HYDROGEOCHEMICAL EVALUATION OF GROUND WATER SYSTEM AROUND YENAGOA AND ITS ENVIRONS, SOUTHSOUTH, NIGERIA.

Uzoegbu, M.U. and Uchebo, A.U.

Department of Geology, College of Physical and Applied Sciences, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

GSM: 08030715958; Email: mu.uzoegbu@mouau.edu.ng

ABSTRACT

This research study involves the determination of the hydrochemistry of groundwater and it suitability for drinking, domestic usage and other purposes in the area. Result shows that pH value ranges from 6.40 to 6.54, indicating that the water is slightly acidic. Hardness range from values 2.68mg/l to 5.05mg/l, with an average value of 3.8mg/l, indicating that the water from the area is soft. Electrical conductivity (EC) level ranges from 6.02$\mu S/cm$ 13.59 µS/cm with a mean value of 9.84µS/cm. TDS range from 9.07mg/l to 17.01m with a mean value of 12.98mg/l. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) range from 2.59mg/l to 4.08mg/l and 0.52mg/l to 1.23mg/l with average values of 2.82mg/l and 0.93mg/l respectively. Potassium (K^+) ranges from 0.21mg/l to 1.61mg/l with a mean value of 0.93mg/l. Chloride (Cl^-) range from 6.26mg/l to 12.70mg/l with an average of 10.2mg/l. Iron (Fe^{2+}) range from 0.02mg/l to 0.97mg/l with an average value of 0.45mg/l. Sodium (Na^+) range from 0.37mg/l to 2.37mg/l. Bicarbonate (HCO_3^-) on the other hand range from 11.20mg/l to 20.48mg/l. The hydrogeochemical data collectively indicates that the ground water within this area is not highly mineralized. The values are within permissible limits when compared with WHO (2006) with exceptions of the pH and iron contents which revealed some high concentrations. Also the Cl^- level indicates no salt water encroachment. The dominant cation and anion in the groundwater from the studied area are Ca^{2+} and HCO_3^- respectively.

Key words: Ground water, Hydrogeology, Geochemistry, Cations and Anions, Drinkability, Yenagoa, Niger Delta.

INTRODUCTION

The studied area (Yenagoa) lies within latitudes 4°51'0" and 5°22'30"N and longititude 6°12'0" and 6°33'0"E and situated in the southern part of the Niger Delta of Nigeria (Fig. 1). It is bounded on the north by Sagbama on the South by Ogbia and Southern Ijaw on the East. The area is accessible by Nun, Arasi, Brass Rivers, road and foot path which links various settlements.

The challenge of ensuring potable water in sufficient quantities to meet the needs of human and ecosystem emerge as of the primary issue of the 21st century. For example, inadequate water supply and poor water quality give rise to health and other social issues, limit agricultural productivity and economic prosperity, and pose national security risk in some countries. Problem of this nature have been increasing in scope, frequency, and severity because the demand for water continue to grow while supply of renewable water remain fixed. It is agreed that water is one of the most important resources with great demand for African Development. The nature of freshwater situation is unfortunately not encouraging. Presently, it is estimated that more than 300 million people live in a water scarce environment. By 2025, 1800 million people will be living in countries or regions with absolute water scarcity and two-third of world's population could be living under water stress.

In many countries, requirement for domestic fresh water use, sanitation, industry and agriculture cannot be met. The situation is getting worse as a consequence of population growth, rapid urbanization changes in climate, increasing agricultural and industrial activities, and lack of adequate capacity to manage freshwater resource.

Yenagoa is a wetland in the Niger Delta with possible serious problems of drinking water. Bayelsa State government had reported that all the surface water bodies in the state were

Fig. 1: Showing the studied location (Microsoft ® Encarta ® 2009. © 1993-2008 Microsoft Corporation).

pollution-laden and hence there is the need to resort to groundwater for consumable, domestic, industrial activities, etc. Water enters the subsurface through water bodies. From rainfall water moves through the subsurface through infiltration, precipitation and percolation from surface water bodies. At varying rates in response to pressure, elevation differences, permeability and geologic materials through which this water moves in the area. Predicting the impact of future water development plans and the quality of water in the area will be necessary; this research deals on evaluating the hydrochemistry of the groundwater in the area.

REGIONAL GEOLOGIC SETTING

Three lithostratigraphic units characterized the area. These are the Benin, Agbada, Akata formation in order of increasing age. The Niger-Delta stratigraphic setting (Fig. 2) was modified by Shannon and Naylor (1989) and Doust and Omatsola (1990).

The Benin Formation is predominantly a sand stone sequence with a few shale intercalations which become more abundant towards the base. The sands of the formation are largely deposits of the continental upper deltaic plain environment ranging in age from the Oligocene in the North to their recent equivalents in the modern delta.

This formation is the major aquiferous layer in the study area. It also have the main source of potable groundwater in the Niger Delta region. The Benin Formation is an extensive stratigraphic unit in the southern Nigeria sedimentary basin, with an average of 4667 in meters feet. Due to its high sand percentage, few minor shale streaks and absence of brackish water and marine fauna, the formation is recognized throughout the Delta.

The sand stone are coarse grain, gravelly, locally fine grained, poorly sorted subanguler to well rounded, it as acts as cap rock in the Delta, structural units common are points bar, channel fill and finer deposits and ox bow fills (Etu-Efeotor and Akpokodje, 1990).

The Agbada Formation underlines the Benin Formation and forms the second of the three strongly diactronous Niger Delta oil, the formations. As the principal reservoir of Niger Delta oil, the formation has been studied in some detail. The works of Weber (1971) is however, quite classic. The Agbada Formation consists mainly of sands, sand stones and silt-stones. It consists of numerous offlap rhythms, the sandy parts of which constitute the main hydrocarbon reservoirs in delta oil-fields. The sales constitute seals to reservoirs and as such are also important. In the Agbada formation, the sequence is divided into an upper unit consisting of sand stone-shale alternations with the former pre-dominating over the later and a lower unit in which the shales predominate and in places are thicker than the inter-calculated sand stones or sands. The structural elevation of the base of the Agbada Formation fluctuates widely throughout the delta because of synsedimentary diaprism largely within the Akata shale and the consequent growth fault development. The Agbada Formation contains beds laid down in a variety of sub-environments which can be grouped together under one broad parallic environment. The Agbada Formation occur almost delta wide beneath the Benin Formation on the landward side of the Niger Delta complex. The Ogwashi-Asaba formation of Oligocene to Miocene probably passes into the Agbada Formation in the subsurface. The top of Agbada is drawn on the highest occurrence of shale yielding a brackish or marine fauna.

This is the basal major time transgressive lithologic unit in the Niger Delta complex. This is a marine pre-delta megafacies, comprising mainly of shales with occasional turbidite sand stones and silt stone. The approximate range of thickness is from 0-6000 meters and the formation crops out subsea in the outer delta area but is not seen on shore. The formation consists of dark grey uniform shales, especially in the upper part. In some areas, it is sandy or silty in the upper part of the formation where it grades into the Agbada Formation.

The hydrogeology of the area has been described by several researchers such as Etu-Efeotor, (1981); Amadi et al., (1989); Etu-Efeotor and Akpokodje (1990) and Udom et al. (1998). The Benin Formation is the water bearing zone of the area. It is overlain by Quaternary deposits (40-50cm) thick and generally consists of rapidly alternating sequences of sands and silty clay which later become increasingly prominent seawards (Efeotor and Akpokodje, 1990). Generally multi-aquifer systems have been identified in the Delta based on strata logs (Etu-Efeotor, 1981). The first aquifer is mostly unconfined, while the rest are confined. The average depths of borehole in Yenagoa are between 20 and 50 metres. In terms of water quality, Udom et al. (1999) have noted that groundwater in most parts of Yenagoa is high in iron content. The static water level in the area ranges from 0-1m during the rainy season and 1-3m during the dry season. Rainfall is the major source of recharge for aquifer in the area.

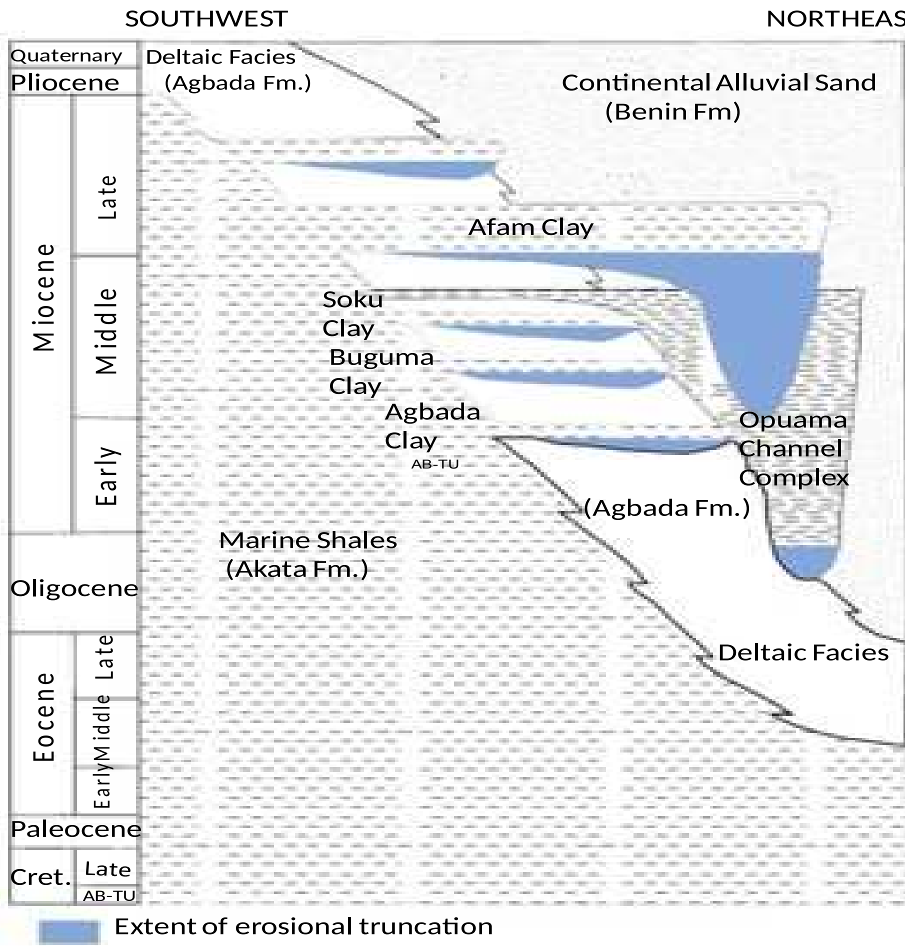

Fig. 2: Stratigraphic column showing the three formations of the Niger Delta. Modified from Shannon and Naylor (1989) and Doust and Omatsola (1990).

MATERIALS AND METHODS

Eight groundwater samples were collected from boreholes and analyzed for physico-chemical parameters. Groundwater samples were collected from boreholes at five minutes interval of pumping to ensure the samples were true representative from the aquifer. The samples were stored in sterilize 1.5litre containers with tightly fitting covers to ensure constant temperature. The containers were first washed with distilled or de-ionized water, and then several times with the sampled water before collection in order to avoid any contamination. The sampled containers were immediately replaced ice-packed containers to minimize contamination and escape of gases. For 24 hours the samples were stored in an ice-packed cooler for analysis.

In the laboratory measurement of pH, Electrical Conductivity (EC), Hardness, Temperature, Total Dissolved Solid (TDS), Calcium (Ca) and Magnesium (Mg), Sodium (Na), Potassium (K), Iron (Fe), Chloride (Cl_2), Bicarbonate (Hco_3^-) and Sulphate (SO_4^-), were taken and data were determined.

RESULT AND DISCUSSION

Eight groundwater samples were selected for analyses. The table 1 below reveals the result of the analyses. Each location was sampled at various intervals and table 2 indicates the determined minimum, maximum, average and range of various parameters used in this study. Table 3 and 4 shows parameter in meq/l and relationship between various ionic ratios.

Table 1: Result of the Groundwater Analysis

S/N	Borehole Locations	Temp (ºC)	pH	Ecm (µs/cm)	Hardness	TDS	Ca^{2+}	Mg^{2+}	K^+	Fe^{2+}	Na^+	HCO_3^-	SO_4^{2-}	Cl^-
					Mg/l									
1.	Agbura	27.0	6.51	8.87	3.71	15.27	2.26	1.07	0.91	0.91	0.90	14.60	2.57	12.68
2.	Azikoro	27. 0	6.44	8.93	3.80	15.28	2.30	1.09	0.92	0.91	0.90	14.62	3.01	12.70
3.	Swali	26.0	6.54	11.65	3.50	9.22	2.67	0.98	1.25	0.31	0.93	15.24	1.03	11.00
4.	Ovom	27.0	6.52	12.61	2.68	11.17	3.24	1.05	0.99	0.97	2.37	20.48	1.62	7.03
5.	Onopa	27.9	6.42	9.06	3.22	17.01	2.59	0.52	1.61	0.23	1.80	12.20	0.91	10.18
6.	Amarata	27.0	6.40	13.50	5.05	14.20	2.77	1.23	0.21	0.01	0.93	11.06	2.53	6.26
7.	Ekeki	28.0	6.40	8.10	4.56	9.07	2.65	0.77	0.78	0.09	1.23	15.90	1.07	9.23
8.	Kpansia	27.0	6.48	6.02	4.03	12.64	4.08	0.73	0.77	0.17	0.37	12.51	0.90	12.62

Table 2: Statistical analysis of parameters used in this studied locations

S/N	Parameters	Minimum	Maximum	Average	Range	WHO (2006)
1	Tem(°C)	26.0	28.0	27.1	26-28	Ambient
2	pH	6.40	6.54	6.46	6.40-6.54	6.5-8.5
3	EC(µS/cm)	6.02	13.50	9.84	6.02-13.50	500
4	Hardness (Mg/l)	2.68	5.05	3.82	2.68-5.05	500
5	TDS(Mg/l)	9.07	17.01	12.98	9.07-17.01	500
6	Ca^{2+} (Mg/l)	2.59	4.08	2.82	2.59-4.08	75
7	Mg^{2+}(Mg/l)	0.52	1.23	0.93	0.52-1.23	50
8	K^+ (Mg/l)	0.21	1.61	0.93	0.21-1.61	200
9	Fe^{2+}(Mg/l)	0.01	0.97	0.45	0.10-0.97	0.3
10	Na^+ (Mg/l)	0.37	2.37	1.18	0.37-2.37	200
11	HCO_3(Mg/l)	11.20	20.48	14.58	11.20-20.48	-
12	SO_4^-(Mg/l)	0.90	3.01	1.71	0.90-3.01	250
13	Cl^- (Mg/l)	6.26	10.21	10.21	6.26-12.70	250

Table 3: Parameter in meq/l.

Location	Ca^{2+}	Mg^{2+}	Na^+	K^+	Fe^+	HCO_3^-	SO_4^-	Cl^-
Agbura	0.1128	0.0881	0.0391	0.0233	0.0163	0.2393	0.0535	0.3572
Azikoro	0.1148	0.0823	0.0391	0.0236	0.0163	0.2396	0.0627	0.3578
Swali	0.1332	0.0806	0.0404	0.0321	0.0055	0.2498	0.0214	0.3099
Ovom	0.1618	0.0864	0.1031	0.0254	0.0173	0.3357	0.0337	0.1980
Onopa	0.1292	0.0428	0.0783	0.0413	0.0041	0.1999	0.0189	0.2868
Amarata	0.1382	0.1012	0.0404	0.0054	0.0002	0.1813	0.0527	0.1763
Ekeki	0.1322	0.0634	0.0535	0.0199	0.0016	0.2606	0.0223	0.2600

Kpasia	0.2036	0.0601	0.0161	0.0601	0.0030	0.2050	0.0187	0.3556

Table 4: Relationship between various ionic ratios of groundwater in the studied area.

Location	Ca^{2+}/ Mg^{2+}	Na^+/ Cl^-	Ca^{2+}/ Cl^-	H^+/ CO_3^-	Mg^{2+}/ Cl^-	K^+/Cl^-	SO_4^{2-}/ Cl^-	Ca^{2+}/ SO_4^{2-}
Agbura	1.28	0.11	0.32	0.67	0.25	0.07	0.15	2.11
Azikoro	1.39	0.11	0.32	0.67	0.23	0.07	0.18	1.8
Swali	1.65	0.13	0.43	0.81	0.26	0.10	0.07	6.22
Ovom	3.78	0.52	0.82	1.70	0.44	0.12	0.17	4.80
Onopa	3.02	0.27	0.45	0.70	0.15	0.14	0.07	6.84
Amarata	1.37	0.23	0.78	1.03	0.57	0.03	0.29	2.62
Ekeki	2.09	0.21	0.51	1.00	0.24	0.08	0.09	5.93
kpansia	3.39	0.05	0.57	0.58	0.17	0.06	0.05	10.89

The pH values in the studied area ranges from 6.40 to 6.54 with an average value of 6.46, (table 2) indicating that the groundwater in the area are slightly acidic since the value are slightly below WHO (2006) standard for potable water (6.5 -8.5). The average value of electrical conductivity (EC) in groundwater samples in the studied area is of 9.84µs/cm, having its highest 13.50µs/cm at Amarata and lowest 6.02µs/cm at Kpansia (table 2). All the water from the sampled boreholes in the studied area has EC values within permissible regulatory limits of the WHO (2006) which is 500µs/cm.

Groundwater hardness in the studied area lies between a range of 2.68mg/l and 5.05mg/l (table 2). The value is within the permissible limits of the WHO (2006) which is 500mg/l for potable water. The total dissolved solids (TDS) concentration in the studied area ranges from 9.07mg/l to 17.01mg and has the average value of 12.98mg/l (table 2). The WHO (2006) permissible limit for TDS is 500mg/l for potable drinking water. The concentration of calcium and magnesium in groundwater in the studied area lies between 2.59mg/l to 4.08mg/l and 0.52mg/l to 1.23mg/l respectively (table 2). The WHO (2006) permissible limits for calcium and magnesium for potable water as 75mg/l and 50mg/l. Concentration levels of these parameters are within acceptable limits for potable water.

The range of values for potassium in groundwater samples in the study area lies between 0.21mg/l and 1.6mg/l (table 2). The WHO (2006) permissible limit for potassium in drinking water is 200mg/l, indicating that ground water in the studied area is suitable for domestic and other uses. However some of the wells (Agbura, Azikoro, Ovom) in the studied area show higher concentration values for iron (0.91mg/l, 0.91mg/l and 0.97mg/l) respectively, with a mean value of 0.45mg/l (table 2). Exposure of water samples to air could cause ferrous (Fe^{2+}) ion to oxidize to ferric (Fe^{2+}) ion which would precipitate a ferric-hydroxide which stain 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). Therefore, the wells in Agbura, Azikoro and Ovom have to be treated for iron.

The concentration of sodium for groundwater samples from the various locations in the studied area ranges between 2.37mg/l to 0.37mg/l with an average value of 1.18mgl (table 2). The WHO (2006) permissible limit for sodium in portable drinking water is 200mg/l. This indicates the portability of the groundwater in the studied area.
The bicarbonate level ranges between 20.48mg/l and 11.20mg/l, with a mean value of 14.58mg/l. The highest bicarbonate ion value 20.48mg/l was recorded in Ovom and the lowest 11.2mg/l in Amarata (table 2). The WHO (2006) standard has no limit for this parameter. It is resulted from CO_2 in the atmosphere and biota production in the soil. The concentration level of sulphate ranges from 3.01mg/l to 0.90mg/l with a mean value of 1.7mg/l (table 2). The WHO (2006) standard for this parameter is 250mg/l. The values obtained were below the WHO permissible limit for portable water. Hence the water is suitable both for domestic and other purposes. Chloride concentration ranges from 6.26mg/l to 12.70mg/l, with an average value of 10.21mg/l (table 2). Generally a concentration of Cl below 20mg/l is regarded as low. Thus there is low chloride concentration in the study area and no indication of salt water encroachment into aquifers. A chloride concentration of 40mg/l and above in the water is an indicative of salt water encroachment. WHO (2006) permissible limit for drinking water is 250mg/l. In the light of this, water from the study area would be free from chloride related problem.
The distribution and concentration of levels of cations and anions in the groundwater from the study area were plotted on a bar chart. Analysis of the result shows the ionic abundance in the order of Ca>mg>Na>K>Fe for cations and HCO_3>Cl>SO_4 for Anions (Fig. 3). The values obtains are generally less than the recommended limits of those parameters for domestic purposes (WHO 2006), with exception of the concentration for iron (Fe) with maximum concentration above 0.3mg/l in Agbura, Azikoro and Ovom. Thus boreholes in these areas should be treated for iron (Fe).

Concentration in meq/l

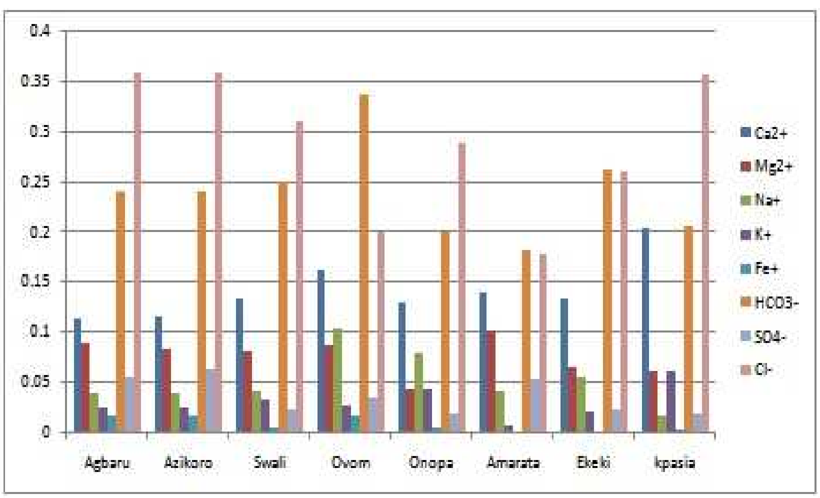

Fig. 3: Bar Chart showing variation of cations and anions in (meq/l) against sample locations

The scatter plots (Fig. 4 and 5) shows the relative concentration of the different ions from the individual samples based on average values for each location. The scatter plot shows lower cation and anions. The Dominant cation and anion in the area are Ca^{2+} and HCO_3^- respectively. The value for these parameters however were below the (WHO 2006) permissible limits for portable water.

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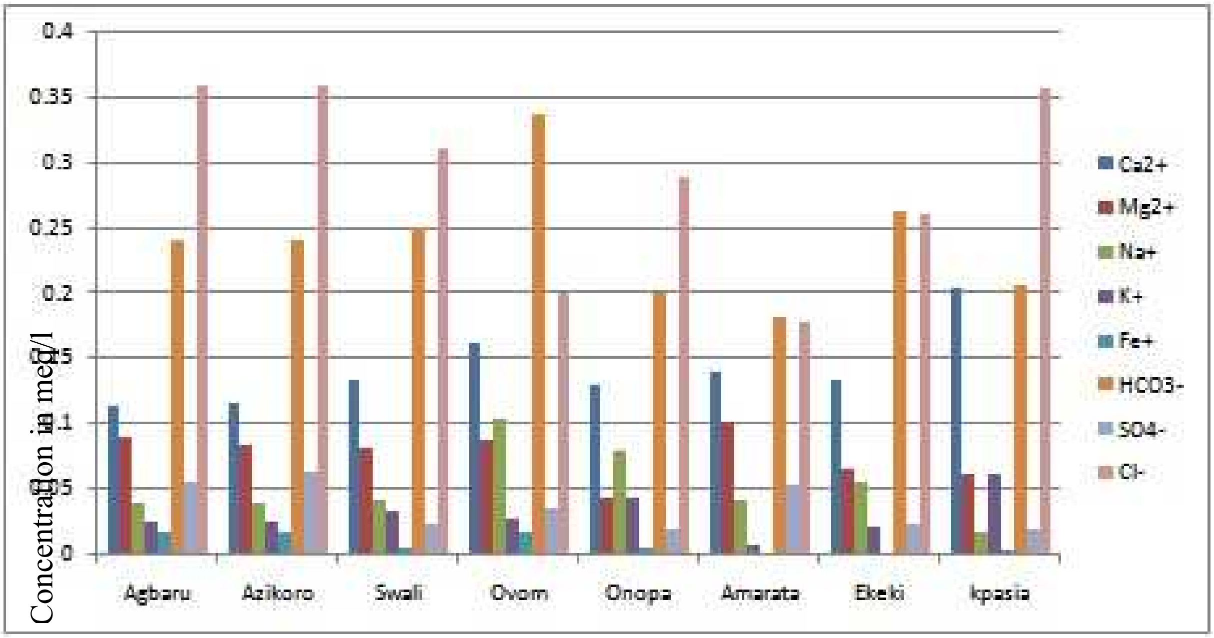

Fig. 4: Plot of Cations versus Sample localities

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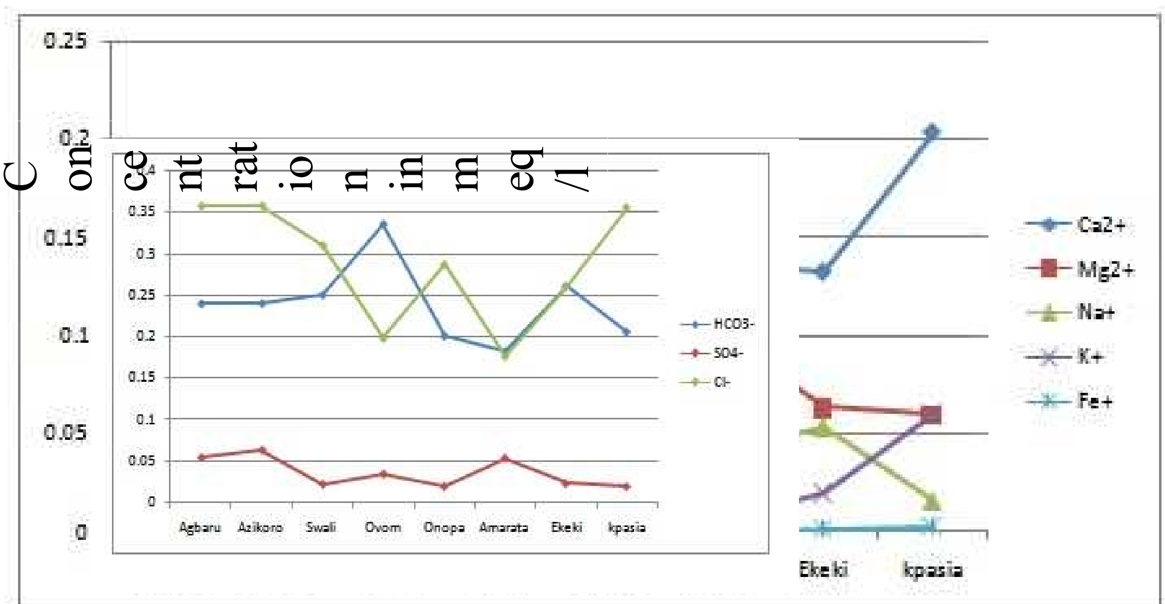

Fig. 5: Plot of anions versus sample localities.

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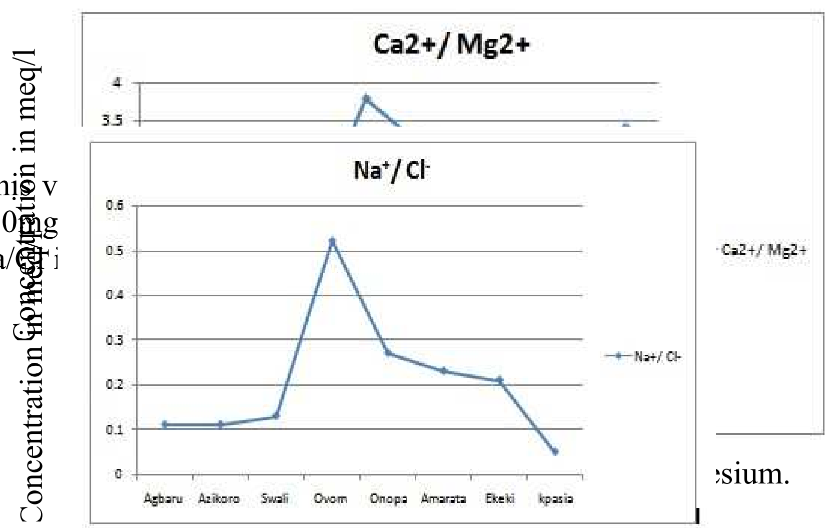

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CONCLUSION

The pH of the water show slightly acid groundwater in area. The acidity arises from gas flaring in most parts of the Niger Delta as well as the presence of organic matter in the soil. The water should be treated to increase the level of pH at locations where values are below 6.5. Iron values are exceptionally highly in some locations. This can be treated when the water is exposed to the air and the iron is precipitated.

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