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Research Article

QUALITY STATUS OF GROUNDWATER IN AKWA IBOM STATE, NIGERIA

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ABSTRACT

Aquifer delineation and hydro geochemical characterization of groundwater resources in Akwa Ibom State was carried out 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. Groundwater flow direction shows northwest – southeast trends in consonance with the regional groundwater flow trend in the Niger Delta. Microbial analysis indicates the presence of coliform bacteria in some of the samples which may be indicative of anthropogenic contamination. This study provides an applicable scenario in hydrogeochemical evaluation and aquifer delineation towards sustainable groundwater management in the study area.

INTRODUCTION

Water is a resource vital to all life on earth (WHO, 2004). Water as a resource may occur either as freshwater or saline water. Both water sources are easily impacted by anthropogenic activities. There is therefore, a strong rationale for characterisation of aquifers and evaluation of their hydrogeochemistry.

Freshwater as a resource, may occur as either surface or groundwater. Groundwater is a major resource of drinking water all over the world (Bear, 2007). Availability of safe and reliable source of water is an essential prerequisite for sustainable development. Current emphasis is not only on how abundant water is, but also on whether its quality is good enough to sustain its various uses (Adepelumi et al, 2009; Udom et al, 1999; 2002).Freshwater quality and availability remain one of the most critical environmental and sustainability issues of the twenty first century (WHO, 2006). Therefore, water and its management will continue to be a major issue with definite and profound impact on our lives and that of our planet earth (Herschy, 1999).

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 and Okereke (2001), the southern part of Akwa Ibom 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.

(a) Location of Study area: The location of study for this research project is Akwa Ibom 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).

(b) Statement of the problem: Aquifers in Akwa Ibom State have not been properly characterised, resulting in a scenario where there is scanty geo-scientific information for the proper management of water resources in the State. The current status of knowledge on groundwater hydrology in Akwa Ibom State further underpins a scenario where information on hydro-geochemistryis too scanty for the proper assessment of the suitability of groundwater for its various uses in different locations across the State.

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.

(c) Relief and Drainage of Study Area: The relief map of Nigeria, where Akwa Ibom State occurs in the southeastern part is shown in figure 1. The elevations in the study area rarely exceed 131meters rarely exceed 131 meters (about 400 feet) above mean sea level (a.m.s.l.). In the northern parts of the state, places like Itu, Ikono, Ibiono Ibom, have topographic heights of about 66 to 131 meters (a.m.s.l.).

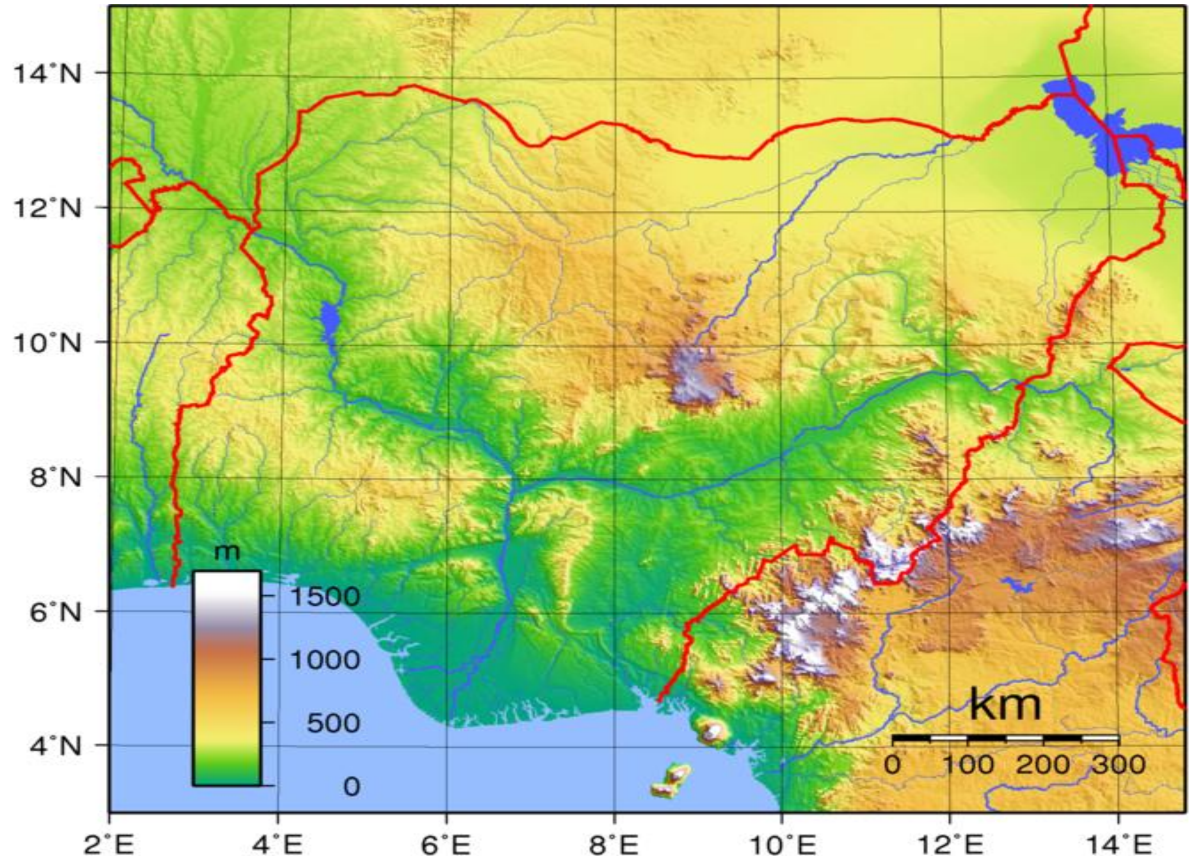

Figure 1: Relief map of Nigeria showing Akwa Ibom State (Modified from Harper Collins, 2009)

The central and southern parts of the state form a low-lying plain, which is characteristic of the Niger Delta, with ground elevations generally below 66 meters (200 feet) a.m.s.l. Some areas of Eket, Mbo and Oron are near sea level. Generally, the landscape in the state slopes towards the Atlantic Ocean. Valleys, marshes and swamps are characteristic of southern areas of Oron, Eastern Obolo, Ikot Abasi and Ibeno due to influence of the Atlantic Ocean, Qua Iboe River and Cross River.

The state is drained by the Cross River on the east, Imo River on the south west, and Qua Iboe River in the south central parts. These rivers flow from the northern highlands of the state and drain in to the Atlantic Ocean in the south.

Akwa lbom State lies entirely on the coastal plain of southeastern Nigeria, where no part constitutes an area of appreciably high relief (Akpokodje,1989). Apart from the northern extreme corner of Obotme and Nkari and the northeastern parts around ltu, Itam, Ibiono and Ini where the land is intensely dissected into a broken "valley and ridge" terrain, the landscape of Akwa lbom State comprises a generally low-lying plain and riverine areas. As noted by the same author, the land rises steadily northward from the sea-level at Eket in the south to 150m at Obotme in the north

Mangrove swamps are extensively developed in the coastal and estuarine areas in the State (Wilcox, 1985). As in other parts of the Nigerian coast, the mangrove ecosystem is extending into the estuaries and flood plains of the Imo River at Ikot Abasi, the Qua Iboe River at Eket and the Cross River at Mbo and Oron. But large tracts of riverine swamp and flood plain environments with wetland characteristics flank the Qua lboe River valley through Etinan and Abak LGAs. Mangrove swamps also occupy the tidal mudflats laced with tidal channels, and the winding waterways, some about 20m wide. Small creeks that meander strongly develop as branches of the main channels (Udom, 2004).

AIM AND OBJECTIVES OF THE STUDY

The aim of the study is to systematically generate applicable hydrogeological data from parts of Akwa Ibom State, and use same to delineate and assess aquifers for proper development of groundwater resources in the state.

LITERATURE REVIEW

Not much 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 , 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.

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).

METHODOLOGY

(a) Sampling: Both fieldwork and laboratory analysis were utilized in this research. Samples 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.

(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.

Parameters	Measurement Method	Standard
Temperature	Mercury –in glas thermometer	-
Colour	Lovi bond Nessleriser 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

(i) pH: 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.

The Niger Delta as a whole is noted for its high acidity (low pH) especially in the mangrove swamp areas. This is typical of most parts of the Niger Delta region (Udom et al, 1998, 1999, 2002). Gas flaring has been pointed out as the major cause of the high acidic waters in the Niger Delta as a whole. This process releases carbon dioxide which reacts with atmospheric precipitation to form carbonic acid, in a chemical reaction process as indicated below.

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

This acid percolates into the groundwater system and increases the acidity of the water, thereby reducing the pH.

The WHO (2006) and NSDWQ (2008) permissible pH range in portable drinking water is 6.5 – 8.5.

Acidic waters are favorable for iron bacteria to thrive, which will severely corrode metal casing used for reticulation and incrustation of pipes (Olarewaju et al., 1996). This study shows that this is a common phenomenon in the study area. Prolonged consumption of acidic water over long periods of time may result in derangement of the balance of acid to base in the human body, This usually results in metabolic acidosis (Ofoma et al, 2005)

(ii) COLOUR AND ODOUR: It is generally believed that colour and odour are major indicators of water quality. Therefore, potable water must be free from any form of colouration, that is, must be colourless and odourless. From visual appearance, the groundwater samples are observed to be clear, that is, not coloured and equally odourless. Colours of the samples were determined using lovibondnessleriser Comparator and expressed in hazen units. 5 hazen units are recorded in all the groundwater samples collected indicating that the colour is acceptable.

(iii) TURBIDITY: The term turbid is applied to water containing suspended particulate matter that interferes with the passage of light through the water (Sawyer et al., 2003). Turbidity is a function of the transparency or visual clarity of water. It is an important consideration in public water supplies for the three major reasons: Aesthetics, Filterability and Disinfection. Turbidity values of groundwater samples in the study area ranged from 0.1-0.3NTU, which is below the WHO (2006) recommended 5NTU guideline for drinking water and is equally below the 1NTU median turbidity recommended in order to achieve adequate terminal disinfection.

(iv) HARDNESS: Hard water is generally considered as hard water when 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. Also, following the classification by Sawyer and McCarthy (1967) and Todd (1980) 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.

(v) NITRATE (NO^-_3): The range of values for nitrate lies between 4.63mg/l and 0.45mg/l (Table 4.3). The highest desirable level from The WHO (2006) and the NSDWQ (2008) is 50mg/l. The low level of nitrate recorded in the study area shows that groundwater is free from pollution, and safe for domestic use. The origin of nitrate in groundwater is commonly from fertilizer as a major source, industrial effluent, plant decomposition, and human sewage.

Nitrate in high concentration in drinking water results in a disease known as blue baby syndrome or methemoglobinemia in infants (Udom, 1989; Twort et al, 2007). This disease is characterized by blood changes and cyanosis in which the hemoglobin apparently becomes incapable of transporting oxygen (Ofoma et al, 2005).

(vi) POTASSIUM: Potassium occurs in various minerals, from which it may be dissolved through weathering processes. Examples are feldspars (orthoclase and microcline).The range of values for potassium in groundwater samples in the study area lie between 16.7mg/l and 0.24mg/l. The WHO (2006) and the NSDWQ (2008) permissible limits for potassium in portable drinking water is 200mg/l. Concentration of potassium in water rarely exceeds 20mg/l (Twort, et al, 2000). In an excess of 50mg/l in the presence of suspended matter can cause foaming which causes an increase in formation of scales and corrosion on boilers (Todd, 1980). It is anticipated that Potassium ions in the study area originate from dissolution of feldspars during the weathering process. This element is generally important for plant and animals as its key for soil fertility. Reverse osmosis can remove excess potassium in water.

(vii) CALCIUM AND MAGNESIUM: Calcium and magnesium in groundwater are generated by the action of carbon dioxide in water on carbonate rocks such as limestone and dolomite, the concentrations of calcium and magnesium in groundwater samples in the study area lie between 33.4mg/l to 1.6mg/l and 16.36mg/l to 0.22mg/l, respectively. The WHO (2006) and the NSDWQ (2008) both have permissible limits for calcium and magnesium in portable drinking water as 75mg/l and 50mg/l, respectively concentration levels of these parameters are within acceptable limits for potable water use. A higher concentration of magnesium in water causes a laxative effect (Todd, 1980). Twort et al, 1980 stated that excesses of calcium ions in form of calcium bicarbonate causes temporary hardness while magnesium causes permanent hardness. High concentrations of calcium in water tend to reduce the lathering effect of soaps and detergents (Offodile, 2002). This also causes an excess scale formation, which may detrimental to facilities and utilities.

(viii) TOTAL COLIFORM: Maximum coliform count (3.00 Cfu/ml) is found at Esit Eket, followed by 2.10 Cfu/ml at Urue Offong-Oruko, then 0.10 Cfu/ml at Abak and Onna. The values of total coliform in the above named areas exceed the WHO (2006) and NSDWQ (2008) limits of 0.00 Cfu/ml for safe drinking water

DISCUSSION OF RESULTS

(A) TRENDS IONS IN GROUNDWATER:

Generally, the chemical composition of groundwater is primarily dependent on the geology as well as the geochemical processes taking place within the groundwater system. Major and minor ions in groundwater from the study area were plotted on a piper diagram using AQqa from Rockworks in order to identify hydrochemical facies in the area of study . Analysis of the results show the ionic abundance in the order of Ca>Mg>Na>K for cations and CL>>HCO_{-3}>SO_4>NO_3 for anions .(Figure 2)

The distribution and concentration levels of the anions and cations in the groundwater were plotted on a Schoeller diagram. The values are generally less than the recommended limits of these parameters for domestic purposes (WHO, 2006 and NSDWQ, 2008) with exception of the concentrations for iron (Fe), with maximum concentration values above 0.3mg/l in majority of the Local Government Areas. Chloride is the dominant anion found in the groundwater of the area of study with a concentration generally higher that 18mg/l..

(B) HYDROCHEMICAL INDICES:

The following ionic relationships were studied to check the salinity and origin of the groundwater in the study area. These include: Mg/Ca, Cl/HCO_3, and the Cation Exchange Value (CEV= [Cl – (Na+K)]/Cl). Mg/Ca values were all less than 5.0 ranging from 0.02meq/l to4.83meq/l. (Table 2). According to the interpretation of this index, the groundwater in the study area appears to be slightly of inland origin, because waters under marine influence would have values of five (5) (Morell et al., 1986) except where other processes such as cation exchange take place. If this happens, the values would be below four (4) or less.

The Cl/HCO_3 values range from 0.01 - 5.65. Revelle (1994) recommended the Chloride – bicarbonate ratio as a criterion to evaluate intrusion. Values of this hydrogeochemical index given for inland waters are between 0.1 and 5 and that for seawater lies between 20 and 50 (Custodio, 1987). In general, the CEV for seawater ranges from +1.2 to +1.3 (Custodio, 1987), where low-salt inland waters give values close to zero, either positive or negative. The CEV values for Groundwater in Akwa Ibom State are generally below 0.7472, ranging from 0.7472 to 0.0506, indicating that the groundwater is inland in some locations with respect to provenance. These results agree with the findings of Bolaji (2009) .The stiff diagrams (Figure 2) represent chemical analyses by four parallel axes. Concentration of cations are plotted to the left of a vertical zero axes and anion to the right; all values are in meq/l. The resulting points, when connected form an irregular polygonal pattern; waters of a similar quality define a distinctive shape. The stiff diagrams plotted for the study groundwater samples show lower cations than anions.

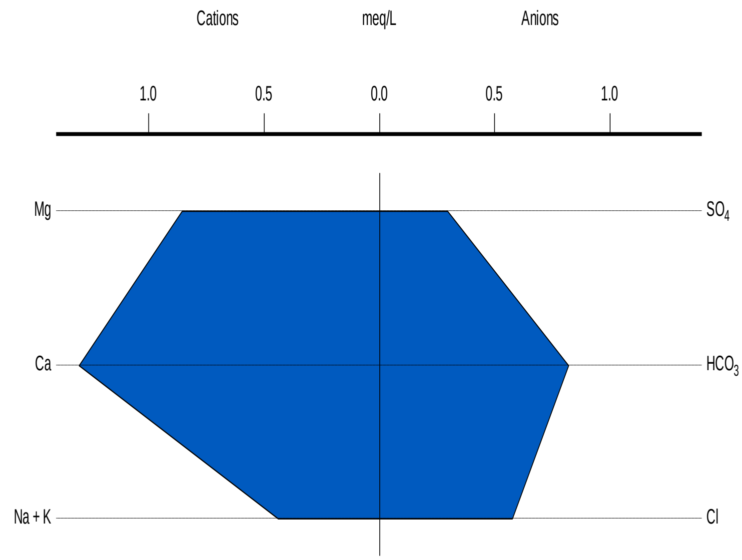

Figure 2: Stiff Diagram for Abak Local Government Area

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

Table 2: Relationship Between Various Ionic Ratios Of Groundwater In The Study Area

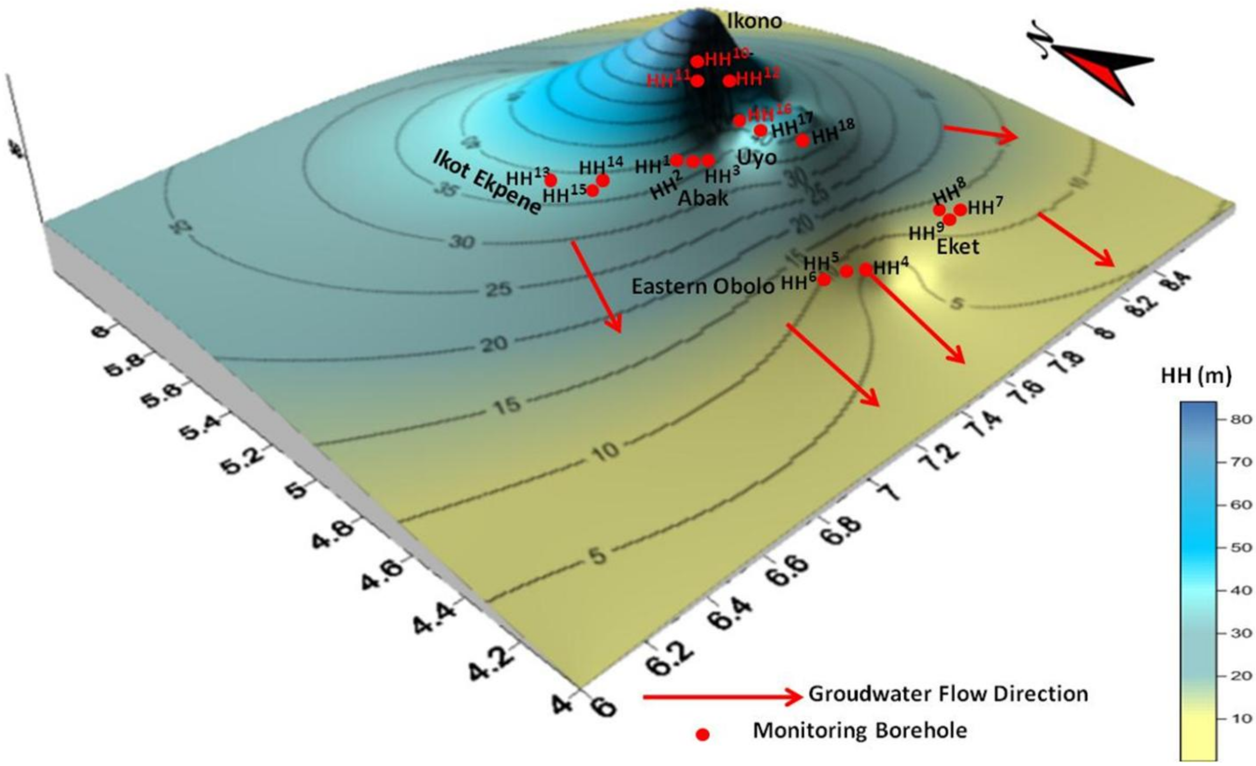

Figure 3: Regional Groundwater Flow Direction in the Study Area

(C) LOCAL AND REGIONAL GROUNDWATER FLOW DIRECTION: Local groundwater flow directions were determined at six locations in the state during this study using borehole data. (See figure 3). These locations were Abak, Eastern Obolo, Eket, Ikono, Ikot Ekpene, and Ini. The determination of groundwater flow direction was done based on plots derived from field data.

Groundwater flow direction in Eket, Ikot Ekpene, Uyo,Eastern Obolo and Ikono is from northwest to southeast. Generally, the flow directions of groundwater in these areas are in consonance with Esu et al, (1999) and with the regional groundwater flow in the Niger Delta which is from the northern highlands southwards towards the Atlantic Ocean. The flow directions are related to the hydraulic heads which are higher at the northern part of the state and decrease gradually to the south. However, this work has identified some localized southwesterly and southeasterly flow trends within the study area).

Knowing the direction of groundwater movement has become increasingly important because of the danger of contaminated groundwater supplies. Sewage or other contaminants can enter the groundwater systems, hence the flow direction of groundwater would help to know the direction of flow of the contaminant plume. This further indicates the significance of determining groundwater flow direction vis-à-vis the direction of flow of the contaminant plume.

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 ground waters 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 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.

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 the study area. Sodium and Potassium ions could also emanate from the feldspars..

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.

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