International Journal of
Science Inventions Today
www.ijsit.com
ISSN 2319-5436
Research Article

HYDROGEOCHEMICAL CHARACTERIZATION OF GROUNDWATER IN AKWA IBOM STATE, NIGERIA

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ABSTRACT

Detailed study of the physical and chemical quality analyses of groundwater samples was carried out in Akwa Ibom State in order to delineate aquifers for the drilling of productive boreholes and evaluate the groundwater quality. Detailed analysis of borehole lithologic samples shows a multi-aquifer system, with a sub-regional trend of upper unconfined aquifer and locally restricted subjacent second and third aquifers. The regionally extensive upper unconfined aquifer was logged across boreholes in Abak, Etim Ekpo, Etinan, Ibiono Ibom, Ikono, Ini, Itu, Nsit Atai, Nsit Ibom, Obot Akara, Okobo, Oron, Uruam and Uyo. The depth of this aquifer varies from 10 - 67 meters from coastal to central areas, and 22.5 - 120 meters towards the north.. Thirty two groundwater samples were analyzed for their physico–chemical and microbiological properties, using standard methods. The average temperature of groundwater samples is 27^{o}C. The water is slightly acidic to slightly alkaline with pH values ranging from 4.28 – 8.92. Electrical conductivity (EC) values range from 20.3 µs/cm to 343.1 µs/cm. Chloride contents in some boreholes are up to 31.30 mg/l, possibly indicating saltwater encroachment in those locations (Ibeno, Mbo, Onna and Udung Uko).. Total Dissolved Solids (TDS) range from 12.60 – 147 mg/l. Total Iron (Fe) values range from 0.01 - 8.5 mg/l. With the exception of Iron, all other analyzed parameters fall within World Health Organisation and Nigeria Standard for Drinking Water Quality permissible limits for potable water. Detailed interpretation of gross hydrogeochemical data suggest that the prevailing hydrogeochemical processes responsible for the groundwater chemistry are attributable to ion exchange, carbonate and silicate weathering, precipitation and dissolution from rocks, through which the water infiltrates.

INTRODUCTION

Globally, rural communities, particularly in developing nations including Nigeria, have as one of the major problems, the lack of adequate potable water supply for domestic use. This is the scenario in several areas, including Akwa Ibom State, because some of the existing water wells which initially produced water have either dried up, diminished in yield or produced non-potable water. The funds lost or wasted on such projects would have been properly utilised, if suitable drill sites or depths were recommended from detailed hydrogeological or geophysical studies.This is the rationale for this research study on Aquifer Delineation and Hydro-geochemistry.

There are several instances within various regional settings where water boreholes became unproductive soon after their installation. Within the Nigerian setting, available information indicates that there was inadequate consideration of existing borehole data to guide the drilling of the boreholes. Studies by Udom et al(1999) indicate high failure rate of over 70% of the boreholes drilled in Akwa Ibom State, Nigeria. It is well known that just as in the upstream petroleum sector, well data and site studies are a useful guide to any drilling operation in the water industry. As a result of these issues, many boreholes have been rendered redundant in the state. Arising from this, there have been issues of insufficient water supply in the state, thus resulting in the utilisation of surface waters for domestic water supply. This scenario increases human exposure to water borne diseases because of vulnerability of surface water to pollution.

Location of Study area: The location of study for this research project is AkwaIbom State. The state occupies part of the southeastern corner of Nigeria. It is located between latitudes $4^0$30'and $5^0$30' North and longitudes $7^0$30' and $8^0$20' East (Fig. 1). Akwa Ibom State is triangular in shape and covers a total land area of about 6,900 square kilometers, encompassing the Qua Iboe River Basin, the western part of the lower Cross River Basin and the eastern part of the Imo River Basin. The State has an ocean front which spans a distance of 129 kilometers from Ikot Abasi in the west to Oron in the southeast.

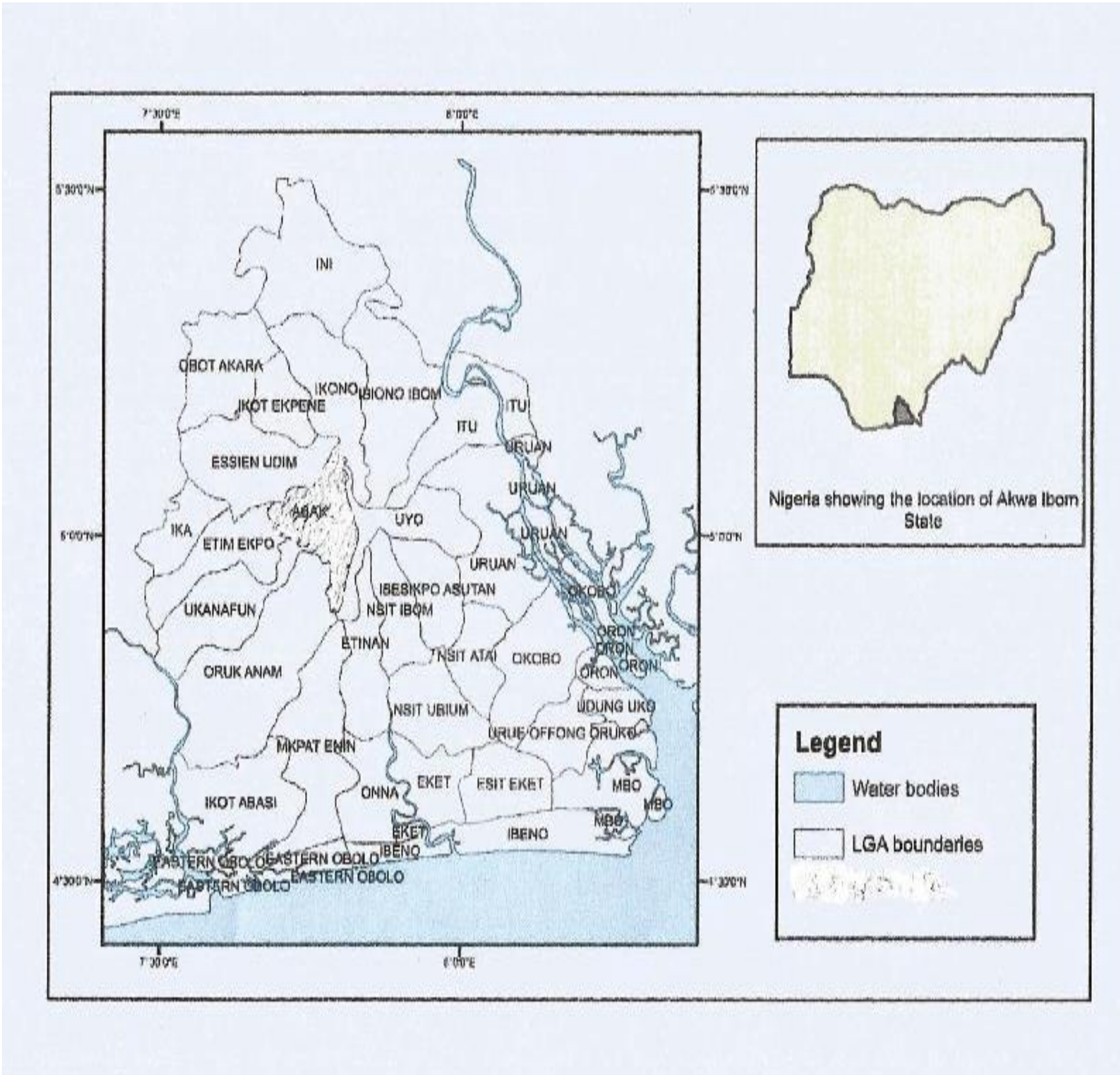

Figure 1: Map of Akwa Ibom State showing the 31 Local Government Areas (modified from FMEMV, 2013)

AIM AND OBJECTIVES OF THE STUDY

To study the physical and chemical water qualities of the groundwater within the area, to determine the dominant cations and anions and their influence on of the area, compare the results of the study with international specification (WHO Standard) in order to determine their suitability for domestic and industrial use

LITERATURE REVIEW

Amajor (1989) appraised groundwater exploitation and asserted that the number and kinds of aquifer, and the fresh/saline water interface is not precisely known. All these studies only cover some aspects of hydrogeochemistry and water supply problems. It is in view of this fact that Etu-Efetor and Akpokodje (1990) attempted a detailed stratigraphic analysis of the various geologic/geomorphological units and they identified a major regional aquifer. However, aquifer parameters and the water qualities of the various aquifers were not determined.

Amajor (1991) discussed the general aquifer characteristics in Rivers State as well as their depositional environment, but did not consider aspects of groundwater quality in the research.

Udom et al (1999, 2002), investigated the hydrogeochemistry of some groundwaters in parts of the Niger Delta and the results show that the water in these areas are soft and low in dissolved constituents (Fe, Zn, Ca, Mg, Na, and K) except Fe. Salt water encroachment is evidenced in these areas from geoelectrical studies (Etu-Efeotor et al., 1989; Oteri, 1990)..

Geology and Hydrogeology of the Study Area: The whole of Akwa lbom State is underlain by sedimentary formations of Late Tertiary and Holocene ages (Edet, 1993; Esu et al, 1999). Deposits of recent alluvium and beach ridge sands occur along the coast and the estuaries of the Imo River and Qua lboe River, and also along the flood-plains of creeks. Inland, a greater part of the state consists of coastal plain sands, now weathered into lateritic layers, especially in Ini, Ikono, Etinan, Ikot Ekpene, Ibiono and ltu LGAs. A belt of shales associated with sandstones and limestones, north of Nkari and Obotme, extends down to ltu. The latter lithologies include the late Cretaceous Nsukka Formation at the base followed by the early Tertiary Imo Shale and the phosphatic Ameke Formation. Upwards, the geologic succession passes imperceptibly into thick sequences of clays, sands and gravel (Udom, 2002).

METHODOLOGY

(i) Sampling:

Both fieldwork and laboratory analysis were utilized in this research. Thirty one (31) boreholes, one from each of the 31 Local Government Areas of Akwa Ibom State were analyzed for physico-chemical parameters. The essence was to provide a regional but detailed overview of the groundwater chemistry of the area. Various maps of the study area were obtained. Also, data in the form of lithologic logs and Static Water Level for each of the Local Government Areas within the entire study area were accessed and interpreted.

(ii) Data Collection and Analysis:

(a) Water Sample Collection: Groundwater samples were collected in the sterilized two- litre containers tightly fitting covers wrapped in black polyethylene plastic bags and put in a cooler to ensure constant temperature. The samples were immediately transported to the laboratory for analysis.

(b) Laboratory Analyses for Water Quality Parameters: All analyses were carried out at a standardized laboratory, using standard methods. The evaluation of water quality was in accordance with the regulatory standards set by the Federal Environmental protection Agency FEPA (1991). The approach ensures that the samples collected were tested in accordance with agreed requirements.

RESULTS AND DISCUSSION

Water samples from the thirty one (31) Local Government Areas of Akwa Ibom State were analyzed to determine their physicochemical characteristics. See Table 1 and 2

(A) PHYSICOCHEMICAL CHARACTERISTICS:

(i) Electrical Conductivity (ec): Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge).The average value of electrical conductivity in groundwater samples in the study area is of 161.6μS/cm, having its highest at 343.1μS/cm in Onna Local Government Area and lowest 20.3μS/cm in Eket Local Government Area.

SN	PARAMETERS	Ibesikpo Asutan	Ibiono Ibom	Ika	Ikono	Ikot Abasi	Ikot Ekpene	Ini	Itu	Statistical Data				Standards	
										Max	Min	Mean	Std.Dev	WHO (2006)	NSDWQ (2008)
1	Temperature (^oC)	28.4	28.9	29.1	26.7	29.8	25.0	29.4	25.0	29.8	25	27.9	**0.62**	-	ambient
2	pH	8	6.3	7.9	8	5.9	5.0	6.7	8.3	8.9	4.2	6.93	**0.58**	6.5-8.5	6.5 – 8.5
3	EC (us/cm)	207.7	213.4	209.6	216.9	160.2	202.4	163.7	125.5	343.1	20.3	161.68	**48.6**	500	1000
4	TDS (mg/l)	107.18	118.71	127.81	122.14	73.5	102.4	77.4	58.9	147	12.6	84.32	**1.75**	500	500
5	Hardness (mg/l)	101.7	107.85	107.64	101.7	67.4	108.9	83.3	86.0	249.4	1.04	82.18	**3.02**	500	500
6	Na^+ (mg/l	2.6	6.3	14.2	2.6	14.28	1.8	6.6	1.5	15.3	0.7	6.20	**2.4**	200	200
7	K^+(mg/l)	3.96	6.42	2.1	3.96	4.93	0.6	3.65	4.8	16.7	0.241	3.43	**4.8**	10	-
8	Ca^{2+} (mg/l)	26.3	26.2	22.6	26.3	13.4	25.6	16.8	33.4	33.4	1.6	15.18	**2.11**	75	75
9	Mg^{2+} (mg/l)	8.82	10.38	12.51	8.82	8.25	11.0	10.06	0.7	16.36	0.22	8.45	**1.9**	50	0.2
10	Cl^- (mg/l)	29.5	20.5	10.9	29.5	16.2	24.2	18.6	4.50	31.3	1.5	18.0	**1.75**	250	250
11	HCO_3^- (mg/l)	20.0	35	55	35	11.0	18.3	8.80	9.3	55	4	21.93	**2.5**	-	-
12	SO_4^{2-} (mg/l)	16.31	14.25	10.87	16.31	16.5	20.9	12.9	4.9	20.9	0	9.35	**2.23**	250	100
13	NO_3^- (mg/l)	4.05	3.62	2.63	4.05	2.85	0.94	4.51	1.24	4.63	0.45	2.34	**1.97**	50	50
14	Fe (mg/l)	1.39	1.60	1.60	1.39	4.00	0.36	1.20	1.04	8.5	0.01	1.83	**4.6**	0.3	0.3
15	Mn^{2+} (mg/l)	2.61	0.15	0.1	2.61	1.63	0.02	2.61	0.01	99.8	0	4.69	**2.0**	0.1	0.2
16	T.Coliform (cfu/ml)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3	0	0.17	**0.05**	-	10

Table 1: Major Ion Concentration Values in Groundwater from some of sampled Locations

Conductivity values are particularly important in water meant for irrigation (Todd, 1980). All the water from the sampled boreholes in the study area have EC values within permissible regulatory limits of the WHO (2006) and the NSDWQ (2008) which is 1400µS/cm.

(ii) Total dissolved solids: Total dissolved solids are a measure of the sum of organic and inorganic solutes in water. The TDS concentration ranges from 12.6mg/l to 147.0mg/l and has an average value of 84.32mg/l within the study area. This shows that groundwater in the area is fresh in most of the locations. The TDS values correlate well with conductivity values. The highest TDS values of 147mg/l and 138.2mg/l were recorded in Etim Ekpo and Onna Local Government Areas, respectively. These areas with the highest Total Dissolved Solids values show corresponding highest Electronic Conductivity values. The WHO (2006) and the NSDWQ (2008) permissible limits for TDS is 500mg/l for potable drinking water. Thus, from results obtained the groundwater samples are potable with respect to TDS. According to Richards (1954), more that 1000mg/l TDS is good for dying textiles and the manufacture of pulp, paper, plastics and rayon.

S/N	Parameters	Average	Maximum	Minimum	WHO (2006)	NSDWQ (2008)
1.	**Temperature (^{0}C)**	27.9	29.8	25	-	ambient
2.	**pH**	6.93	8.9	4.2	6.5-8.5	6.5 – 8.5
3.	**EC (us/cm)**	161.68	343.1	20.3	500	1000
4.	**TDS (mg/l)**	84.32	147	12.6	500	500
5.	**Hardness (mg/l)**	82.18	249.4	1.04	500	500
6.	**Na^+(mg/l)**	6.20	15.3	0.7	200	200
7.	**K^+(mg/l)**	3.43	16.7	0.241	10	-
8.	**Ca^{2+}(mg/l)**	15.18	33.4	1.6	75	75
9.	**Mg^{2+} (mg/l)**	8.45	16.36	0.22	50	0.2
10.	**Cl^-(mg/l)**	18.0	31.3	1.5	250	250
11.	**HCO_3^-(mg/l)**	21.93	55	4	-	-
12.	**SO_4^{2-} (mg/l)**	9.35	20.9	0	250	100
13.	**NO_3- (mg/l)**	2.34	4.63	0.45	50	50
14.	**Fe (mg/l)**	1.83	8.5	0.01	0.3	0.3
15.	**M_n^{2+} (mg/l)**	4.69	99.8	0	0.1	0.2
16.	**T.Coliform (cfu/ml)**	0.17	3	0	-	10

Table 2: Statistical Analysis of Values of Analyzed Parameters Averaged Over the Study Locations.

(iii) $_P$H: The pH (hydrogen-ion concentration) of a solution is used to express the intensity of acidity or alkalinity conditions of that solution. The pH scale ranges from 0-14, values below 7 indicate levels of increased acidity as the value reduces. Increasing values from 7-14 show increase alkalinity. A solution that shows a value of 7 at 25^{0}C represents absolute neutrality. The pH values in the study area range from 4.2 to 8.9, indicating that the groundwater in some areas are weakly acidic to very slightly alkaline..

(iv)Temperature: Groundwater temperature is a physical parameter which is widely used in hydrogeophysical investigation. The range for the groundwater temperature in the study area lies between

25^0C and 29.8^0C with a mean temperature of 27.9^0C. However, The WHO (2006) and the NSDWQ (2008) present no standard value for potable groundwater temperature. Groundwater temperatures have been used to determine forms of heat transport in karst aquifers (Bundschuh, 1993; Liedl and Sauter, 1998). Distribution of temperatures within the study area are approximately the same (figure 2).

(v) Iron: The WHO (2006) and the NSDWQ (2008) have permissible limit for iron in portable drinking water as 0.3mg/l. However, majority of the wells in the area of study show higher concentration values for iron**.** The concentration values ranges from 0.01 – 8.5mg/l with a mean value 1.8 mg/l. Exposure of water samples to air could cause ferrous (Fe^{2+}) ion in them to oxidize to ferric (Fe^{3+}) ion which would precipitate a ferric-hydroxide which stains laundry, plumbing fixtures and cooking utensils (Udom et al, 1999). High iron concentration in groundwater poses potential hazards for many industrial processes such as high pressure boiler feed water, process water, fabric dying, paper making, brewery, distillery, photographic film manufacture, ice making and food processing which require water that is almost completely iron free (ASTM, 1969

(vi) SODIUM (Na): The ranges of sodium concentration values for groundwater samples from the various study locations lie between 15.3mg/l to 0.7mg/l (Table 4.3).The WHO (2006) and the NSDWQ (2008) permissible limit for sodium in portable drinking water is 200mg/l. This indicates the portability of groundwater in the study area, based on the consideration of this parameter.

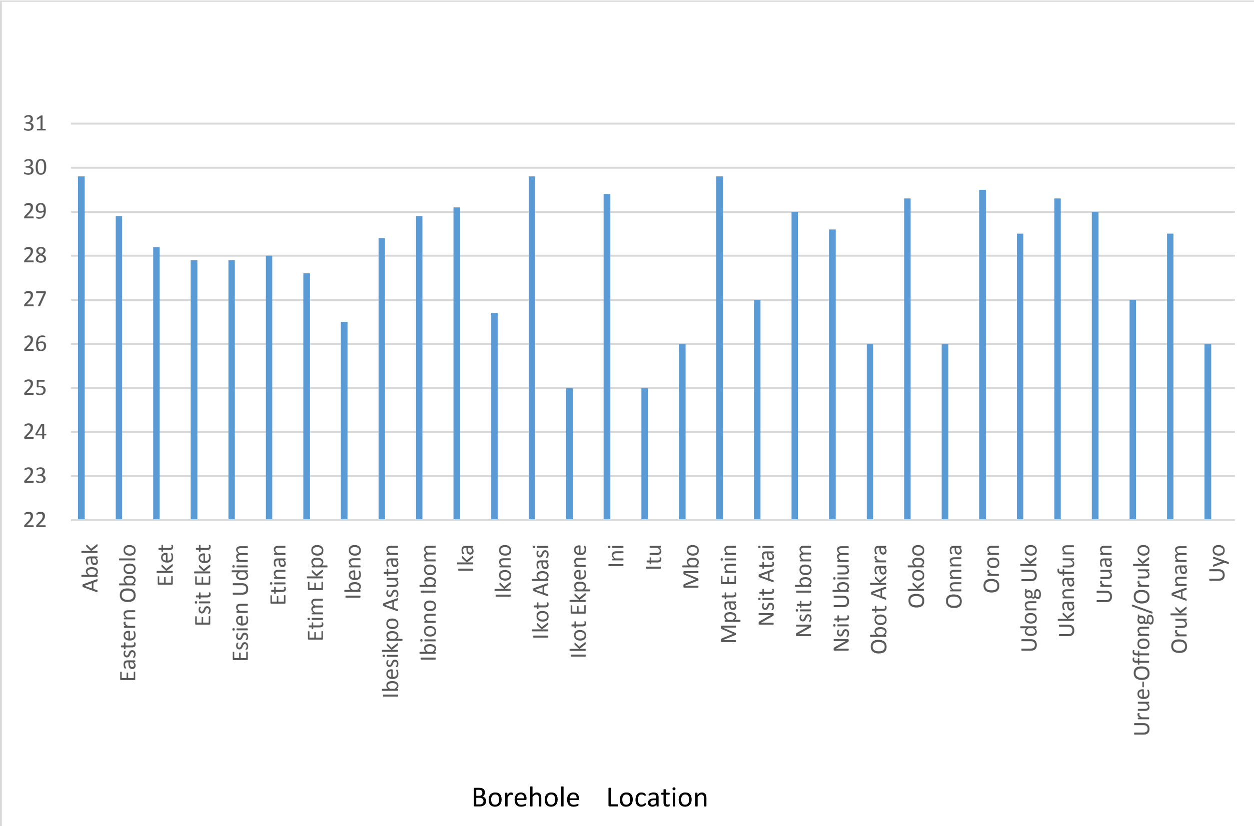

Figure 2: Overall Groundwater Temperatures of Study Area

(vii) Hardness: Hard water is generally considered as water containing large quantities of dissolved salts, for example, calcium and magnesium ions. Groundwater hardness in the area of study lies between a range of 249.4mg/l and 1.04mg/l. The values are within the permissible limits of the WHO (2006) and the NSDWQ (2008) which is 500mg/l for potable water.. Most of the water in the study area is within soft to moderately hard, except for Etim Ekpo (169.52 mg/l) and Onna (249.4 mg/l), which fall within classification of hard. High levels of calcium and magnesium account for hardness at these few locations.

(B) HYDROCHEMICAL FACIES:

The diagnostic chemical character of water solutions in hydro systems has been determined with the application of the concept of hydrochemical facies (Back, 1966). This Approach enables convenient subdivision of water compositions by identifiable categories and reflects the effect of chemical processes occurring between the minerals within the subsurface rock units and the groundwater.

Hydrogeochemical spatial display diagrams, such as Piper, Schoeller and Stiff diagrams (Figs. 3 and 4) are used to recreate the scenario into hydrochemical processes operating in the groundwater system within the area of study. The Piper diagram (figure 3) shows the relative concentrations of the different ions from the individual samples based on average values for each location. The Piper diagram was used to characterize the various water types within the area of study. It also permits the cations and anion compositions of characterizing the various groundwater types within the area. It permits the cation and anion compositions of many samples to be represented on a single graph in which major grouping or trends in the data can be discerned visually (Freeze and Cherry, 1979).

Piper diagram for the study area shows that there is a mixture of two types of water with variable concentration of major ions. These are Ca-Mg-Cl-SO_4 type and Na-K-Cl-SO_4 water types. The second is influenced by NO_3 (Fig. 4)

The Schoeller Logarithmic plots (figure 4) (major ion distribution for cations and anions) of data further confirmed this water type. The peaks indicate the dominant ions in the water samples while the troughs indicate the less dominant ions. In this study, the dominant ions are Ca, Mg for cations and Cl, HCO_3 for anions.

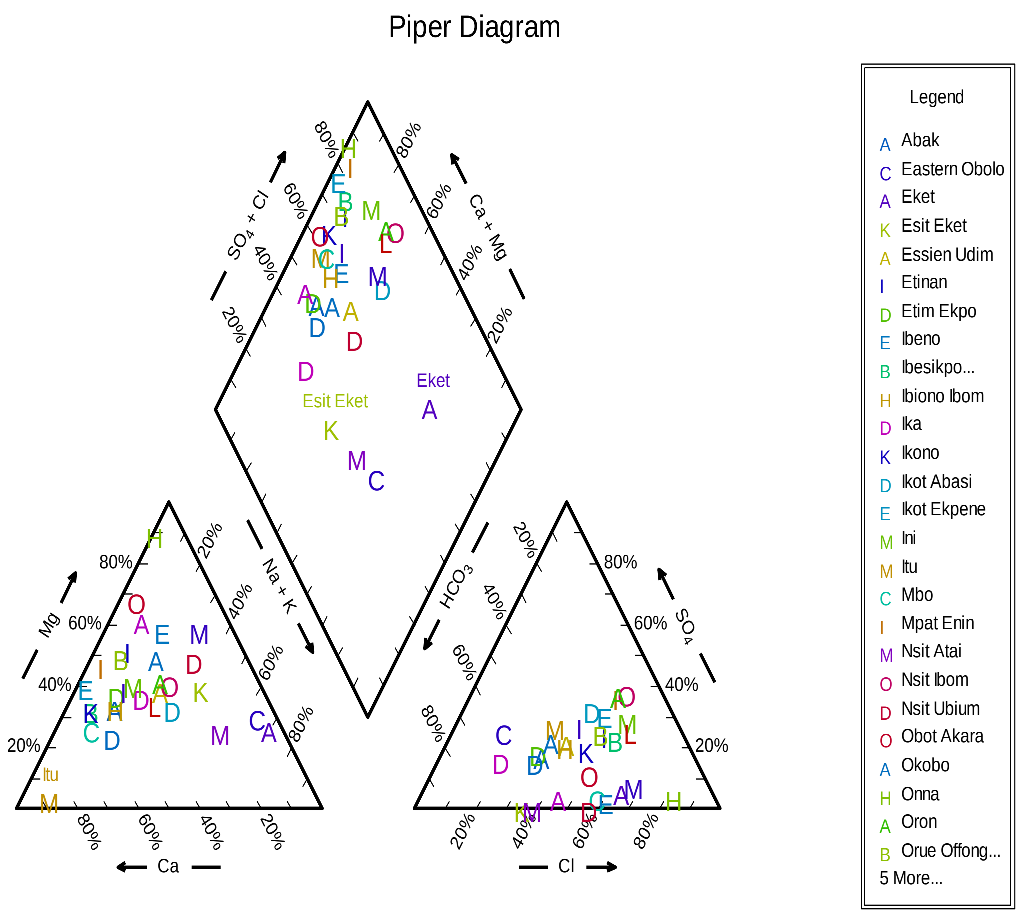

Figure 3: Piper Diagram of Study Area

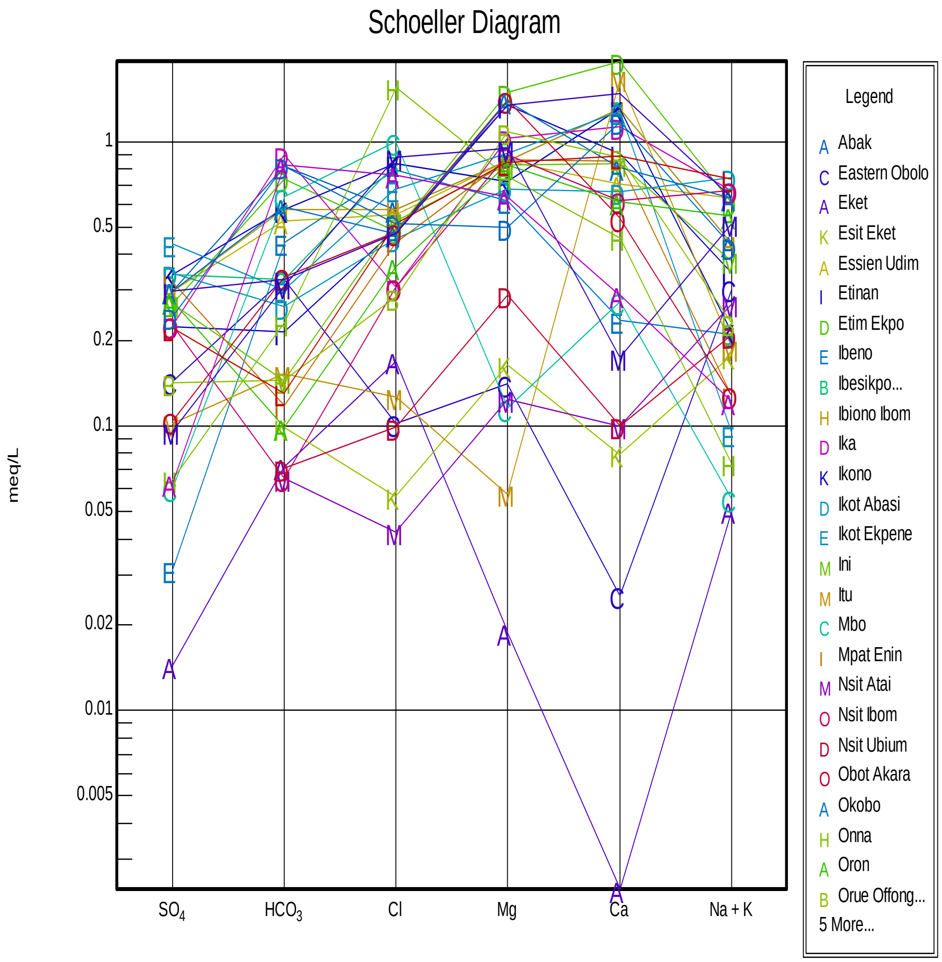

Figure 4: Schoeller diagram showing ionic distribution for major cations and anions

(C) CATIONS AND ANIONS DISTRIBUTION:

The concentration levels of the cations (Na^+, K^+,Ca^{2+}, and Mg^{2+}) and anions (HCO_3^-, NO_3^-,SO_4^{2-} and Cl^-) in the groundwater system are presented in Tables 2. With the exception of SO_4^{2-} and CI^- concentrations, with maximum values in some boreholes, others are generally less than the WHO (2006) recommended limits for domestic applications. From the stiff diagrams all the plots show lower cations than anions, indicating the abundance /enrichment of anions.

Hydro-geochemical studies have been aimed at determining and differentiating the potential sources of salinization. The hydrochemical evidence as shown in this study suggests further that the saline water bodies themselves are sourced from mixing both recent and past seawater intrusion of the aquifers of the area. This means that the hydro-geochemistry of the aquifer is the result of interplay between various natural and anthropogenic processes. An especially useful indicator of groundwater ages for the saline components is provided by the dissolved SO_4/Cl ratios, increased values reflecting longer residence time and thus greater rock-water interaction.

The physico-chemical characteristics of the groundwater in the study area generally reflect a situation of salinization that is associated principally with marine intrusion. This can be appreciated from the Stiff diagrams nevertheless, some deviations from this simple scheme occur. These deviations can be significant and reveal some interesting hydro- geochemical and hydrodynamic aspects.

Groundwater contamination by chloride can also result from other means than by seawater intrusion. Hem (1985) suggested that seawater intrusion into coastal aquifers may also be indicated by sulphate ionic proportions similar to that in seawater, and by low Ca and Mg concentrations. Industrial activities and urbanization can alter groundwater chemistry as reported by Knuth et al. (1989) which presents an integrated approach involving hydrogeological, geochemical, and geophysical methods to determine the source of salinity contaminating a groundwater supply in the area.

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