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Determination of the Influence of Geology and Anthropogenic Activities on Water Quality in Agenebode and Environs, Southwestern Nigeria

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INFORMATION

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ABSTRACT

This study investigated the influence of geology and anthropogenic activities on water chemistry and quality in Agenebode and environs, southwestern Nigeria. Agenebode and environs is underlain by the Ajali and Mamu Formations of the Anambra Basin and is drained by the River Niger. 10 groundwater and surface water samples were collected and analyzed in the laboratory. The results revealed ranges of values for the parameters such as pH 5.8 - 6.7, EC 11.4- 228.1 µmhos/cm, Ca 0.48 - 2.73 mg/l, Mg 0.32 - 1.8 mg/l, Na 0.15 - 0.97 mg/l, K 0.28 - 2.73 mg/l, SO_4 0.014 - 0.181 mg/l, Cl 10.4 - 124.1 mg/l, HCO_3 30.3 - 85.4 mg/l, NO_3 0.354 - 1.843 mg/l, Fe 0.081 - 0.304 mg/l, Mn 0.019 - 0.081 mg/l, Cu 0.011 - 0.063mg/l and hardness 2.512 - 14.205mg/l. The values of pH, Fe and Pb are above the limits in some of the samples (NIS, 2015; WHO, 2017). When plotted on a piper plot, the samples ranged from Magnesium Bicarbonate water type to Calcium Chloride water type, but the dominant type was the Mixed type and the distribution of ions was as follows $Mg^{2+} > Na^{+} + K^{+} > Ca^{2+}$ and $Cl^{-} >> HCO_3^{-} > NO_3^{-} > SO4_2^{-}$. Correlation and regression analyses showed that the pH of the groundwater in Agenebode is influenced negatively by the TDS, EC, Salinity, COD, DO and the Major and Minor constituents. Hierarchical cluster analysis showed that the samples taken on and close to the River Niger shared similar characteristics, while samples taken further inland shared similar characteristics but all these samples differed in characteristics from the sample taken from the Mamu Formation. It is recommended that biological parameters should be measured in the study area in order to gain a clearer picture of the water quality especially from the anthropogenic point of view.

1. Introduction

Groundwater is crucial to the social and economic life of Nigerians, in terms of its domestic, industrial and agricultural utility, (Edet et al., 2011). Akujieze et al. (2003) estimated the total amount of groundwater resources to be 50 million trillion litres/year. Gibbs (1970) proposed that rock weathering, atmospheric precipitation, evaporation and crystallization control the chemistry of surface water. Despite the poor assessment in Nigeria, the influence of geology on water chemistry and quality is widely recognized (Gibbs, 1970; Langmuir, 1997; Lester and Birkett, 1999; Uliana, 2012).

Sedimentary aquifers are the most important of all aquifers because they tend to have the highest porosities and permeabilities (Earle, 2006). Sedimentary rocks are exposed on over 70% of the Earth's land surface. Yields in Sedimentary terrains are controlled by thickness, degree of sorting and coarseness of aquifer material (Ariyo, 2005; Idowu and Ajayi, 1998).

A lot of the work on groundwater chemistry and quality is skewed towards comparing analytical results with existing national and international standards for drinking, domestic and agricultural purposes; with the geologic input not being given enough consideration. (Edet et al., 2011). The present study examines the influence of the Geology and human activities on groundwater chemistry and quality.

2. Study Area

2.1. Physical Setting and Climate

The study area is located between Longitude 6°30' 0" and 6°

44' 30'' and Latitude 7° 0'0'' and 7° 12' 0'' with an area of about 169 km². The major towns in the study area include Agenebode, Agor, Etwotsor, Aviodor and Fugar. The study area can be accessed primarily by the Auchi-Agenebode and Agenebode-Uromi roads. The climatic condition of the study area is tropical and there are two major seasons: wet and dry seasons. The wet season is from March to October, while the dry season is from November to March. Temperature ranges from 25°C during the brief harmattan period to about 35°C at the peak of the dry season (Obiadi et al., 2012).

The vegetation falls within the guinea savannah grassland with lush vegetation of tall trees, shrubs and grasses. The study area is drained majorly by the River Niger (Fig. 1).

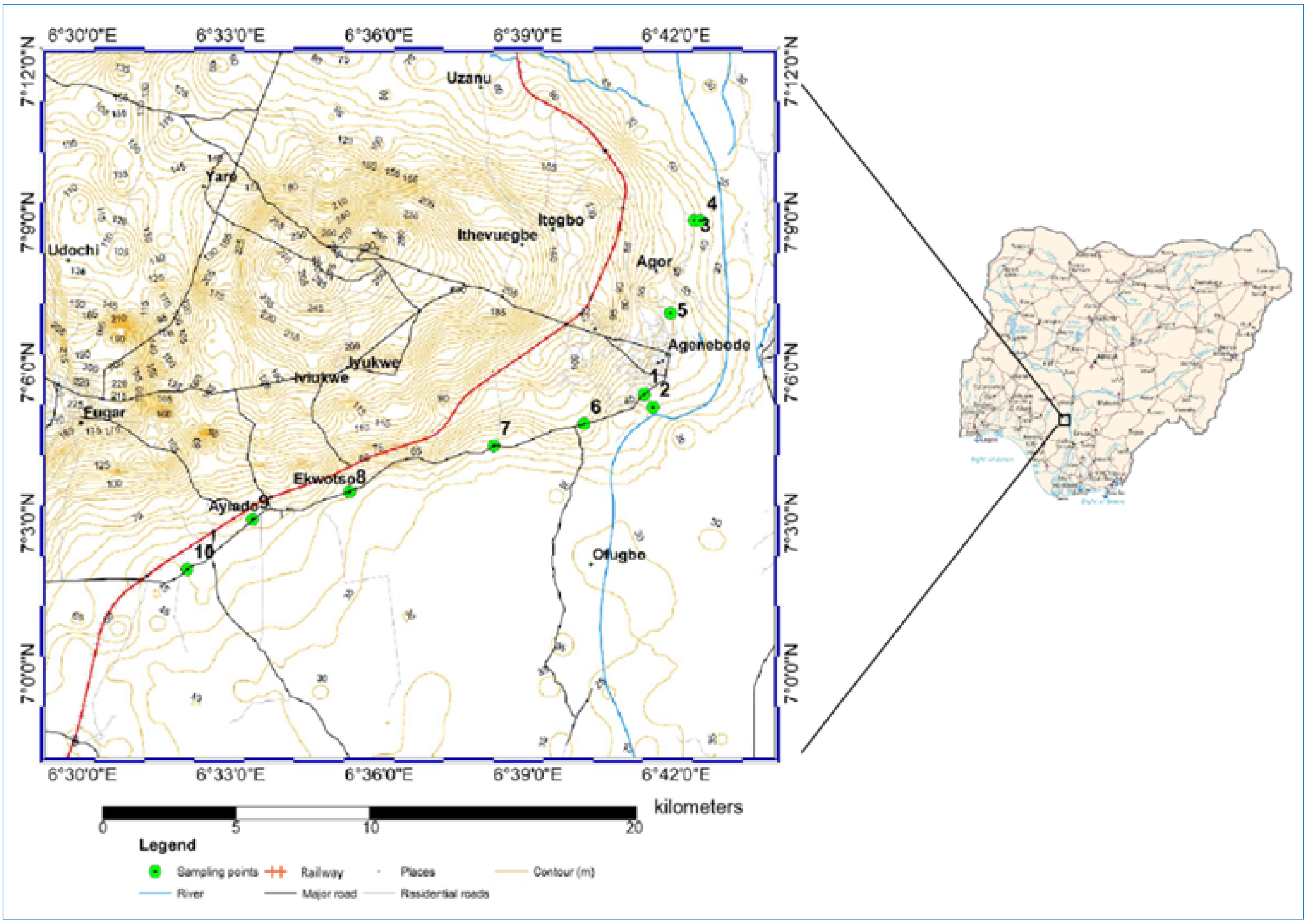

Fig. 1. Topographic map of Agenebode and Environs showing sample points

1.1. Local Geology

Agenebode and environs is underlain by the Anambra Basin. The Sedimentation in the Anambra Basin commenced with the Campanian-Maastrichtian, continental to marine rocks of the Nkporo Group which consists of the Afikpo, Nkporo, Lokoja, Owelli and Enugu Formations in stratigraphic order from bottom to top. This is overlain by the estuarine-deltaic sands, shales, coals and ironstones of the Mamu Formation. The deltaic-fluvio sandstones of the Ajali Formation lie on the Mamu Formation (Fig. 2).

Maastrichtian - Early Paleocene marginal marine - marine conditions, led to the deposition of the carbonaceous shales interbedded with silts, coals, sands, ironstones and limestones of the Nsukka Formation. The marine shales of the Imo Formation overlie the Nsukka Formation (Umeji and Nwanjide, 2007; Nwajide, 2013; Edegbai et al., 2019). The northern part of the study area is underlain by ironstones of the Mamu Formation while the Ajali Formation underlies the southern part of the study area and consists of friable, white cross-bedded sandstone with thin beds of whitish claystones. The cross-beds are large scale and dip about 20–30° towards the West (Ogala et al., 2015).

The sand units display thin, poorly defined cyclothems. There are numerous bands of variegated, carbonaceous shales and mudstones of the Nsukka Formation that top the Sandstone cyclothems. The Ajali Formation is Maastrichtian in age with a thickness of up to 500m in some places (Reyment, 1965) and often shows a fining-upward sequence. In the subsurface, the Ajali Sand is dominantly fine-grained and calcareous.

It is usually shaly, and pyritic or carbonaceous, and may contain ostracods and arenaceous foraminifera (Agagu et al., 1985). The Ajali Formation aquifer is highly sought after and is one of the eight (8) giant regional aquifer systems in Nigeria (Akujieze et al., 2003).

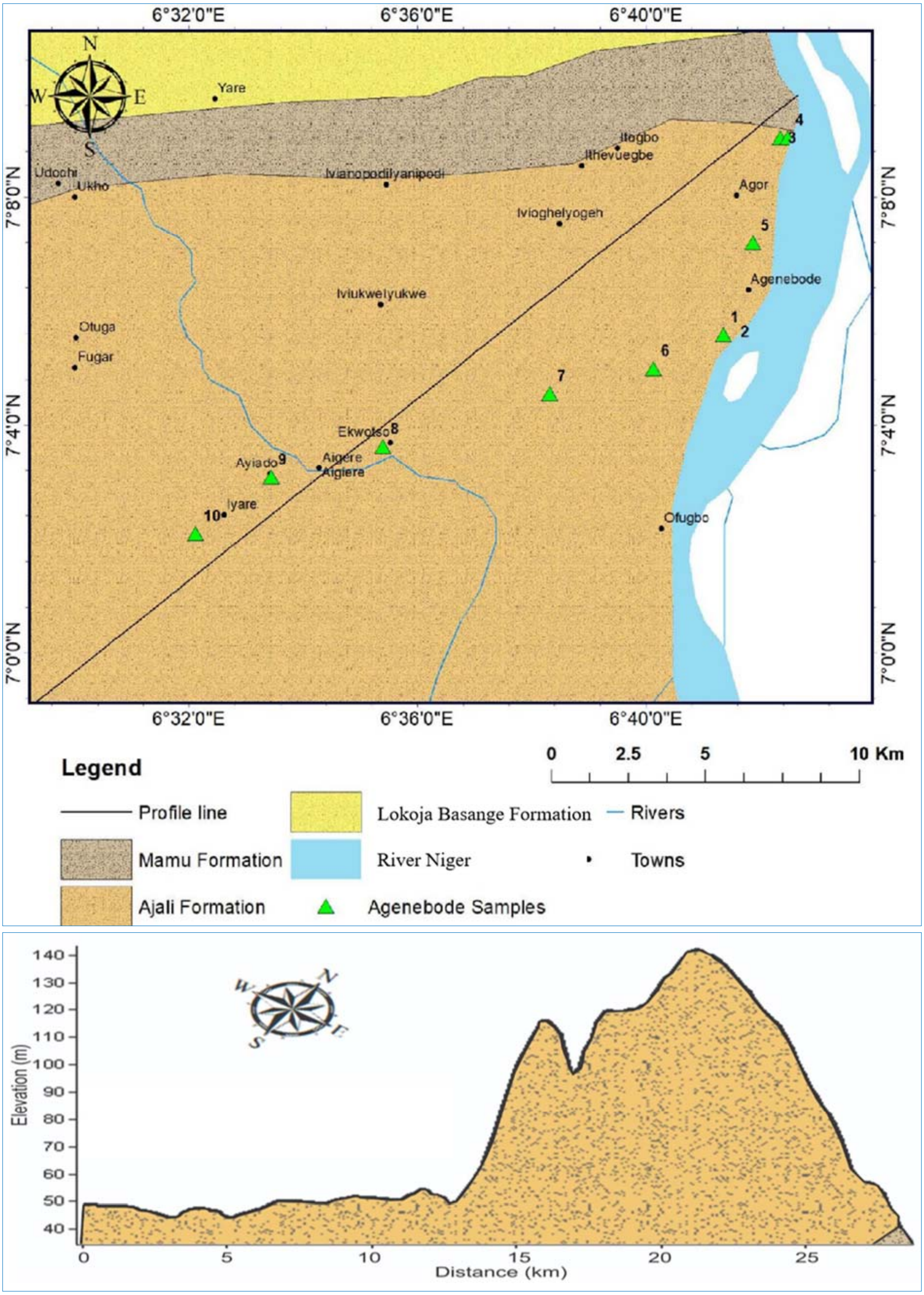

Fig. 2. Geologic map (previous page) and cross section of Agenebode and Environs showing sample points (modified after Edegbai and Emofurieta, 2015)

3. Methodology

The study area was partially mapped using a Global Positioning System (GPS) device. This was used to determine the longitude and latitude as well as the elevation of the locations of the boreholes and other places of interest for the map production. Eight (8) groundwater samples and two (2) surface water samples were collected for geochemical analysis.

Fig. 3. Groundwater sample collection at Agenebode

Fig. 4. Surface water sample collection at Agenebode

The samples were collected in 1.5 L high-density, cleaned polythene containers, 300 mL BOD and 300 mL DO bottles and rinsed 3–4 times before sampling using the water to be sampled. Collected samples were stored in a cool environment before being transported to the laboratory for analysis in less than twenty-four (24) hours after collection.

Table 1. Statistical summary of the surface water and groundwater physicochemical parameters in Agenebode

		Surface water (n = 2)					Groundwater bode (n = 8)				
Parameters	**Unit**	**Mean**	**Median**	**Min**	**Max**	**Std Dev**	**Mean**	**Median**	**Min**	**Max**	**StdDev**
pH	-	6.2	6.2	6.1	6.3	0.141421	6.35	6.4	5.8	6.7	0.298
EC	µmhos/cm	71.25	71.25	67.3	75.2	5.586144	48.5	18	11.4	228.1	74.717
Sal.	g/L	0.032	0.032	0.03	0.034	0.002828	0.02188	0.008	0.005	0.103	0.034
TDS	mg/L	35.45	35.45	33.5	37.4	2.757716	24.2	9.05	5.4	114.4	37.543
Hardness	mg/L	5.69	5.69	5.20	6.19	0.704990	4.882	3.632	2.512	14.205	3.83683
COD	mg/L	30	30	28	32	2.828427	17.3	16.4	6.4	32	7.976
DO	mg/L	3.35	3.35	3	3.7	0.494975	1.6	1.5	0.5	3.8	0.997
BOD	mg/L	1.05	1.05	1	1.1	0.07071	1.4375	1.35	0.8	2.1	0.4658
HCO_3	mg/L	74.2	74.2	69.1	79.3	7.212489	47.25	42.7	30.3	85.4	19.791
Na	mg/L	0.595	0.595	0.51	0.68	0.120208	0.3575	0.255	0.15	0.97	0.275
K	mg/L	0.305	0.305	0.28	0.33	0.035355	0.18625	0.13	0.05	0.63	0.187
Ca	mg/L	0.99	0.99	0.93	1.05	0.084853	0.93	0.69	0.48	2.73	0.740
Mg	mg/L	0.785	0.785	0.7	0.87	0.120208	0.62375	0.465	0.32	1.8	0.485
Cl	mg/L	97.5	97.5	88.6	106.4	12.5865	41.2375	25.15	10.4	124.1	40.464
P	mg/L	0.089	0.089	0.061	0.117	0.039598	0.05538	0.0485	0.024	0.143	0.038
NO_2	mg/L	0.0405	0.0405	0.038	0.043	0.003536	0.02475	0.02	0.011	0.061	0.017
NO_3	mg/L	1.2025	1.2025	1.021	1.384	0.25668	0.72763	0.5765	0.354	1.843	0.473
NH4N	mg/L	0.292	0.292	0.29	0.294	0.002828	0.25963	0.2605	0.225	0.301	0.023
SO_4	mg/L	0.1495	0.1495	0.133	0.166	0.023335	0.05788	0.039	0.014	0.181	0.055
Fe	mg/L	0.151	0.151	0.151	0.151	0	0.17513	0.1575	0.081	0.304	0.068
Mn	mg/L	0.0235	0.0235	0.022	0.025	0.002121	0.04625	0.0395	0.019	0.081	0.022
Zn	mg/L	0.066	0.066	0.066	0.066	0	0.08325	0.0845	0.048	0.11	0.020
Cu	mg/L	0.0145	0.0145	0.014	0.015	0.000707	0.03388	0.0305	0.011	0.063	0.018
Cr	mg/L	0.009	0.009	0.008	0.01	0.001414	0.023	0.0235	0.006	0.037	0.011
Cd	mg/L	0.0035	0.0035	0.003	0.004	0.000707	0.01013	0.0085	0.001	0.021	0.007
Ni	mg/L	0.003	0.003	0.003	0.003	0	0.00813	0.007	0.001	0.017	0.005
Pb	mg/L	0.006	0.006	0.005	0.007	0.001414	0.01763	0.0165	0.005	0.033	0.010
V	mg/L	0.002	0.002	0.002	0.002	0	0.0055	0.0045	0.001	0.011	0.003

Laboratory results which included: physical parameters (Electrical Conductivity, Total Dissolved Solids, Salinity, Chemical Oxygen Demand, Biochemical Oxygen Demand, Dissolved Oxygen and pH); basic cations (Calcium and Magnesium, Sodium and Potassium) and anions (Chloride, Bicarbonate, Sulphate and Nitrate) alongside Phosphorus, Nitrate, Nitrite, Ammonium, Iron, Manganese, Zinc, Copper, Chromium, Cadmium, Nickel, Lead and Vanadium were subjected to descriptive and graphical statistical analysis using Microsoft Excel package, SPSS software, Piper and Durov components of GW Chart software (mean, median, minimum and maximum values, standard deviation, correlation analysis, regression analysis, pie charts, histograms, radar plots, piper plots, Hierarchical cluster analysis dendograms). The results were also compared against the WHO standards and Nigerian standards to ascertain the suitability of the water for domestic uses.

4. Results and Discussion

Table 1 presents the statistical summary of the surface and groundwater physicochemical parameters from Agenebode.

The pH of both the surface water and groundwater samples in Agenebode (Table 1) are acidic, with pH ranges of 6.1 - 6.3 and 5.8 - 6.7 and median values of 6.2 and 6.4 respectively which is similar to what Wali et al. (2020) and Amadi et al. (2020) found for the Ajali Formation. The water samples in Agenebode and environs have low Electrical Conductivity (EC), Salinity, Total Dissolved Solids (TDS) and Hardness as well as a low concentration of major and minor ions and this is the case because the study area is underlain by mature sands that have been weathered from the southwest Basement Massifs (which includes the Igarra Basement Complex rocks) and the Oban Massif (Tijani et al., 2010; Osazuwa and Opeloye, 2014), which have very little mineral constituents to be dissolved. This is similar to what has been reported by Fasunwon et al. (2010), Danhalilu et al. (2018) and Huneau et al. (2019). This therefore suggests that water from sedimentary aquifers would have low concentration of ions, although there is an exception to this rule and this is when the water interacts with carbonate deposits (Nwankwo et al., 2020), which often leads to higher EC, Salinity, TDS, and Hardness as well as a higher concentration of the ions.

Table 2 shows a moderate to strong negative relationship in Agenebode between the pH and EC, Salinity, TDS, COD, DO, and the major and minor ions, while there is a weak to moderate positive relationship with the BOD and the heavy metals. It can be interpreted therefore, that the higher the EC, Salinity, TDS, COD, DO, and major and minor ions values, the lower the pH would be in Agenebode. This is because when the pH of a water sample is below 7, it has a negative relationship with the EC and when it is above 7, a positive relationship is present (Celzard, 2013).

Table 2. Correlation analysis of the physicochemical parameters of water samples (surface water and groundwater) from Agenebode

1		Agene	pH	EC	Sal	TDS	COD	HCO3	DO	BOD	Na	K	Ca	Mg	Cl	P	NO2	NO3	NH4N	SO4	Fe	Mn	Zn	Cu	Cr	Cd	Ni	Pb	V
2	Agene	1.00																											
3	pH	0.52	1.00																										
4	EC	-0.56	-0.81	1.00																									
5	Sal.	-0.57	-0.81	1.00	1.00																								
6	TDS	-0.56	-0.81	1.00	1.00	1.00																							
7	COD	-0.71	-0.64	0.76	0.76	0.76	1.00																						
8	HCO3	-0.69	-0.75	0.81	0.81	0.81	0.97	1.00																					
9	DO	-0.63	-0.68	0.80	0.80	0.80	0.97	0.96	1.00																				
10	BOD	0.43	0.56	-0.65	-0.65	-0.65	-0.89	-0.87	-0.83	1.00																			
11	Na	-0.54	-0.80	0.92	0.92	0.92	0.91	0.95	0.93	-0.84	1.00																		
12	K	-0.52	-0.79	0.97	0.97	0.97	0.85	0.89	0.90	-0.79	0.98	1.00																	
13	Ca	-0.41	-0.75	0.98	0.98	0.98	0.69	0.75	0.75	-0.66	0.90	0.96	1.00																
14	Mg	-0.46	-0.77	0.99	0.99	0.99	0.77	0.81	0.83	-0.70	0.94	0.99	0.99	1.00															
15	Cl	-0.59	-0.79	0.83	0.83	0.83	0.95	0.98	0.96	-0.87	0.97	0.92	0.78	0.84	1.00														
16	P	-0.47	-0.64	0.89	0.89	0.89	0.88	0.90	0.92	-0.80	0.96	0.95	0.88	0.93	0.91	1.00													
17	NO2	-0.59	-0.78	0.91	0.91	0.91	0.93	0.96	0.95	-0.87	0.99	0.98	0.88	0.93	0.98	0.95	1.00												
18	NO3	-0.57	-0.76	0.93	0.93	0.93	0.91	0.93	0.95	-0.79	0.98	0.98	0.90	0.95	0.95	0.98	0.98	1.00											
19	NH4N	-0.58	-0.57	0.73	0.73	0.73	0.97	0.93	0.94	-0.94	0.89	0.86	0.71	0.77	0.92	0.87	0.93	0.88	1.00										
20	SO4	-0.62	-0.74	0.83	0.83	0.83	0.95	0.97	0.99	-0.82	0.96	0.92	0.78	0.85	0.98	0.93	0.97	0.96	0.93	1.00									
21	Fe	0.38	0.41	-0.63	-0.63	-0.64	-0.79	-0.73	-0.73	0.92	-0.74	-0.74	-0.68	-0.69	-0.71	-0.73	-0.78	-0.71	-0.88	-0.69	1.00								
22	Mn	0.51	0.48	-0.60	-0.60	-0.60	-0.91	-0.87	-0.84	0.98	-0.80	-0.74	-0.59	-0.64	-0.84	-0.76	-0.84	-0.76	-0.96	-0.81	0.92	1.00							
23	Zn	0.55	0.70	-0.79	-0.79	-0.79	-0.93	-0.94	-0.90	0.97	-0.93	-0.89	-0.78	-0.82	-0.94	-0.86	-0.95	-0.88	-0.96	-0.90	0.90	0.95	1.00						
24	Cu	0.53	0.56	-0.62	-0.62	-0.62	-0.92	-0.89	-0.86	0.98	-0.82	-0.76	-0.61	-0.66	-0.87	-0.77	-0.86	-0.78	-0.96	-0.83	0.91	0.99	0.97	1.00					
25	Cr	0.62	0.67	-0.71	-0.71	-0.71	-0.96	-0.97	-0.92	0.96	-0.89	-0.82	-0.67	-0.73	-0.95	-0.83	-0.92	-0.85	-0.96	-0.91	0.83	0.96	0.98	0.98	1.00				
26	Cd	0.53	0.47	-0.65	-0.64	-0.65	-0.92	-0.86	-0.86	0.97	-0.82	-0.78	-0.64	-0.69	-0.84	-0.80	-0.86	-0.79	-0.97	-0.83	0.94	0.99	0.95	0.97	0.94	1.00			
27	Ni	0.49	0.49	-0.63	-0.63	-0.64	-0.91	-0.85	-0.84	0.98	-0.81	-0.77	-0.64	-0.68	-0.84	-0.78	-0.85	-0.78	-0.97	-0.81	0.95	0.99	0.95	0.98	0.94	1.00	1.00		
28	Pb	0.54	0.54	-0.62	-0.62	-0.63	-0.94	-0.90	-0.87	0.98	-0.83	-0.76	-0.60	-0.66	-0.89	-0.79	-0.87	-0.79	-0.97	-0.85	0.90	0.99	0.96	1.00	0.98	0.98	0.98	1.00	
29	V	0.48	0.54	-0.62	-0.61	-0.62	-0.89	-0.88	-0.84	0.99	-0.81	-0.76	-0.62	-0.66	-0.86	-0.76	-0.85	-0.77	-0.95	-0.82	0.92	0.99	0.96	1.00	0.96	0.97	0.98	0.99	1.00

The pH is interpreted to be low mostly because the water is fresh and was recently recharged from rainfall. The heavy metals and BOD values have a weak positive relationship with the pH, indicating that the higher their concentration, the higher the pH would be.

In Fig. 5, a negative relationship is observed between the pH and Magnesium concentration in Agenebode with an R^2 of 0.5852, indicating that, the Magnesium concentration influences the pH negatively by about 58%. This relationship is similar for the major and minor ions in the study area, but is not the case for the Heavy metals. A positive relationship exists between the pH and Zinc values in Agenebode with an R^2 value of 0.493. The Zinc concentration influences the pH positively by about 49.3%. This relationship is similar for the other heavy metals in the study area.

The water samples from Agenebode range from Magnesium Bicarbonate type to Calcium Chloride type, but the dominant type is the mixed type (Fig. 6).

The water samples that represent the Magnesium Bicarbonate type (water samples 5, 6, 7 and 8) may have slightly interacted with the carbonaceous units of the Ajali Formation, thus impacting the groundwater with carbonaceous elements. Based on the concentration of ions in the water samples, sample three (3) in Agenebode is an outlier (Figs. 7-8) and this is the case because unlike the other samples, the chemistry of the water has been altered by the Mamu Formation which underlies the sample location of samples 3 and 4, although sample four (4) was taken from the River Niger, thus, its chemistry is influenced to a lower degree by the Mamu Formation due to dilution from direct precipitation and a lower interaction rate with the geology; even then the concentration of the ions in sample four (4) is the second highest after sample three (3), therefore demonstrating the influence of the geology on water chemistry.

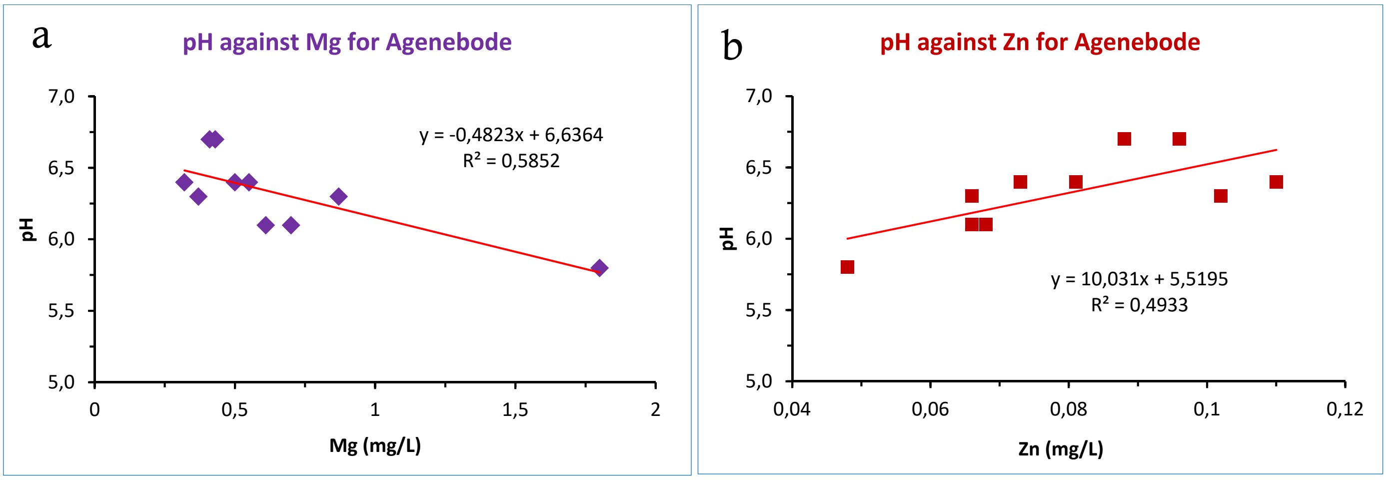

Fig. 5. Scatter plot of pH against magnesium values (a) and zinc values (b)

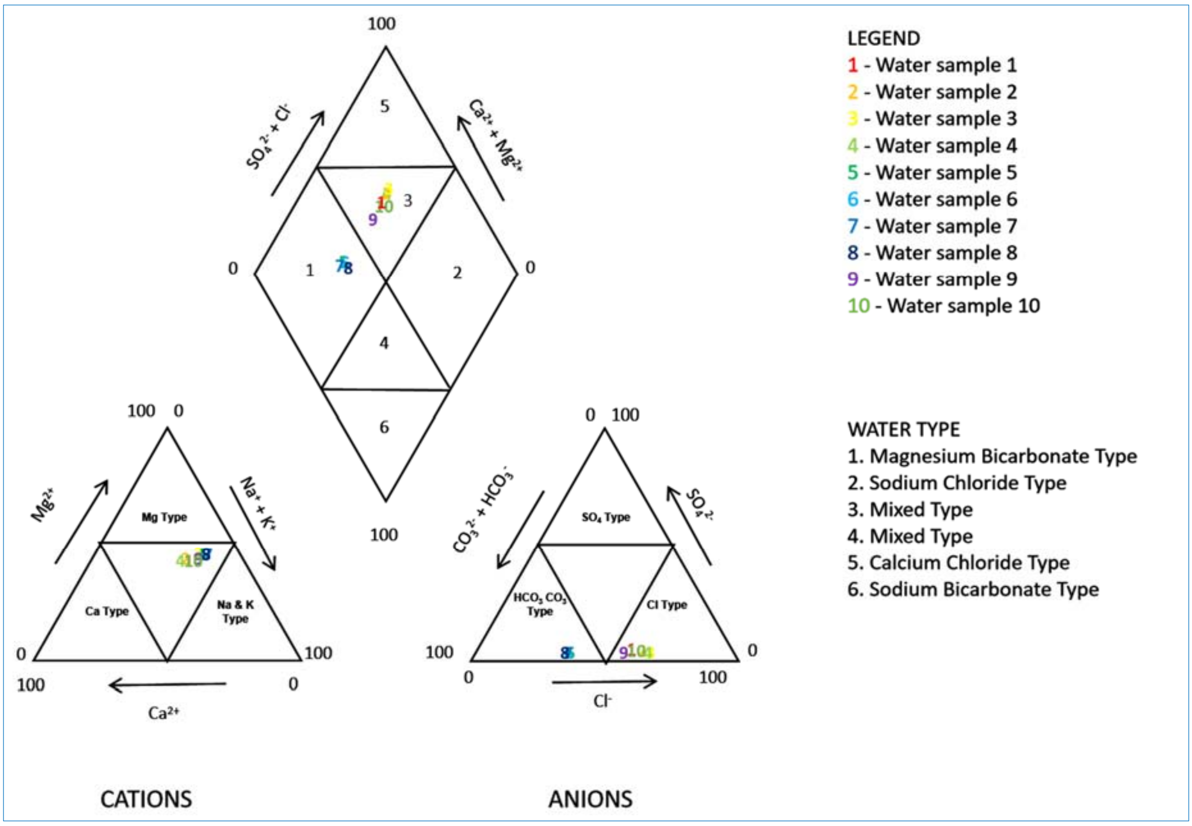

Fig. 6. Piper diagram of water samples (surface water and groundwater) from Agenebode (Adapted from Piper, 1944)

Water samples 1, 2, and 4 (Fig. 9) which were taken close to the River Niger, with sample 2 and 4 taken on the River Niger (Fig. 4), share similar chemical characteristics; it is interesting that sample 1 which is a Groundwater sample is similar to the Surface water samples and this may point to influent flows from the River Niger when the flow volume is high. The samples taken farther from the River Niger; samples 5, 6, 7, 8, 9 and 10 share similar chemical characteristics themselves but sample three (3) which is influenced by the Mamu Formation is an outlier.

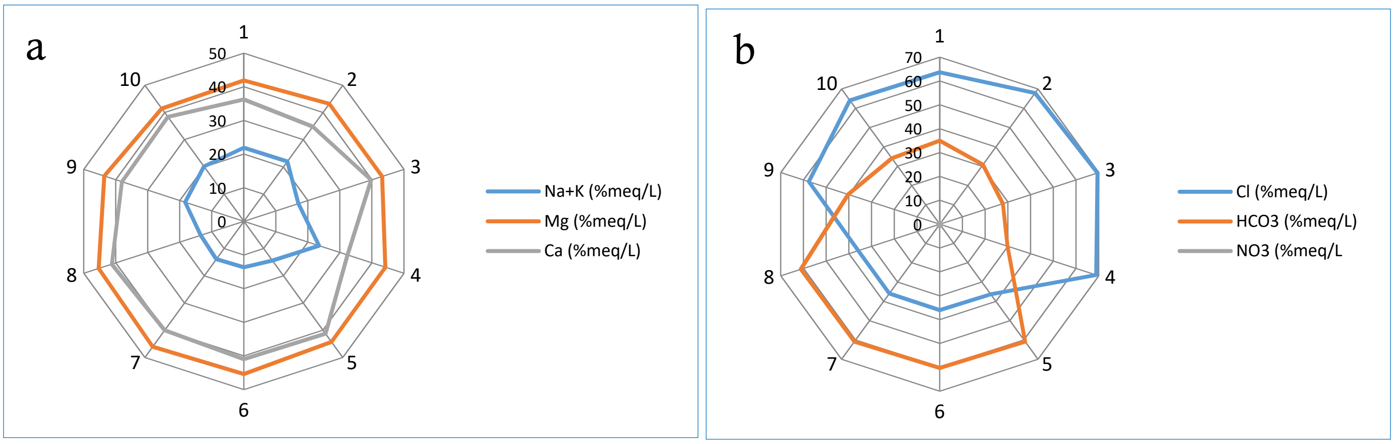

Fig. 7. Radar diagram of cation (a) and Anion (b) variation in Agenebode (% meq/L)

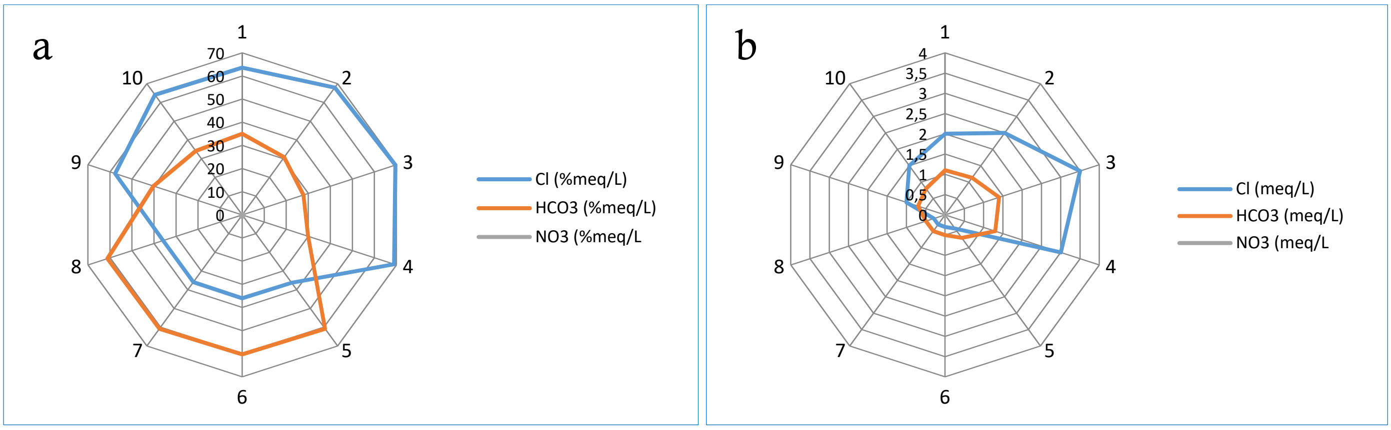

Fig. 8. Radar diagram of cation (a) and Anion (b) variation in Agenebode (meq/L)

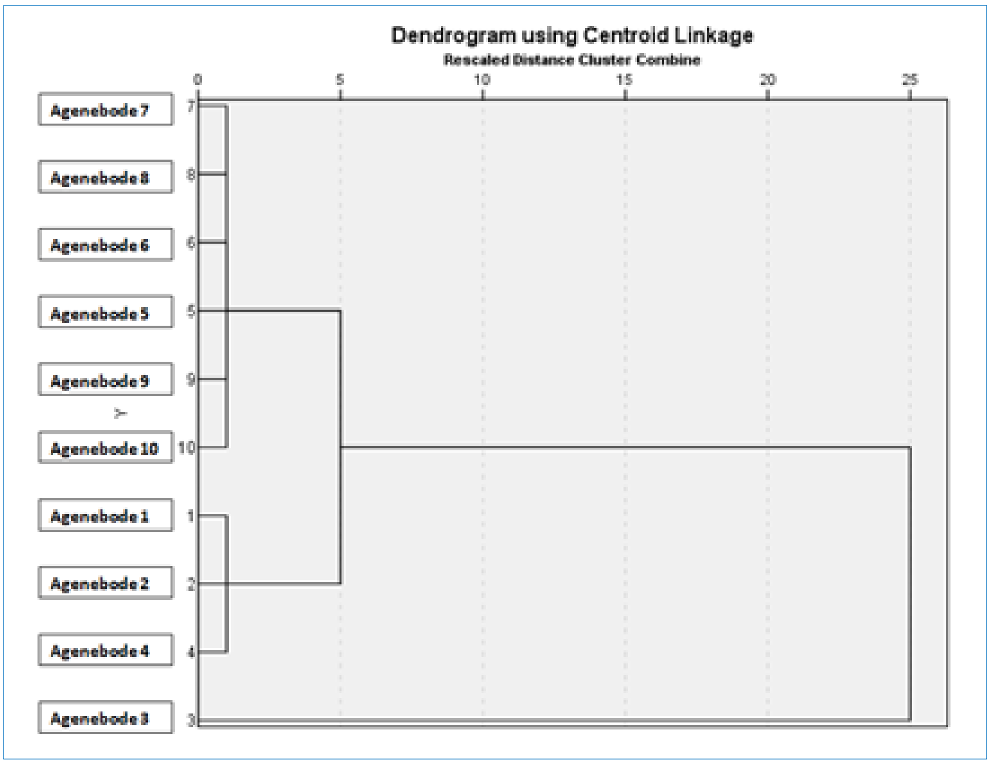

Fig. 9. Hierarchical Cluster Analysis for Agenebode Data

The acidity of all the samples in Agenebode fall below the accepted pH range for drinking water (Tables 3 and 4), except for samples 5 and 6, which are both acidic but are within the range. Although pH has no health impact, low pH can be corrosive to pipes. The high concentration of Iron in Agenebode sample 8 (Fig. 3) may be due to the iron casing used for the well. The concentration of Lead also exceeds established standards in Agenebode 5, 6, 7, 8, 9 and 10.

Table 3. Comparison of physicochemical parameters of water samples (surface water and groundwater) from Agenebode with some water quality standards (WHO, 2017; NIS, 2015)

Agenebode	Unit	1	2	3	4	5	6	7	8	9	10	WHO, 2017	NIS, 2015
pH	-	6.1	6.1	5.8	6.3	6.7	6.7	6.3	6.4	6.4	6.4	6.5 - 8.5	6.5 - 8.5
EC	µmhos/cm	66	67.3	228.1	75.2	18	15.1	13.3	11.4	18	18.1	-	1000
Sal.	g/L	0.03	0.03	0.103	0.034	0.008	0.007	0.006	0.005	0.008	0.008	-	-
TDS	mg/L	33.1	33.5	114.4	37.4	9	7.3	6	5.4	9.1	9.3	1000	500
Hardness	mg/L	4.676	5.195	14.205	6.192	3.413	3.206	2.842	2.512	3.85	4.355	-	150
COD	mg/L	24.8	28	32	32	16	15.2	10.4	6.4	16.8	16.8	-	-
HCO3	mg/L	67.1	69.1	85.4	79.3	42.7	30.5	30.3	30.5	42.7	48.8	-	-
DO	mg/L	2	3	3.8	3.7	1.5	1	1	0.5	1.5	1.5	-	-
BOD	mg/L	1.1	1.1	0.8	1	1.5	1.7	2	2.1	1.2	1.1	-	-
Na	mg/L	0.48	0.51	0.97	0.68	0.2	0.18	0.17	0.15	0.31	0.4	200	200
K	mg/L	0.21	0.28	0.63	0.33	0.11	0.09	0.07	0.05	0.15	0.18	-	-
Ca	mg/L	0.87	0.93	2.73	1.05	0.66	0.61	0.53	0.48	0.72	0.84	-	-
Mg	mg/L	0.61	0.7	1.8	0.87	0.43	0.41	0.37	0.32	0.5	0.55	-	20
Cl	mg/L	70.9	88.6	124.1	106.4	14.8	10.6	10.4	10.4	35.5	53.2	250	250
P	mg/L	0.06	0.061	0.143	0.117	0.044	0.041	0.025	0.024	0.053	0.053	-	-
NO2	mg/L	0.033	0.038	0.061	0.043	0.018	0.015	0.011	0.011	0.022	0.027	3	0.2
NO3	mg/L	0.841	1.021	1.843	1.384	0.522	0.51	0.466	0.354	0.631	0.654	50	50
NH4N	mg/L	0.271	0.29	0.301	0.294	0.26	0.254	0.235	0.225	0.261	0.27	1.5	-
SO4	mg/L	0.083	0.133	0.181	0.166	0.037	0.023	0.022	0.014	0.041	0.062	500	100
Fe	mg/L	0.151	0.151	0.081	0.151	0.16	0.183	0.234	0.304	0.155	0.133	0.3	0.3
Mn	mg/L	0.028	0.025	0.019	0.022	0.042	0.056	0.074	0.081	0.037	0.033	0.5	0.2
Zn	mg/L	0.068	0.066	0.048	0.066	0.088	0.096	0.102	0.11	0.081	0.073	5	3
Cu	mg/L	0.018	0.015	0.011	0.014	0.033	0.045	0.051	0.063	0.028	0.022	2	1
Cr	mg/L	0.011	0.01	0.006	0.008	0.025	0.031	0.034	0.037	0.022	0.018	0.05	0.05
Cd	mg/L	0.006	0.004	0.001	0.003	0.009	0.011	0.018	0.021	0.008	0.007	0.03	0.03
Ni	mg/L	0.005	0.003	0.001	0.003	0.008	0.009	0.014	0.017	0.006	0.005	0.07	0.02
Pb	mg/L	0.009	0.007	0.005	0.005	0.018	0.022	0.028	0.033	0.015	0.011	0.01	0.01
V	mg/L	0.003	0.002	0.001	0.002	0.005	0.008	0.009	0.011	0.004	0.003	-	-

Table 4. Ratio of the parameters that exceed NIS, 2015 standard to the NIS, 2015 standard for water samples (surface water and groundwater) from Agenebode (Pollution index for Agenebode)

Agenebode	1	2	3	4	5	6	7	8	9	10
pH	1.07	1.07	1.12	1.03	0.97	0.97	1.03	1.02	1.02	1.02
Fe	0.50	0.50	0.27	0.50	0.53	0.61	0.78	1.01	0.52	0.44
Pb	0.90	0.70	0.50	0.50	1.80	2.20	2.80	3.30	1.50	1.10

Table 5. Suitability of water for irrigation comparison (Ayers and Westcot 1985; Wilcox, 1948)

Class	TDS (mg/L)	RSC (mg/L)	SAR	SSP (%)	Sustainability for irrigation
I	<117.51	<1.25	<10	<20	Excellent
II	117.51-508.61	1.25-2.5	10-18	20-40	Good
III	>508.61	>2.5	18-26	40-80	Fair
IV	-	-	>26	>80	Poor

Agenebode	1	2	3	4	5	6	7	8	9	10	Average
TDS	33.10	33.50	114.40	37.40	9.00	7.30	6.00	5.40	9.10	9.30	26.45
RSC	1.01	1.03	1.12	1.18	0.63	0.44	0.44	0.45	0.62	0.71	0.76
SAR	0.10	0.10	0.11	0.12	0.05	0.04	0.04	0.04	0.07	0.08	0.08
SSP	21.90	22.01	17.02	23.47	14.42	13.64	13.90	13.44	18.35	20.15	18.54

Generally, the water samples from Agenebode appear to be of relatively good quality with regards to irrigation (Table 5) and domestic use with the need for minor treatment and this is similar to what Wali et al. (2020) and Amadi et al. (2020) found for the Ajali Formation, but a biological analysis would need to be done to gain a clearer understanding of the water quality.

5. Conclusion

The geology of the area where groundwater is present plays an important role in determining its chemistry and quality. The water samples from Agenebode are acidic which is similar to what was reported by Wali et al. (2020) and Amadi et al. (2020). This is interpreted to be as a result of geologic influences. The water samples have a low EC (53 µmhos/cm), TDS (27 mg/L) and pH because of the maturity of the siliciclastic lithology which significantly reduced the potentials for materials to be dissolved from the Ajali Formation sands. This paucity of dissolvable materials leads to lower values of all the parameters measured in Agenebode. The sequence for the distribution of ions is $Mg^{2+} > Na^{+} + K^{+} > Ca^{2+}$ and $Cl^{-} >> HCO_3^{-} > NO_3^{-} > SO4_2^{-}$. The water samples range from Magnesium Bicarbonate type to calcium chloride type, but the dominant type is the mixed type. The water samples from Agenebode are good for domestic use but the water would have to be treated due to the low pH, and the high Fe and Pb concentrations in some of the samples.

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