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Hydrochemistry of Groundwater in Umuahia South Local Government Area, Abia State, Nigeria

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Research Article

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ABSTRACT

Twenty-seven boreholes in Umuahia South Local Government Area were studied using standard field and laboratory techniques of water resource investigation to assess the quality status of groundwater in the area. This was done to appraise the suitability of the water for domestic uses. Na^+ and Ca^{++} dominate the cations with average values of 11.6mg/l and 5.22mg/l respectively, while HCO_3^- and Cl^- dominate the anions and show respective mean values of 55.6mg/l and 15.6 mg/l. The low Cl^- concentration shows that the salt water contamination in the adjacent coastal aquifers of the Niger Delta has not reached Umuahia, which is more hinterland. The water is low in dissolved constituents. However, the acidic status of the water (pH values from 4.39 to 6.56) calls for treatment. Treatment is also needed for iron in boreholes with concentration more than 0.3 mg/l. These treatments would make the water potable for drinking and other domestic purposes with respect to the parameters analysed. The major source of the ions in the water includes mineral assemblage in the rocks, geochemical processes operating within the groundwater system, as well as atmospheric precipitation. Exploitation of water from different depths, local geochemical processes in the aquifer, as well as concentration of elements in boreholes located in areas of low hydraulic heads are some of the reasons for haphazard variations in the geochemical parameters from one borehole to another.

Keywords: Groundwater quality; hydrochemistry; aquifers; saline water intrusion; domestic purposes; Umuahia; Nigeria;

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1. INTRODUCTION

The demand for water in Umuahia South Local Government Area is on the increase due to population increase. Groundwater is the major source of water supply in the area, although a few people still resort to stream and rain water for their domestic water needs. Since most people depend on groundwater in the area, it has become necessary to undertake a baseline study of its status for the identification of any future degradation of the water. The results obtained from this study would also be used to assess the suitability of groundwater in the area for domestic purposes.

The study area lies within the South eastern part of the Niger Delta Basin of Nigeria, between longitudes $7^0 22^I$ and $7^0 33^I$ E and latitudes $5^0 26^I$ and $5^0 34^I$ N (Fig.1). It is within the sub-equatorial belt which is characterized by the wet and dry seasons. The wet season lasts from April to September with a peak in June and July, while the dry season lasts from October to March. Rainfall in the area is high, with an average of about 400cm, while relative humidity values are well over 70%. Mean annual temperature is about 27^0C (Fig. 2).

The area is drained by Imo River and its tributaries which flow in a southerly direction and empty into the Atlantic Ocean.

2. GEOLOGY AND HYDROGEOLOGY

The study area is within the Eastern Niger Delta (Fig. 3). The geology of the Niger Delta has been extensively described by Allen (1965), Reyment (1965), Short and Stauble (1967), Aseez (1976), Wright *et al* (1985), Kogbe (1989), and others. The Formations in the Niger Delta include the Akata-, Agbada-, and Benin-Formations in order of decreasing age (Table 1). However, all boreholes in the Delta tap water from the Benin Formation. This Formation, also called the Coastal Plain Sands, is Miocene to Recent in age and made up of sands which are mostly medium- to coarse-grained, pebbly, moderately sorted with local lenses of poorly cemented sands and clay. Based on petrographic analysis, Onyeagocha (1980) contends that the rocks are made up of about 95-99% quartz grains; Na+K_mica, 1-2.5%; feldspar, 0.5-1.0%; and dark coloured minerals 2.3%.

The sand/clay intercalations in the area suggest a multi-aquifer system. A typical log of a borehole in Umunwanwa (Fig. 4) shows this. Two aquifers are identified in this borehole; a thin upper unconfined aquifer between 30 and 40 meters depth, and a thicker confined aquifer between the depth of 60 and 120 meters. These two aquifers are separated by a 20-meter thick clayey unit. The aquifers in the area obtain their recharge mainly through precipitation. Static Water Levels vary from 28 to 40m, depending on the season.

3. METHODOLOGY

3.1 Sampling and Analytical Techniques

Water samples were collected from the boreholes shown in Fig.1 in clean 500ml plastic bottles after pumping the wells for about five minutes to ensure stable conditions. After sampling, the bottle was capped immediately to minimize oxygen contamination and the escape of dissolved gases. Analysis was done within 24 hours after sampling.

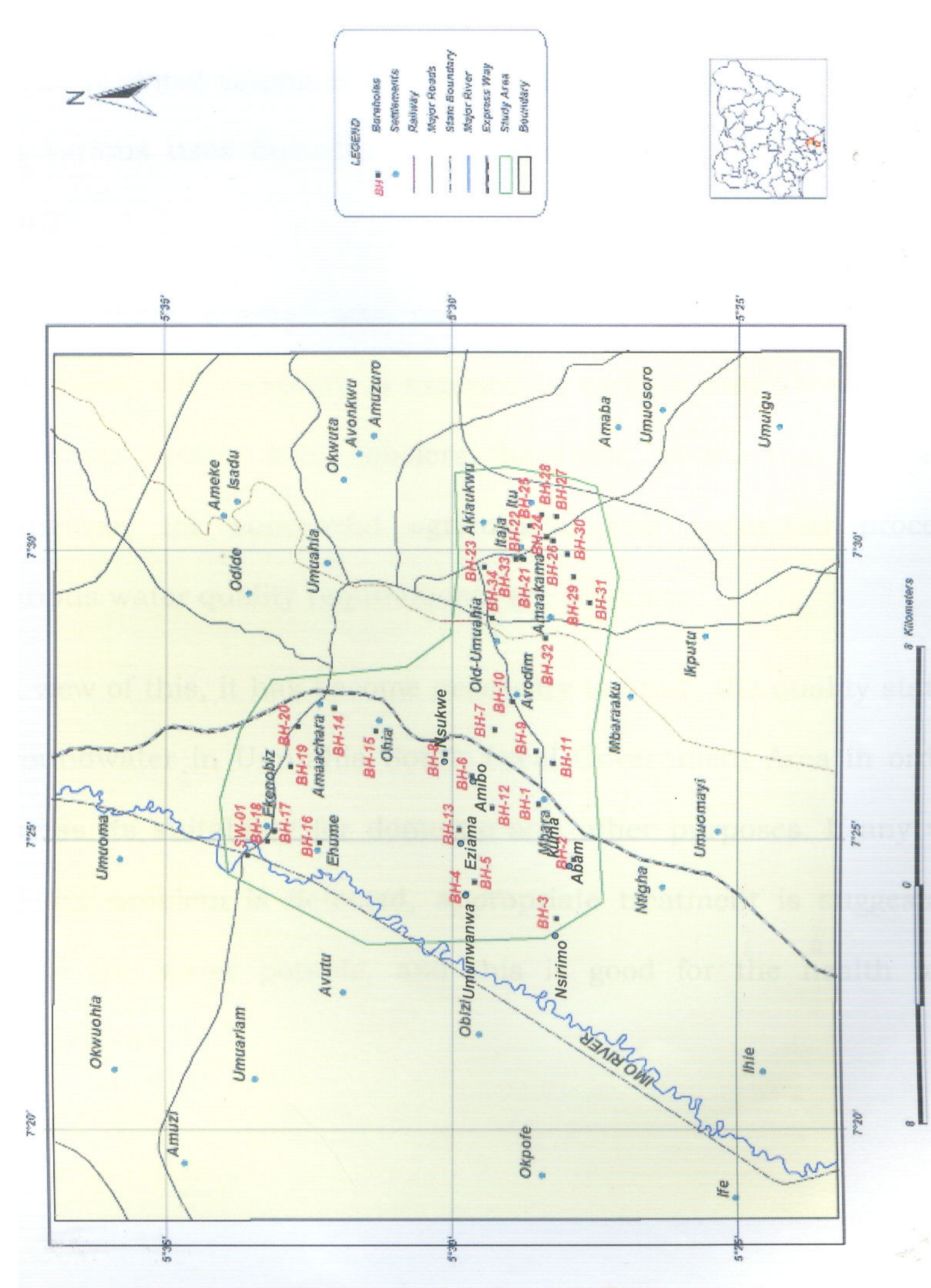

Fig. 1. Map of study area showing sampled borehole locations

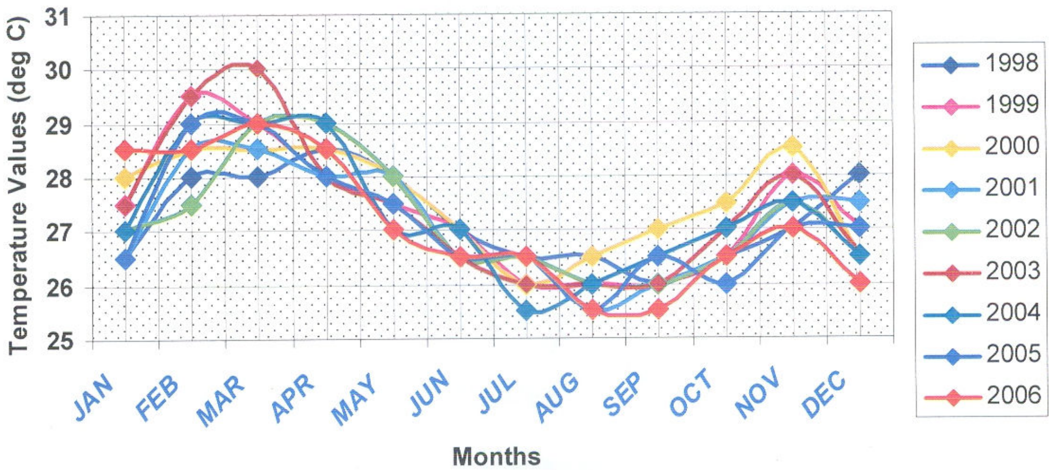

Fig. 2. Temperature pattern in the study area

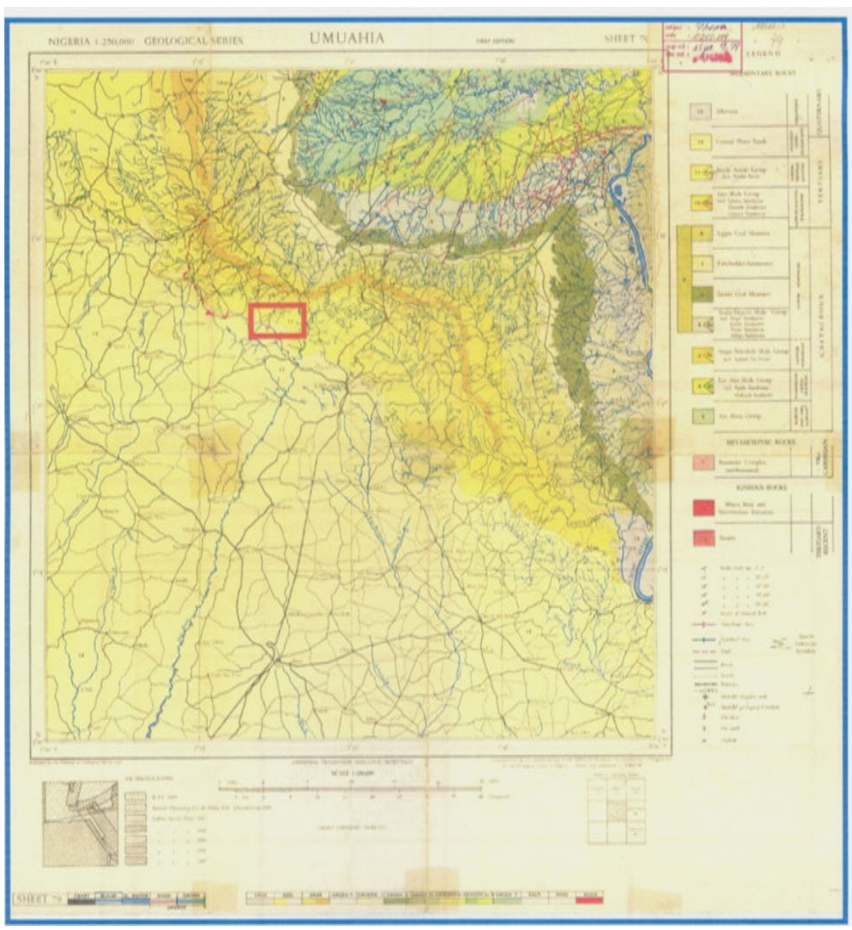

Fig. 3. The geologic map of Umuahia and its Environs.
(Source: GSN, Sheet No. 79, 1957)

Table 1. Stratigraphic correlation chart of the Niger Delta (After Amajor, 1986)

AGE	SURFACE OUTCROP EQUIVALENT FORMATIONS		SUBSURFACE FORMATIONS	MEGA-DEPOSITIONAL ENVIRONMENTS
PLIOCENE-RECENT	COASTAL PLAIN SANDS		BENIN FM	PARALIC CONTINENTAL
MIOCENE-RECENT	OGWASHI-ASABA FM	IJEBU FM	AFAM CLAY MBR.	CONTINENTAL DELTA PLAIN
EOCENE-RECENT	AMEKI FM	ILARO FM OSHO-SHUN FM	AGBADA FM	PARALIC DELTA FRONT
PALEOCENE-RECENT	IMO FM	EWEKORO FM	AKATA FM	MARINE PRODELTA
CAMPANIAN-MAASTRICHTIAN SANTONIAN	NSUKKA FM AJALI SST MAMU FM NKPORO-ENUGU SHALE			UPPER CRETACEOUS PRO NIGER DELTA SUCCESSION

Samples meant for anion determination were acidified and the choice of acid depended on the anion. For example, sample meant for iron determination was primed with 0.5M solution of nitric acid to keep the iron in solution. On-site measurements were done for conductivity, temperature and pH due to their unstable nature; while the rest of the parameters were analysed in the laboratory using analytical techniques shown in Table 2.

Table 2. Summary of Analytical Methods used

Determination	Analysis Method
Temperature	Thermometer
pH	pH meter (Bromthymol Blue pH kit)
Conductivity	Conductivity Meter (Mark V Electronic Swithgear)
Cl^-,HCO_3^-, Ca^{2+},Mg^{2+}	Titration
Iron	Colourimetric
TDS,SO_4^{2-},NO_3^-,	Gravimetric
Na^+,K^+	Flame photometric

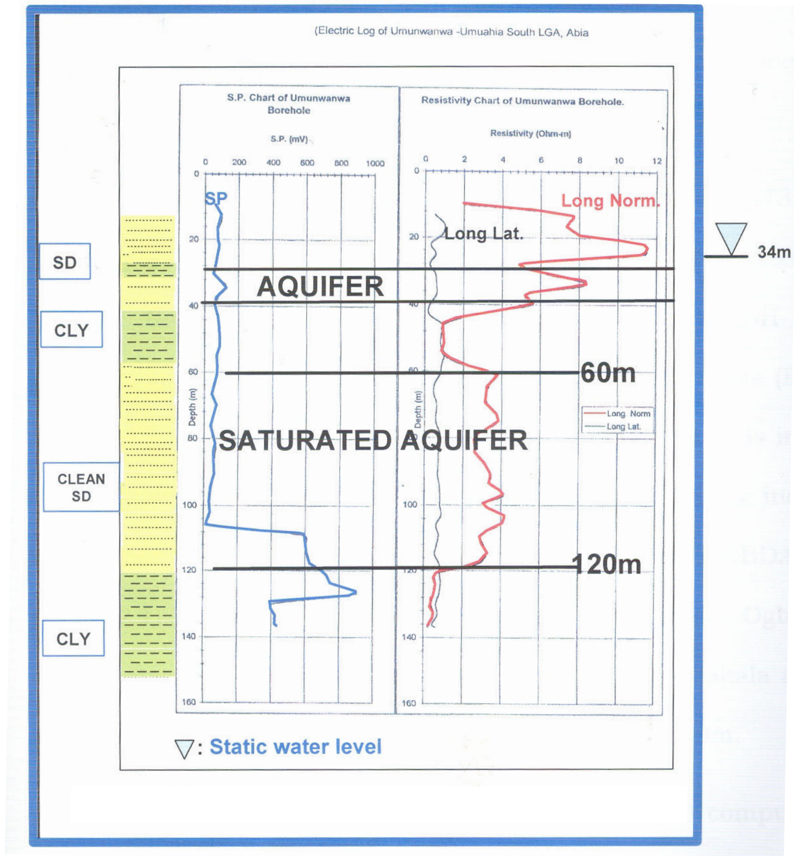

Fig. 4. SP-Resistivity log of Umunwanwa borehole (BH-5).
(Source Data: Anambra-Imo River Basin Development Authority, Owerri)

4. RESULTS AND DISCUSSION

Results of the analysis done are presented in Table 3. In the Table, the results are also compared to WHO (2004) standards for drinking water. The mean temperature value for groundwater in the area is 29.4^{0}C, with a range of 28.0^{0}C to 31.0^{0}C. This is reflective of the physiogeographic conditions of the area. The water temperature remained approximately constant throughout the period of sampling.

The pH values of groundwater in the area lie between 4.39 and 6.56. This shows acidic groundwater in the area. Electrical conductivity has a range of 14.1 µS/cm to 101.5 µS/cm and an average value of 30.2 µS/cm. These values (Table 3) indicate that the water is not saline; hence objectionable tastes are not expected in the water. Conductivity values have direct relationship with total dissolved solids (TDS). In the area TDS values are also low (2.38-50.7 mg/l) and much below the stipulated standard by WHO (2004). TDS above 1000mg/l indicates saline water.

The cations studied include iron (Fe^{2+}), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), and potassium (K^+). Of these, Na^+ and Ca^+ dominate the rest. Na^+ has a range of 1.92mg/l-5.54mg/l, and a mean of 2.67 mg/l.

Table 3. Results of physico-chemical composition of groundwater samples in the study area

Bore hole	Borehole Locations	Temp (°C)	Cond. (µS/cm)	pH	TDS (mg/l)	TSS (mg/l)	Fe^{2+} (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{2+} (mg/l)	K^{+} (mg/l)	HCO_3^- (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	NO_3^- (mg/l)
BH-1	Agbara Akuma	29.5	23.4	5.54	11.70	BDL	0.01	0.48	0.07	2.14	0.16	45.00	4.69	BDL	
BH-2	Abam	29.0	27.3	5.07	13.60	BDL	0.02	0.44	0.07	2.12	0.11	30.50	4.96	BDL	BDL
BH-3	Nsirimo	28.0	14.7	5.07	7.30	BDL	0.01	0.43	0.06	2.14	0.09	30.50	5.32	BDL	BDL
BH-4	Umunwanwa	30.0	41.5	4.47	20.60	BDL	0.01	0.42	0.06	2.17	0.09	30.50	5.32	BDL	BDL
BH-6	Amibo	31.0	23.8	4.47	11.90	BDL	0.02	0.57	0.11	3.14	0.18	45.75	4.96	BDL	BDL
BH-7	Nsukwe-1	31.0	21.1	4.52	10.80	BDL	0.01	0.54	0.09	3.14	0.16	45.75	5.67	BDL	BDL
BH-8	Nsukwu-2	30.0	19.0	5.40	9.50	1.0	0.11	0.34	0.07	2.26	0.12	30.50	5.67	BDL	BDL
BH-9	Laguru	31.0	14.1	4.94	7.00	1.0	0.02	0.42	0.06	2.11	0.13	30.50	5.52	BDL	BDL
BH-10	Avodim	30.0	20.2	4.80	10.10	BDL	0.02	0.53	0.11	2.11	0.16	30.50	5.67	BDL	BDL
BH-11	Umuoshi	28.0	23.7	4.73	11.80	1.0	0.11	0.55	0.12	1.92	0.16	30.50	4.60	BDL	BDL
BH-12	Amuzu Ubakala	28.0	20.7	4.64	10.30	1.0	0.09	0.53	0.12	2.72	0.14	30.50	6.05	BDL	BDL
BH-13	Eziama Ubakala	28.5	21.9	4.63	10.90	BDL	0.03	0.49	0.11	2.08	0.13	30.50	5.67	BDL	BDL
BH-14	Ogbodi Ukwu	29.0	35.6	5.28	17.70	BDL	0.04	0.77	0.21	3.04	0.21	45.75	5.67	BDL	BDL
BH-15	Ohia	29.5	46.8	4.39	23.40	1.0	0.10	1.07	0.26	3.05	0.91	30.50	5.32	BDL	BDL
BH-16	Ehume Umuokpara	29.0	37.4	4.25	18.50	2.0	0.13	0.65	0.11	2.81	0.20	30.50	5.67	BDL	BDL
BH-17	Ekenobizi Umuokpara-1	29.0	21.6	4.79	10.80	BDL	0.02	0.52	0.08	2.12	0.17	30.50	5.67	BDL	BDL
BH-18	Ekenobizi Umuokpara-2	29.0	20.5	4.85	10.20	1.0	0.02	0.38	0.05	2.11	0.13	30.50	5.67	BDL	BDL
BH-19	Ogbodi Ukwu Umuokpara	30.0	32.2	4.65	16.10	7.0	0.73	0.62	0.15	3.12	0.20	30.50	4.96	BDL	BDL
BH-20	Amachara	28.0	20.8	4.56	10.40	BDL	0.06	0.48	0.07	2.02	0.16	30.50	6.03	BDL	BDL
BH-22	Ahiaukwu Olokoro	30.0	31.4	4.94	15.70	BDL	0.01	0.42	0.06	2.34	0.12	30.50	5.67	BDL	BDL
BH-23	Umuobia Ahiaukwu	31.0	14.9	4.84	7.40	1.0	0.02	0.53	0.09	2.43	0.15	30.50	5.32	BDL	BDL
BH-24	Itaja-Obuohia Olokoro	30.0	32.9	4.77	16.40	1.0	0.02	0.52	0.08	3.02	0.14	30.50	5.32	BDL	BDL
BH-25	Umuika-Ukwu Olokoro	28.5	-	6.45	2.38	25.48	0.11	7.75	1.42	3.57	2.55	-	0.01	BDL	BDL

Table 3 continues…..

BH-26	Itaja Olokoro Umuokpayi	30.0	42.2	5.07	21.10	3.0	0.41	1.68	0.63	3.06	0.61	45.00	5.32	BDL	BDL
BH-27	Amizi	29.5	101.5	4.44	50.70	1.0	0.41	5.12	1.06	5.54	1.79	30.50	10.64	BDL	BDL
BH-28	Umuajata-Olokoro	28.0	52.9	4.64	26.40	8.0	0.24	1.22	0.37	2.79	0.41	30.50	8.86	BDL	BDL
BH-29	Amakama-Olokoro	30.0	22.0	5.10	10.90	4.0	BDL	0.78	0.13	3.14	0.23	45.00	4.96	BDL	BDL
Maximum		31	101.5	6.56	50.7	25.84	2.78	7.75	1.42	5.54	2.55	45.7	8.86	BDL	BDL
Minimum		28.0	14.1	4.39	2.38	BDL	0.01	0.42	0.06	1.92	0.12	30.5	0.01	BDL	BDL
Range		28-31	14.1-101.5	4.39-6.56	2.38-50.7	BDL-25.84	0.01-2.78	0.42-7.75	0.06-1.42	1.92-5.54	0.12-2.55	30.5-45.7	0.01-10.64		
UK(1998)Standard		25	1500	5.5-9.5	50-750	NS	0.2	250	50	150	12	30	400	250	250
WHO(2004)Standard		NS	NS	6.5-8.5	1000	NS	0.3	NS	NS	200	NS	NS	250	250	50
Average		29.4	30.2	4.87	14.58		0.10	1.05	0.22	2.67	0.36	32.68	5.54		

BDL =Below Detection Limit; NS = Not Stated

The wells in the area penetrate clay layers to reach lower, more permeable beds and obtain water high in dissolved solids (including sodium) from the clay layers. These clay layers are noticeable in Fig. 4.

Calcium has a range in concentration between 0.42 mg/l and 7.75 mg/l, and a mean of 1.05 mg/l. Calcium in the water is probably derived from silicates and feldspars which characterize the Benin Formation where the boreholes tap water from, as well as the adjoining Imo Shale in the Anambra Basin.

The other cations, Fe^{2+}, Mg^{2+}, and K^{+}, are also geologically controlled. Iron is widely distributed in iron bearing minerals such as haematite, and goethite in the Benin Formation, while magnesium and potassium come from feldspars. Fe^{2+}, Mg^{2+}, and K^{+}, have mean concentration levels of 0.01 mg/l, 0.22 mg/l, and 0.36mg/l respectively. These values are low. However, the concentration levels of iron are slightly higher than the stipulated standard of 0.3mg/l by WHO (2004). In BH 25 (Amizi) and BH 24 (Itaja-Olokoro, umuokpayi). This could be explained by the fact that these boreholes have lowaer hydraulic heads. The ions tend to have higher concentrations at such locations. Higher iron at these locations could cause objectionable tastes and stain plumbing fixtures and laundered clothes. Iron could be treated in the boreholes through aeration and filtration method. High iron concentration in groundwater from other parts of the Niger Delta has already been noticed by Udom et al (1998, 1999, 2002) and Udom and Acra, (2006).

The anions studied are bicarbonate (HCO_3^-), chloride (Cl^-), and sulphate (SO_4^-). HCO_3^- concentration in the water ranges between 30.5 mg/l and 45.7mg/l. This parameter owes its source in the water from CO_2 in the atmosphere and activity of biota in the soil. Cl^- content in the water averages 5,54mg/l, with a minimum value of 0.01mg/l in Umuika-Okwu Olokoro borehole (BH23) and a maximum value of 10.64mg/l in Amizi. When compared to the stipulated value of 250mg/l for potable water (WHO, 2004), the water is considered suitable for domestic use in view of this parameter. The low concentration of this parameter is also indicative of absence of salt water contamination in the study area. However, salt water intrusion has been reported in coastal aquifers of the Niger Delta by Udom *et al* (1998), and Udom and Acra (2006). Chloride contents greater than 40.0mg/l in aquifers indicate salt water contamination (Trembley et al., 1973). Rainwater is the major source of aquifer recharge in the area, and chloride is a constituent of rainwater primarily due to physical processes which cause marine solutes to enter the air at the surface of the sea.

Sulphate concentration is below detection level of the equipment used in all the borehole water samples. This very low level of sulphate suggests absence of any abuse of the water by septic tanks which are common in the area.

Table 3 shows that there is an erratic variation in the parameter values for borehole water samples in the area. This is because the boreholes are producing from different depths in the aquifer, or the borehole water is affected by local geochemical processes.

4.1 Hydrochemical Facies

Two water types were identified in the area from Piper plots (Fig. 5). These are: $Na+K-HCO_3$ Facie (Facie-1) and Ca^+ and Ca^+ $Mg-HC0_3$ Facie (Facie-2). However, Facie-1 dominates.

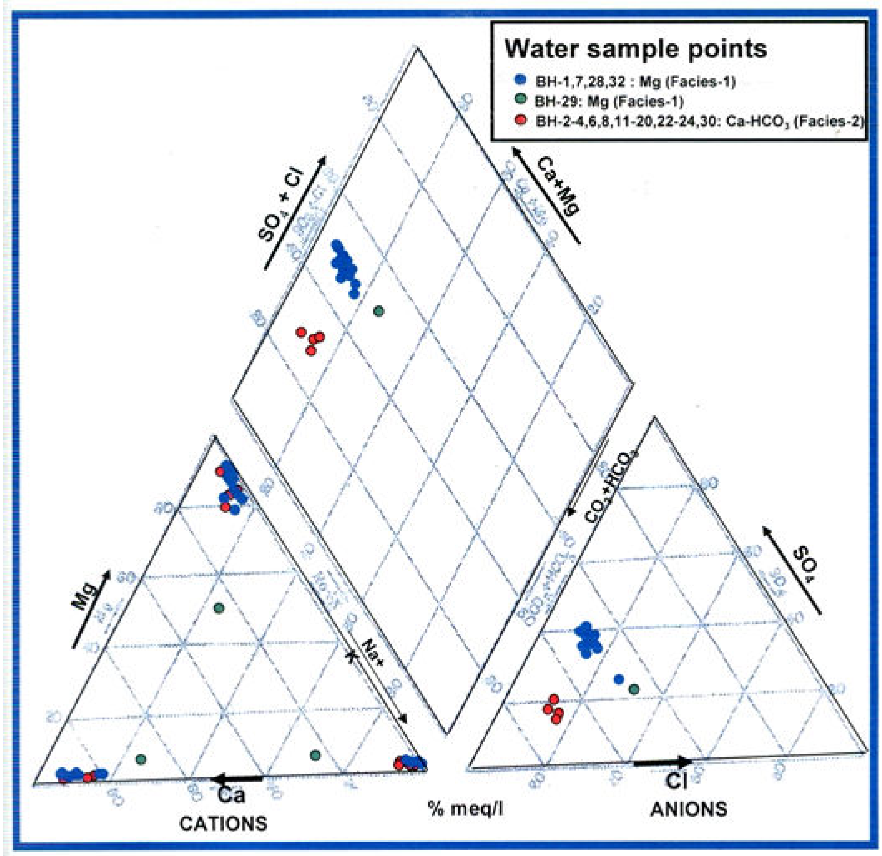

Fig. 5. Trilinear diagram plot of the water samples in the study area.

4.2 Water Treatment

Treatment of the water is necessary for acidity in all the boreholes. The pH values should be raised to between 6.5 and 8.5 as stipulated by WHO (2004).the water could be allowed to pass through granules of dolomite. The granules are normally made in a way that they slowly dissolve as water passes through them. Treatment is also needed for iron in BH24 and BH25. Aeration and filtration method is suggested.

5. CONCLUSION

(i) **R**esults show that groundwater in the area is low in dissolved constituents and suitable for drinking and other domestic purposes if treated for iron and acidity.
(ii) Since the pH values (4.39-6.56) show that the water is acidic, polyvinyl chloride (PVC) pipes and other non-corrosive materials should be used for borehole construction in the area because acidic waters can be very aggressive (Hem, 1985).
(iii) The effects of salt water intrusion Fe^{2+}, Mg^{2+}, and K^{+}, in the coastal parts of the Niger Delta Sedimentary Basin (Rivers, Bayelsa, and Akwa Ibom States) are not felt in the study area.
(iv) The water types in the area are: Na+K-HCO_3 Facie (Facie-1) and Ca^{+} and Ca^{+} Mg-HCO_3 Facie (Facie-2). However, Facie-1 dominates.

(v) The source of most of the parameters in the water is dissolution from the rocks as the water percolates underground. However, percolation and geochemical processes within the groundwater system also account for some of the parameters.

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