Asian Journal of Geological Research

4(4): 134-149, 2021; Article no.AJOGER.81746

Petrology and Hydrogeochemistry within the Lateritic Profiles Over the Biotite Granites and Pegmatized Granite Schists of Ogbe and Environs, South-South Nigeria

Izeze Elijah Ovie [a*] and Okumoku Dokumo [a]

[a] Department of Earth Sciences, Federal University of Petroleum Resources Effurun, Lecturer I, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

Editor(s):
(1) Dr. Mohamed M. El Nady, Egyptian Petroleum Research Institute, Egypt.
Reviewers:
(1) P. Chandra Reddy, Annamacharya Institute Of Technology & Science, India.
(2) Jicheng Zhang, Northeast Petroleum University, China.
Complete Peer review History, details of the editor(s), Reviewers and additional Reviewers are available here:
https://www.sdiarticle5.com/review-history/81746

Original Research Article

Received 15 October 2021
Accepted 18 December 2021
Published 20 December 2021

ABSTRACT

This research work was aimed at studying the petrology of the different rock types and evaluating the quality of groundwater from streams, ponds and bored holes in Ogbe and its environ. Ogbe lies within latitude N 07 19' 15.00'' and longitude E 006 05' 31.5'' and is part of Igarra schist belt, southwestern Nigeria. The study area forms part of the Mesozoic Older Granite Complex, which intruded the Pre-Cambrian Crystalline Basement. The study area is composed of biotite granite, quartz-biotite granite, granitic schist and pegmatite occurring as dykes. Groundwater samples collected from boreholes and ponds were subjected to physical and chemical analysis. Physical parameters (pH, Ec, TDS and temperature) were measured insitu using standard equipment. Chemical analysis like Anions (NO^{3-}, Cl^{-}) and cations (Mg^{2+}, Ca^{2+}, K^{+}, Na^{+}) were measured in the laboratory using ion chromatography and heavy metals (Cu, Zn, Pb, Mn) were analysed using voltammetric stripping analysis. The mean concentration of the element measured were temp (30.6500˚C), T.D.S (144 ppm), E.C (µs), Ph (7.0250 mg/l), Na (24.7950 mg/l), K (10.3700 mg/l), Ca (23.9400 mg/l), Mg (7.3600 mg/l), Cl (51.7700 mg/l), Fe (.0155 mg/l), Zn (.0050 mg/l), Pb (.0010

---

*Corresponding author: Email: izeze.ovie@fupre.edu.ng;

mg/l) and Mn (.0010 mg/l) the results were compared with WHO and EPA standards to determine the quality of the groundwater and it was found that the percentage of alkali earth metals and alkali metals were dominant in borehole and pond respectively which was the main source of water in the community.

Keywords: Groundwater; dykes; alkali metals; alkali earth metals.

1. INTRODUCTION

Petrology is the process by which the exact minerals present in a rock is determine in the petrological laboratory using the thin section analysis [1-3]. Water is known to be naturally occurring, an essential commodity that has no substitute and is indispensable. Where there is scarcity of it, there is bound to be crisis of water borne diseases, as every source of water could serve as possible repository of such diseases [4-8]. Groundwater is used for irrigation, domestic and industrial water supply and irrigation all over the world. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialization [9,10]. Human health is threatened by most of the agricultural development activities particularly in relation to excessive application of fertilizers and unsanitary conditions [11-15]. Groundwater includes all water found beneath the earth's surface in a saturated zone of the aquifer [16-18]. They are formations that contain sufficient saturated permeable materials to yield sufficient quantities of water to wells and springs. Groundwater can be extracted by means of HDWs (Hand Dug Wells) and boreholes at various depths. A large percentage of the world population depends on groundwater as their main source of drinking water, this is because it is accessible anywhere; it is less capital intensive to develop and maintain; it is less susceptible to pollution and seasonal fluctuations and of natural good quality [19-22].

The relationship between minerals present in rock and groundwater is to check for the impact due to chemical weathering of the surrounding rocks on the suitability and quality of water, if it meets with World Health Organization (WHO, 2017) standard of portable water, as well as relate the minerals present in the rock types as situated in the study area.

2. AIM AND OBJECTIVES

The aim of this work is to determine through geochemical analyses the different element present in the groundwater (the concentration of heavy metals, anions and cations) in the study environment, the petrology of the different rock types present and the structural geology of the area.

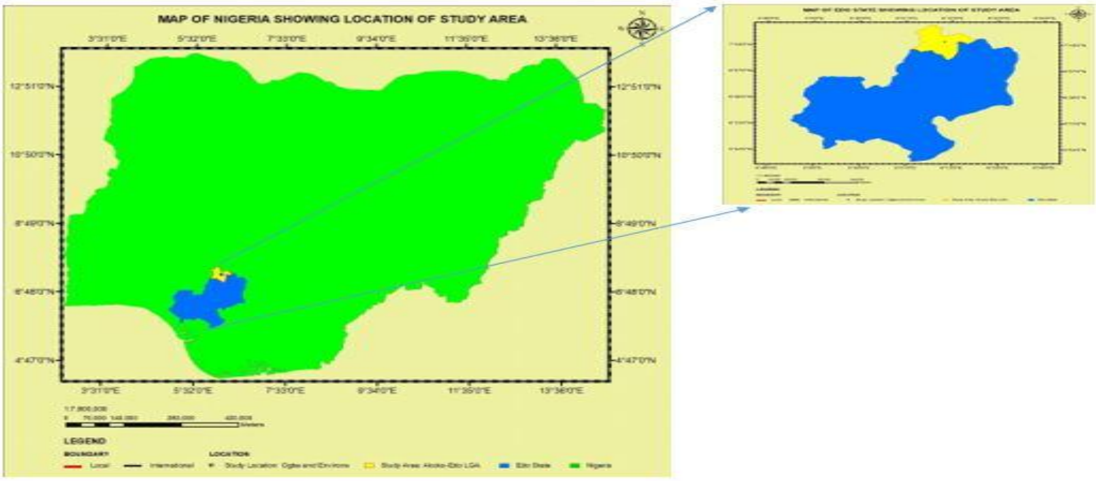


Fig. 1. a) Map of Nigeria showing the location of study area and b) Map of Edo state showing the location of Ogbe and its environs

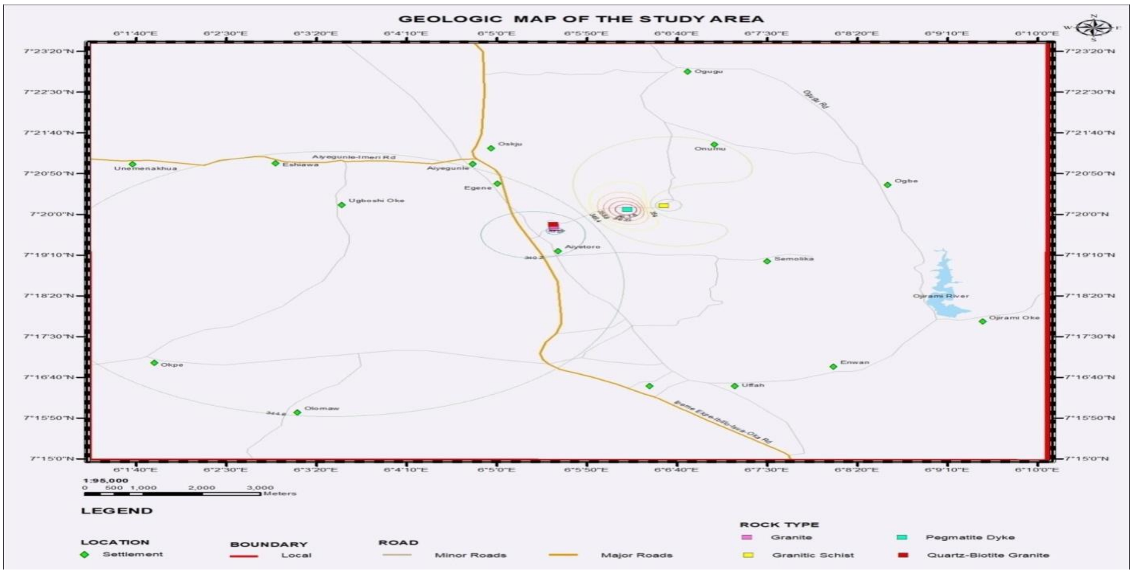


Fig. 2. Geologic map showing the rock sampling points from the study area

2.1 Location and Accessibility

The study areas lie between longitudes 6° 5' 00"E and 6° 6' 30"E, and latitudes 7° 19' 00"N and 7° 20' 30"N Ogbe, and longitudes 6° 6' 00"E and 6° 7' 30"E, and latitudes 7° 18' 00"N and 7° 16' 00"N Igarra (Fig. 1b). The study area falls under Igarra town with an area coverage of about 3000 km2, and ogbe, a village along the Igarra – Auchi Road just after aiyetoro in Akoko Edo Local Government, Edo State.Accessible via Lokoja-Benin Road, with a junction linking up to Auchi. Though characterized by a rugged topography, accessibility was on the average since there exist a fair network of roads and footpaths which helped to easily locate some outcrops, streams and ponds for sample collection.

3. METHODOLOGY

This discusses the field procedure and precaution of sample collection and also the analysis carried out in-situ (on the field) at the sampling point e.g., pH, temperature, total dissolved solids (TDS) and conductivity using pH meter and TDS/EC/Temperature Meter. writing/interpretation of results. All data used in this work was a product of the field mapping undertaking withinOgbe community and its environs and the laboratory analysis of the samples.

3.1 Field Procedure

A total of ten (10) samples were obtained from the study area. Seven rock samples from different strategic point,were retrieved form the study area and after proper observation were found to be of same rock types. Water samples (3) were obtained from two boreholes and one stream. Of the three water samples, two (2) were collected from Ogbe and one (1) gotten at the entrance of Aiyetoro.The samples were kept in different sample bottles and well labeled to avoid mixture. The samples were taken to the laboratory for rock thin section analysis, geochemical analysis and AAS (Atomic Absorption Spectrometry) analysis for the water and soil samples.

Table 1. Rock sample locations from the study area

S/N	Rock type	Sample code	Elevation	Latitude	Longitude
1	Granite	**RS1**	**331m**	**N**07˚19'42.1"	**E** 006˚05'32.0"
2	Granite	**RS2**	**340m**	**N** 07˚19'45.3"	**E** 006˚05'31.7"
3	Quartz-BiotiteGranite	**RS3**	**341m**	**N** 07˚19'47.3"	**E** 006˚05'31.5"
4	Pegmatite dyke	**RS4**	**377m**	**N** 07˚20'05.8"	**E** 006˚06'12.3"
5	Granitic Schist	**RS5**	**342m**	**N** 07˚20'10.5"	**E** 006˚06'32.9"

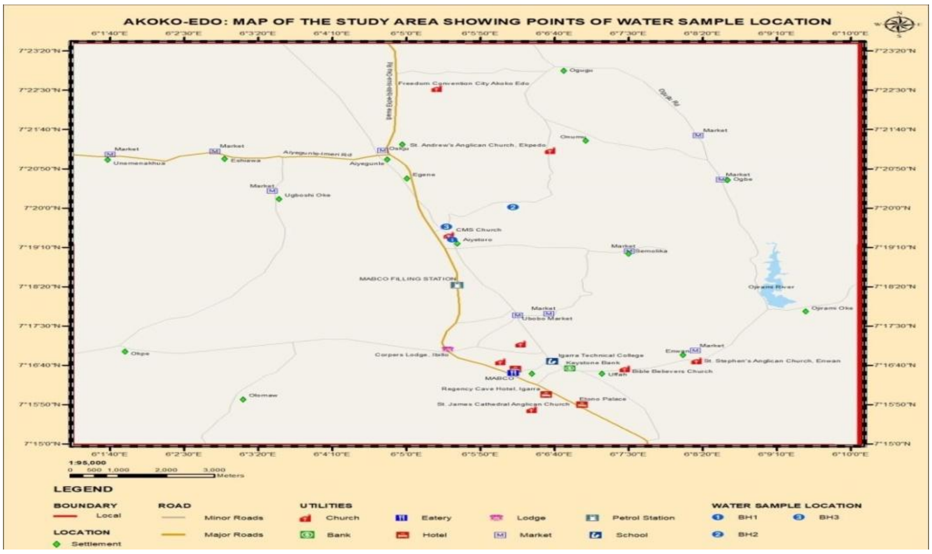


Fig. 3. Base Map showing the water sampling points from the study area

Table 2. Water sample locations from the study area

S/N	**Location**	**Sample code**	**Cordinates**	**Elevation**	**Description of location**
1	OGBE **1**	**BH1**	**N** 07˚19'19.9" **E** 006˚05'30.9"	**319m**	Borehole
2	OGBE **2**	**BH2**	**N** 07˚20'01.0" **E** 006˚06'11.9"	**349m**	Pond (one of the source of water in Ogbe)
3	OGBE **3**	**BH3**	**N** 07˚19'36.2" **E** 006˚05'26.9"	**314m**	------

Table 3. Phyisco-chemical parameters of water samples collected from the study area

S/N	**Sample code**	**pH**	**TDS**	**EC**	**TEMP (°)**
1	**BH1**	**6.97**	**192ppm**	**385µs**	**27.4˚C**
2	**BH2**	**7.08**	**96ppm**	**92µs**	**33.9˚C**
3	**BH3**	**-**	**-**	**-**	**-**

3.2 Petrological Procedure

The rock samples were gotten from fresh unweathered surfaces in order to source for the unaltered fresh rock where the mineralogy of the rock has not been affected. The samples were stored in air tight sample bags and later taken to the laboratory to petrographic analysis. Seven rock samples were obtained different strategic points. The rock samples were prepared for thin sectioning. The process involves cutting rock pieces into sizes of 4 to 6mm in thickness to attain adequate rigidity and slices are trimmed to have a margin of 2mm or more for convenience in bonding such that adhesive does not run over the edge of the glass and onto the back face. The above was followed by the smooth lap first face of rock slice using the LP50 Precision Free Abrasive Flat Lapping Machine, but can be done manually. The third step is described in washing and drying rock samples as well as the glass slides using liquid soap. Bonding of the rock samples to the glass is done using the jig bond, the excess rock mass after bonding is removed using the Automatic Pre-section thin section cut-off saw.

Plate 1. Thin Section Preparation

Plate 2. In-Situ analysis of physical parameters of water sample

3.3 Hydrogeochemical Procedure

A total of three water samples were obtained from the study area. One was collected from a stream and two were collected from boreholes at Ogbe. Tables 2-3 gives the locations and coordinates of where the samples were collected. The pH, Total dissolved content, Electrical conductivity and temperature were obtained.

250ml sample was measured into a beaker and 5ml Nitric Acid (HNO_3) is added. The solution was evaporated to near dryness on a hot plate, making sure that the sample does not boil. The beaker was allowed to cool and another 5ml of Conc. HNO_3 added. The beaker is covered with a watch glass and returned to the hot plate. A gentle refluxing action of the solution is set by increasing the temperature of the hot plate. Heating will continue with addition of acid as necessary until digestion is completed (light colored residue obtained). 1.2ml Conc. HNO_3 will be added to dissolve the residue. The residue is then washed with distilled water and filtered to remove silicate and other insoluble materials. The volume of the solution will be adjusted to 100ml in a volumetric flask. A reagent blank determination will be carried out, samples and reagent blank will be analyzed for total heavy metals with the flame Atomic Absorption Spectrometry Analysis Method (AAS). The AAS measures quantities of chemical element present in environmental samples by measuring the absorbed radiation by the chemical element of interest.

4. PRESENTATION OF RESULTS

4.1 Petrological Study

The microscopic analysis was carried out under a polarizing microscope. The properties of minerals under plane and cross polarized light were studied. The optical features of the various minerals observed are thus described below;

4.1.1 Biotite

They can occur in distinctive plates. They have a moderate relief and a perfect cleavage in plane polarization. It is brownish in plane polarization but pleochroic from brown to yellow. It is brownish in cross polarization with a parallel extinction

4.1.2 Quartz

Occurred as an anhedral, colorless crystals having a low relief in plane polarization, it is whitish in cross polarization and shows undulose extinction

4.1.3 K feldspar/ microcline

Occurred as a tabular subhedral crystal that are cloudy in plane polarization. It is grayish in color in cross polarization and has an oblique extinction.

4.1.4 Plagioclase

Occurred as a prismatic colorless crystal having a low relief in plane polarization, it is a grey yellow interface in cross polarization.

4.2 Biotite Granite

The biotite granite found was massive, covering a large area and was about 331m above the sea level. Thin section analysis, disclosed the granite composed more of feldspar and quartz. Alkali feldspar (orthoclase) with some measuring up to 0.8cm, coarsed quartz and micas (both muscovite and biotite), small amount of plagioclase and other accessary minerals like; Hornblende, Garnet, Zircon and Magnetite.

The images plate 3 clearlyshow identified minerals present in the rock under the microscope.

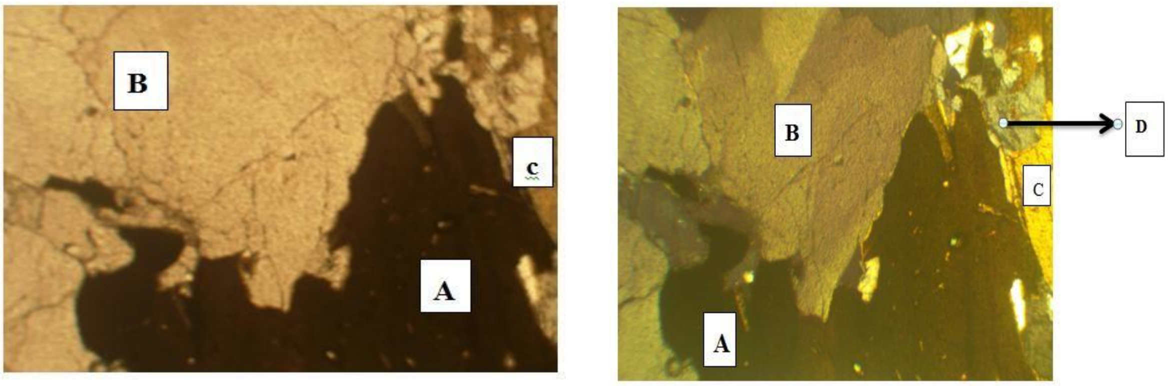
4.3 Pegmatites

The Pegmatites found in the area occur in form of a dyke cutting across the lateritic profiles present in ogbe. Analysis based on thin sectioning, unravels the pegmatites composure as;very coarsegrained alkali feldspar (orthoclase) with some measuring up to 0.8cm, coarse quartz and micas (both muscovite and biotite), other accessary minerals like; topaz, beryl, toumaline and Pyroxene(greenish). Pegmatite dykes' grains are not coarse as those of the pegmatite bodies. The pegmatite dykes were defined to be leucocratic in color and distinguished from other bodies based on colour.

4.4 Quartz-biotite Granite

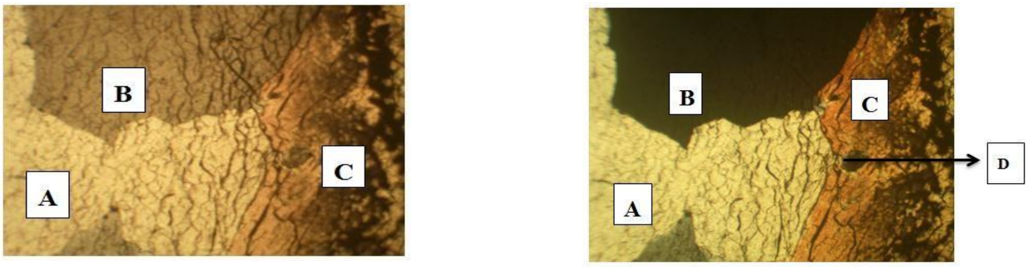
The quartz-biotite granite observed was massive, about 341m above the sea level. From the thin-section analysis, the granite was composed more of quartz and alkali feldspar (orthoclase) and micas (both muscovite and biotite), biotite very coarsed grained and small amount of plagioclase and other accessary minerals like; Hornblende, Garnet, Zircon and Magnetite. The granite was composed mainly of minerals that are melanocratic and leucocratic in color and the dominant minerals are quartz and biotite.

The pictures plate 5 show clearly all the minerals present in the rock under the microscope.



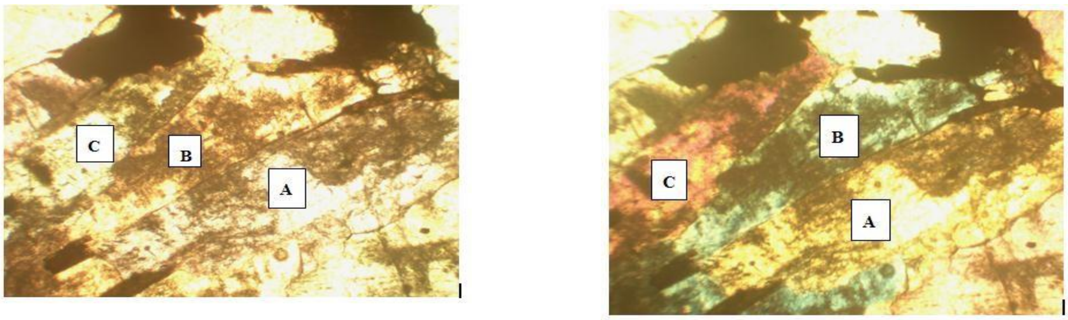
A= Biotite, B= Quartz and C= Alkali and D=Magnetite (an Accessary mineral)

Plate 3. Granite under plane polarized light (X40) b) Granite under cross polarized light (x40



A= Quartz, B= Biotite and C= K-Feldspar and D = Pyroxene

Plate 4. a) Pegmatite under plane polarized light (X40) b) Pegmatite under cross polarized light (x40)



A= Quartz, B= Mica and C= Alkali-Feldspar

Plate 5. a) Quartz-biotite granite under plane polarized light (x40) b) Quartz-biotite granite under cross polarized light (x40).

A= Quartz, B= Mica and C= Feldspar

Plate 6. a) Granitic schist under plane polarized light (x40) b) Granitic schist under cross polarized light (x40)

4.5 Granitic Schist

The granitic schist found in the area was 342 m above the sea level. From the thin section analysis, it was revealed that the granite was composed of mica, quartz, feldspar and little percentage of garnet at high temperature. The granitic schist was formed from granite that underwent metamorphism and as such it will contain most of the minerals present in granite. The pictures below show clearly minerals present in the rock under the microscope.

4.6 Structural Geology

During mapping exercises, numerous structures were observed. Studies conducted on these structures observed on rock exposures, aided in deciphering the geologic history of the area.The structural elements observed include; veins, dykes, folds, foliation, joints/fractures.

4.7 Veins

Veins of quartz, granitic materials and pegmatite were observed to run along weak foliation planes on the granitic rocks. Some of the veins cut across the foliation directions. Some were highly fractured. Most of them occur as in fillings in joints and fractures. The width of veins ranges from 3.0mm to 5cm with lengths of over 8 m.

4.8 Dykes

Dykes are tabular or sheet like bodies which are discordant to the country rock in which they occur (Phillip 2001). Dykes re believed to be emplaced during the last phase of the Pan African Orogeny. In the study area, pegmatite dykes were distributed and observed on the basement rocks. They are of variable thickness, ranging from 3cm to about 1.5m. The dominant structural trends of the dykes in the area NW-SE and N-S.

Plate 7. Quartz vein cutting across a granite

Plate 8. Pegmatite dyke

4.9 Joints and Fractures

They occur as cracks on rock outcrops without any relative displacement of blocks, some of the joints/fractures were seen to cut across the granites. Some of the joints have been refilled with secondary minerals or by recrystallization of the original minerals. Fractures in the intrusive igneous rock can be attributed to exposure of granitic plutons to the surface temperature and release of over burden pressure. It was also observed that biological weathering lead to most of the joint/fractures in the studied area.

Plate 9. Fractures present in granite

4.10 Hydrogeochemical Study

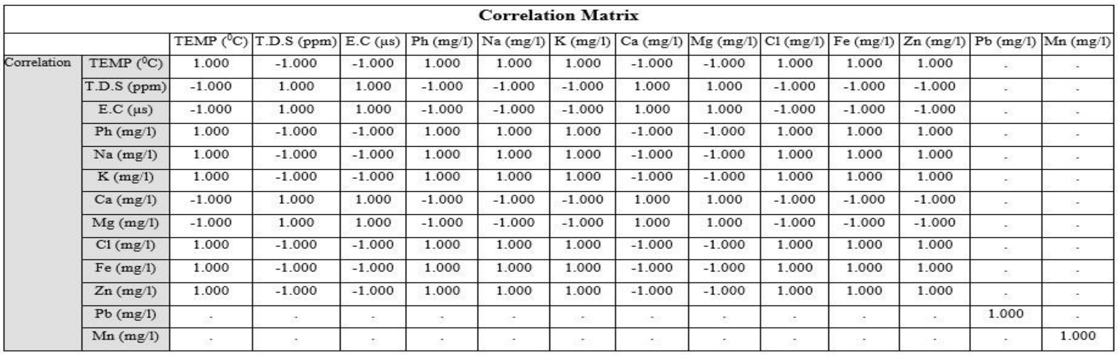
Table 4. Showing the mean and standard deviation of the analyzed parameters from the water sample collected at different location in the studied area

		Descriptive Statistics			
	BH1	**BH2**	**Mean**	**Std. Deviation**	**Analysis N**
TEMP (^{0}C)	27.4	33.9	30.6500	4.59619	2
T.D.S (ppm)	192	96	144.0000	67.88225	2
E.C (μs)	385	92	238.5000	207.18229	2
Ph (mg/l)	6.97	7.08	7.0250	.07778	2
Na (mg/l)	19.45	30.14	24.7950	7.55897	2
K (mg/l)	7.78	12.96	10.3700	3.66281	2

Descriptive Statistics					
	BH1	**BH2**	**Mean**	**Std. Deviation**	**Analysis N**
Ca (mg/l)	39.2	8.68	23.9400	21.58090	2
Mg (mg/l)	10.74	3.98	7.3600	4.78004	2
Cl (mg/l)	40.61	62.93	51.7700	15.78262	2
Fe (mg/l)	0.003	0.028	.0155	.01768	2
Zn (mg/l)	<0.001	0.009	.0050	.00566	2
Pb (mg/l)	<0.001	<0.001	.0010	.00000	2
Mn (mg/l)	<0.001	<0.001	.0010	.00000	2

4.11 Pearson's Correlation

Table 5. Showing the correlation matrix



Correlation Matrix

		TEMP (^{0}C)	T.D.S (ppm)	E.C (µs)	Ph (mg/l)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)	Fe (mg/l)	Zn (mg/l)	Pb (mg/l)	Mn (mg/l)
Correlation	TEMP (^{0}C)	1.000	-1.000	-1.000	1.000	1.000	1.000	-1.000	-1.000	1.000	1.000	1.000	.	.
	T.D.S (ppm)	-1.000	1.000	1.000	-1.000	-1.000	-1.000	1.000	1.000	-1.000	-1.000	-1.000	.	.
	E.C (µs)	-1.000	1.000	1.000	-1.000	-1.000	-1.000	1.000	1.000	-1.000	-1.000	-1.000	.	.
	Ph (mg/l)	1.000	-1.000	-1.000	1.000	1.000	1.000	-1.000	-1.000	1.000	1.000	1.000	.	.
	Na (mg/l)	1.000	-1.000	-1.000	1.000	1.000	1.000	-1.000	-1.000	1.000	1.000	1.000	.	.
	K (mg/l)	1.000	-1.000	-1.000	1.000	1.000	1.000	-1.000	-1.000	1.000	1.000	1.000	.	.
	Ca (mg/l)	-1.000	1.000	1.000	-1.000	-1.000	-1.000	1.000	1.000	-1.000	-1.000	-1.000	.	.
	Mg (mg/l)	-1.000	1.000	1.000	-1.000	-1.000	-1.000	1.000	1.000	-1.000	-1.000	-1.000	.	.
	Cl (mg/l)	1.000	-1.000	-1.000	1.000	1.000	1.000	-1.000	-1.000	1.000	1.000	1.000	.	.
	Fe (mg/l)	1.000	-1.000	-1.000	1.000	1.000	1.000	-1.000	-1.000	1.000	1.000	1.000	.	.
	Zn (mg/l)	1.000	-1.000	-1.000	1.000	1.000	1.000	-1.000	-1.000	1.000	1.000	1.000	.	.
	Pb (mg/l)	.	.	.	.	.	.	.	.	.	.	.	1.000	.
	Mn (mg/l)	.	.	.	.	.	.	.	.	.	.	.	.	1.000

From the Tables above, the following results can be deduced:

1. TEMPERATURE

High correlation: There is presence of very strong positive correlation between Temp/Cl, Temp/Fe, Temp/Zn, Temp/pH, Temp/Na, Temp / K.

Low correlation**:**There is presence of very negative correlation between Temp/TDS, Temp/E.C, Temp/Ca,Temp/Mg.

2. TDS

High correlation:There is presence of very strong positive correlation between TDS/E.C, TDS/Ca , TDS/Mg

Low correlation:There is presence of very negative correlation between Temp/TDS, TDS/pH, TDS/Na,TDS/ K,TDS/Cl, TDS/Fe,TDS/Zn.

3. E.C

High Correlation:There is presence of very strong positive correlation between TDS/E.C, E.C/Ca, E.C/Mg

Low correlation: There is presence of very negative correlation between Temp/E.C, E.C/pH, E.C/Na,E.C/ K,E.C/Cl,E.C/Fe,E.C/Zn..

4. pH

High correlation; There is presence of very strong positive correlation between pH/Cl, pH/Fe, pH/Zn, pH/Temp, pH/Na, pH/K.

Low correlation: There is presence of very negative correlation between pH/TDS, pH/E.C, pH/Ca, pH/Mg.

5. Na

High correlation: There is presence of very strong positive correlation between Na/Cl, Na/Fe, Na/Zn, Na /pH, Temp/Na, Na/K.

Low correlation: There is presence of very negative correlation between Na/TDS, Na/E.C, Na/Ca, Na/Mg.

6. K

High correlation: There is presence of very strong positive correlation between K/Cl, K/Fe, K/Zn, K/pH, Temp/ K, Na/ K.

Low correlation: There is presence of very negative correlation between K/TDS, K/E.C, K/Ca, K/Mg.

7. Cl

High correlation: There is presence of very strong positive correlation between K/Cl, Cl/Fe, Cl/Zn, Cl/pH, Na/Cl, Temp/Cl.

Low correlation: There is presence of very negative correlation between Cl/TDS, Cl/E.C, Cl /Ca, Cl/Mg.

8. Fe

High correlation: There is presence of very strong positive correlation between K/Fe, Cl/Fe, Fe/Zn, Fe/pH, Temp/Fe, Na/ Fe.

Low correlation: There is presence of very negative correlation between Fe/TDS, Fe/E.C, Fe/Ca, Fe/Mg.

9. Zn

High correlation: There is presence of very strong positive correlation between K/Zn, Cl/Zn, Fe/Zn, Zn/pH, Temp/Zn, Na/Zn.

Low correlation: There is presence of very negative correlation between Zn/TDS, Zn/E.C, Zn/Ca, Zn/Mg.

10. Ca

High correlation: There is presence of very strong positive correlation between TDS/Ca, E.C/Ca, Ca/Mg.

Low correlation: There is presence of very negative correlation between Temp/Ca, Ca/pH, Ca/Na, Ca/K, Ca/Cl, Ca/Fe, Ca/Zn.

11. Mg

High correlation: There is presence of very strong positive correlation between TDS/Mg, E.C/ Mg, Ca/Mg

Low correlation**:** There is presence of very negative correlation between Temp/Mg, Mg/pH, Mg/Na, Mg/K, Mg/Cl, Mg/Fe, Mg/Zn

4.12 Piper and Durov Diagram

The geochemical evolution of water in general (groundwater in particular) can be understood by constructing Piper (1944) trilinear diagram and Durov (1948) plot. Piper diagram is a multifaceted plot wherein milliequivalents percentage concentrations of major cations (Ca2+, Mg2+, Na+ and K+) and anions (HCO3 -, SO4 2-, and Cl-) are plotted in two triangular fields, which were then projected further into the central diamond field.

In contrast, Durov diagram is a composite plot consisting of 2 ternary diagrams where the milliequivalents percentages of the cations of interest were plotted against that of anions of interest; sides form a central rectangular, binary plot of total cation vs. total anion concentrations. Both diagrams reveal similarities and differences among water samples because those with similar qualities will tend to plot together as groups (Todd, 2001). But, in Piper diagram, it is the data plotted on the subdivisions of diamond-shaped field which decides the water type / hydrochemicalfacies in a water sample. Contrast to this, intersection of lines extended from the points in ternary diagrams and projected on the sub-divisions of binary plot of Durov diagram define the hydrochemical processes involved along with water type.

4.13 Piper's Result

From the piper's diagram shown above, the following results can be deduced:

BH1 Sample falls in zone I which demonstrates a dominance of alkali Earth over Alkali. It belongs to Ca^{2+} - Mg^{2+} - Cl^{-} — SO_4^{2-} and strong acidic anions over weak acidic anions. Dominance of Ca and Mg in groundwater samples suggests an inverse exchange process. During this process, CA from the Aquifer matrix will be exchanged by Na from groundwater. It falls within a water type of Earth alkaline water with increased portions of alkalis with prevailing sulfate and chloride

BH2 Sample falls in the hydro-geochemicalfacies that is dominated by Na^{+}-K^{+}-. It falls within a water type of Alkaline water with prevailing sulfate or chloride

4.14 Durov's Result

From the Durov's diagram shown above the following results can be deduced:

BH1 Sample falls in the field 4 along the ion exchange. Based on the classification of (Lloyd and Heathcoat 1985), the trend can be attributed to SO_4 dominates, or anion discriminant and Ca dominant, Ca and SO_4 dominant, frequently indicates recharge water in lava and gypsiferous deposits, otherwise mixed water or water exhibiting simple dissolution may be indicated.

BH2 falls in the field 7 along the ion exchange. Based on the classification of (Lloyd and Heathcoat 1985), the trend can be attributed to Cl and Na dominant is frequently encountered unless cement pollution is present. Otherwise the water may result from reverse ion exchange of Na-Cl waters.

4.15 Stiff Diagrams

Stiff (1951) developed are graphical representation of water chemical analyses. A polygonal shape is created from the three or four parallel horizontal axes extending on either side of a vertical zero axes. Cations are plotted in milliequivalent per litre on the left side of the zero axis one to each horizontal axis and anions are plotted on the right side.

4.16 STIFF'S RESULT

From the Stiff's diagram above, the following results can be deduced:

In BH1 Sample, the stiff diagram revealed the following hydrogeochemicalfacies (water type): Ca$^-$Na$^+$K$^-$Cl$^-$ Overall cation concentration shows a trend of Ca>Na+K>Mg. In BH2 Sample, the stiff diagram revealed the following hydrogeochemicalfacies (water type): Na$^+$ K$^+$Cl$^-$. The overall cation concentration shows a trend of Na+K>Ca>Mg. The different hydrogeochemical water types interpreted is based on the respective shapes of the different stiff plot.

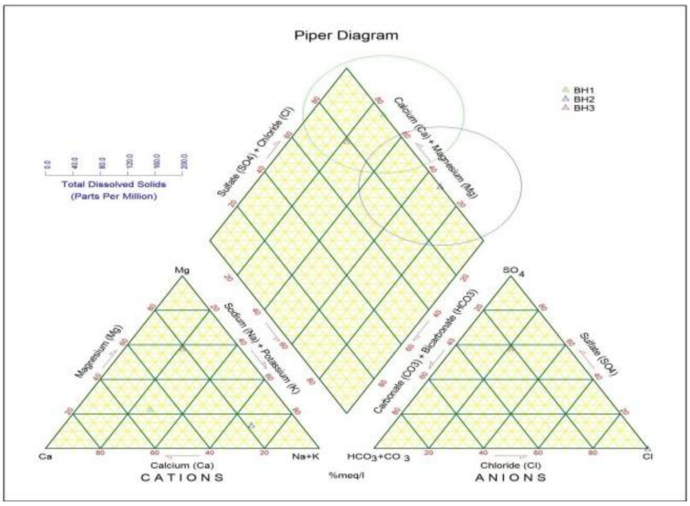


Fig. 4. Piper diagram

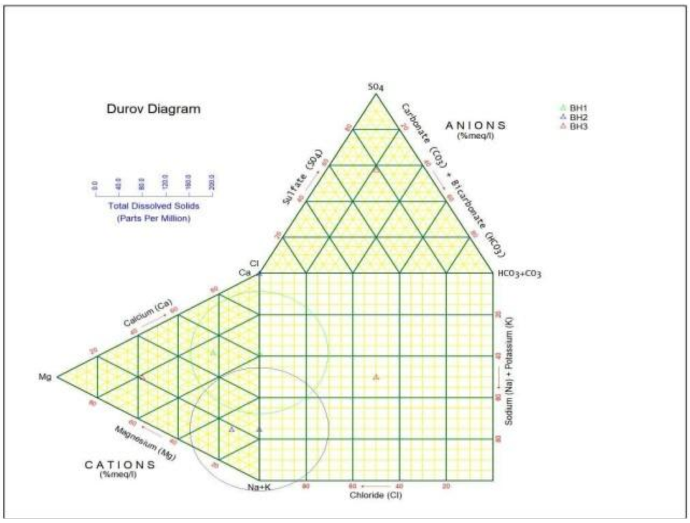


Fig. 5. Durov diagram

4.17 Major Elements

Magnesium and Sodium

From the data obtained from above, the following results can be inferred:

BH1 which has a concentration of 10.74 mg/l is greater than 5.37, but in BH2, the concentration was 3.98mg/l lesser than mean threshold value of Magnesium in the study area.

The sodium concentration in BH1 was 19.45 mg/l and 30.14 mg/l in BH2 being greater than 15.07mg/l which is the mean threshold value of Sodium in the study area.

Potassium and Calcium

From the data obtained above, the following results can be inferred:

BH1 and BH2 had concentrations of 7.78 mg/l and 12.96mg/l respectively and is greater than 6.48mg/l which is the mean threshold value of Potassium in the study area.

The concentration of calcium in BH1 and BH2 are 39.2 mg/l and 8.86mg/l. BH1 exceeds the standard threshold being 19.6mg/l but BH2 is within the threshold in the study area.

4.18 Trace Elements

Manganese and Zinc

From the data obtained from above, the following results can be inferred based on (WHO, 2011) drinking water guidelines:

BH1 and BH2 hadmanganese concentrations of <0.001 mg/l and is lesser than the maximum permissible limit of 0.4 mg/l

Zinc concentration in BH1 and BH2 which has a concentration of <0.001 mg/l is lesser than the maximum permissible limit.

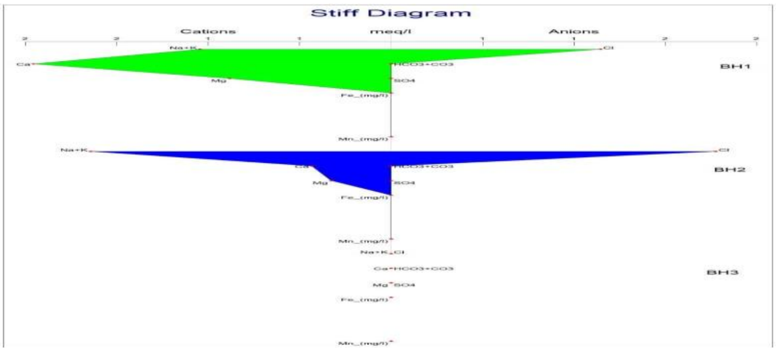


Fig. 6. Stiff diagram

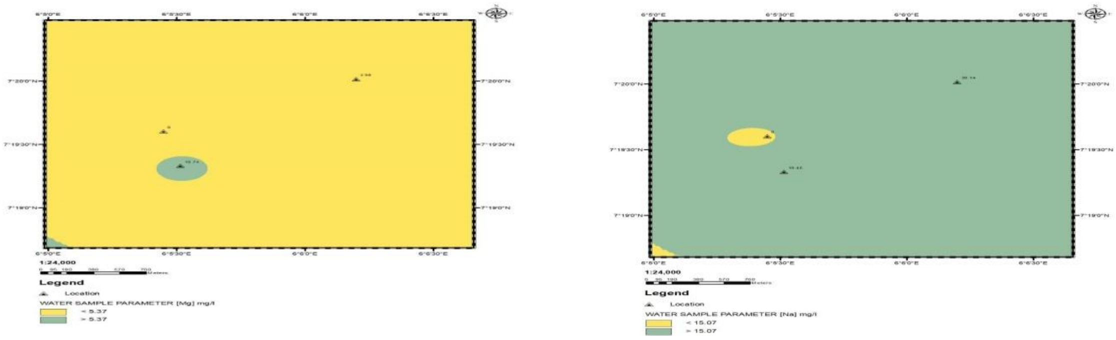


Fig. 7. Spatial diagram showing the concentration of a) magnesium and b) Sodium in the study area

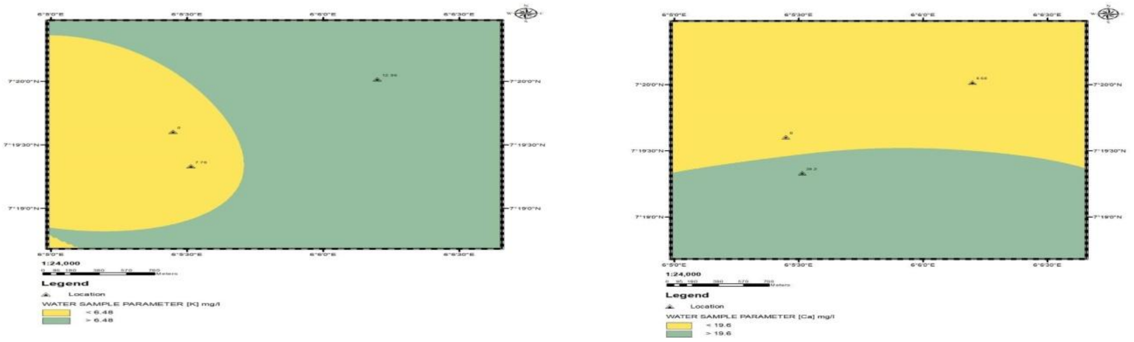


Fig. 8. Spatial diagram showing the concentration of potassium in the study area

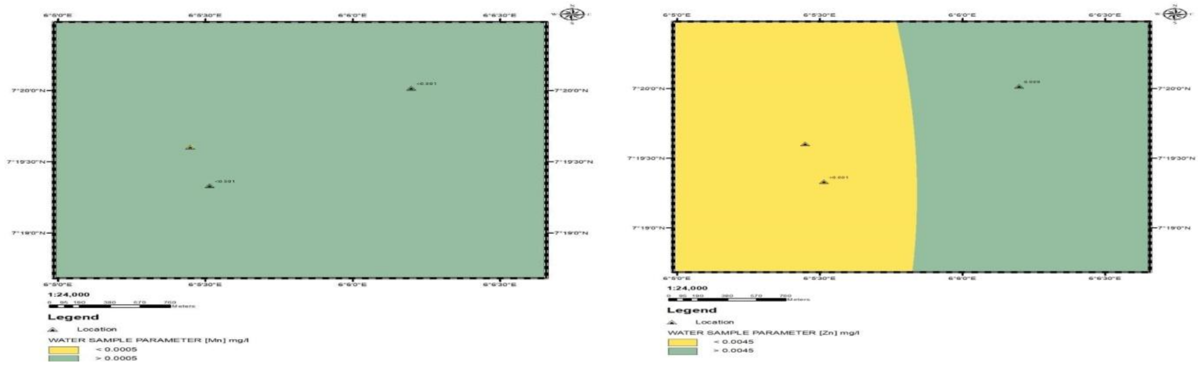


Fig. 9. Spatial diagram showing the concentration of a)manganese and b) Zinc in the study area

Lead and Iron

From the data obtained from above, the following results can be inferred based on (WHO, 2011) drinking water guidelines:

The concentration of Pbin BH1 and BH2 had concentrations<0.001 mg/l and is lesser than the maximum permissible limit of 0.01mg/l.

For Fe concentration in BH1 and BH2are 0.003 mg/l and 0.028 mg/l is lesser than the maximum permissible limit of 0.1 mg/l .

4.19 Physio Chemical Elements

pH and TDS

From the data obtained from above the following results can be inferred:

pH level of BH1 and BH2 of 6.97 and 7.08 mg/l is within the range of 6.5 to 8.5 which falls within the EPA standard

From WHO (2011) standard, observed TDS values inBH1 and BH2 had concentrations of 7.78 mg/l and 12.96 mg/l which is below the limit of 500 mg/l in the study area

Temperature

From the data obtained from above, the following results can be inferred using (WHO, 2011):

BH1 and BH2 which has a concentration of 27.4 mg/l and 33.9mg/l which are greater than the mean threshold value.

5. DISCUSSION AND FINDINGS

5.1 Petrography

Microscopic analysis from the thin section showed that both granitic rocks consist more of quartz (SiO_2), alkali feldspar with general formula [(AT_4O_8) in which A= potassium, sodium, or calcium and T= silicon(Si) and aluminum(Al), with a Si:Al ratio ranging from 3:1 to 1:1, albite ($NaAlSi_3O_8$), potassium feldspar ($KAlSi_3O_8$) and anorthite ($CaAl_2Si_2O_8$)], mica and small amount of plagioclase.

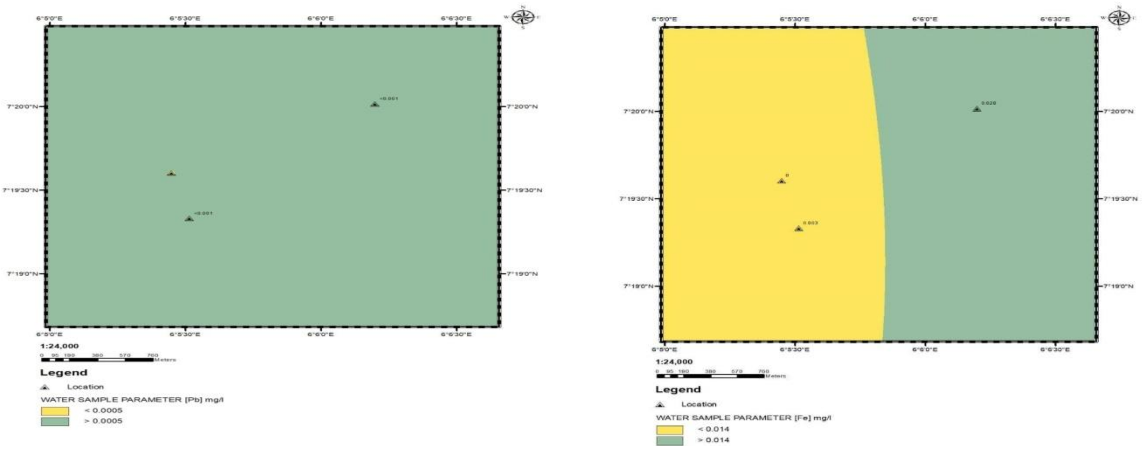


Fig. 10. Spatial diagram showing the concentration of a) Lead and b) Iron in the study area

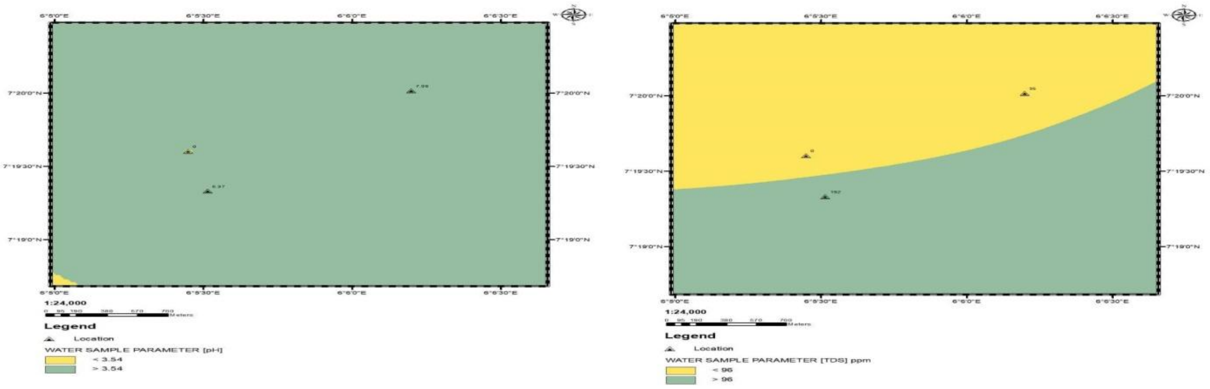


Fig. 11. Spatial diagram showing the concentration of a) pH and b) TDS in the study area

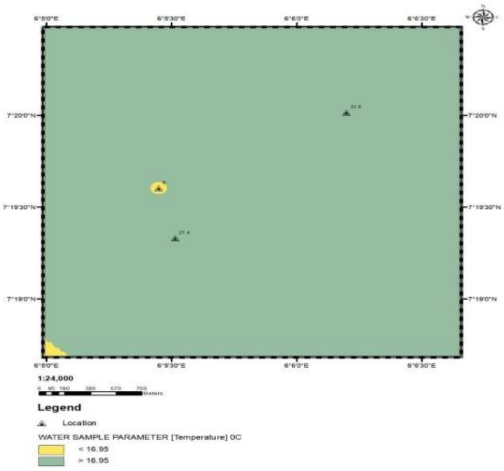


Fig. 12. spatial diagram showing the level of temperature in the study area

The dominant mineral in the biotite-granite was biotite and also high percentage of feldspar and quartz (SiO_2) was also observed under the microscope, while the dominant mineral observed in the quartz-biotite granite was quartz (SiO_2) and biotite. It was also observed that the percentage of feldspar was also found to be relatively noticeable.

The pegmatite under the microscope revealed that the dominant minerals were quartz (SiO_2), feldspars and mica and accessary mineral like pyroxene which was greenish was also seen to be present as well.

The granitic schist was revealed to have quartz (SiO_2), mica and feldspar under the microscope from the thin section analysis. The schist was formed from granitic rocks and as such will contain most of the minerals that are present in the granite.

The geochemical analysis revealed that the major contaminant for BH1 is calcium and the major contaminants for BH2 were sodium and potassium. The pH values fall within the EPA standard that ranges from 6.5 to 8.5. It also revealed that the presences of trace elements like Zn, Mn, Pb and Fe were below the maximum permissible limit for WHO.The results of the water geochemistry of the study area showed a certain degree of resemblance though gotten from different location and their sources is also relatively different.

BH1

This was a borehole water source which showed a high amount/concentration of Ca^{+} with average concentration of Mg^{+}, Na^{+}, K^{+}cations and the anioins are Cl^{-}which had the highest concentration with a minimal conc. Of $CO_3^{2-}$and SO_4^{2-}.

BH2

The pond according to the piper, deciphers that the dominant ion i.e. the ion with the highest concentration was Na^{+} and K^{+}. The person's correlation revealed that the Ca^{+} and the dominant ion present in the bh2 were not correlated which means they are of different sources. Finally, the stiff showed that the concentration of $CO_3^{2-} > HCO_3^{-} > SO_4^{2-}$.

5.2 Findings

The source of contamination of BH2 is from the surrounding rocks. During weathering, because feldspars are not resistant to weathering unlike quartz that are very resistant, it gives off Na^{+} and K^{+} which are then washed into the groundwater through percolation.

BH1 from the geochemical analysis revealed to be polluted with calcium which source is unknown.

6. CONCLUSION

Petrography reveals the rock units compose of quartz, biotite, plagioclase, orthoclase feldspar, muscovite and so forth as the rock forming minerals. Zircon, Pyroxene, Garnet, Hornblende etc. occur as accessories. The structural features include; dykes, joints, veins which were observed in the study area.

The following conclusions are hereby made;

1. The geologic structures in the study area are significant to the rock orientation of the area which is the Basement complex.
2. The major minerals present in all rock types found in the studied area were; biotite, feldspar, and quartz.
3. Sodium and Potassium are from the same source of contamination while Calcium is from a different source; this was deciphered by the correlation matrix.
4. That BH1 sample falls in zone I from the piper's diagram which demonstrates a dominance of alkali Earth over Alkali. It belongs to Ca^{2+} — Mg^{2+} —Cl^{-} — SO_4^{2-} and strong acidic anions over weak acidic anions.
5. BH2 Sample falls in the hydrogeochemicalfacies that is dominated by Na^{+}— K^{+}— HCO_3^{-}.
6. The source of contamination of BH2 is from the surrounding rocks. During weathering, because feldspars are not resistant to weathering unlike quartz that are very resistant, it gives off Na^{+} and K^{+} which are then washed into the groundwater through percolation.
7. BH1 from the geochemical analysis revealed to be polluted with calcium which source is unknown.
8. Igneous and Metamorphic rocks tend to depict certain characteristics when impacted by Geologic events such as plate tectonism, chemical and mechanical weathering with volcanic eruptions. These geologic actions gave rise to the structural geology of the area shaping the rock formations. Their impact also gave influence to the mineralogy and elemental makeup of the area which made it rich in materials and mineral resources of fairly economic potentials and raw materials for construction purposes.

7. RECOMMENDATIONS

We recommend that more work on rock, groundwater and soil geochemistry be carried out in the study area to have a better understanding of the anthropogenic and geogenic causes of contamination in the groundwater of the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Akure, Southwestern Nigeria. Geological survey of nigeria publication, Nigeria; 231-239.
2. Back W, Hanshaw BB. AdvHydrosci. 1965;2:49–109.
3. Back W. Hydrochemicalfacies and groundwater flow patterns in northern part of Atlantic Coastal Plain. US.
4. Nigerian Industrial Standard (NIS). Nigerian Standard for drinking water Quality. NIS. 2007;554.
5. Odeyemi IB. Preliminary report on the field relationship of the Basement Complex around Igarra, Midwest Nigeria. In: C.A. Kogbe (Ed). Geology of Nigeria, Elizabethan Press, Lagos. 1976;365-369.
6. Olarewaju VO. Petrology and geochemistry of the charnockitic and Associated Granitic rocks of Ado-Ekiti. 1988;1:87-102.
7. Omo-Irabor O, Izeze EO, Akpere O. Assessment of heavy metal contamination in groundwater of agbor, Ika south l.g.a Delta State, Nigeria; 2018.
8. Oyawoye MO. The geology of Nigerian basement complex. Journal of Nigeria Mineral geology and metallurgical society. 1964;1.
9. Christos N, Miltiadas T, Theodore K. Zinc in soils, water and food crops. Journal of Trace elements in Medicine and Biology. 2018;49(4):252-260.
10. Fourth Edition. WHO library cataloguing-in-publication data. 1-518.
11. Geological Survey Professional Paper 1966, 498–A. USGS, Washington DC.
12. Imaseun IO, Izeze OE. 46th IAH Congrass-Malaga, spain. Geoenvironmental investigation of the metallic concentration of ground water in parts of sapele and warri, Delta state, Nigeria; 2019.
13. Izeze EO, Uzokwe C. Assessment of heavy metal concentration in groundwater of uvwie local government areaand environs, Delta state, Nigeria; 2019.
14. Jones HA, Hockey RD. The geology of part of South-Western Nigeria, Geological Survey of Nigeria Bulletin. 1964;30.
15. McCurry P. The geology of the precambrian to lower paleozoic rocks of northern Nigeria – a review. Inn; C.A. Kogbe (ed) Geology of Nigeria, Elizabethan Publishing Co., Lagos. 1976;58-63
16. Back W. US Geol. Surv. Prof. Paper. 1966;498-A:42.
17. Chaanda MS, Izeze EO, Osaze TI. Marble mining in Nigeria: Environmental Geochemistry of Igarra Marble Mining; 2019.
18. Chilingar G.V., Transactions - American Geophysical Union. 1956;37:193–196.
19. Rahaman MA. Polyphase metamorphism in politic schists around Aiyetoro, Western Nigeria. Paper read at Annual Conference of Nigeria Mining Geological and Metallurgical Society in Jos, Dec; 1973.
20. Rahaman MA. Recent advances in the study of the basement complex of Nigeria. In: Precambrian geology of Nigeria, Geological Survey of Nigeria Publication, Kaduna. 1988;11-43.
21. Rahaman MA. Recent advances in the study of the Basement Complex of Nigeria. In: Precambrian geology of Nigeria, Symposium on the Geology of Nigeria, Obafemi Awolowo University, Nigeria; 1988.
22. World Health Organization (WHO). Guidelines for drinking-water quality; 2012.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/81746