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Editorial Office
Department of Geology
University of Ibadan,
Ibadan, Nigeria.

***E-mail*:** bimbosah@yahoo.com
af.abimbola@mail.ui.edu.ng

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Geochemical characterisation of aquifers in the basement complex-sediment transition zone around Ishara, southwestern Nigeria

*Ariyo, S.O., **Adeyemi, G.O. and *Odukoya, A.M

* *Department of Earth Sciences, Olabisi Onabanjo University, Ago-Iwoye*
** *Department of Geology, University of Ibadan, Ibadan*

Abstract

Geochemical investigation involving chemical analyses of water samples was carried out in the area around the contact between the basement complex and sedimentary rocks around Ishara, Southwestern Nigeria. This was with a view to determine the relationship between groundwater chemistry and the lithology through which they flow in the area.

Chemical and physical characteristics of 19 water samples collected from available wells and surface water were determined.

Results obtained from the analysis of water samples reveal higher values of total dissolved solids and electrical conductivity in Basement complex than in those from the sedimentary terrain. Statistical analysis of the geochemical and physical parameters of surface water samples (one from each terrain) show no significant difference probably due to little time of interaction with the lithology through which they flow. Apart from Silica and Nitrate, all other parameters are higher in concentration/values in water from the Basement complex than those from the sedimentary terrain due to the mineral composition of the aquifer materials.

The overall results show that there is a strong relationship between the aquifer materials in the study area and water chemistry.

Introduction

Water in adequate supply and quality is a necessity for everyday life. It is difficult to imagine any programme for human development that does not require a readily available supply of water. Readily available for much of the world's population, water has traditionally been regarded as an inexhaustible gift of nature by many societies. Such complacency about this life-giving resource threatens human welfare development and indeed life itself in the years to come.

The largest available source of fresh water lies underground. This is referred to as ground water and it is the water held in the subsurface within the zone of saturation under hydrostatic pressure below the water table. The quantity, chemical and biological characteristics of water determine its usefulness for industry, agriculture or domestic uses. Naturally surface water is in short supply and in varying quality as a result of seasonal nature of many of them, as such one has to depend partly or wholly on groundwater.

Location

Figure 1. Shows the location of the study areas. These area are Ode-Remo, Ishara, Ipara and Fidiwo, in Southwestern Nigeria. The areas covered by the study are located between latitudes 60°57' and 70°04' North and longitudes 30°39' and 30°43' East. They are bounded to the east by Ibadan-Ijebu-Ode axis, to the south by Sagamu and to the west by Abeokuta.

Most parts of the study area are accessible and linked with good motorable roads.

1.2 Objectives of Study

In a geological contact or transition zone, like the study area, a general lateral movement from basement rocks to sedimentary rock is marked by noticeable local and regional geomorphologic changes (Adeyemi, 1992). This is likely to result in marked difference in the occurrence of ground water and their physical or chemical properties. The objectives of this study are as follow:

1. To investigate the geochemical and physical

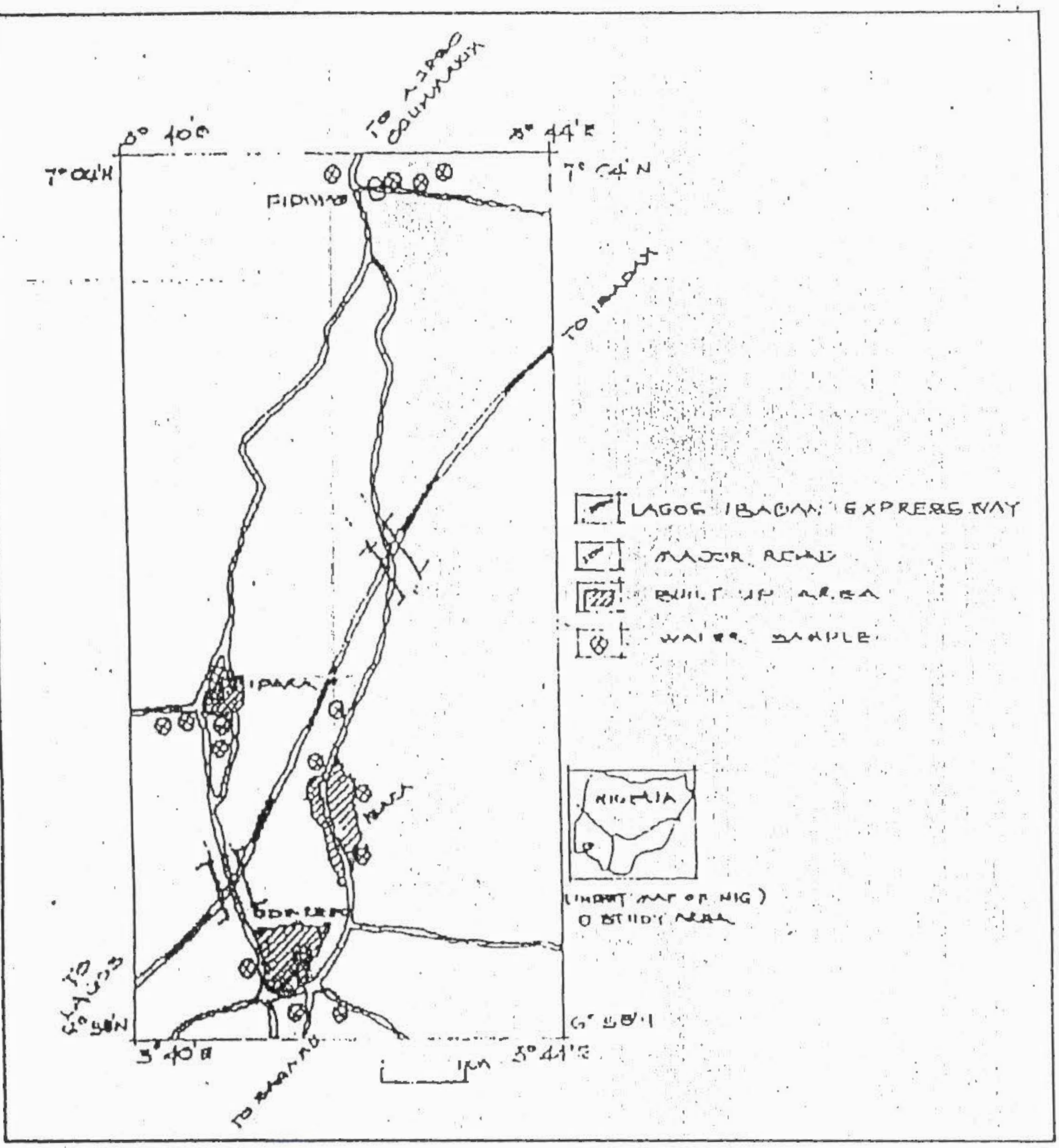

Fig. 1. Location map of the study area showing sample points.

properties of groundwater found in these terrains and

2. Establishing the possible correlations between the geology and ground water chemistry in the study area.

Genereal Topography

The relief of the study area is closely associated with underlying rocks because they are the expression of the rock unit of the area. The contact between the basement rocks and the sedimentary rocks separates the gently undulating relief of the sedimentary terrain from the rugged one of the basement complex area. The sedimentary zone-comprising Ode- Remo, Ishara-Remo and Ipara-Remo has a fairly rugged relief characterized by inselgebrgs.

Local Geology

Both crystalline and sedimentary rocks were represented in the study area (Fig. 2). The basement complex rocks found in the study area are quartz -mica schist (QMS) and to a lesser extent Migmatite-gneiss (MG). The Quartz-mica schist outcrops poorly in the study area. Its susceptibility to weathering is probably responsible for the scarcity of outcrops. From the field observation, the mineral contents of this rock are biotite, quartz, and feldspar. The migmatite gneiss in the study area is highly foliated and folded with a mixture of granite (quartzo-feldspathic) and mafic highly foliated bands. From the field observation,the minerals content of this rocks in order of abundance are quartz, biotite,muscovite and feldspars while the sedimentary part of the study area falls within the Abeokuta group that consists of Ise,Afowo and

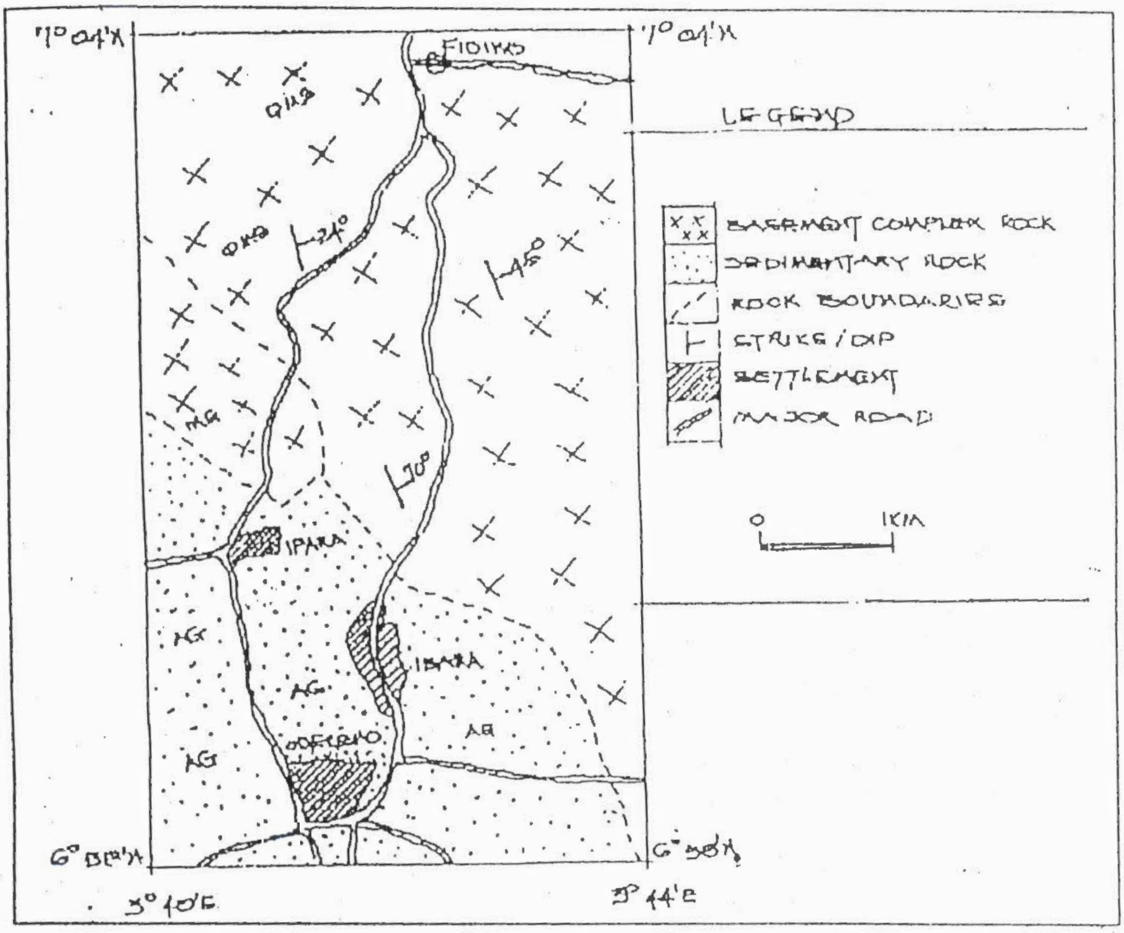

Fig. 2. Geological map of the study area (modified after Adeyemi, 1998)

Araromi Formation (Omatsola and Adegoke, 1981). This Abeokuta Group is of Maastrichitian age and of marine deposit.

i) Ise Formation

It consists essentially of continental sandstones, grits and siltstones. They are pebbly at some places and highly indurated and massive. They overlie the basement complex rocks and attain a maximum thickness of about 609m at the Dahomey border. The basal unit is predominantly conglomeratic sandstones succeeded by gristly coarse to medium grain loose sands interbedded with creamy/whitish kaolinitic clays. It is Neocomania in age (Omatsola and Adegoke, 1981).

ii) Afowo Formation

This overlies the Ise Formation and it consists of medium to fine grained limestone consisting of thick interbed of shale and siltstones. The Afowo sediments were deposited as a transitional to marginal marine environment, ranging in age from Turonian to Maastrichtan (Omatsola and Adegoke, 1981).

iii) Araromi Formation

This is the topmost formation within the Abeokuta Group. It consists of fine-grained to medium-grained sands at the bottom and grade into siltstones and shale within intercalation of limestone, sand and lignite towards the top. The age of this formation is between Maastrichtan to early Paleocene (Omatsola and Adegoke, 1981). From the field observation of these sandstones, the major mineral constituent is quartz and this quartz grains are fairly angular, which may be an indication of a short distance transport.

Hydrogeology

The hydrogeology of an area is usually controlled by such factors as geology and climate of that area. This is due to the fact that geological formations underlying the area and structures contained in them determine the types of aquifer to be encountered and how the aquifers are recharged while the climate determines the amount and rate of recharge of the aquifers. (Nkereuwen, 1991, Ariyo, 2004). Unaltered basement complex rocks are very poor aquifers because of their low porosity and permeability and for them to become good aquifers; they must be fractured or weathered. Unlike the sedimentary terrain, the permeability and porosity of basement complex rocks depend on secondary structural pattern of fractures such as the existence and concentration of a unique pattern of fracture system as well as on the nature and thickness of the overburden. The Sedimentary terrain covered by the study area belongs to the Abeokuta group (Omatsola and Adegoke, 1981). The aquifer in this group, which is close proximity to the basement rocks, is thin due to the occurrence of the fresh basement near the surface of the ground. This situation is very prominent at Ipara-Remo that has a boundary with the basement complex rock found in Fidiwo. As we move away from the contact zone towards the sedimentary terrain in the study area, most especially Ode-Remo, the depth of occurrence of groundwater is very deep because of the unconfined nature of the aquifer. This is due largely to the nature of the lithology of the formation, which consists of variety of sands/sandstones varying from coarse-grained size to fine grained milky colour. This lithology is soft and friable with high degree of porosity and permeability that allow quick percolation of ground water to a greater depth (Emenike, 2001).

Methodology

Two (2) methods are involved in this study and these are:

1. Geological investigation
   This involves the detailed geological mapping of the entire area of study with emphasis on texture, composition and structures of the rocks.
2. Hydro geological investigation
   Standing water level was randomly taken from all the available hand dug wells and boreholes located within the study area. 19 water samples were collected from the two terrains and analyzed in order to establish the relationship between the water chemistry and the lithology.

Results and discussion

Results of chemical analysis of water samples from stream, hand dug wells and boreholes in the study area are presented in Tables 1 and 2. From the summary of the results (Tables 1 & 2). Calcium, Magnesium, Sodium, Bicarbonate, Silica and Chlorine ions constitute the major ions while Sulphate, Iron, and Nitrate constitute the minor ions in most cases.

Table 1. Summary of chemical parameters (Cationic and Anionic) (PPM)

	SL	SS	Na+	Mg^{2+}	Ca^{2+}	Fe^{2+}	SO_4^{2-}	NO_3^-	Cl^-	HCO_3^-	Si
1	ODE-REMO	BH	2.07	6.31	6.40	0.09	2.00	3.32	8.25	16	3.50
2	..	BH	0.85	1.46	2.40	0.09	1.03	2.88	6.38	20	3.40
3	..	BH	17.70	22.84	40.00	0.10	1.81	4.52	27.75	16	4.43
4	..	BH	1.56	2.43	7.20	0.13	1.97	3.16	4.50	32	2.80
5	ISARA	SW	2.22	8.75	14.40	0.93	2.00	6.62	6.00	20	2.20
6	..	HDW	10.07	16.52	17.60	0.48	2.06	3.18	20.25	8	6.40
7	..	HDW	11.44	18.47	17.60	0.15	1.80	3.54	20.25	24	7.76
8	..	HDW	3.78	4.86	16.80	0.14	1.77	8.23	7.13	30	3.25
9	..	HDW	2.67	5.83	10.40	0.12	2.00	5.57	6.00	14	6.00
10	FIDIWO	HDW	12.70	17.01	38.40	0.72	1.76	4.01	10.15	20	11.60
11	..	HDW	9.63	10.69	24.00	0.21	1.83	2.87	14.25	65	7.33
12	..	ST	2.70	1.94	11.20	0.59	1.79	2.91	5.25	24	2.10
13	..	HDW	7.39	6.80	24.00	0.38	1.93	4.26	16.50	40	5.45
14	..	HDW	15.85	19.44	41.60	0.10	1.85	4.31	25.88	44	5.90
15	IPARA	BH	3.74	2.92	25.60	0.09	1.78	2.58	4.88	36	1.55
16	..	HDW	2.43	8.26	21.60	0.13	2.05	3.01	12.00	20	2.32
17	..	HDW	8.88	10.21	20.60	0.12	1.96	3.58	21.75	20	6.23
18	..	HDW	13.81	24.80	44.80	0.11	1.90	4.59	13.50	28	2.18
19	..	HDW	7.40	10.21	17.00	0.10	1.55	3.63	3.00	6	2.10

* In MgCaCO3/L
BH = Borehole S L == SAMPLE LOCATION
HDW = Hand-dug Well SS == SAMPLE SOURCE
ST = Stream
SEDIMENTAAY AREA ARE ODE-REMO, ISHARA-REMO AND IPARA-REMO WHILE THE BASEMENT PORTION IS FIDIWO.

Table 2. Summary of physical parameters

	Sample Location	Sample Source	TDS	pH	CD	TA	TH
1	ODE-REMO	BH	56	6.4	92	8	42
2	"	BH	23	6.38	34	12	12
3	"	BH	478	5.90	783	8	164
4	"	BH	42	5.82	68	12	28
5	ISHARA	ST	60	6.64	96	8	72
6	..	HDW	272	6.50	464	4	112
7	..	HDW	309	6.28	508	16	120
8	..	HDW	102	5.62	171	12	62
9	..	HDW	74	5.79	119	8	50
10	FIDIWO	HDW	343	7.11	560	6	146
11	..	HDW	260	7.62	429	4	104
12	..	ST	73	7.05	110	6	36
13	..	HDW	199	6.18	322	12	88
14	..	HDW	428	6.90	705	8	144
15	IPARA	BH	101	6.92	168	8	76
16	..	HDW	201	7.18	333	4	88
17	..	HDW	240	7.21	390	4	94
18	..	HDW	373	7.63	611	4	153
19	..	HDW	200	7.38	330	24	86

TDS – ppm; TDS = Total Dissolved Solids
Conductivity – umhas/cm; CD = Conductivity
Total acidity – MgCaCO3/L; TA = Total Acidity
Total hardness – MgCaCO3/L; TH = Total Hardness

SEDIMENTAAY AREA ARE ODE-REMO, ISHARA-REMO AND IPARA-REMO WHILE THE BASEMENT PORTION IS FIDIWO.

The concentration of calcium varies from 11.2 to 41.6 mg/l in water from the basement complex portion of the study area and 2.4 to 44.8 mg/l in the sedimentary portion with an average of 27.8 mg/l and 18.8mg/l respectively. Sodium concentration ranges from 2.7 to 15.9mg/l in water from the basement complex portion and 0.9 to 13.8 mg/l in sedimentary portion (average of 9.7mg/l and 6.3mg/l respectively). Concentration of magnesium range from 1.9 to 19.4mg/l and 1.5 to 22.8 mg/l for water from basement complex and sedimentary portion respectively. Bicarbonate concentration ranges between 20 to 65 mg/l (average 38.5 mg/l) and 6 to 36 mg/l (average 20.7 mg/l) for water from basement complex and sedimentary portion of the study area respectively. Chloride concentration varies between 5.3 to 25.9 mg/l (average 14.5mg/l) for water from basement complex and 3.0 to 27.8 mg/l (average 11.5mg/l) for water from sedimentary portion.

From the summary of the results (Tables 1 & 2), Calcium, Magnesium, Sodium, Bicarbonate, Silica and Chloride ions constitute the major ions while Sulphate, Iron, and Nitrate constitute the minor ions in most cases.

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Concentration of magnesium range from 1.9 to 19.4mg/l and 1.5 to 22.8 mg/l for water from basement complex and sedimentary portion respectively.

Bicarbonate and chloride are most dominant anions in the study area.

Bicarbonate concentration ranges between 20 to 65 mg/l (average 38.5 mg/l) and 6 to 36 mg/l (average 20.7 mg/l) for water from basement complex and sedimentary portion of the study area respectively. Chloride concentration varies between 5.3 to 25.9 mg/l (average

14.5mg/l) for water from basement complex and 3.0 to 27.8 mg/l (average 11.5mg/l) for water from sedimentary portion.

Conversely, Sulphate, Nitrate, Iron and silica ions are in trace amount in most cases.

Total hardness as should be expected reflects the trend in the concentration of calcium and magnesium with values ranging between 36 and 184 mg/l $CaCO_3$ (average 103.6 Mg $CaCO_3$/l) and 12 and 164 Mg $CaCO_3$/l (average 82.9 Mg $CaCO_3$/l for water from basement complex and sedimentary section respectively.

The specific electrical conductivity of 110 to 705 umhas/cm and 34 to umhas/cm and 34 to 783 umhas/cm were also recorded for water samples from the basement complex and sedimentary sections respectively with corresponding calculated Total Dissolved Solids (TDS) values of 73 to 428 mg/l (average 260.6 mg/l) and 23 to 478 mg/l (average 180.8mg/l).

Total.acidity ranging from 4-12 mg $CaCO_3$--/l (average 7.2 mg $CaCO_3$/l) for water samples from basement and 4 to 24 mg $CaCO_3$/ l for water samples from sedimentary sections of the study area.

Characterization of the groundwater

The concentrations of major ions in milli-equivalent per litre (Meq/l) were calculated and were used in plotting the Piper's trilinear in which the ions in milli-equivalent per litre are expressed in percentages of cations and anions Fig.3.

The overall chemical character as shown in the trilinear diagram is that of normal alkaline earth fresh water type (Ca-Mg) and subdivided into a, b, and c i.e. predominantly HCO_3^- water, predominantly HCO_3^- SO_4^{2-} and predominantly SO_4^{2-} water respectively. This water types are those whose chemistry is controlled by precipitation, dissociation of carbonic acid and to a lesser extent by weathering, dissolution, and Base Exchange.

Based on total hardness classification after Kunium (1972), majority of the sampled waters are soft to moderately soft while some are slightly /moderately hard based on the total dissolved solids (TDS) after Todd (1980), the sampled water in the study area can be classified as fresh water. All these are value are still within the permissible limit of WHO recommendation.

From the statistical correlation results, Calcium and Magnesium ions have high positive correlation (0.758 and 0.934) with total ion, conductivity, total dissolved solids and total hardness. This high correlation between Calcium and Magnesium shows that the total hardness of the water sample is primarily caused by Calcium and Magnesium. The results of statistical correlation of the surface water in the study area show positive correlation (0.984). These indicate that there is no significant difference in their physical and chemical parameters. All this may be attributed to the fact that surface water has very little time to interact with the bedrock unlike the percolating groundwater.

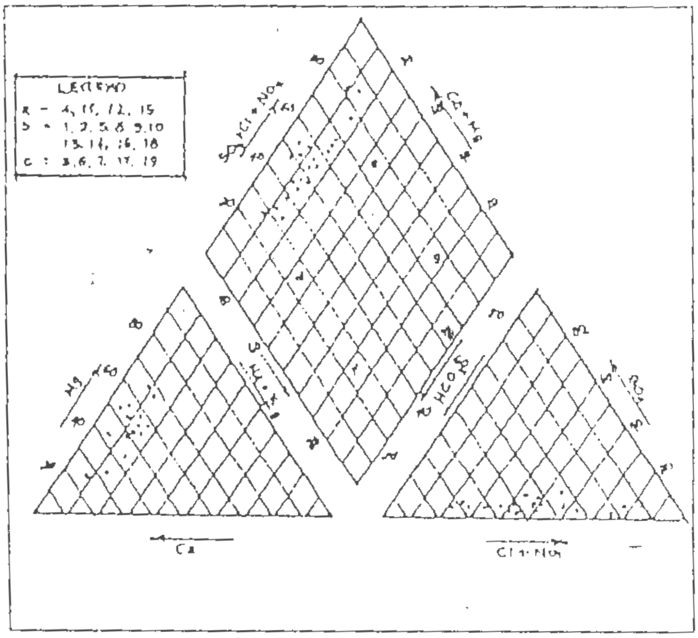

Fig. 3. Pipe trilinear diagram showing the chemical characters of the water resources in the study area.

Comparison of physical and chemical parameters of groundwater and surfacewater

A summary and comparison of some available results of chemical analysis of water obtained from the basement complex and sedimentary aquifers are presented in Table 3 and Fig 4.

Basement complex rocks in situ by aggressive Carbon (iv) oxide charged water and the relatively slow intra-aquifer flow rate resulting in longer rock-water interaction cause water in the basement aquifers to acquire more dissolved constituents. Comparatively, the sedimentary aquifers materials are mainly transported, reworked and secondary material with not as much constituents to be dissolved (Idowu and Ajayi, 1998). In the study area, the result obtained also indicate high TDS in basement complex area than that of sedimentary area, apart from Sulphate and Nitrate, all other parameters are higher in water from basement complex than those from sedimentary terrain. A similar results as obtained by (Idowu and Ajayi, 1998). Their work was aim at providing insight into the basic control of geology on the nature of groundwater occurrence in both basement and sedimentary environments of southwestern Nigeria. In their final results it was observed that apart from Silica and Nitrate, all other parameters tested for have higher concentration in water from basement complex than those from sedimentary area.

Table 3. Comparison of water chemistry parameters						
	BASEMENT COMPLEX			SEDIMENTARY TERRAIN		
PARAMETERS	RANGE	MEAN	STD	RANGE	MEAN	STD
Calcium	11.2-41.6	27.8	12.3	2.4-44.8	15.4	3.1
Magnesium	1.9-19.4	11.2	7.2	1.5-22.8	10.9	6.2
Sodium	2.7-15.9	9.7	5.0	0.9-13.8	6.2	4.5
Iron	0.1-0.7	0.3	0.2	0.1-0.9	0.3	0.2
Nitrate	2.6-4.3	3.6	0.7	2.9-8.2	5.3	2.2
Chlorine	5.3-25.9	14.4	7.6	3.0-27.8	11.9	7.6
Bicarbonate	20-65	38.6	17.9	6-36	19.2	8.6
Sulphate	1.8-1.9	1.8	0.1	1.0-2.1	1.9	0.1
pH	6.2-7.6	7.0	0.5	6.4-7.6	6.2	0.4
TDS	73-428	260.6	135.8	23-478	163.4	117.7
Conductivity	110-705	425.2	227.2	34-783	271.6	198
Total hardness	36-184	103.6	85	12-164	82.4	64

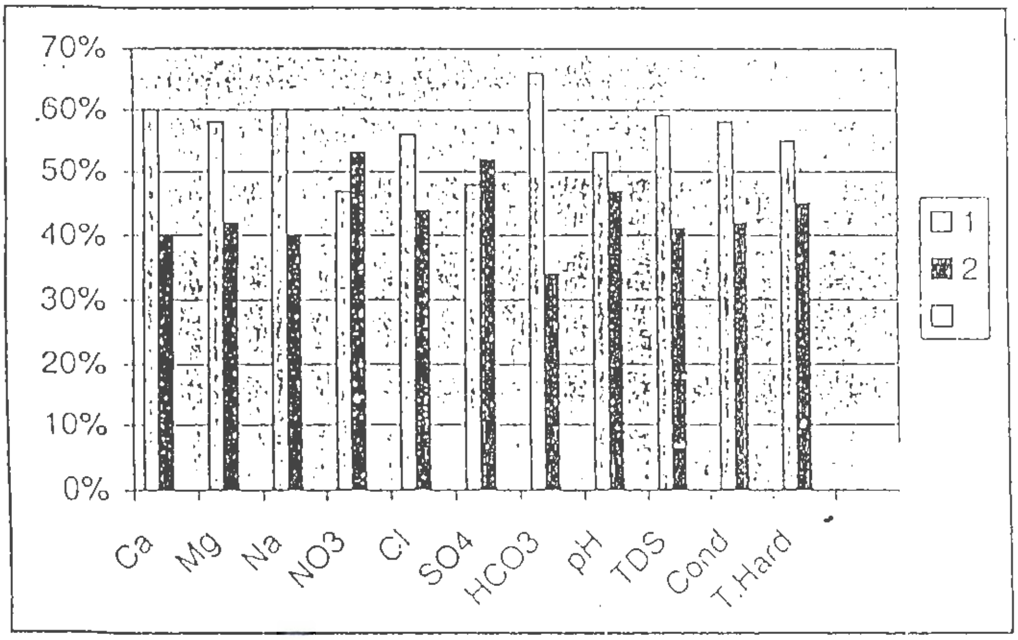

Fig. 4. Comparison of chemical and physical parameters of water samples from the study areas. 1 Basement complex 2 Sedimentary terrain

Conclusion and recommendation

The groundwater system in the area is essentially normal earth alkaline water (Ca-Mg) and predominantly of HCO_3^- water type HCO_3^- - SO_4^{2-} water type and SO_4^{2-} water type. The surface and ground water resources in the study area are suitable for domestic (drinking) purposes. This is due to the fact that the ionic concentrations fall within the permissible leval as compared with the World Health Organization (WHO) standard.

The correlation between Cl^- and NO_3^- is -0.081 (indirect and poor) while that between Cl^- and TDS is +0.822 (direct and good). These two results show that there is no visible pollution of the water resources in the study area (Ariyo, 2004).

The total ionic concentration is slightly higher in the water obtained from basement complex than that obtained from sedimentary terrain. This may be due to the mineralogical composition of the aquifers units. Finally, it can be concluded that there is a weak relation-' tween the geology of the area and the water chemis y of water sampled from the area.

The difference in aquifers material is re ected in the chemistry of the groundwater resources found in the study area. As such it can be concluded that there is a strong relationship between the geology of the area and the water chemistry found within the area.

It is recommended that bacteriological analysis be carried out in the study area to ascertain level of pollution of both the surface and underground water that cannot be detected /determined through their physical and chemical analysis in the study area.

Finally this research work has given baseline information on the physical and chemical properties of groundwater in the two different geological environments, which will help in groundwater exploration and exploitation in the nearest future in the study areas.

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