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Article

Hydro-Geochemical Studies of Groundwater Around Oke-Ebo and Within Ajayi Crowther University Campus, Oyo Town, Southwestern Nigeria

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Abstract

Major ionic chemical composition and physico-chemical parameters of eighteen (18) groundwater samples within Ajayi Crowther university (ACU) and Oke-Ebo area of Oyo town, southwestern Nigeria were analysed for hydro-geochemical facies characterisation. The pH ranges from 6.2 to 7.5 and the total dissolved solids (TDS) was between 240 and 1570 mg/L. The total dissolved solids were found higher in samples within the ACU premises compared to those in other areas. The spread of major ions concentration in mg/L are Ca^{2+} 16 – 62, Mg^{2+} 7.5 – 23.3, Na^{+} 4.13 – 13.1; K^{+} 2.12 – 7.18 and for anions; HCO_3^- 50 – 180, SO_4^{2-}, 10 – 48, NO_3^-, 1.36 – 8.04; and Cl^- 18.71 – 65.58. From the average concentrations, the relative abundance of the cations is in the order of $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ while for anion, it is $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^-$. For hydro geochemical facie classification using piper plot, the groundwater is predominantly the $Ca\text{-}HCO_3$ water type.

Keywords: Groundwater, Major-ions, Hydrochemical-facies, Water-type.

1. Introduction

Groundwater is a major source of fresh water for the global population and is used for domestic, agricultural and industrial purposes [1]. The human population both in the rural and urban areas largely rely on groundwater due to its accessibility, reliability and renewability [2]. Groundwater is the main water supply in most developing country where piped borne water is not within reach of many people, Hydro geo-chemical studies are vital for the supply of adequate groundwater of suitable quality and sustainable management of groundwater resources [2]. A variety of methods in these recent years has been employed to help determine the hydro geochemical processes influencing the physiochemical properties of groundwater [3]. However, the quality of groundwater is dependent on the amount and types of chemical constituents as well as the degree of exposure to contamination [1].

Total dissolved Solid is the sum of concentration of soil dissolved solids in water, the total concentration of dissolved mineral in water is a general indication of its suitability for a particular purpose. Water that contains less than 500mg/l of dissolved solid is generally good for domestic and industrial use. Water that contains more than 1000mg/l of dissolved solid contains minerals that gives a distinctive taste or make it unsuitable in other ways.

Electrical conductivity (EC) is the ability of a substance to conduct electrical current. Current flows in ionized water because the ions are electrically charged and they tend to move towards the current source that will neutralize them. The higher the conductivity, the greater the potential for electrochemical action. Oladunjoye et al [4] suggested that crystalline rocks have poor water bearing capacity due to their low porosity and low permeability. Hence, hydrogeological characteristics of these rocks depend on the intensity of weathering and fracturing of the underlying rock within the basement complex. Sources of contamination can be chemical, physical, or biological in nature, and they frequently have an impact on the groundwater's natural state or intended use. Some dissolved solids are beneficial to humans, while some are harmful, for instance, most trace elements are necessary for human health while key elements like magnesium and calcium, are poisonous to humans if they are present in amounts greater than recommended dosage [5]. Aquifer susceptibility to contamination depends on porosity, permeability and overburden thickness of geologic formation [6]. The majority of these trace elements are found naturally in water as well, although a lot of them are human-induced i.e anthropogenically. These factors are connected to human activity in rural areas, including open garbage incineration and the combustion of coal and wood.

The assessment of main ions of trace elements in the ground water system is part of the groundwater quality analysis for current investigation since a substantial number of people, especially those in Oyo town in southwestern part of Nigeria rely on groundwater [7]. The present study was carried out to evaluate groundwater quality in Oke-Ebo and within Ajayi Crowther University campus, Oyo and its suitability for drinking, domestic and agricultural purposes. The objectives of this work is to investigate the distribution of ionic concentration in the groundwater, evaluation of groundwater quality, its suitability for drinking purpose and hydrochemical classification of groundwater around Oke-Ebo and within Ajayi Crowther University Campus, Oyo. This is achieved by collecting water samples from randomly selected hand dug wells within the study area.

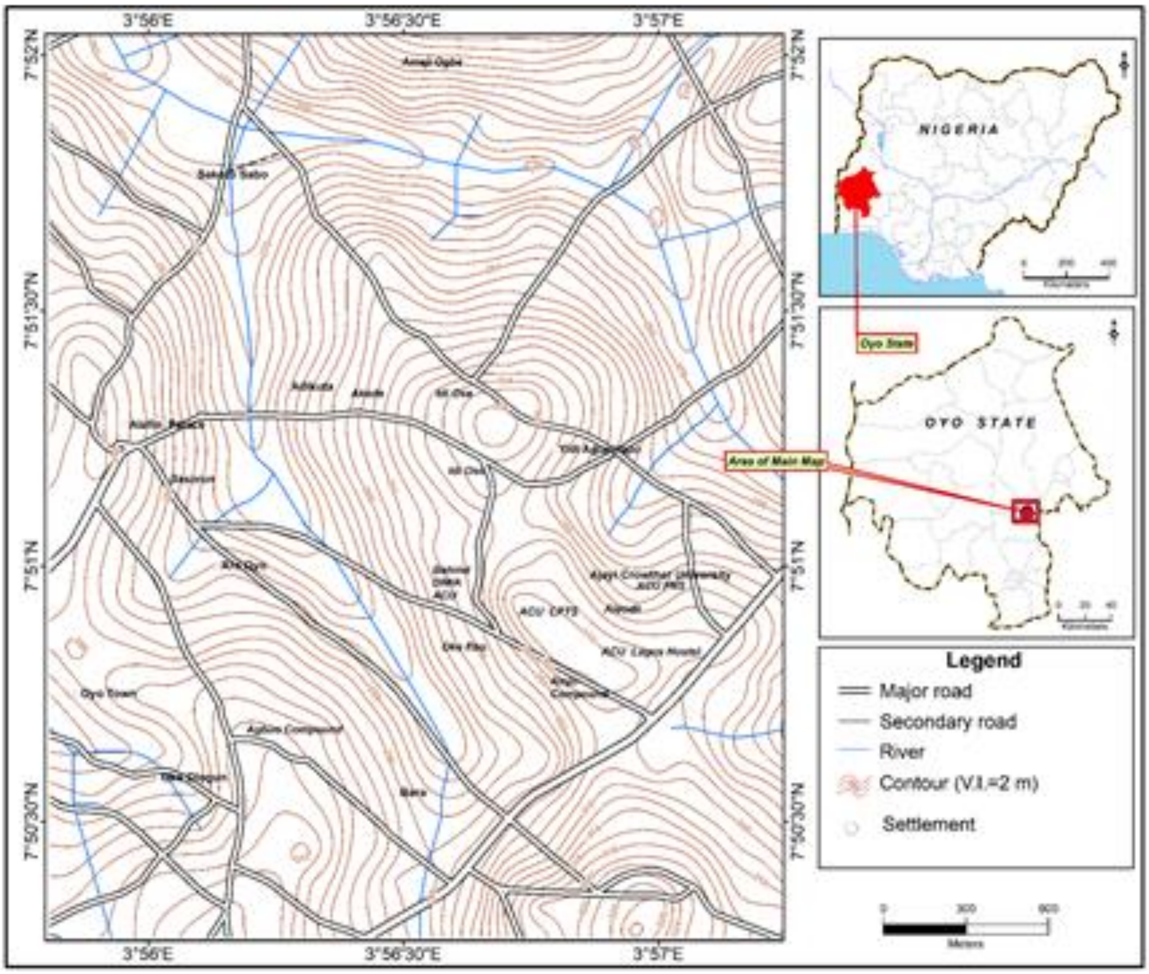

Figure 1: Topographic map of study area.

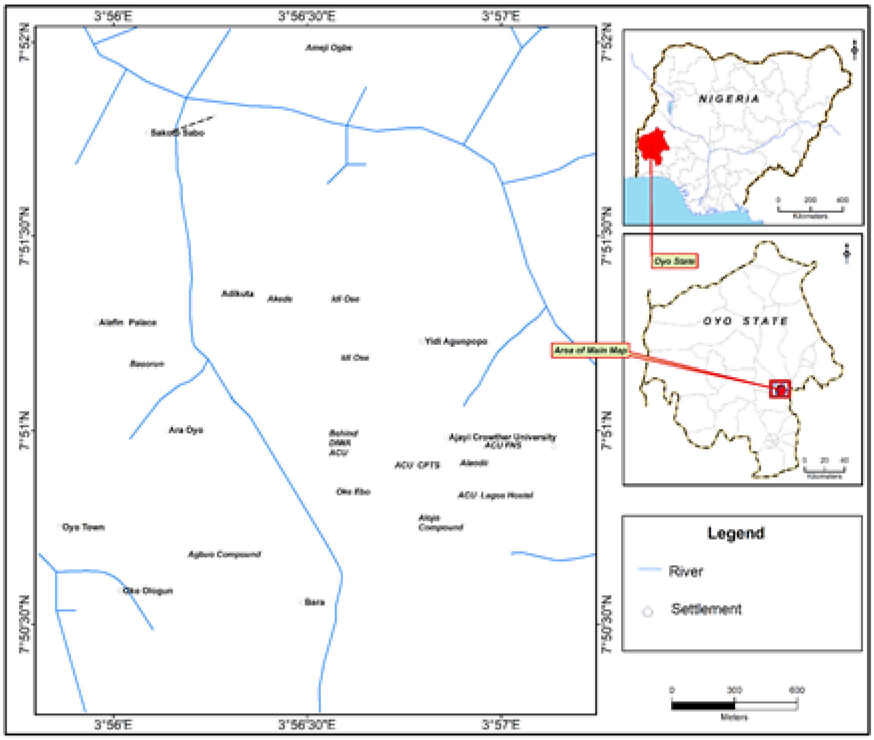

Figure 2: Drainage map of study area

2. Methodology

The study area is located in Oyo town, Oyo state. The area includes Ajayi Crowther University campus, Oke-ebo, Ameji Ogbe, Basorun, Akede, Idi-Ose, Alaodi, Alojo, Agbuo, and Akujo. The area falls within the basement complex terrain of south-western Nigeria and bounded by latitude $7^0$50’N to $7^0$52’N and longitude $003^0$56’E to $003^0$57’E (Figure 1). Average daily temperature ranges between 27^0C and 35^0C, almost throughout the year [8]. The area typically receives about 1200 millimeters of precipitation and has 208.28 rainy days (57.06% of the time) annually [9]. The vegetation pattern is that of rain forest. Cocoa and palm produce are mostly grown in the area. The topography of the area ranges from medium to low terrain above the sea level and ranges from 264m to 326m. The northwestern part of the area is a low lying area of which its elevation is about 264m. The peak of the topography is located at the southeastern part of the area which is about 326m high (Figure 1). The area is well drained. Majority of the rivers flows in a northwestern direction. The drainage pattern is the rectangular drainage pattern (Figure 2).

It is located within the Basement Complex of South Western Nigeria. Major lithological units are basically crystalline basement rocks. These rocks include undifferentiated schist, quartzite and migmatite (Figure 3). The extreme deformational structures of these rocks allow sufficient aquifer properties needed to generate the well water. Eighteen (18) water samples were collected randomly from hand-dug wells. The samples were collected in 1lilter capacity plastic bottles after rinsing with the sample and preserved airtight in order to avoid evaporation. Physical parameters such as temperature, EC, TDS, and pH of the sampled water were determined in situ using pH/EC/TDS/temp Hannan H19812-5 multi-meter. Samples were kept under air-condition prior to analysis. Major ions' concentrations (Na^+, K^+, Mg^{2+}, Ca^{2+}) were determined by ion exchange chromatography at TEMSOL Consulting Ltd Ibadan, while the major anions (Cl^-, NO_3^-, HCO_3^-, SO_4^{2-} and CO_3^-) were determined by flame photometry emission. Alkalinity measurements were carried out by acid titration with 0.02N H_2SO_4 added to each sample to reach its titration end point marked by a pH of 4.5. For quality control of the chemical measurements, standards and blanks were used in between runs to provide a measured of background noise, accuracy and precision.

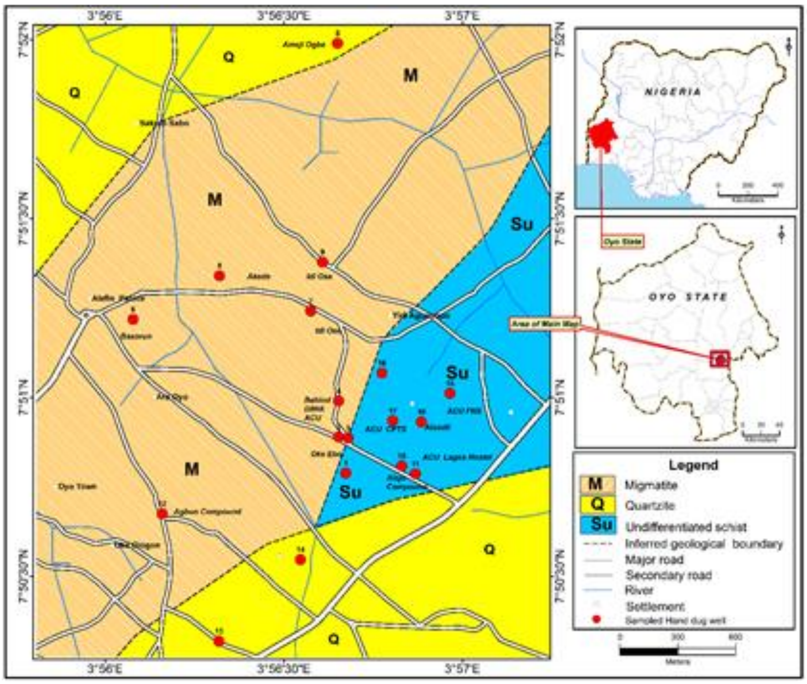

Figure 3: Geological map of the study area showing sampling points.

3. Results and Discussion

The results of the physicochemical analyses are presented in Table 1. The summary of analyzed cations and anions are presented in Table 2. The chemical composition of groundwater depends greatly on the general geology of the underlying rocks, degree of chemical weathering of various rock types and quality of recharge water and anthropogenical inputs resulting from human activities. It is therefore important to understand the groundwater chemistry as it is a main factor in determining its sustainability for drinking, domestic, agricultural and industrial purposes [10]. In this study, the results of cations and anions were subjected to statistical analysis. It was observed that there were significant and wider variability within the anions and the cations with the following order of magnitude among the major elements, the cationic order constituents in the water is $Ca^{2+}>Mg^{2+}>Na^{+}>K^{+}$ while the anion is in order of $HCO_3^{-} >Cl^{-} >SO_4^{2-} > NO_3^{-}$. (Tables 2). However, this order of absolute concentrations is not an indication of the relative degree of contamination but depends largely on the threshold values of the respective anions or cations.

Table 1: Summary of physcio-chemical parameters of the analyzed water samples.

Sample code	Longitude	latitude	pH	EC	TDS (ppm)	Temp (℃)	Elevation (m)	Well depth (m)	Treatment	Well condition
OK1	07°50′47.3″	003°56′40.4″	6.9	390	190	30	298	5.2	Untreated	Cased
OK2	07°50′53.4″	003°56′39.2″	6.4	880	430	29	301	6.1	Untreated	Cased
OK3	07°50′53.2″	003°56′40.8″	6.4	490	240	29	305	10.2	Untreated	Cased
OK4	07°50′59.4″	003°56′39.2″	7.2	530	260	28	302	9.62	Untreated	Cased
OK5	07°51′59.4″	003°56′39.0″	7.5	1120	550	29	305	4.8	Untreated	Cased
OK6	07°51′13.1″	003°56′04.7″	6.8	1570	780	29	298	2.33	Untreated	Cased
OK7	07°51.6′14.5″	003°56′14.5″	7.1	1090	540	30	286	4.03	Untreated	Cased
OK8	07°51′10.4″	003°56′19.2″	7.0	1150	570	30	283	2.73	Untreated	Cased
OK9	07°51′22.7″	003°56′36.5″	6.3	790	390	31	315	8.86	Untreated	Cased
OK10	07°50′55.9″	003°55′53.1″	6.2	1240	620	30	303	8.03	Untreated	Cased
OK11	07°50′47.2″	003°56′52.1″	6.5	1140	570	30	300	6.35	Untreated	Cased
OK12	07°50′40.5″	003°50′09.6″	6.3	990	490	30	303	8.4	Untreated	Cased
OK13	07°50′36.3″	003°56′19.1″	6.4	880	440	30	319	8.44	Untreated	Cased
ACU14	07°50′32.8″	003°56′23.8″	6.7	1000	500	30	318	6.5	Untreated	Cased
ACU15	07°51′00.7″	003°56′57.9″	7.2	430	210	33	298			
ACU16	07°51′04.1″	003°56′46.5″	6.6	240	120	32	311			
ACU17	07°50′56.1″	003°56′48.3″	7.0	260	130	31	311			
ACU18	07°50′48.5″	003°56′49.8″	6.3	250	120	31	317			

Table 2: Major ion concentration in the study area

S/CODE	Ca	Mg	Na	K	HCO3	SO4	Cl	NO3
OK1	48.41	15.24	8.681	5.675	153.000	26.000	36.895	4.105
OK2	56.76	18.50	10.431	6.210	158.000	32.000	55.234	5.81
OK3	50.81	19.45	9.921	5.720	154.000	28.000	51.870	4.32
OK4	52.00	18.00	10.261	6.110	148.000	36.000	49.960	1.48
OK5	57.13	22.62	12.251	6.290	162.000	42.000	59.190	8.32
OK6	56.02	25.58	13.011	6.120	160.000	48.000	58.680	8.04
OK7	42.41	18.30	9.990	5.150	154.000	30.000	38.910	2.96
OK8	62.03	26.30	13.090	6.450	180.000	44.000	68.580	9.35
OK9	46.82	20.34	10.330	5.121	142.000	34.000	47.870	4.41
OK10	56.01	23.03	12.210	5.052	160.000	40.000	57.710	5.38
OK11	56.39	19.21	10.042	5.070	152.000	38.000	55.630	3.81
OK12	50.04	18.42	9.680	5.030	150.000	34.000	53.290	1.83
OK13	53.24	21.64	11.380	7.180	158.000	42.000	51.870	4.62
ACU14	52.23	20.33	10.431	6.320	162.000	36.000	49.920	3.49
ACU15	16.00	7.46	4.130	2.320	50.000	10.000	23.320	1.36
ACU16	34.42	12.75	6.132	2.141	130.000	16.000	19.912	2.36
ACU17	35.21	11.73	6.110	2.580	132.000	14.000	19.960	2.05
ACU18	34.79	11.45	5.521	2.120	134.000	18.000	18.710	1.96

The pH of the samples is generally low with a range of 6.2 to 7.5 with an average value of 6.7 indicating the water samples falls within slightly acidic to neutral based on the classification by [10] (Table 3a), Such low pH value less than 8 is said to be an indication of the presence of free COs and the dissolved carbonates in HCO, ion. Table 1 shows that the groundwater samples ranges from 6.2 to 7.5 on the pH scale are neutral. The concentrations of hydrogen ions in the water sample at OK2, OK9, OK10, OK12, OK13, OK18 were not within stipulated range.

The TDS of the groundwater samples taken from the locations in the study area is less than 1000mg/l, the TDS values of the water samples ranges from 120-750 mg/l. All samples obtained from OK1 - 14 and ACU15 - 18, all falls into the fresh water category (Table 3b). According to WHO [11] the approved limit of TDS is 1000mg/L therefore, the groundwater samples gotten from OK1 – 14 and ACU15 - 18, are all potable for human consumption.

Table 3a: Classification based on pH [12]

pH	**Classification of water**
<5	Acidic
5-6	Slightly acidic
7	Neutral
7.5-8.5	Slightly alkaline
>8.5	Alkaline

Table 3b: Classification of water based on TDS [13]

TDS(mg/L)	**Classes of water**
<1000	Fresh
1000-3000	Slightly Saline
3000-10,000	Moderately Saline
10,000-35,000	Very Saline
>35,000	Brine

The electrical conductivity (EC) in the study area ranges from 240 to 1570µs/cm. The maximum limit of EC in drinking water which was according to WHO is 1500µs/cm. It was observed that the groundwater sample that was collected from OK6 exceeded the maximum WHO limit and OK5, OK7, OK8, OK10, OK11 and OK14 have relatively high values.Calcium concentration ranges from 16.00 to 62.03mg/l with an average value of 47.82mg/l. The location with the highest concentration (ACU15) with a value of 16.00mg/l while the location with the lowest concentration is OK8 is 26.30mg/l. The desirable limit of Ca^{2+} for drinking water is specified by WHO (2012) as 200mg/l, it was observed that all the samples were within the limit.

The location with the highest concentration is ACU15 with a value of 7.46mg/l while the lowest concentration is OK8 with a value 26.30mg/l. The approved limit of magnesium for drinking is specified by WHO [12] is 150mg/l, it is observed that all samples were within the limit. Sodium concentration in the groundwater sample ranges from 4.130mg/l to 13.090mg/l with an average of 9.64mg/l. The location with the highest concentration (ACU15) with a value 4.130mg/l while the location with the lowest concentration (OK8) with a value of 13.090mg/l. The desirable limit of sodium for drinking water specified by WHO [12] as 200mg/l, it is observed that all samples were within the limit.

Potassium concentration in the groundwater samples ranges from 2.120mg/l to 7.180mg/l with an average of 5.04mg/l. The location with the highest concentration (ACU18) with a value of 2.120mg/l while the location with the lowest concentration (OK13) with a value of 7.180mg/l. The limit of potassium in drinking water specified by WHO [12] is 12mg/l. All samples were within that limit. The concentration of bicarbonates in the study area ranges from 50mg/l to 180mg/l with an average of 146.6mg/l. The location with the highest bicarbonate concentration is ACU15 with a value of 50mg/l while the location with the lowest concentration is OK8 with a value of 180mg/l. The specified limit of bicarbonate by WHO [12] is 500mg/l, it is observed that all samples falls within the limit. Chloride is the second most abundant anion in the groundwater sample. In the study area, the concentration of chloride ranges from 18.71mg/l to 68.080mg/l with an average of 44.3mg/l. The location with the lowest concentration is ACU18 with the value of 18.710mg/l while the location with the lowest concentration is OK8 with the value of 68.080mg/l. The low value of chloride ions is an indication of low salinity of the groundwater samples of the study area. The desirable limit of chloride for drinking water specified by WHO [12] is 600mg/l, it is observed that all samples were all within the limit. The concentration of sulphate in the study area ranges from 10mg/l to 48mg/l with an average of 31.6mg/l. OK6 is the location of the groundwater sample with the highest sulphate concentration with the value of 48mg/l while ACU15 is the location of the groundwater sample with the lowest sulphate concentration with a value of 10mg/l. The desirable limit of sulphate in drinking water specified by the WHO [12] is 250mg/l, it is observed that all samples were within the limit.

The concentration of nitrate in the study area ranges from 1.36mg/l to 8.04mg/l with an average of 4.20mg/l. The location with the lowest concentration of nitrate is ACU15 with a value of 1.36mg/l while the location with the highest concentration of nitrate is OK6 with a value of 8.04mg/l. Low values of nitrate shows that there will also be low value of bacterial contamination because bacteria feed on the nitrate present in groundwater, also as the depth of the well increases, the bacteria presence reduces because of the increase in temperature and pressure, because bacteria cannot survive high temperature. The approved limit of nitrate in drinking water that was approved by the WHO [12] is 45mg/l, it was observed that all the groundwater samples are within this limit.

3.1 Hydrogeochemical Facies Classification

Hydro geochemical facie is a classification method used to group similar types of water based on their chemical composition. There are several methods for hydro geochemical facies classification, including the Piper diagram. From the average concentrations (Table 4), the cationic order constituents in the water is $Ca^{2+}>Mg^{2+}>Na^{+}>K^{+}$ while the anion is in order of $HCO_3^{-} >Cl^{-} >SO_4^{2-} > NO_3^{-}$. For hydro geochemical facie classification using piper plot, the groundwater is predominantly the $Ca\text{-}HCO_3$ water type (Figure 4). The descriptive Statistics, drinking water guidelines and health effects is presented in Table 5.

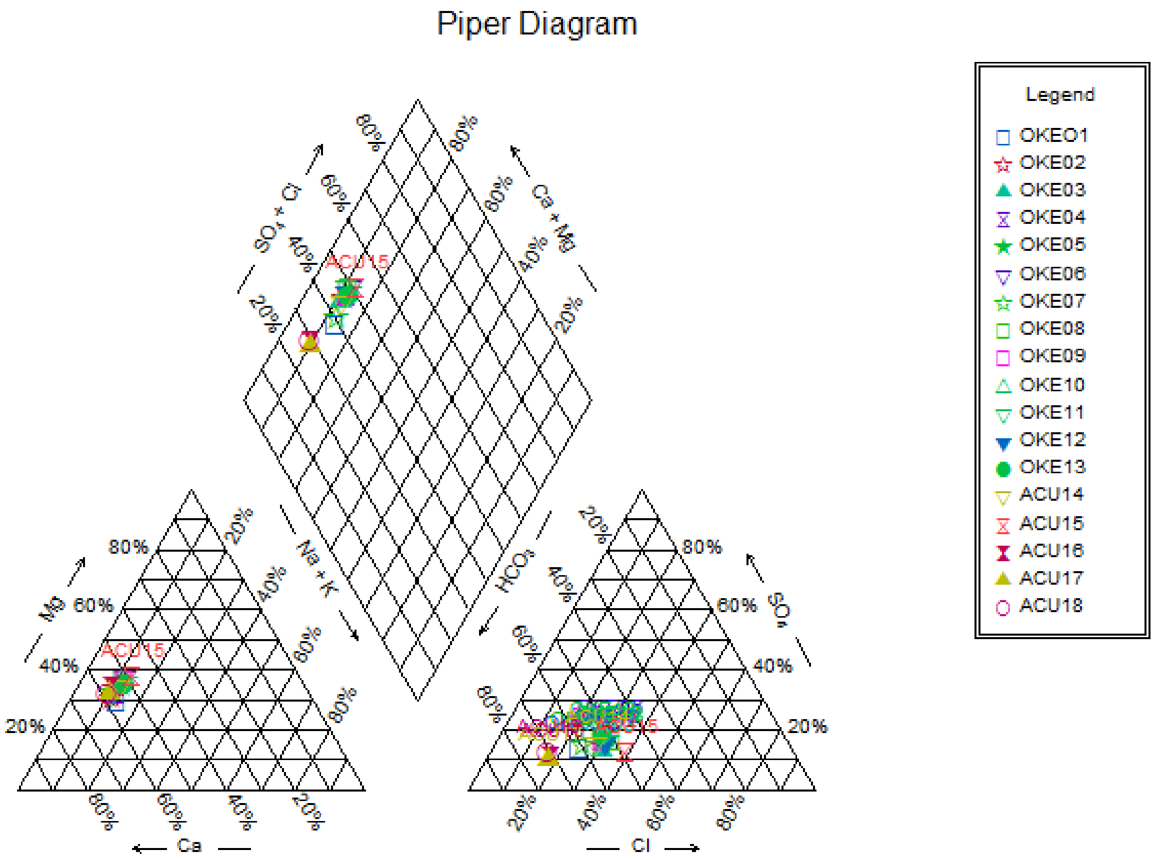

Figure 4: Piper diagram showing different dominant hydro chemical facies

Table 4: Hydro geochemical facie and water type

Sample Code	Longitudes	Latitude	Water Facie
OKE 01	07°50′47.3″	003°56′40.4″	Ca-HCO3
OKE 02	07°50′53.4″	003°56′39.2″	Ca-HCO3
OKE 03	07°50′53.2″	003°56′40.8″	Ca-HCO3
OKE 04	07°50′59.4″	003°56′39.2″	Ca-HCO3
OKE 05	07°51′59.4″	003°56′39.0″	Ca-HCO3
OKE 06	07°51′13.1″	003°56′04.7″	Ca-HCO3
OKE 07	07°51.6′14.5″	003°56′14.5″	Ca-HCO3
OKE 08	07°51′10.4″	003°56′19.2″	Ca-HCO3
OKE 09	07°51′22.7″	003°56′36.5″	Ca-HCO3
OKE 10	07°50′55.9″	003°55′53.1″	Ca-HCO3
OKE 11	07°50′47.2″	003°56′52.1″	Ca-HCO3
OKE 12	07°50′40.5″	003°50′09.6″	Ca-HCO3
OKE 13	07°50′36.3″	003°56′19.1″	Ca-HCO3
ACU 14	07°50′32.8″	003°56′23.8″	Ca-HCO3
ACU 15	07°51′00.7″	003°56′57.9″	Ca-HCO3
ACU 16	07°51′04.1″	003°56′46.5″	Ca-HCO3
ACU 17	07°50′56.1″	003°56′48.3″	Ca-HCO3
ACU 18	07°50′48.5″	003°56′49.8″	Ca-HCO3

Table 5: Descriptive Statistics, Drinking water Guidelines and Health Effects

Parameters	**Min.**	**Max.**	**Mean**	**WHO Guideline (2012)**	**Health effect on human**
pH	6.2	7.5	6.7	6.5-8.5	Not pertinent
EC (µ/cm)	120	750	397.2	1500	Not pertinent
TDS	240	1570	802.2	1000	Unpalatable taste
Ca^{2+} (mg/l)	16	62.03	47.82	150	Kidney stone formation
Mg^{2+} (mg/l)	7.46	23.30	18.4	200	Osmotic diarrhea
Na^{+} (mg/l)	4.130	13.090	9.64	200	Unacceptable taste
K^{+} (mg/l)	2.120	7.180	5.04	12	Not pertinent
HCO_{3-} (mg/l)	50	180	146.6	500	Not pertinent
SO_{4}^{2-} (mg/l)	10	48	31.6	250	Not pertinent
NO_{3-} (mg/l)	1.36	8.04	4.20	45	Laxative effect
Cl^{-} (mg/l)	18.71	68.58	44.3	600	Detectable taste

Fourty seven percent (47%) of the data was used for the plot of calcium against TDS. 47% of the variation can be accounted for by TDS. As TDS increase by 1mg/l, Calcium increases by 0.39mg/l. The plot has a high correlation coefficient of 0.68 as seen in Figure 5. 70% of the data was used for the plot of magnesium against TDS. 70% of the variation can be accounted for by TDS. As TDS increase by 1mg/l, Calcium increases by 0.21mg/l. The plot has a very high correlation coefficient of 0.83 as seen in Figure 6. 70% of the data was used for the plot of sodium against TDS. 70% of the variation can be accounted for by TDS. As TDS increase by 1mg/l, sodium increases by 0.011mg/l. The plot has a high correlation coefficient of 0.834 as seen in Figure 7. 42% of the data was used for the plot of potassium against TDS. 42% of the variation can be accounted for by TDS. As TDS increase by 1mg/l, potassium increases by 0.0053mg/l. The plot has a high correlation coefficient of 0.65 as seen in Figure 8. 28.3%% of the data was used for the plot of bicarbonate against TDS. 28.3%% of the variation can be accounted for by TDS. As TDS increase by 1mg/l, bicarbonate increases by 0.072mg/l. The plot has a high correlation coefficient of 0.53 as seen in Figure 9. 74% of the data was used for the plot of sulphate against TDS. 74%% of the variation can be accounted for by TDS. As TDS increase by 1mg/l, sulphate increases by 0.05mg/l. The plot has a very high correlation coefficient of 0.9 as seen in Figure 10. 65.2% of the data was used for the plot of chloride against TDS. 65.2% of the variation can be accounted for by TDS. As TDS increase by 1mg/l, chloride increases by 0.05mg/l. The plot has a very high correlation coefficient of 0.81 as seen in Figure 11. 44.1% of the data was used for the plot of nitrate against TDS. 44.1% of the variation can be accounted for by TDS. As TDS increase by 1mg/l, nitrate increases by 0.0081mg/l. The plot has a high correlation coefficient of 0.66 as seen in Figure 12.

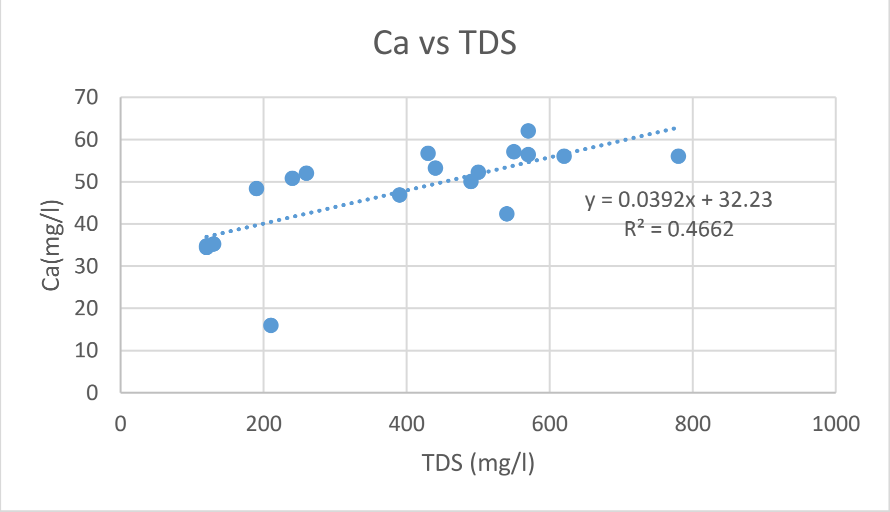

Figure 5: A Scattered plot and a correlation line showing the relationship between calcium concentration and TDS

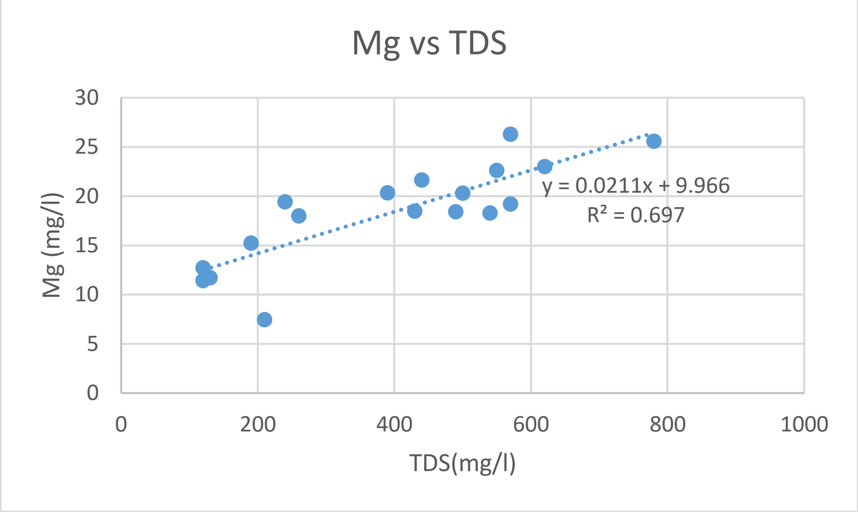

Figure 6: A Scattered plot and a correlation line showing the relationship between magnesium concentration and TDS

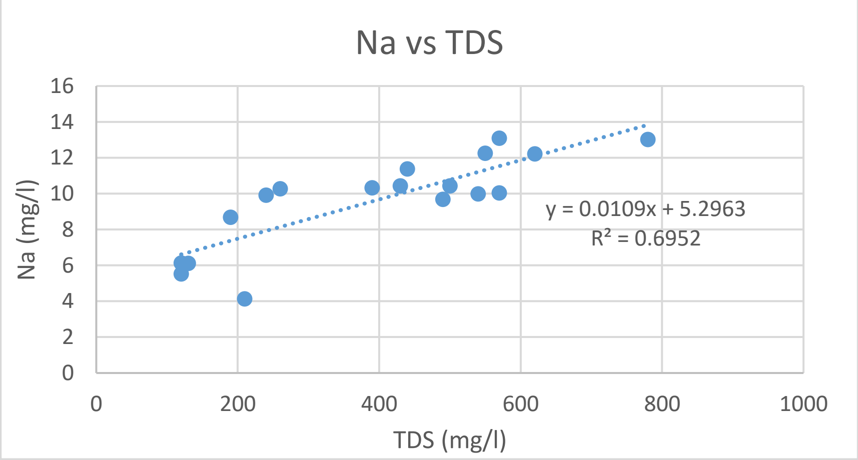

Figure 7: A Scattered plot and a correlation line showing the relationship between Sodium concentration and TDS

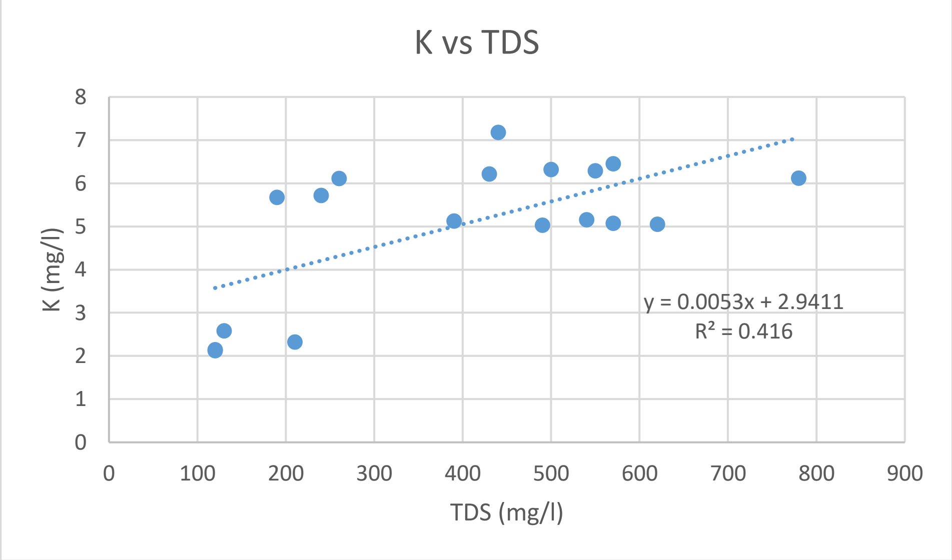

Figure 8: A Scattered plot and a correlation line showing the relationship between potassium concentration and TDS

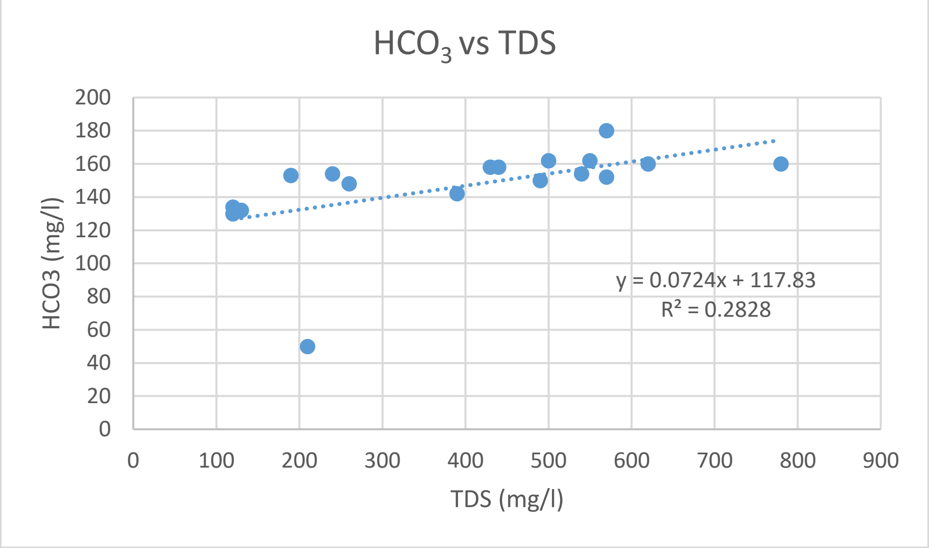

Figure 9: A Scattered plot and a correlation line showing the relationship between bicarbonate concentration and TDS

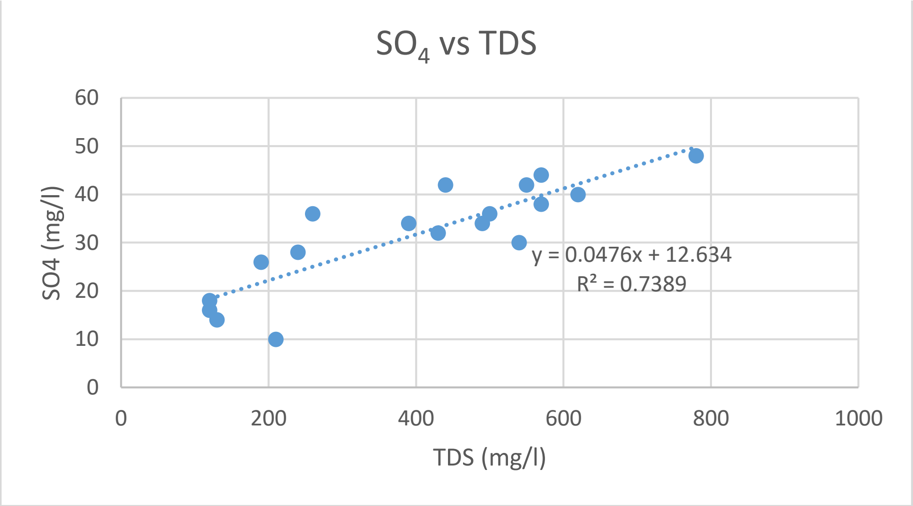

Figure 10: A Scattered plot and a correlation line showing the relationship between sulphate concentration and TDS

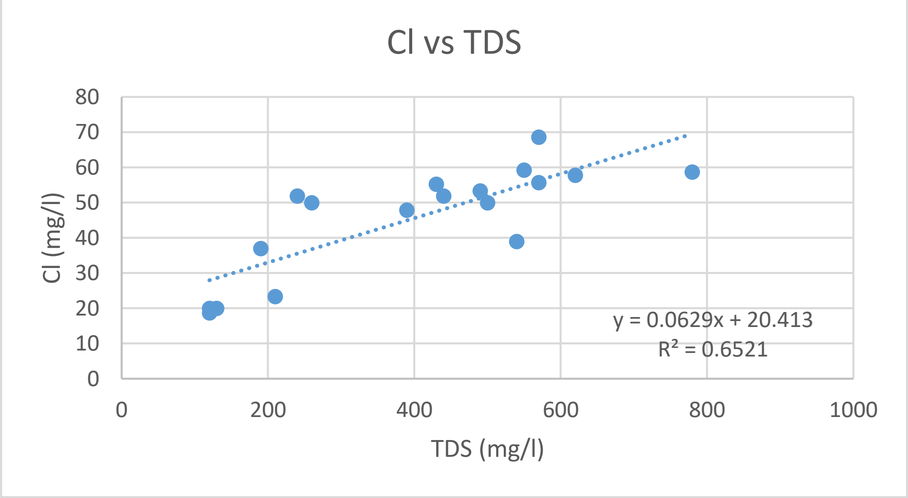

Figure 11: A Scattered plot and a correlation line showing the relationship between chloride concentration and TDS

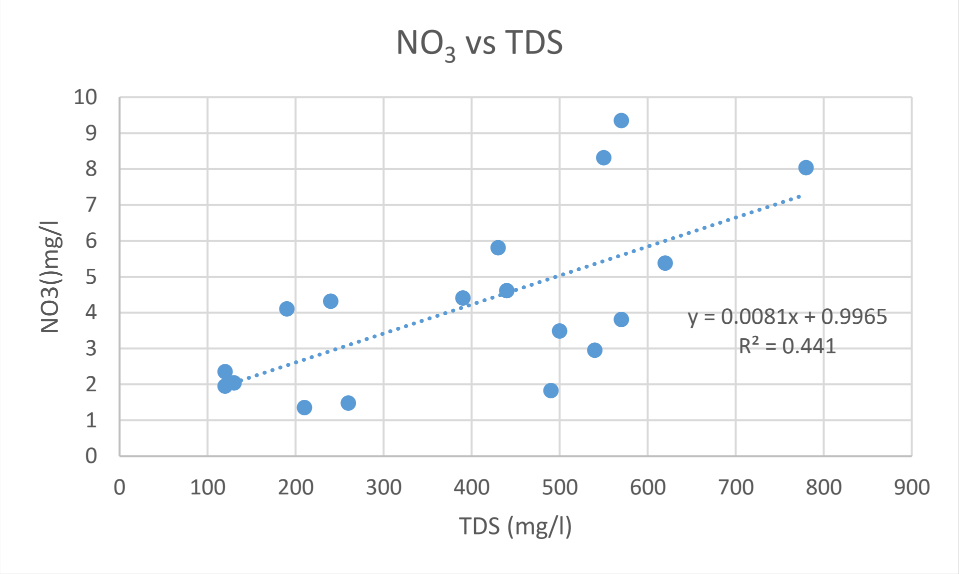

Figure 12: A Scattered plot and a correlation line showing the relationship between nitrate concentration and TDS

The dominancy of the major elements in the cation is calcium (Ca) and magnesium (Mg), followed by sodium (Na) and potassium (K). (Figure 13). The abundance of Calcium (Ca) and magnesium (Mg) is because of the enrichment of the ferromagnesian minerals which is present in the underlying rock of the study area which clearly demonstrates the interactions between the groundwater and the underlying bedrocks. The mean values of the selected major elements were compared with one another and with the WHO (2012) standard. Calcium (Ca) and magnesium (mg) with the average mean of 47.82mg/l and 18.4mg/l falls within the WHO (2012) standard.

The most dominant major elements in the anion is Bicarbonate (HCO_3) followed by Chloride (Cl^-) Sulphate (SO_4) and Nitrate (NO_3), (Figure 14). The abundance of Calcium (Ca) and Magnesium (Mg) is because of the enrichment of the ferromagnesian minerals which is present in the underlying rock of the study area. This is as a result of dissociation of migmatite gneiss in the area which clearly demonstrates the interactions between the groundwater and the underlying bedrocks. The mean values of the selected major elements were compared with one another and with the WHO (2012) standard. All the major elements in the anion falls within the approved value of the WHO (2012) standard.

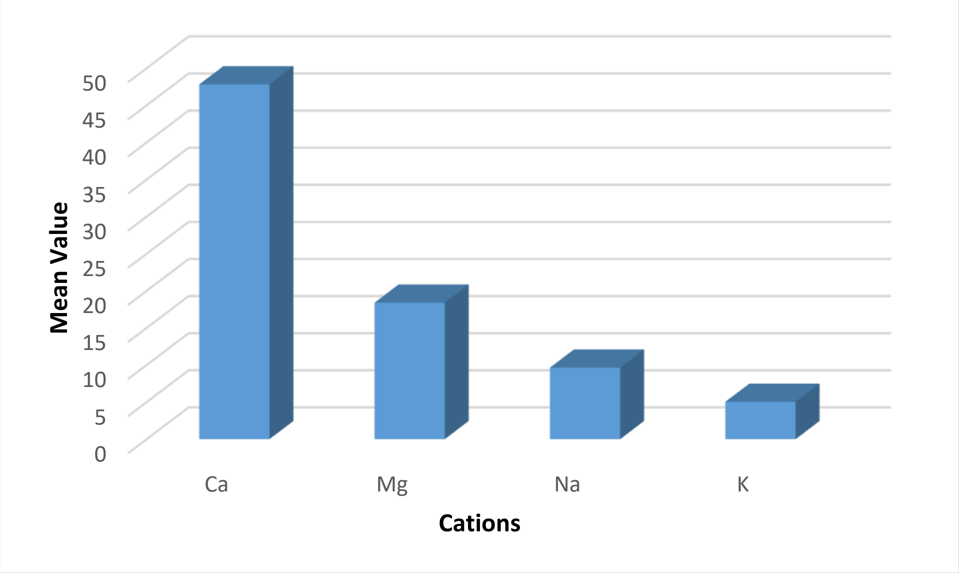

Figure 14: Comparison of the mean values of the cations

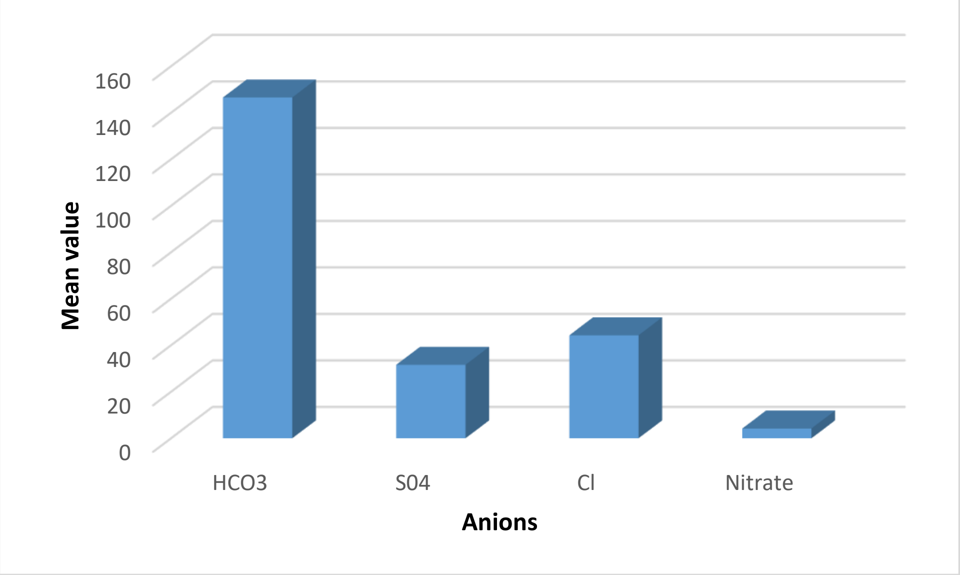

Figure 15: Comparison of the mean values of the anions.

4. Conclusion

Hydro chemical characteristics of the eighteen (18) water samples analyzed revealed the general cationic concentration in the order of $Ca^{2+}>Mg^{2+}>Na^{2+}>K^{+}$ while the anionic concentration is in the order of $HCO_3^{-}>Cl^{-}>SO_4^{2-}>NO_3^{-}$. The pH ranges from 6.2 to 7.5 with an average of 6.7 indicating the water is slightly acidic to neutral, samples from OK2, OK9, OK10, OK12, OK13, OK18 were not within stipulated range. The TDS is generally lower than 1000mg/l indicating fresh water. However, sample that was collected from OK6 exceeded the maximum WHO limit, OK5, OK7, OK8, OK10, OK11 and OK14 have relatively high values, Piper trilinear diagram showed the dominant Ca-HCO_3 water facies indicating their suitability for drinking purposes when compared with the WHO standard. The interactions of the cation and anion with TDS from statistical analysis showed a strong correlation. Ca^{2+} and Mg^{2+} are the dominant cation while HCO_3^{-} and Cl^{-} are the dominant anion respectively from the dissolution of the underlying bedrocks. All the water samples analyzed are suitable for drinking purposes when compared with the WHO standard.

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