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Physico-chemical characteristics of surface and groundwater in Obajana and its environs in Kogi state, Central Nigeria

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The present work was aimed at assessing the surface and groundwater quality of the area within and around Obajana using physico-chemical characteristics. Surface and groundwater samples were collected at the peak of dry season in March, 2013, from 24 locations within Obajana and its surrounding areas and were subjected to a comprehensive quality analysis. The following parameters were considered; pH, total dissolved solids, electrical conductivity, turbidity, dissolved oxygen, redox, potassium, sodium, calcium, magnesium, iron, zinc, chloride, nitrate, sulphate and bi-carbonate. Different statistical tools were used to analyse the results. Piper diagrams and Schoeller plots were used to suggest models for predicting water quality. Results from the physico-chemical analysis revealed that the concentrations of the analyzed parameters were within the acceptable limits for drinking water recommended by the World Health Organisation except for iron which had elevated concentration in one location. Surface and groundwater within Obajana and environs are thus considered safe for drinking and domestic use with respect to these analyzed parameters but needs to be protected from the perils of contamination by pollution from the continuous production of cement from the cement company over time. Plots on Piper and Schoeller diagrams indicate a Ca-Mg- HCO_3^- water type.

Key words: Obajana, water resources, physico - chemical, cation, anion and pollution.

INTRODUCTION

Water plays a vital role in sustaining life. It is important for domestic, agricultural and industrial use especially in developing countries such as Nigeria. Groundwater is the largest source of fresh water in the world and accounts for about one third of one percent of the earth's water. It is of major importance to civilization being the largest reserve of drinkable water that can be used by humans. This is due to long retention time and natural filtering

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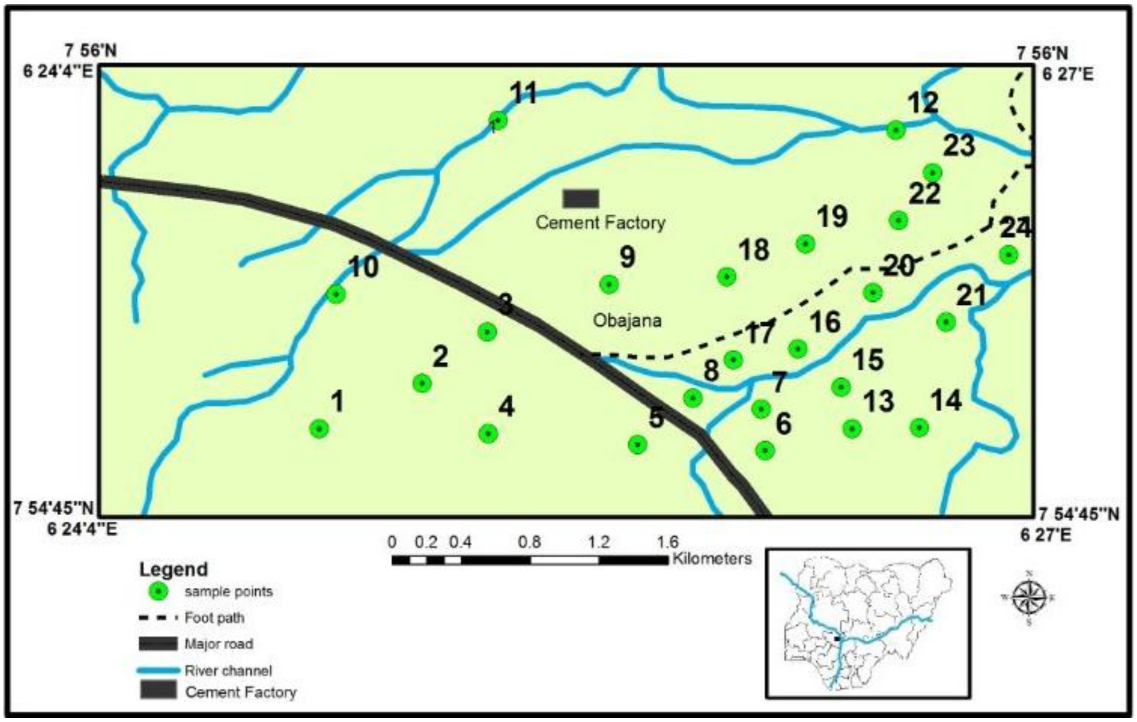

Figure 1. Location map of the study area.

effect of earth materials. It is also an ultimate and most suitable fresh water resource with nearly balanced concentration of the salts for human consumption naturally. Buchanan (1983) and Bouwer (2002): in Omada et al. (2011) quotes, "groundwater accounts for about 98% of the world's fresh water resources". Therefore, increase in the search and use of potable water, is as a result of the speedy expansion in urban population, industrial activities, commercial and agricultural developments.

Quality of surface and groundwater does not depend solely on the clarity but it takes into account the mineral content of the water as well. Groundwater quality is controlled by three main factors; climate, water depth, and soil or sediment. Water in shallow wells is closer to the surface potential sources of contamination, such as fertilizers, sewage and effluents. In contrast, contamination is less likely to occur in deeper groundwater reservoirs because contaminants have to travel greater depths to reach the water.

According to World Health Organization (1996), about 80% of all human diseases are caused by water. Once the groundwater is contaminated, its quality cannot be restored easily, hence there is need to communicate information on the quality of water to the concerned citizens and policy makers, analysis of water is utmost importance. It has become an important process in the assessment and management of water resources in all the countries of the world. Determination of the suitability of water for drinking and domestic purposes has been the subject of many researches. Egbunike (2007) indicated that though groundwater may be of good quality, it may be contaminated by weathering of feldspars, leaching of clay, sewage pollution, and limestone lenses through which it percolates and flows. Similarly studies carried out in other area of the world include those of Janardhana et al. (2013) in India and Lucie et al. (2010) in Ontario, Canada. In general, quantities of inorganic constituents dissolved in groundwater may vary depending on the local geology or human activities within the immediate environment. The objective of the present work was to ascertain and re-appraise the physical and chemical quality of the water resources in Obajana and environs. Data obtained can be used as base-line for future environmental monitoring in the area.

Location and climate

Obajana lies within longitudes 6°24'E and 6°27'E and latitudes 7°54'N and 7°56'N (Figure 1). It covers an area of approximately 696.81 Km^2 and has an undulating surface and slopes gently downward in a southwest - northeast trend.

The area is characterized by wet and dry seasons. The wet season starts in April and last until November. The wet season on the average lasts for about 217 days while the dry season starts from November- March and lasts

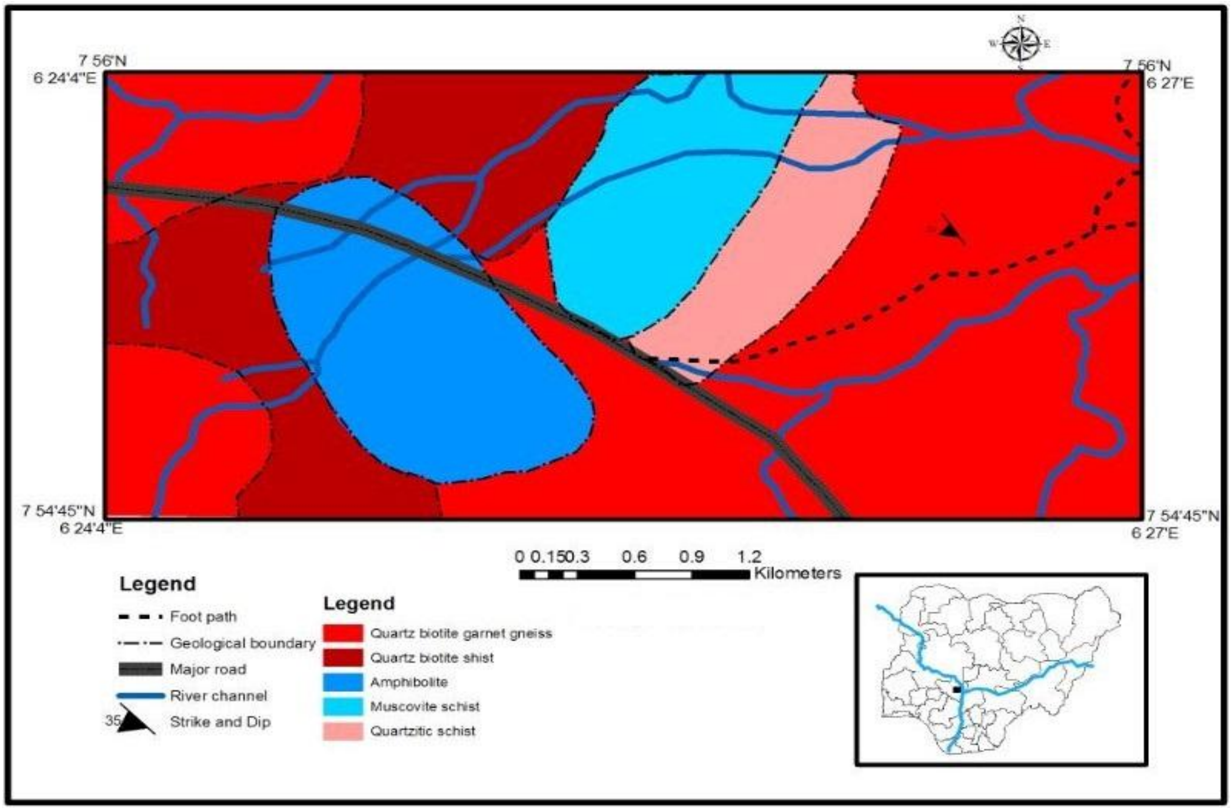

Figure 2. Geological map of the study area (Ameh et al., 2011).

for about 151 days (Walter, 1977). The vegetation is guinea savannah consisting of tall grasses, low trees and shrubs. In the wet season, this vegetation grows to become thick and impenetrable in some parts. In the dry season however, the grasses become dry and are burnt annually.

Geology of the study area

The study area lies within the Benin-Nigeria shield, situated in the Pan-African mobile zone extending between the ancient Basement of West African and Congo Cratons in the region of Late Precambrian to Early Palaeozoic orogenies (Rahaman, 1976; Ekwueme, 2003). The Basement Complex rocks of Nigeria are composed predominantly of migmatite gneiss; slightly migmatised to unmigmatised para-schists and meta-igneous rocks; charnockitic, older granite suites and unmetamorphosed dolerite dykes. (Rahaman, 1976).

The Precambrian Basement rocks of Obajana area, Southwestern Nigeria comprise of schists and gneisses which have been subjected to major supracrustal tectonic events such as the Dahomeyan (3000 ±200 Ma), Eburnean (1850 ± 250 Ma), Kibaran (1000 ± 100 Ma), and Pan-African (550 ± 100 Ma). The Obajana gneisses (Figure 2) comprise of three types of rocks designated as quartz-biotite gneiss; quartz-biotite-hornblende-pyroxene gneiss and quartz biotite-garnet gneiss (Rahama, 1976). According to this author, igneous rocks of this area occur as small, circular to oval outcrops and include members of the older granite suite mainly granites, granodiorites and syenites while associated schists in the area are: quartz-biotite schist, amphibolite schist, muscovite schist and quartzitic schist.

METHODOLOGY

A total of twenty four (24) water samples were collected for analysis in April, 2012, before the beginning of the wet season to ensure that effluents from surface run- off did not contaminate the samples taken. Fifteen samples were collected from hand-dug wells, six samples from boreholes and three samples were collected from surface water bodies. The surface water was collected from Angwa Tivi River and Oyo - Iwaa River.

The samples were collected in white plastic containers which were rinsed initially with the water to be sampled before proper sampling, labelling, storage and quality evaluation. *In-situ* test was carried out for the conductivity and pH, using conductivity and pH meters respectively; other parameters studied were total dissolved solids (TDS), and dissolved oxygen (DO). These parameters were measured directly by the use of HANA multi parameter ion specific metre (HI 83200). The concentrations of cations such as Fe^{2+}, Cu^{2+}, Zn^{2+}, K^{+}, Na^{+}, Mg^{+}, and Ca^{2+} were determined by the use of Atomic Absorption Spectrophotometer (Bulk scientific model 210VGP) at the department of soil sciences, Kogi state University, Anyigba. The

Table 1. Physical and chemical composition of groundwater samples taken from hand dug wells.

Parameter	Hand-dug wells														SON MPL
Locations	**L1**	**L2**	**L3**	**L5**	**L6**	**L15**	**L16**	**L17**	**L18**	**L19**	**L20**	**L21**	**L22**	**L23**	**L24**	
pH	7.0	7.1	6.9	7.2	6.4	6.9	6.8	6.5	6.8	7.0	6.7	6.7	6.8	6.8	6.9	6.5-8.5
TDS (mg/l)	42.0	68.0	134.0	44.0	111.0	73.0	53.0	48.0	35.0	3.0	39.0	49.0	42.0	48.0	72.0	500
EC (µs/cm)	0.047	0.001	226.000	0.014	0.133	0.022	0.038	0.093	0.621	0.034	0.074	0.038	0.058	0.019	0.045	
Turbidity (mg/l)	26	15	41	13	29	118	17	8	35	21	18	18	72	28	41	
DO (mg/l)	7.20	7.40	7.30	8.20	6.50	5.00	5.00	5.00	8.20	4.90	7.00	5.60	6.00	5.89	6.20	
REDOX (mV)	246	454	452	536	312	311	300	300	527	639	617	153	203	202	407	
Major cations and trace elements (mg/L)																
K^+	4.13	3.51	0.06	2.00	2.04	5.68	4.13	9.05	5.14	4.03	1.27	2.87	2.54	4.17	8.69	
Mg^{2+}	9.14	2.47	2.57	0.64	4.71	8.04	0.99	2.51	3.59	1.22	3.01	3.82	2.92	4.05	1.38	0.2
Fe^{2+}	0.055	0.123	0.049	0.034	0.007	0.031	0.075	0.032	0.281	0.156	0.041	0.023	0.627	0.072	0.057	0.3
Na^+	11.68	5.22	5.12	4.21	6.82	8.11	3.42	5.22	6.53	7.45	4.80	7.92	5.38	5.44	9.36	200
Cu^{2+}	0.002	0.020	0.010	0.002	0.005	ND	0.003	0.012	0.085	ND	0.085	0.001	0.011	ND	0.052	1
Ca^{2+}	12.25	10.22	19.24	8.93	10.87	8.19	10.49	12.22	14.56	22.86	17.21	10.97	7.54	11.45	12.28	
Zn^{2+}	ND	0.035	0.030	0.040	0.030	0.004	0.010	0.062	0.048	0.044	0.041	0.039	0.007	0.004	0.032	3
Anion (mg/L)																
NO_3^-	0.019	0.117	0.054	ND	0.002	0.195	0.004	0.038	0.051	0.004	0.002	0.142	0.002	0.087	0.002	50
SO_4^{2-}	0.245	0.004	0.011	0.004	0.021	0.013	0.106	0.008	0.064	0.011	0.029	0.036	0.021	0.046	0.003	100
Cl^-	2.358	1.067	8.140	1.042	0.032	1.081	3.210	2.050	0.050	3.425	2.003	2.011	0.004	4.079	3.013	250
HCO_3^-	27	66	134	93	37	56	74	18	110	40	61	121	58	107	67	

concentrations of anions such as NO_3^- and SO_4^{2-} were determined by the use of spectrophotometer (Model Genesys 20) while those for HCO_3 and Cl^- were determined by titration method in the Geochemistry laboratory of the University.

Results of the analysis carried out were processed with the AQUACHEM 4.0 software. This software was used to prepare Piper and Schoeller plots, determine the Hydrochemical facies of the water and carry out some statistical analysis of the data.

RESULTS AND DISCUSSION

Results of the physico-chemical characteristics for Water samples from three streams, 15 hand-dug wells, and six borehole wells in Obajana and its environs are presented in Tables 1, 2 and 3.

Physical characteristics

The pH values for the sampling points L10, L11 and L12, corresponding to the stream sources ranged from 6.9 to 7.1 with a mean value of 7.00 as shown in Tables 3 and 4 respectively. For the groundwater sources, pH values of water samples from hand-dug wells ranges from 6.4 - 7.2 (represented by sampling points L1, L6, L15, and L24 in Table 1) with a mean value of 6.83, while pH of groundwater samples from boreholes (L4, L7, L8, L9, L13 and L14) ranges from 6.6 to 7.4 with a mean value of 6.87, as shown in Table 2. The values are however, within the permissible limits of 6.5 - 8.5 set by W.H.O. The present study reveals a pattern of pH values that range from weakly acidic to weakly basic for groundwater and surface water in the area (Table 1).

Results from analysis, also show a similarity in trend between values of total dissolved solids (TDS) and electrical conductivity (EC) in the area under study. The trend decreases in the order; hand-dug wells > stream sources > boreholes (Figure 3a). From stream samples, TDS gives

Table 2. Physical and chemical composition of groundwater samples taken from boreholes.

Parameter	Borehole						SON MPL
Location	L4	L7	L8	L9	L13	L14	
pH	6.7	7.1	6.8	6.6	6.6	7.4	6.5-8.5
TDS(mg/l)	35.7	42.4	50.7	48.8	64.0	64.5	500
EC (µs/cm)	0.080	0.090	0.040	0.150	0.105	0.070	
Turbidity (mg/l)	18	22	29	27	25	32	
DO (mg/l)	7.6	6.5	7.5	8.3	7.5	6.6	
REDOX (mV)	307	311	324	342	625	298	
Major cations and trace elements (mg/l)							
K^+	6.84	5.07	3.73	5.26	3.18	4.82	
Mg^{2+}	3.78	3.22	5.22	2.93	2.88	4.81	0.2
Fe^{2+}	0.014	0.012	0.028	0.013	0.044	0.021	0.3
Na^+	4.38	3.22	5.50	4.82	8.32	4.75	200
Cu^{2+}	0.001	0.010	0.006	0.002	0.020	0.001	1.0
Ca^{2+}	9.20	11.60	9.24	10.70	11.62	8.70	
Zn^{2+}	0.052	0.066	0.043	0.047	0.040	0.032	3.0
Anions (mg/l)							
NO_3^-	0.054	0.003	0.002	0.024	0.004	0.040	50
SO_4^{2-}	0.006	0.115	0.131	0.003	0.014	0.207	100
Cl^-	6.240	7.180	5.210	5.800	2.500	9.730	250
HCO_3^-	53	62	92	17	97	69	

Table 3. Physical and chemical characteristics of surface water samples.

Parameter	Surface water			WHO MPL	SON MPL
Location	L10	L11	L12		
pH	7.0	6.9	7.1		6.5-8.5
TDS (mg/l)	64.0	67.0	68.0		500
EC (µs/cm)	90.0	75.0	81.0		
Turbidity (mg/l)	32	27	38		
DO (mg/l)	8.1	6.8	7.8		
REDOX (mV)	365	544	511		
Major cations and trace elements (mg/l)					
K^+	0.10	0.33	0.43		
Mg^{2+}	4.97	3.87	1.93		0.2
Fe^{2+}	0.101	0.078	0.036		0.3
Na^+	1.98	2.29	1.66		200
Cu^{2+}	0.006	0.008	0.007		1.0
Ca^{2+}	22.47	9.62	6.41		
Zn^{2+}	0.011	0.020	ND		3.0
Anions (mg/l)					
NO_3^-	0.001	0.007	0.016		50
SO_4^{2-}	0.745	0.394	0.256		100
Cl^-	5.940	1.350	5.500		250
HCO_3^-	61	92	104		

range of 64 to 68 mg/l and a mean value of 66.33 mg/l. Hand-dug wells recorded a range of 3.0 to 134.0 mg/l and mean value of 57.4 mg/l. For borehole samples, TDS values range from 35.7 to64.5 mg/l and a mean value

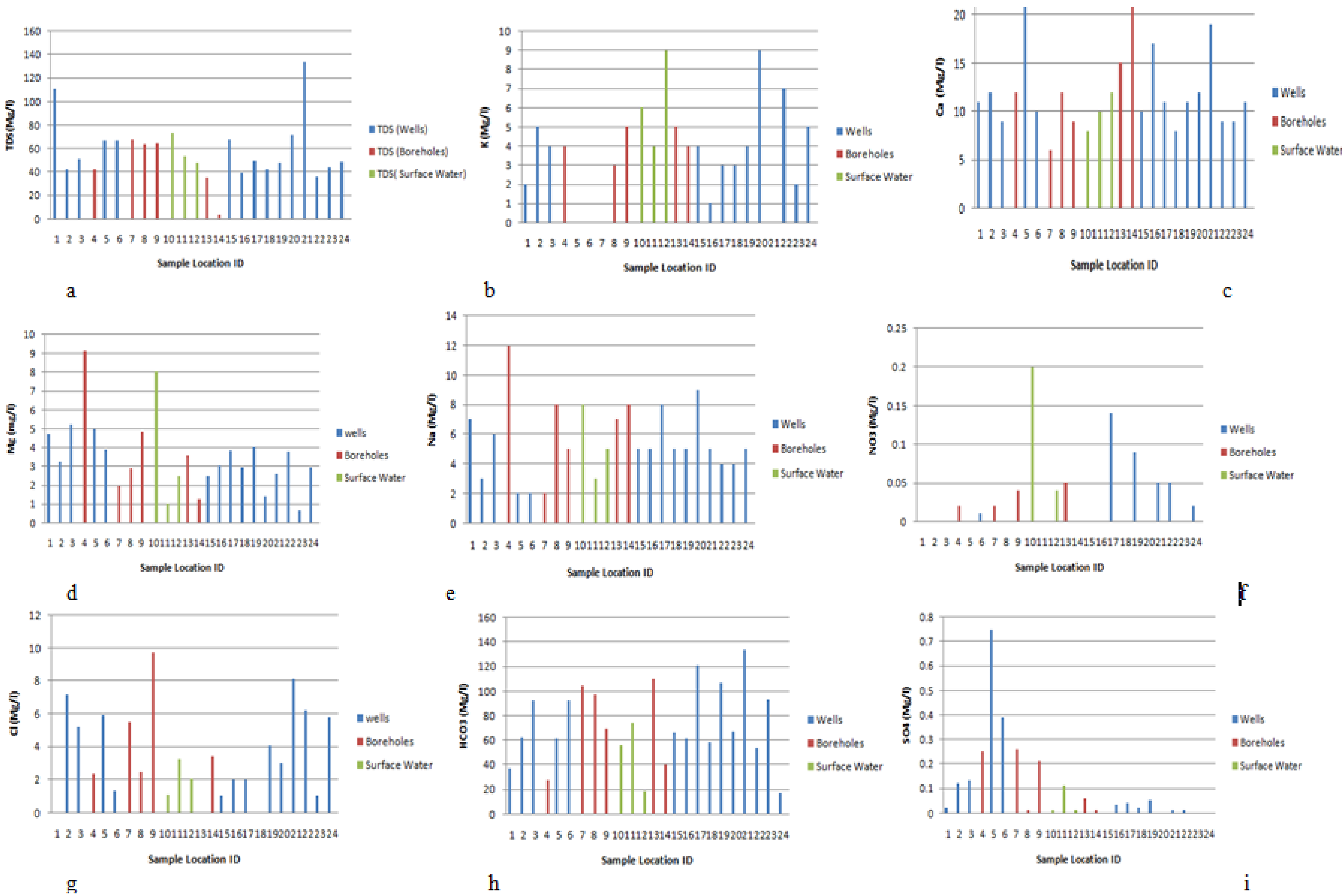

Figure 3. Bar chart representation of concentration of Elements. Compilation: 1- 24 (sample locations) blue graph (wells) red graph (boreholes) green graphs (surface water).

Table 4. Physical and chemical characteristics of surface and groundwater samples.

Parameter	Stream source		Han-dug well source		Borehole source		WHO (2011)	SON (2007)
	Range	Mean	Range	Mean	Range	Mean		
pH	6.9 - 7.1	7	6.4 - 7.2	6.833	6.6 - 7.4	6.87	6.5 - 9	6.5 - 8.5
TDS (mg/l)	64 - 68	66.33	3.0 - 134	57.4	35.7 - 64.5	51.02	1500	500
EC (µs/cm)	75 - 90	82	0.001 - 226.000	15.149	0.04 - 0.15	0.09	250	1000
Turbidity (mg/l)	27 - 38	32.33	8 - 118	33.333	18 - 32	25.5	NA	NA
DO mg/l	6.8 - 8.1	7.57	4.90 - 8.20	6.359	6.5 - 8.3	7.33	NA	NA
REDOX mV	365 - 544	473.33	153 - 639	377.933	298 - 625	367.83	NA	NA
K^+ (mg/l)	0.10 - 0.43	0.29	0.06 - 9.05	3.954	3.18 - 6.84	4.82	NA	NA
Mg^{2+} (mg/l)	1.93 - 4.97	3.59	0.64 - 9.14	3.404	2.88 - 5.22	3.81	150	0.2
Fe^{2+} (mg/l)	0.036 - 0.101	0.072	0.007 - 0.627	0.111	0.012 - 0.044	0.022	0.3	0.3
Na^+ (mg/l)	1.66 - 2.290	1.98	3.42 - 11.68	6.445	3.22 - 8.32	5.165	200	200
Cu^{2+} (mg/l)	0.006 - 0.008	0.007	0.000 - 0.085	0.019	0.001 - 0.02	0.007	2.0	1.0
Ca^{2+} (mg/l)	6.41 - 22.47	12.83	7.54 - 22. 86	12.619	8.70 - 11.62	10.177	200	NA
Zn^{2+} (mg/l)	0.000 - 0.020	0.01	0.000 - 0.062	0.028	0.032 - 0.066	0.047	3.0	3.0
NO_3^- (mg/l)	0.001 - 0.016	0.008	0.000 - 0.195	0.048	0.002 - 0.054	0.021	50.70	50
SO_4^{2-} (mg/l)	0.256 - 0.745	0.465	0.003 - 0.245	0.041	0.003 - 0.207	0.079	50	100
Cl^- (mg/l)	1.350 - 5.940	4.263	0.004 - 8.140	2.238	2.50 - 9.73	6.11	250	250
HCO_3^- (mg/l)	61 - 104	85.67	18 - 134	71.27	17 - 97	65	600	NA

of 51.02 mg/l. All samples analyzed had TDS concentration below SON (2007) (500 mg/l) and WHO (2011) 500 to 1000 mg/l for maximum permissible limit. Mean value of EC for stream water sources was 82 µs/cm, 15.149 µs/cm for hand-dug wells and borehole sources give 0.09 µs/cm. However, these values suggest that TDS and EC values are lower for groundwater sources than stream water sources. But according to Schoeneich (2001) EC for groundwater in the Crystalline Hydrogeological Province should be the same for surface water. Higher values in the stream/surface water sources could be attributed to slightly high content of Na^+, Cl^-, NO_3^-, and SO_4^{2-}. This can also be linked to effluent discharges from industries into the surface water and other anthropogenic activities.

Thus, it can be inferred that range and mean values for the TDS, EC and dissolved oxygen are within the permissible limits of W.H.O and Standard organization of Nigeria, with details represented in Tables 1, 2, 3 and 4. Given the range of values obtained for EC in the Obajana area, groundwater resources available can be classified as low salinity water.

DO of water samples analyzed ranges from 6.8 - 8.1 mg/l with a mean of 7.57 mg/l for surface water, 4.9 - 8.2 mg/l and a mean of 6.359 mg/l for groundwater from hand dug wells, while DO in water samples obtained from boreholes ranges from 6.5 - 8.3 mg/l with mean value of 7.33 mg/l (Tables 1, 2 and 3).

From the results presented in Table 4 above, NA means not available, WHO means World Health Organisation Geneva (2011) and SON means Standard organization of Nigeria (2007).

Chemical characteristics

The result of chemical analysis of the water sample in the study area shows that concentrations of Fe^{2+}, Zn^{2+} and Cu^{2+} are all below the permissible limits of the World Health Organisation (2011) and Standard Organization of Nigeria (2007). Guideline values have not been established for potassium and calcium. Potassium (K^+) concentration in groundwater within the studied area ranges from about 0.06 to 9.05 mg/l with an average of 3.954 mg/l in hand dug wells (Table 1), 3.18 to 6.84 mg/l with an average of 4.82 mg/l in boreholes (Table 2) while surface water haD potassium concentration ranging from 0.10 mg/l to 0.43 mg/l with an average of 0.29 mg/l (Table 3). The highest concentration of potassium was observed in samples taken from stream and hand dug wells (Figure 3b). Calcium (Ca^{2+}) concentration rangeD from 7.54 to 22.86 mg/l with an average of 12.619 mg/l in hand dug wells, 8.70 to 11.62 mg/l with an average of 10.18 mg/l while surface water had concentration ranging from 6.41 to 22.47 mg/l with an average of 12.83. Calcium concentration in groundwater samples analyzed exceeds that of surface water (Figure 3c). This is expected because of the water - rock interaction which has resulted in the dissolution of more calcium from subsurface rocks. Potassium in groundwater results from weathering of orthoclase and microcline. The abundance of potassium and sodium is about the same but potassium is commonly less than one tenth of sodium in natural water because many potassium minerals have higher resistance to weathering.

Magnesium in groundwater within the study area ranges from 0.64 to 9.14 mg/l for samples from hand dug wells, 2.88 to 5.22 mg/l for borehole samples while surface water (stream) had concentration range of 1.93 to 4.97 mg/l. Magnesium concentration in borehole samples exceeds those of stream and hand dug wells (Figure 3d).

Sodium concentration in all water sources sampled is far below the maximum permissible limit of 200 mg/l recommended by WHO (2011) and SON (2007) (Table 4). Groundwater and surface water within the study area is thus safe for drinking and domestic purposes with respect to their sodium content.

The concentration of iron in all the water samples analyzed were all within the maximum permissible limits of 0.3 mg/l set by SON and WHO except SL22 which has iron concentration of 0.627 mg/l (Table 1). Water from this location is considered unsafe for drinking with respect to its iron concentration. The iron in the groundwater source could have resulted from leaching from lateritic soils of predominantly the gneissic bedrocks. High Fe^{2+} content in water may impact stains on laundered cloth, scaling in metal pipes and affects taste of drinking water (Walter, 1981; Olarewaju et al., 1996).

The study also shows that the concentration of zinc and copper in both surface and groundwater are below the WHO and SON permissible limits of 3 and 1 mg/l set for zinc and copper respectively (Table 4). Water within the study area is thus considered safe for drinking and domestic use with respect to these parameters.

Concentration of cations in groundwater samples reveals that on the average, $Ca^{2+} > Na^{2+} > K^{+} > Mg^{2+}$, while in surface water samples, $Ca^{2+} > Mg^{2+} > Na^{2+} > K^{+}$. Though, variations exist from one sample point to another. This composition is evident that the water here is derived from source rocks rich in Ca-feldspars, notably plagioclases in the parent rock of metamorphic origin. Thus, water in the area is hard as its cationic content has more concentrations of slightly insoluble Ca^{2+} and Mg^{2+} over the soluble Na^{+} and K^{+}. The concentrations of cations in all the water samples are below permissible limits for good and safe drinking according to World Health Organisation (1996) and Standard organization of Nigeria (2005).

Anionic concentrations from water samples reveal that HCO_3^- is dominant. It ranges from 61 to 104 mg/l with a mean value of 85.67 mg/l in surface water. In groundwater generally, it ranges from 17 to 134 mg/l with mean values 71.27 mg/l in hand-dug wells and 65 mg/l in boreholes. In all samples, the order of abundance in anionic content is of the order $HCO_3^- > SO_4^{2-} > NO_3^- > Cl^-$ for surface water and $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^-$ for groundwater. The high content of HCO_3^- in water from the study area is a reflection of the fact that groundwater is being recharge directly from rainfall sources and not probably any other pollution source.

Nitrate concentration in both water sources analyzed is far below the recommended permissible limit of 50 mg/l by SON. This is an indication that here has not been much contamination of the water sources by effluents, sewage or agricultural fertilizers.

Piper plots and Schoeller diagram

Plot of the chemical compositions of Groundwater according to Lonergan and Cange (1994), presented in Piper's trilinear diagram is shown in Figure 4. Here, dominant cation and anion fields are classified. A similar plot for the study (Figure 4) using a hydrogeological software AQUACHEM 4.0 reveals that the groundwater is $Ca^{2+} + Mg^{2+} + HCO_3^-$ and bicarbonate water type which represents recently recharged water of meteoric origin that resulted from the dissolution of alluminosilicate minerals. Comparison of the chemical characteristic of groundwater in Obajana and its environs, and the WHO/SON baseline standard for drinking water quality confirms that at the moment, there level of water pollution in water samples from the area is very minimal or almost non-existent.

The Schoeller diagram represents the combination of major and minor constituents of groundwater in the study area (Figure 6) and the result obtained indicates that HCO_3 is dominant and SO_4 was the least in the following order: HCO_3^-, Ca, Na, Mg, Cl, SO_4^{2-}. This plot again buttresses the composition of major cations and anions present from water samples in the study area, and that they are in consonance with plot from the piper diagram.

The correlation coefficient reveals some relevant hydrochemical relationships; the content of TDS has high positive correlation with Fe^{2+} and so does Zn^{2+} and K^{+} (Table 4). This positive correlation indicates that the ions may have been derived from the same source. All other nutrient concentrations in the water samples analyzed either have very weak positive correlation or negative correlations. Negative correlation between most of these nutrient concentrations suggests that they are not of the same source but could have been derived from ion exchange processes between water and rocks. The rock source deduction component of the aquachem 4.0. Software confirms some of the inferences made from the interpretation of the correlation coefficients (Table 5) between the measured parameters. Deductions from this software reveals that sodium in the water is sourced from albite and ion exchange processes, calcium and bicarbonate are sourced from weathering of carbonate and silicate rocks and chloride from rock weathering. Deductions could not be made on the sources of the other parameters because data on some chemical facies needed to do so are lacking.

Conclusion

Water is of immense importance to both rural and urban dwellers of developing nations. Classification of the water

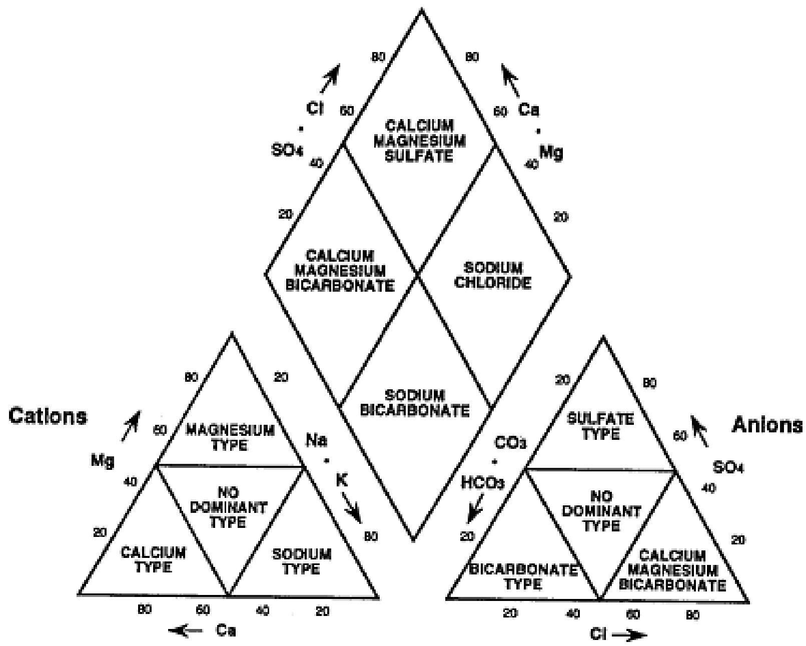

Figure 4. Piper Diagram showing dominant cation and anion fields in the Lower triangles and Hydrochemicals Facies in the upper diamond. Source: Lonergan and Cange (1994).

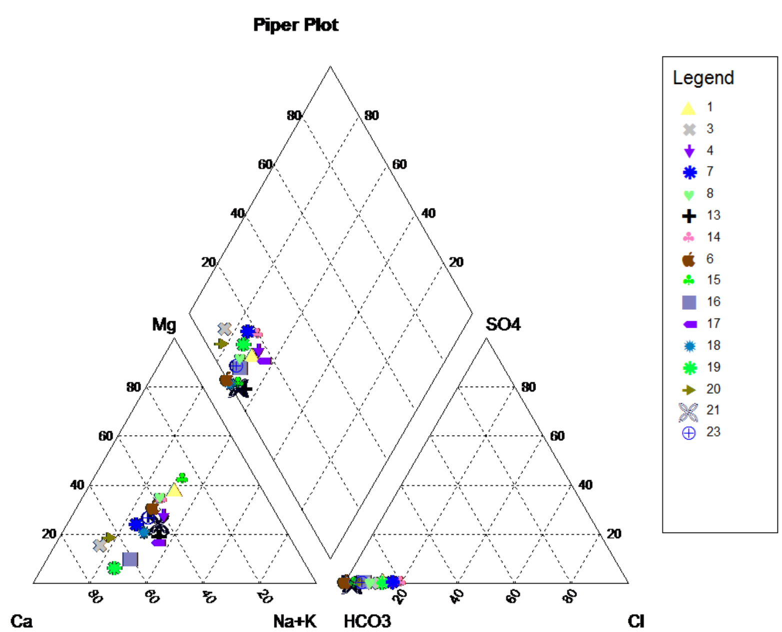

Figure 5. Piper diagram plot for water samples from the study area, where; 1, 2, 3, to 16 represent sample location numbers.

in the study area based on its pH shows that the water is slightly acidic to slightly basic but however falls within the acceptable permissible limit recommended by the World health Organization (2011) and the standard organization of Nigeria (2007). Groundwater in Obajana and environs has been evaluated for its chemical composition and suitability for drinking.

The abundance of chemical concentrations in surface water within the study area is in the order of Ca > Mg > Na > K for the cations and HCO_3^- > SO_4^{2-} > NO_3^- > Cl^- for

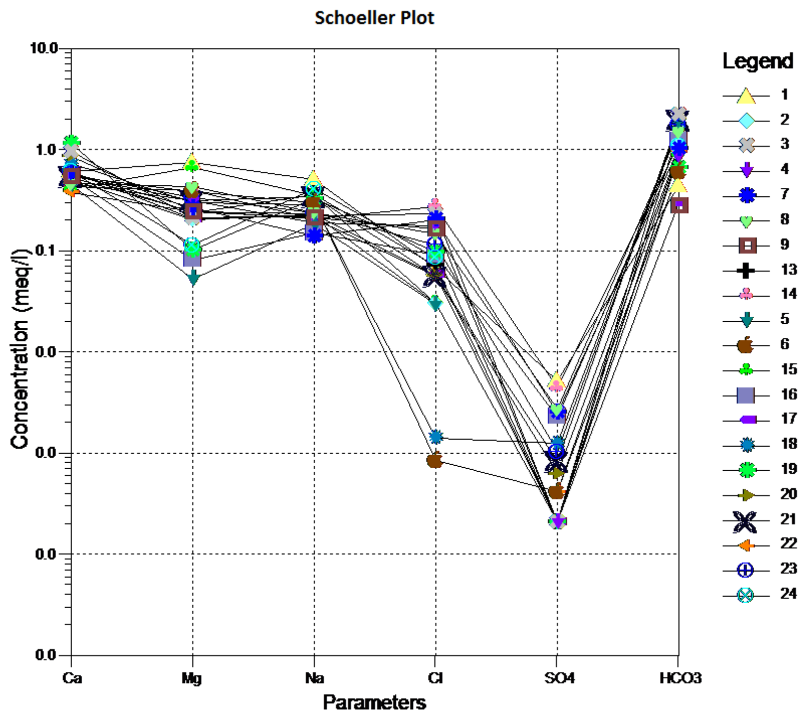

Figure 6. Schoeller diagram for water samples from the study area, where; 1, 2, 3 to 16 represent sample location numbers.

Table 5. Correlation matrix of measured parameters.

	Correlation coefficient												
	DS	**Na**	**K**	**Ca**	**Mg**	**Fe(II)**	**Cu**	**Zn**	**Cl**	**HCO_3**	**NO_3**	**SO_4**	**O_2**
TDS	1.00	-0.07	-0.34	-0.04	0.11	0.57	-0.39	-0.31	0.13	0.29	0.06	0.08	0.13
Na		1.00	0.40	0.06	0.40	-0.04	0.34	0.17	-0.37	-0.18	0.40	-0.45	-0.26
K			1.00	-0.20	0.02	-0.34	0.19	0.52	-0.03	-0.46	0.18	-0.44	-0.36
Ca				1.00	-0.11	0.35	0.29	-0.08	0.10	-0.04	-0.12	0.23	-0.01
Mg					1.00	-0.11	-0.17	-0.03	-0.03	-0.21	0.38	0.23	0.01
Fe(II)						1.00	-0.13	-0.19	0.33	0.41	-0.07	-0.17	0.08
Cu							1.00	0.20	-0.44	0.12	0.49	-0.24	0.23
Zn								1.00	0.02	-0.18	0.11	-0.46	0.11
Cl									1.00	0.08	-0.32	0.23	0.17
HCO_3										1.00	0.18	-0.02	0.20
NO_3											1.00	-0.58	-0.66
SO_4												1.00	0.42
O_2													1.00

the anions while the order of abundance for groundwater is Ca > Na > K > Mg for cations and HCO_3^- > Cl^- > SO_4^{2-} > NO_3^- for the anions. The dominant hydrochemical facies identified here is of the Ca-Mg- HCO_3^- type. Groundwater and surface water within the study area is of excellent quality for drinking and domestic use with respect to TDS, pH, magnesium, sulphate, nitrate, chloride, zinc, copper and iron (only has elevated concentration in one location, L22) as the concentration of these parameters fall within the recommended permissible limits of the world health organization (2011) and the standard organization of Nigeria (2007).

It is however recommended that a well designed groundwater monitoring program be put in place to periodically access the suitability water for drinking and other domestic purposes. This is to ensure that the introduction of hazardous contaminants is detected on time and necessary steps taken to avoid health hazards or deaths that may result from drinking such contaminated water.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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