0.13mg/L with a mean value of 0.03 mg/L as the nitrite concentrations in the samples were below allowable limit of 0.20 mg/L (WHO, 2004) and (NSDWQ, 2007). The Fluoride in the studied groundwater is found within the permissible limit of 1.5 mg/L (WHO, 2006). The low concentration of Phosphate in the studied groundwater is possibly because of phosphate adsorption by soils as well as its limiting factor nature due to which whatever phosphate is applied to in the agricultural field is used up by the plants.

Arsenic is found widely in the earth's crust, but in Kafin-Koro and environs, the concentration of Arsenic and Nickel are negligible when compared with (WHO, 2007 and NSDWQ 2007). Copper is an essential nutrient which contaminates drinking water. It has various uses, its' concentration in the water was much in primary sources and most of these are corrosion of internal copper plumbing. It ranges in concentration from 0.00 to 0.35 mg/L (table 2).

Iron concentration ranges from 0.01 to 0.50 mg/L and the mean concentration of 0.14 mg/L which is below the recommended limit of 0.3 mg/L except for 3 (A1, A5 and A14) (table 2)samples which have values higher than the safe limit of 0.3mg/L stipulated by WHO (2004) and NSDWQ (2007) for drinking water.

Manganese concentration ranges from 0 to 0.34mg/L and the mean concentration of 0.11mg/L which is higher than the WHO (2006) and NSDWQ (2007) permitted limits of 0.05 and 0.1 mg/l. Manganese in water supplies at levels exceeding 0.1 mg/L, may cause an undesirable taste in beverages, stains sanitary wears and laundry. According to WHO (2006), presence of Manganese in drinking water just like iron may lead to the accumulation of deposits in the distribution system. However at a concentration of 0.2 mg/l, manganese often forms coating on pipes which usually slough off as a black precipitate. Table 2 reveals that Zinc and Chromium contents in all sampled sources are generally low when compared to the WHO (2004) regulatory limit of 5.0 mg/l and NSDWQ (2007) limit of 3.0 mg/L.

Hydrochemically, groundwater in the study area can be classified into 2 (two) facies, namely; Ca (Mg)-HCO_3 (CalcuimMagnesiun bicarbonate) and $CaNaHCO_3$facies (fig.1a). The Ca (Mg)-HCO_3facies are found in groundwater samples such as GW1, GW2, GW3, GW4 GW5, GW6 GW7 GW8, GW10, GW11, GW12, GW13 and GW14 and are underlain by granite gneiss and granite rock units. The mixed $CaNaHCO_3$facies (mixed calcium bicarbonate) is observed in ground sample of location GW9 and GW15 and underlain by the granite gneiss. The Schoeller plot (Fig.2b) reveal that the dominant ions are HCO_3^-, Ca^{2+} with Cl^- and Mg^{2+} ions (fig. 2c and b). **Based on the Gibbs plot,** the overall quality of groundwater in the study area appears to be controlled by lithology (figure 2d).

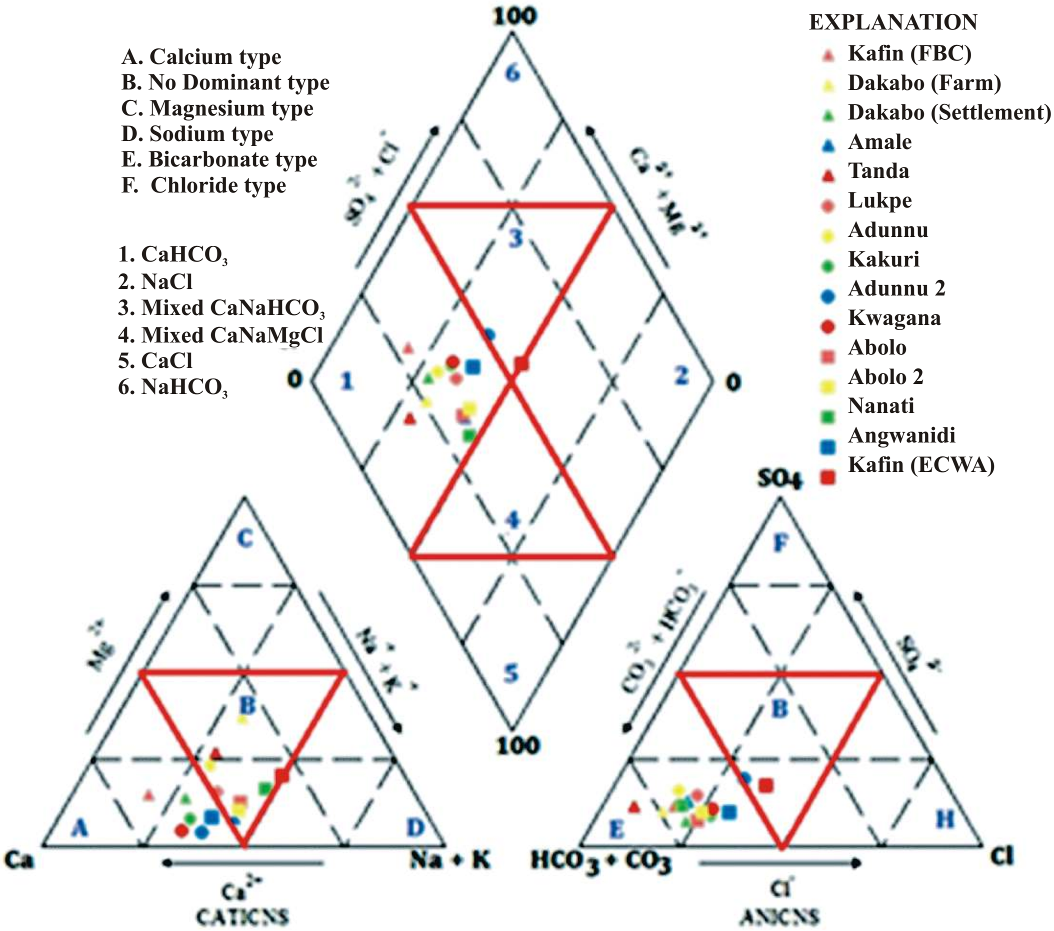


Fig. 2(a): Piper diagram

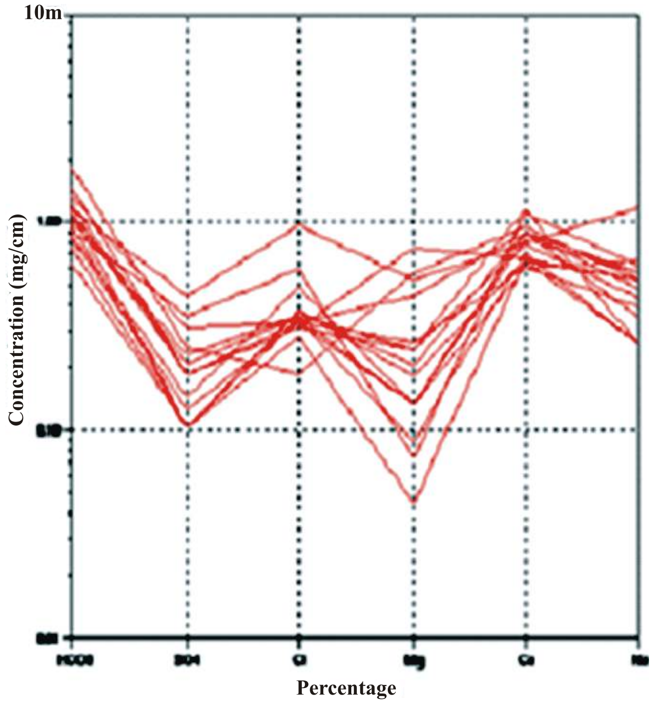
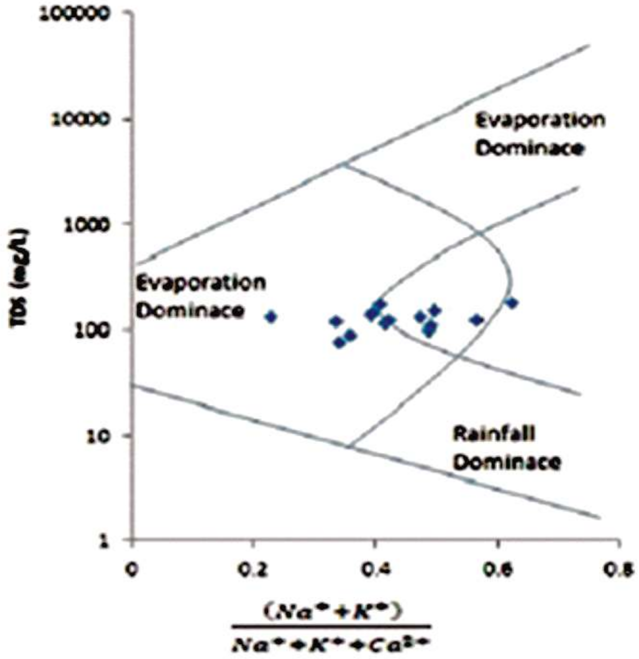


Fig. 2(b): Schoeller diagram



(c)

Fig. 2(c): Gibbs plot for cations

Furthermore, according to (Adams *et., al* 2001), samples showing correlation coefficient of r < 0.5 are Considered weak, r > 0.5-0.7 is considered moderate, coefficient of r > 0.7 are considered to be strongly correlated while correlation coefficient of r=1 is considered perfect.

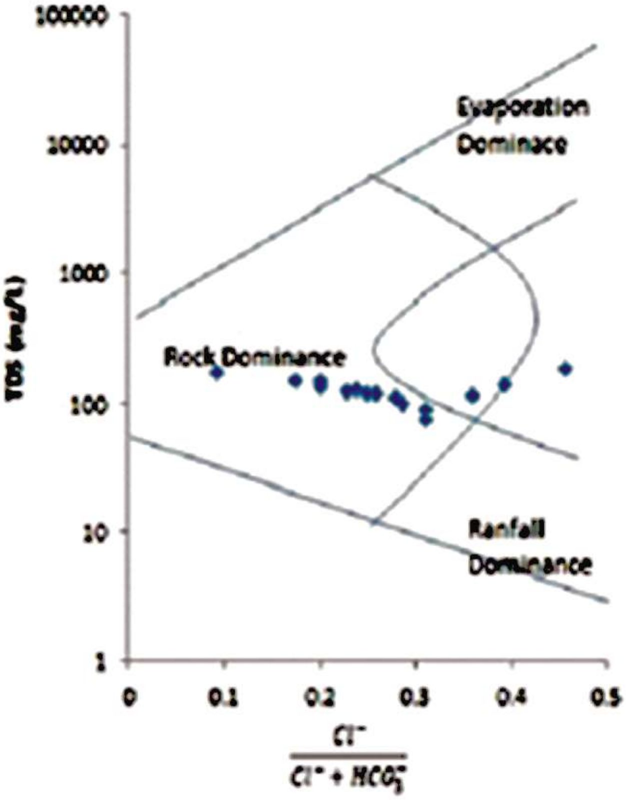


Fig. 2(d): Gibbs plot for anio

There is strong correlation between EC and TDS (0.991), TH (0.843), Mg (0.892), Na (0.750), HCO_3 (0.747),table 3 and other parameters which indicates mineralisation. strong correlation was also recorded between SO_4 and other elements like Mn (0.956), Cu (0.945), F (0.847), Cu (0.833), NO_3- (0.895), NO_2^- (0.840) which suggest anthropogenic activities (Adams *et., al* 2001). Chloride also have moderate to strong correlations with Nitrate (0.820), Fluoride (0.533), Nitrite (0.652) and Copper suggesting anthropogenic sources.

Conclusions

The hydrochemical assessment of the groundwater in Kafin-Koro reveal that the water can be classified as suitable for agriculture as well as for domestic purposes. The groundwater is hard and silicate weathering appears to be dominant hydrochemical process controlling the chemical composition of the groundwater in the study area.

The strong correlation between EC and TDS, TH, Mg, Na and HCO_3 and other parameters suggests an influence of mineralisation.

The overall quality of groundwater in the study area is controlled by lithology as well as the local environmental condition. Seasonal variation in the water quality parameters should be assessedin the future for further understanding of the groundwater quality in the area.

References

Adams, S., Titus, R., Pietersen, K., Tredoux, G. and Harris, C.A. (2001). Hydrochemical characteristics of Aquifers near Sutherland in Western Karoo,South Africa. Journal of Hydrology. 241(1), 91-103.

Cruise, J.F. and Miller, R.L. (1994). Interpreting water quality of Mayaguez Bay, Puerto Rico using remote sensing, hydrologic modeling and coral reef productivity. In Proceedings of Second Thematic Conference on remote sensing for Marine and Coastal environments, New Orleans, LA.

McCurry, P. (1976), "A General Review of Geology of the Precambrian to Lower Paleozoic Rocks of Northern Nigeria", In CA. Kogbe (Ed.), Geology of Nigeria (pp. 1-27). Lagos, Elizabethan Publication Company.

Mohsen, J. (2010), Hydrogeochemistry of groundwater and its suitability for drinking and agricultural use in Nahavand, Western Iran. Natural Resources Research, DOI: 10.1007/S 11053-010-9131-z.

Nigerian Standard for Drinking Water Quality (NSDQW). 2007. Nigerian Industrial Standard NIS 554, Standard Organization of Nigeria: Lagos, Nigeria.

Rahaman, M. A. (1988). Recent Advances in the Study of the Basement Complex of Nigeria. In P. O. Oluyide, W. C. Mbonu, A. E. Ogezi, I. G. Egbuniwe, A. C. Ajibade& A. C. Umeji (Ed.), Precambrian Geology of Nigeria (pp. 11-41). Geological Survey of Nigeria.

Sawyer, N.N., McCarty, P.L. and Parkin, G.F. (2003).Chemistry for Environmental Engineering and Science. 5th Edition McGraw-Hill. New York, pp:752.

WHO (2006).Guidelines for Drinking-Water Quality, Volume 1, Recommendations 1st Addendum to 3rd edition. World Health Organization, Geneva (Electronic version). http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en/index.ht_ml Accessed on the 14/02/2009

World Health Organisation (WHO), 2004. Guidelines for drinking water quality: incorporating 1st and 2nd vol. 1 recommendations 3rd ed., Geneva.