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Research Article

PORTABILITY AND HYDROGEOCHEMICAL STUDY OF GROUND WATER IN AKWA IBOM STATE, NIGERIA

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ABSTRACT

Aquifer delineation and hydrogeochemicalcharacterization of groundwater resources in Akwa Ibom State was carried out in order to delineate aquifers for the drilling of productive boreholesand 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. 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). Microbial analysis indicates the presence of coliform bacteria in some of the samples (Esit Eket, Onna, and Urue-Offong/Oruko), which may be indicative of anthropogenic contamination. 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 and coliform values in borehole water samples in some locations, all other analyzed parameters fall within World Health Organisation and Nigeria Standard for Drinking Water Quality permissible limits for potable water. Both Piper trilinear and Stiff pattern diagrams were used to determine groundwater types and visualize groundwater chemistry trends. Compositionally, the trends indicate groundwatercomprising mainly of mixtures of alkaline earth and alkali metal types. Detailed interpretation of gross for the groundwater

chemistry are attributable to ion exchange, carbonate and silicate weathering, precipitation and dissolution from rocks, through which the water infiltrates. The study provides an applicable scenario in hydrogeochemical evaluation and aquifer delineation towards sustainable groundwater management in the study area

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.

As further background to this research, a lot of studies have shown that increase in groundwater abstraction in coastal areas is largely responsible for the encroachment of seawater into coastal groundwater aquifers (Edet and Okereke, 2001; Udom et al, 1999, 2002). According to Edet andOkereke (2001), the southern part of AkwaIbom State, which contributes more than 30% of Nigeria's crude oil is presently experiencing an increase in human and industrialisation levels. This has resulted in an increase in the rate of potable water abstraction, with potential impact on groundwater quality, including saltwater encroachment in the coastal areas.

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.

(A) 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. 1.1). Akwa Ibom State is triangular in shape and covers a total land area of about 6,900 squarekilometers, 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.

(B) AIM AND OBJECTIVES OF THE STUDY: The aim of the study is to systematically generate applicable hydrogeological data, including hydrogeochemical and lithological, from parts of Akwa Ibom State, and use same to delineateand assess aquifers for proper development of groundwater resources in the state.

Directly deriving from the aim of the study, the specific objectives of this research are:

- To use borehole data to delineate the aquifers in the study area.
- To determine local groundwater flow direction
- To evaluate the hydrogeochemical characteristics of groundwater in Akwa Ibom State with a view to assessing its suitability with internationally accepted standards for specific uses.

LITERATURE REVIEW

Several research has been done on water quality status of groundwater in the study area, although several studies have shown effects of increase in human and industrial activities in the Niger Delta (Odigi, 1989; Amadi and Amadi, 1990; Udom, 2004). Uzoukwu (1981) reviewed the importance of groundwater in Nigeria and highlighted inadequate supply of potable water as the main factor limiting human and economic activities in many parts of Nigeria, particularly in the eastern Niger Delta. Etu-Efeotor and Odigi (1983) discussed the groundwater quality problems of the eastern Niger Delta. This was an expansion of the findings of Etu-Efeotor (1981) on the groundwater hydrogeochemistry in parts of the Niger Delta.

Amajor (1986), outlined the general geochemical characteristics of groundwater in parts of the Niger Delta, and stressed the high iron and chloride concentrations in some localities. Oteri (1988) interpreted oil well logs in terms of water quality, and mapped the freshwater/saline water distribution in aquifers of the eastern Niger Delta.

Amadi and Amadi (1990) in their assessment of the hydrogeochemistry of groundwater in various parts of the Niger Delta concluded that the geochemical characteristics of the groundwater are closely related to the peculiar geologic and hydrologic conditions that prevail in the Niger Delta. They noted that the freshwater aquifers in the Niger Delta occur in three zones: the Northern zone of shallow aquifers generally less than 100m deep, characterized by continental deposit; Transitional zone of marine and continental deposits, located southwards towards the coast; and a third aquifer zone that occurs within the sand bars and beaches of the coastal areas and at depths greater or equal to 200m.

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).

Edet and Okereke (2001) presented a scheme for detection and monitoring of seawater intrusion in the Tertiary – Quaternary aquifer systems of the coastal Akwa Ibom State,

HYDROGEOLOGY OF THE STUDY AREA: The Benin Formation forms the main aquifer system in the Niger Delta, with a total thickness of 1892m (6000ft) around Warri. The lithologic composition is mainly (90%) sands and sandstones (Offodile, 1979). The remaining percentage is made up of clay and lignite beds that are hardly continuous over any significant distance, occurring mostly in lenses. The major source of recharge to this large aquifer system is from rainfall, while discharge sources include interflow and baseflow to the river systems and abstraction through boreholes from the basin (Offodile, 1979).

The dominant freshwater aquifer is found within the Benin Formation which consists mostly of continental sands with clay and silt.These materials are believed to have been deposited in a continental fluviatile to deltaic environment. The clay units have variable thickness ranging from 1m to as much as 15m in some places. The sand and clay intercalations give rise to a multi aquifer system, characteristic of the Niger Delta (Etu-Efeotor and Odigi, 1983; Amajor, 1989).

Etu-Efeotor (1981) delineated three (3) main aquifer zones in the Niger Delta (upper, middle and lower zones). The aquifer of the upper zone are made up of sand, gravels and clay materials. They are encountered at shallow depth of about 60m. The yield of the aquifer is high. The middle zone comprises of the mangrove and fresh swamps. There is a common occurrence of clay lenses within the aquifers of this region and the aquifers occur at lower depth. In the mangrove swamp zone, marine conditions prevail; thick lenses of marine clays are enclosed. Saline conditions characterize this zone due to the influence of the deltaic front. Within the sand bars and beaches of the lower region, boreholes must be deep in order to reach good freshwater aquifers.

Aquifers frequencies have been used to delineate the different units within the multi-layered aquifer system of the Niger Delta (Etu-Efeotor and Akpokodje, 1990; Akpokodje et al, 1996).The variations in frequency of aquifers with depth shows that all the aquifers are generally overlain by sands/silt clay or clay at their respective surfaces, with the exception of coastal beach islands. The stratigraphic sequences of the Niger Delta Basin with aquifer prospectivety are shown in Table 2.4.

A thick clay layer below overlies the regional aquifer. The thick clay layer below the perched aquifer is partially continuous laterally, and therefore, constitutes a semi-confining aquitard with very small pressure head (0.6m above the base of clay).

Ngah (1990) identified three (3) aquiferous zones in the Niger Delta, namely:

- An upper unconfined aquifer extending throughout the Benin Formation with its thickness ranging between 15- 80m, while the static water level varies between 4- 21m.
- A middle aquifer system, semi-confined and consisting of thick medium to coarse grained pebbly

sands with thick clay lenses. Its thickness varies between 30-60m.

- A lower aquifer system that extends from 220-300m and consists of coarse grained sands and some gravels with some interlayer clay.

The majority of the groundwater supply wells abstract water from the first and second aquifers (>150m deep). The water table are affected by climate, rainfall and drainage conditions. In the unconfined aquifer, the water table increases and falls during the dry season (Esu et al, 1999; Udom, 2004

METHODOLOGY

(i) Sample Collection: A detailed field sampling exercise was carried out. This is a very important step in collecting analytical samples. The groundwater samples were collected observing globally accepted sampling protocols to maintain sample integrity. Samples were collected after allowing the water from the source run to for at least five (5) minutes. This was to ensure collection of representative samples. Samples were collected in three (3) labeled, well drained plastic containers, tightly corked. The choice of plastic containers is to minimize contamination that could alter the water constituents. The first container was 250ml for microbial test. The second (1 litre container) was acidified with two (2) drops of concentrated Nitric acid (HNO_3) for cations determination, in order to homogenize and prevent absorption/adsorption of metals to the wall of the plastic container. Acidification equally stops most bacterial growth, inhibits oxidation reactions and precipitation of cations. The third plastic container (1litre) was used for anion determination. These samples were preserved in coolers to keep the temperature below 20^0C for eventual transfer to the laboratory for analysis within the standard period of twenty four (24) hours.

(ii) Data Collection: Data collation and collection involved compilation of requisite data including maps, lithologic logs, borehole data, Static Water Levels. Most of these data were obtained from privately owned producing boreholes, Akwa Ibom State Rural Water and Sanitation Agency (AK-RUWATSAN) and Akwa Ibom State Water Corporation (AKSWC)

(iii) Laboratory Analyses: The analysis of physico-chemical parameters was done at POCEMA Laboratory (Port Harcourt), Anal Concept Laboratory, Port Harcourt and University of Port Harcourt laboratories using standard techniques. The analytical methods used in the determination of water chemistry are in accordance with the American Standard for Testing Materials (ASTM, 1969) and American Public Health Association (APHA, 1992) standards and procedures (Table 1).\\

Parameters	Measurement Method	Standard
Temperature	Mercury –in glass thermometer	-
Colour	LovibondNessleriser comparator	-
EC	Electrical Resistivity tester	APHA 2510B
pH and Eh	Hanna HI 8314 membrane meter	APAH 4500H
Turbidity	HACH 2100AN Turdidimeter	APHA 2130B
Total hardness	Titration Method	APHA 2340-B
Chloride	Sliver Nitrate Titration	ASTM 512-B
Biocarbonate	Phenolphthalein Alkalinity Method	APHA 2302-B
Nitrate	Ultraviolet Spectrophotometer Screening Method	ASTM 4500-NO_3B
Sulphate	Turbidimetric Method	ASTM S-516
Phosphate	Ascorbic acid Method	APHA 4500-PE
Magnesium	Direct Atomic Absorption	ASTM D511-93
Calcium	Direct Atomic Absorption	ASTM D511-93
Manganese	Direct Atomic Absorption	ASTM D858
Iron	Direct Atomic Absorption	ASTM D1068
Potassium	Direct Atomic Absorption	ASTM D4192-97

Table 1: Methods used for the Hydrogeochemical Analysis of Groundwater Samples.

PRESENTATION OF RESULTS

(a) DATA ANALYSES: The laboratory results obtained in the study are compared with WHO (2006) and NSDWQ (2008) (Table 3). The results presented for each parameter per study location is the mean value for the locations .The statistically analyzed values showing the range in values and the mean values for each parameter averages for all the study locations are presented in Table 3

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 2: Major Ion Concertration Values in Groundwater from Sample Locations in Ibesikpo/Asutan, Ibiono Ibom, Ika, Ikono, Ikot Abasi, Ikot Ekpene, Ini and Itu LGA's

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

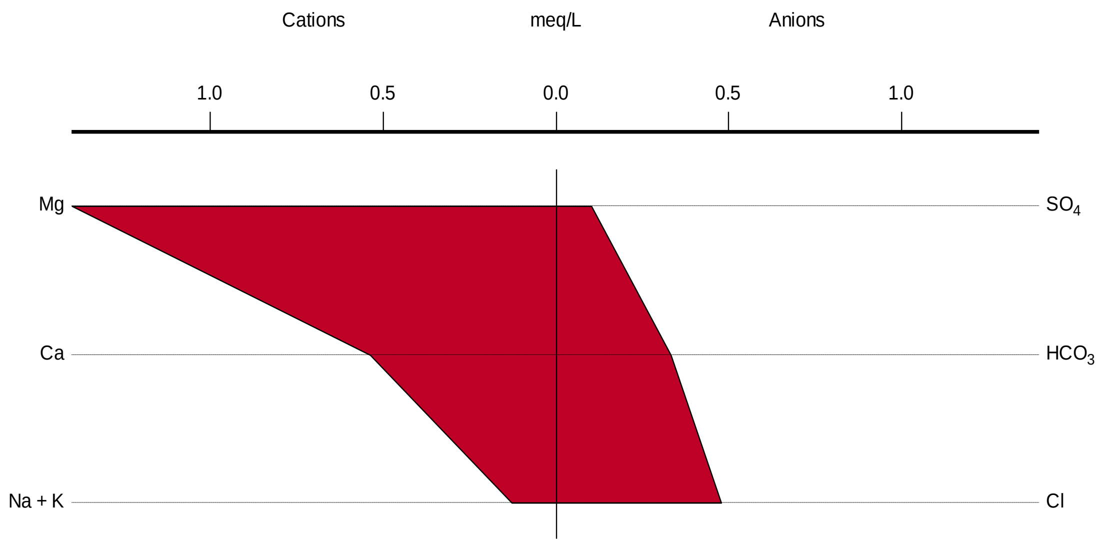

Figure 1: Stiff Diagram for Obot Akara Local Government Area

(b) Cations and Anions distribution: The relationship between various ionic ratios in the groundwater system are presented in Tables 4 and figure 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 (See figure 1) all the plots show lower cations than anions, indicating the abundance /enrichment of anions.

LGA	HCO_3/Cl	Na/Ca	Na/Cl	Ca/Cl	Mg/Cl	K/Cl	SO4/Cl	Mg/Ca	Ca/SO_4	Ca/HCO_3
Abak	2.44	0.24	0.31	1.28	0.51	0.31	0.70	0.40	1.84	0.52
Eastern Obolo	5.56	11.13	1.56	0.14	0.48	0.64	1.91	3.37	0.07	0.03
Eket	0.73	21.77	0.17	0.01	0.04	0.04	0.11	4.83	0.07	0.01
Esit Eket	3.00	1.91	1.53	0.80	1.00	0.85	0.00	1.25	0.00	0.27
Essien Udim	1.63	0.79	0.57	0.72	0.53	0.28	0.73	0.73	0.99	0.44
Etinan	0.75	0.36	0.38	1.06	0.95	0.14	0.62	0.90	1.70	1.40
Etim Ekpo	2.62	0.89	0.64	0.72	0.47	0.29	0.75	0.66	0.96	0.27
Ibeno	0.96	0.57	0.10	0.17	0.27	0.13	0.05	1.60	3.13	0.17
Ibesikpo Asutan	0.68	0.10	0.09	0.89	0.30	0.13	0.55	0.34	1.61	1.32
Ibiono Ibom	1.71	0.24	0.31	1.28	0.51	0.31	0.70	0.40	1.84	0.75
Ika	5.05	0.63	1.30	2.07	1.15	0.19	0.99	0.55	2.08	0.41
Ikono	1.19	0.10	0.09	0.89	0.30	0.13	0.55	0.34	1.61	0.55
Ikot Abasi	0.68	1.07	0.88	0.83	0.51	0.30	1.02	0.62	0.81	1.22
Ikot Ekpene	0.76	0.07	0.07	1.06	0.45	0.02	0.86	0.43	1.22	1.40
Ini	0.47	0.39	0.35	0.90	0.54	0.20	0.69	0.60	1.30	1.91
Itu	2.07	0.04	0.33	7.42	0.16	1.07	1.09	0.02	6.82	3.59
Mbo	1.10	0.20	0.03	0.16	0.04	0.01	0.08	0.25	1.90	0.14
Mkpat Enin	0.46	0.04	0.04	1.09	0.66	0.24	0.98	0.61	1.11	2.39

Nsit Atai	2.67	2.13	3.41	1.60	1.33	1.20	0.00	0.83	0.00	0.60
Nsit Ibom	0.37	0.63	1.30	2.07	1.15	0.19	0.99	0.55	2.08	5.65
Nsit Ubium	1.24	1.63	1.11	0.69	0.57	0.43	0.00	0.83	0.00	0.55
Obot Akara	1.20	0.10	0.15	1.58	0.64	0.04	0.29	0.40	5.36	1.31
Okobo	2.14	0.43	0.76	1.76	0.97	0.18	0.85	0.55	2.07	0.82
Onna	0.25	0.09	0.03	0.27	0.17	0.01	0.06	0.62	4.81	1.06
Oron	0.39	0.83	0.80	0.96	0.78	0.32	1.03	0.81	0.93	2.46
Udung Uko	0.61	0.57	0.06	0.11	0.37	0.53	0.15	3.29	0.76	0.18
Ukanafun	2.75	0.33	0.42	1.29	0.33	0.20	0.64	0.26	2.02	0.47
Uruan	1.86	0.21	0.04	0.21	0.29	0.10	0.11	1.34	1.93	0.12
Urue Offong - Oruko	0.88	0.22	0.40	1.78	1.31	0.23	0.68	0.74	2.61	2.02
Oruk Anam	0.44	0.86	0.84	0.98	0.56	0.16	0.58	0.58	1.67	2.23
Uyo	1.19	0.43	0.76	1.76	0.97	0.18	0.85	0.55	2.07	1.48

Table 4: Relationship Between Various Ionic Ratios Of Groundwater In The Study Area

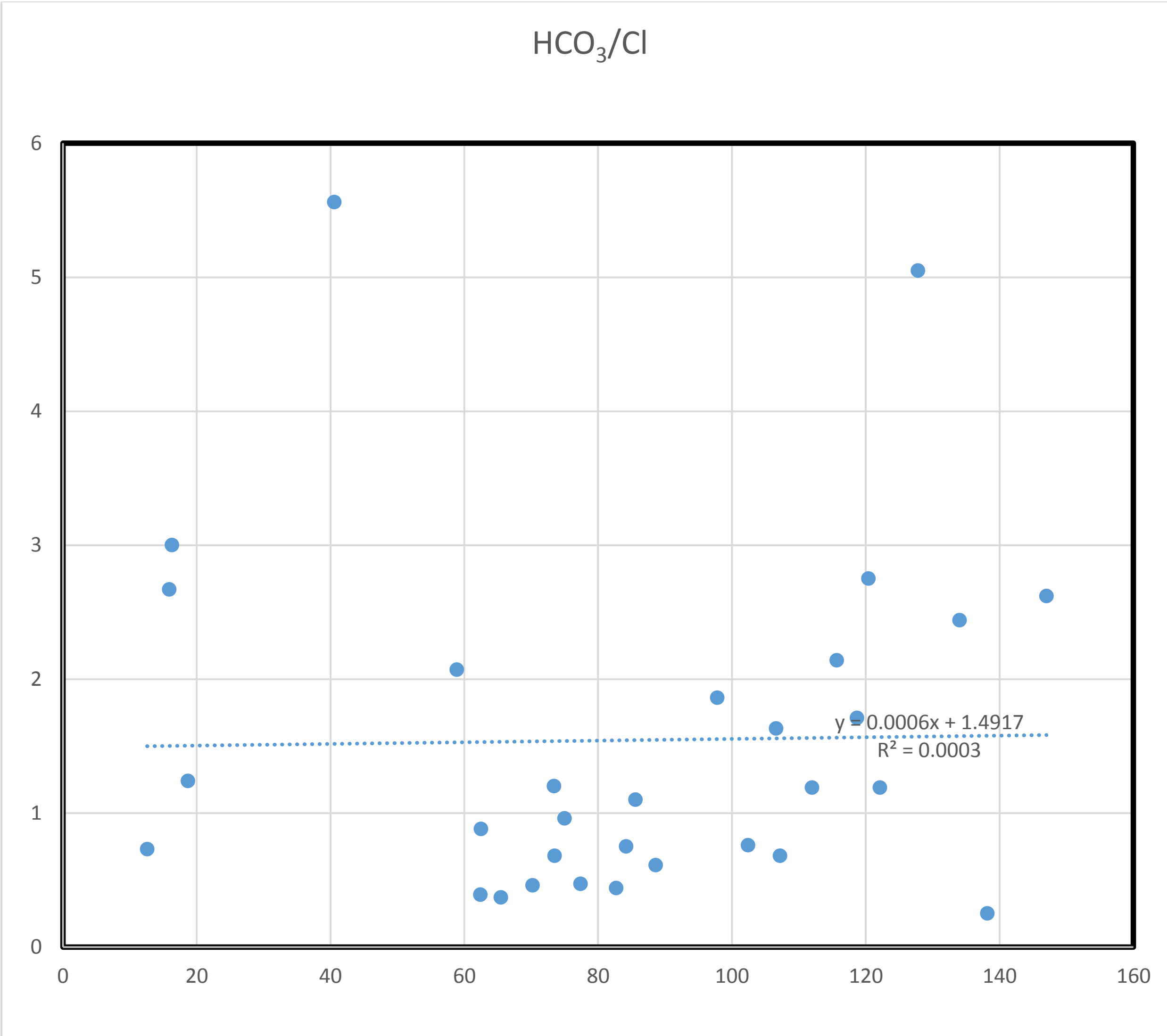

Figure 2: Ionic Ratio of HCO_3/Cl against TDS

DISCUSSION OF RESULT

Aquifer delineation and evaluation of hydrochemical characteristics of groundwater in Akwa Ibom State, Nigeria was carried out to ascertain the quality of groundwater and its suitability for domestic use and related applications.

The results of physico-chemical parameters show the following ranges: T (25.00-29.80^{0}C) with a mean of 27.92^{0}C, pH (3.84-7.72) with a mean of 6.93, EC (20.30-343.1µS/cm) with a mean of 161.68µs/cm, TDS (12.60-147.00.00mg/1) with a mean of 84.32mg/1, Hardness (1.04-249.40g/1) with a mean 82.18mg/1, CI (1.50 -31.30mg/1) with a mean of 18.00mg/1, SO_4^{2-} (0.00-20.90mg/1) with a mean of 9.35mg/1, Fe (0.01-

8.50mg/1) with a mean of 1.83, NO_3^- (0.45-4.63mg/1) with a mean of 2.34mg/1, Ca^{2+} (1.60-33.40mg/1) with a mean of 15.18mg/1, Na^+(0.7-15.3mg/1) with a mean of 6.20mg/1,Mg^{2+} (0.22-16.36mg/1) with a mean of 8.45, K^+ (0.24-16.70mg/1) with a mean of 3.43mg/1, Mn_2^+ (0.00-99.80mg/1) with a mean of 4.69mg/1, HCO_3- (4.00-55.00mg/1) with a mean of 21.93mg/1, and T. Coliform (0.00-3.00cfu/m1) with a mean value of 0.17cfu/ml.

The results show that the pH values of the groundwater in the study area ranges from slightly acidic to slightly basic. At locations where pH values are less than 6.50, the water should be treated to raise the value to the acceptable WHO standard of 6.50-8.50, the treatment may base on an exchange method with dolomite which is suitable for treating the parameter. Acidic groundwaters are aggressive, hence boreholes in the area should be constructed with PVC pipes and other non-corrosive materials. This is imperative because if pH and iron are treated for at location where they exceed their limits, the water will be potable and suitable for drinking and other domestic purposes. Regular flushing of boreholes and distribution systems can help remove buildup of ferruginous material deposits. For agricultural purposes, the water is suitable in view of the low Sodium Adsorption Ratio (SAR) values.

The study also reveals saltwater contamination in the area as chloride contents in some boreholes are up to 40mg/l, (31.30mg/l) which also agrees with Amadi (2004) who reported a chloride concentration of 72.306mg/1, using the specification of Tremblay et al., (1973). This shows saltwater encroachment at those locations. This is probably due to the closeness of these location to the sea.

This study has shown that most of the area, including the reclaimed land with a large amount of trapped old seawater and organic matter, indicates that the reclamation processes in essence impacts on the groundwater quality in the coastal area, the groundwater in some of the areas affected by saline water intrusion resulted from the present seawater but also the trapped old seawater, and reduction processes. The effects of these factors may be different through its flow paths, due to residence time in the residual environment and the vicinity of the coastline.

The study indicates that of the cations and anions analyzed for in the water, chloride (cl^-) and sulphate dominate. this agrees with the findings of Amadi (2004). However, the concentration levels of most chemical parameters are below the stipulated standards (WHO, 2006), showing that the water is potable in view of these parameters. Calcium concentration ranges from 33.4mg/l to 1.6mg/l. Calcium (Ca) in the water probably owes its origin to silicates and feldspars which characterize the coastal plain sands where the boreholes tap water from, while magnesium comes from ferromagnesian minerals in the adjourning Oban Massif, or partly from the sea.

The concentration values of K^+ ions are lower than Ca^+ and Mg^{2+} in the water groundwater in te study area. Sodium and Potassium ions could also emanate from the feldspars.

The study has shown that the local geology is the principal factor controlling the chemistry of groundwater in term of the water types and the processes. The main processes include chloride solution and ion exchange.

Microbial studies show that groundwater samples from three (3) locations have detectable values of coliform counts in them. Maximum coliform count (3.00Cfu/ml) is found at Esit Eket, followed by 2.10 Cfu/ml at Orue Offong Oruko, then 0.10 Cfu/ml at Abak and Onna. The values of total coliform counts in groundwater samples in the above named areas exceed the WHO and NSDWQ limits of 0.00 Cfu/ml for safe drinking water, and are generally due to fecal contamination from nearby facilities like soak-away pits. This poses high risk of cholera and stomach disorder upon consumption. This is enhanced by poor borehole constructions in the study area.

REFERENCES

1. Akpokodje, E.G., Etu-Efeotor, J.O.,& Mbeledogu,I.U (1996)"A study of environmental effects of deep subsurface injection of drilling waste on water resources of the Niger Delta" CORDEC, University of Port Harcourt, Choba, Port Harcourt, Nigeria.

2. Alabo, D.M; Matsuo, G; Suchy, M; Abbey, D.G (2001) A multidisciplinary approach to studying the nature and occurrence of saline groundwater in the gulf islands, british Columbia, Canada.

3. Amajor, L.C. (1991) Aquifer in the Benin Formation (Miocene-Recent), Eastern Niger Delta, Nigeria: Lithostartigraphy, Hydraulics, and Water Quality. Environ. Geol. Water Sci., Vol.17, No. 2: 85-101.

4. American Society Testing Materials (1969) Manual on Water, 14th Edition. Hamilton D.E., Philadelphia, Pp 171-227

5. Asseez, L. O. (1989). Review of the Stratigraphy, Sedimentation and Structure of the Niger Delta. In Kogbe C. A. (Ed), Geology of Nigeria. Jos: Rockview (Nigeria) Limited.

6. Back W (1966) Hydrochemical Facies and Groundwater Flow Patterns in Northern Part of Atlantic Coastal Plain: Us Geological Survey Professional Paper 498-A, 42pp

7. Beka, J. E. (2014). Assessment of Hydrocarbon Pollution Potential of Aquifers in Parts of Akwa Ibom State, Nigeria. Paper Presented at 7th NAPE Mini – Conference for Tertiary Institutions, 5th – 8th June, 2014; University of Port Harcourt, Nigeria.

8. Bolaji, T.A. (2009). Hydrogeochemistry and quality index of groundwater in Port Harcourt, Nigeria. Msc Thesis, University of Port Harcourt, Nigeria. Pp186..

9. Etu-Efeotor, J.O. (1981) Preliminary Hydro Chemical Investigations of Subsurface Water in Parts of the Niger Delta. Jmg Vol. 18, No.1, 163-443.

10. Etu-Efeotor, J.O. and Akpokodje , E.G (1990) Aquifer Systems of Niger Delta. JMG Vol. 26 No 2, 279-284.

11. Knuth, M; Jackson, J.L; And Whittemore, D.O (1989) An Integrated Approach To Identifying The Salinity Source Contaminating A Groundwater Supply. Groundwater 28 (2): 207-214.

12. Omoboriowo, A.O et al (2012) Appraisal of the Groundwater Quality in Arochukwu Area, Afikpo Basin, Nigeria . International Journal of Science and Technology ,Volume 2 (11): 788-793

13. Udom, G. J. (2004). Regional Hydrogeology of Akwa Ibom State, Nigeria Using Lithological, Pump Testing and Resistivity Data. Unpolished PhD Thesis, University of Calabar.

14. Udom,G. J., Esu, E.O. and Ekwere, S. J. (1998).Quality status of groundwater in Calabar municipality, southeastern Nigeria. Global Journal of pure and Applied Sciences. Vol.4 (2):163-169.

15. Udom, G. j.; Etu-Efeotor, J.O. and Esu, E.O. (1999). Hydro chemical evaluation of groundwater in parts of Port Harcourt and Tai-Elemi Local Government Area, River., Global Journal of pure and Applied Sciences, Vol.5,pp546-552.

16. Udom G..j.; Etu-Efeotor, J.O. and Ekere,S. J. (1998). Quality Status of Groundwater in Calabar Municipality, Southeastern Nigeria. Global Journal of pure and Applied Sciences