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Research Article

CHARACTERIZATION AND QUANTITATIVE INDICATORS OF GROUND WATER QUALITY IN OKRIKA, RIVERS STATE, NIGERIA

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ABSTRACT

The study aims at appraising the suitability of the water for domestic purposes. The p^H values as recorded in the area range from 6.2 – 7.7 with a mean of 6.9, indicating that the groundwater is weakly acidic to alkaline. The low acidity of groundwater in the area probably results from industrial wastewaters. The electrical conductivity values ranges from 12.25 – 92.7 (µS/cm) with an exception at George-Ama (Location 6) with 486.0µS/cm. Apart from this location all others fall within the WHO stipulated range of 150µS/cm. Total Dissolved Solids (TDS) ranges between 6.12 – 237.0mg/l against the WHO standard of 250mg/l. BH 1, BH 3, BH 5, BH 6, BH 8, BH 11, BH 12, BH 14 and BH 16, all exceed 250mg/l. The high concentration is also reflected in the conductivity of the area with BH 1, BH 3, BH 5, BH 6, and BH 11, all showing increasing conductivity with increasing TDS. Total suspended solids (TSS) ranges from 0.00mg/l – 58.00mg/l. Chloride concentration ranges between 18.00mg/l – 300mg/l. Chloride concentration above 40mg/l in groundwater is an indication of saltwater intrusion BH 1, BH 2, BH 6, BH 8 and BH 13 show values higher than 40mg/l with BH 2 (Gream-Ama) having 300mg/l. Apart from BH 2, all other areas fall within the WHO standards of 250mg/lIron values ranges from 0.01 to 2.50mg/l. This falls below the standard of 0.3mg/l, except in Ogoloma (BH 4) and Ogbogbo (BH 5) with 2.50mg/l and 0.3mg/l, respectively. The average total hardness recorded in the area is 31mg/l, this is indicative of soft groundwater in the area. The area has a low static water level and minor records of salinity, which does not render the water unsuitable. A comparison of the results with internationally accepted standards shows that the water is suitable for drinking and other domestic purposes and for agricultural and industrial purposes. From the Piper's trilinear diagram of the concentrations of the major cations and anions in groundwater samples, the hydrochemical facies has been delineated as Sulphate – Chloride - Calcium – Biocarbonate (Cl-Ca-HCO_3^-). It is suggested that the aquifers should be protected against pollution and monitoring of groundwater quality on a regular basis to identify any future degradation of the water in the area.

Keywords: Groundwater, hydrochemicalfacies, aquifers, quality, Okrika.

INTRODUCTION

In the Okrika Island, the residents depend on groundwater as their sources for drinking water, hence the several boreholes drilled in the area. There is the presence and concentrations of six polynuclear aromatic hydrocarbons (PAHs) in groundwater resulting from effluent discharges from a petroleum refinery operation in Okrika Mainland [1]. Groundwater is often polluted by human activities; the use of engine oil left to be washed away by rains, herbicide, fertilizers, deliberate dumping of waste, leaks from underground tanks (mainly gasoline), and septic tanks [2]. Contaminated groundwater sources pose risk to the local water consumers as well as the natural environment [3], [4]. It is therefore imperative to determine the suitability of groundwater before use through certain indicators. The chemistry of groundwater in any geological environment is controlled by several factors such as the chemistry of the infiltrating water at the recharge source, the chemistry of the porous media including the interstitial cement or matrix of the aquifer, the rate of groundwater flow in the aquiferous medium and hence the permeability of the aquifer [5].

Several researchers have carried out hydrogeochemical studies of groundwater in parts of Rivers State [6], [7]. Other researchers have also explained that over abstraction of groundwater due to population increase in Port Harcourt and its environs as the major cause of saltwater encroachment [6], [8]. According to these authors, groundwater in the area is potable and suitable for domestic, agricultural, and some industrial purposes. This study therefore aims at identifying and evaluating the indicators/factors affecting groundwater quality in the area as well as classifying and characterizing groundwater quality using statistical analysis. To accomplish this purpose, physico-chemical properties of groundwater have been examined.

Study Area Description:

Okrika Island is located within the Niger Delta Sedimentary Basin (Fig. 1). Okrika Island (Fig.2) is situated between latitudes 4^035^1 and 4^08^1 N and longitudes 6^058^1 and 7^015^1 E in the Okrika Local Government Area of Rivers State, Eastern Niger Delta, Nigeria. The area lies within the subequatorial region of Nigeria. This region is characterized by two major seasons – wet and dry seasons [9]. The wet season begins in March and ends in October, with a peak in June and July. There is commonly a period of little or no rain in August, popularly called 'August Break'. Annual mean rainfall in the area is over 3000mm [10]. The study area is characterized by high temperature and humidity as is common with humid tropical climate. Average annual temperature in the area is about 27^{0}C [11], with maximum values in the months of March and April, and the lowest in July and August [12]. The climatic conditions have an intimate relationship with vegetation type in the area. The high rainfall and humidity promote thick vegetation termed tropical rainforest type of vegetation in the area [9].

The major aquiferous formation in the study area is the Benin Formation. It is about 2100m thick at the basin centre and consists of coarse-medium grained sandstones, thick shales and gravels. The upper section of the Benin Formation is the quaternary deposits which is about 40 – 150m thick and comprises of sand and silt/clay with the later becoming increasingly more prominent seawards [13]. The formation consists of predominantly freshwater continental friable sands and gravel that have excellent aquifer properties with occasional intercalations of claystone/shales [14]. The Benin Formation is highly permeable, prolific, productive and is the most extensively tapped aquifer in the Niger Delta [15], [13], [5], [7]. All the boreholes in the study area are drilled into it. The Benin Formation consists of fluvial and lacustrine deposits deposits whose thicknesses are variable but generally exceed 1970 meters [16]. The lithologies of the Benin Formation include sands, silts, gravel and clayey intercalations. The sands are fine to coarse-grained, gravelly, poorly sorted and sub-angular to well rounded. According to Onyeagocha (1980), the rocks of the Benin Formation are made up of about 95 – 99% quartz grains, Na+K – Mica 1 -2.5%, feldspar 0.5 1.0% and dark minerals 2.3%. These minerals are loosely bound by calcite and silica cement. The clayey intercalations have given rise to multi-aquifer systems in the area.

The main source of recharge is through direct precipitation where annual rainfall is as high as 2000 – 2400mm. The water infiltrates through the highly permeable sands of the Benin Formation to recharge the aquifers. Groundwater in the study area occurs principally under water table conditions. Multi-aquifer systems occur in the study area and the upper aquifers are generally unconfined [15], [5], [18], [19].

Geologically the study area lies within the Niger Delta Sedimentary Basin. Lithostratigraphically, these rocks are divided into the oldest Akata Formation (Paleocene), the Agbada Formation (Eocene) and the Youngest Benin Formation (Miocene to Recent). Generally, the present knowledge of the geology of the Niger Delta was derived from the works of several researchers [20], [21], [22], [23], as well as the exploration activities of the oil and gas companies in Nigeria. The formation of the so called proto-Niger Delta occurred during the second depositional cycle (Campanian-Maastrichtian) of the southern Nigerian basin. However, the modern Niger Delta was formed during the third and last depositional cycle of the southern Nigerian basin which started in the Paleocene.

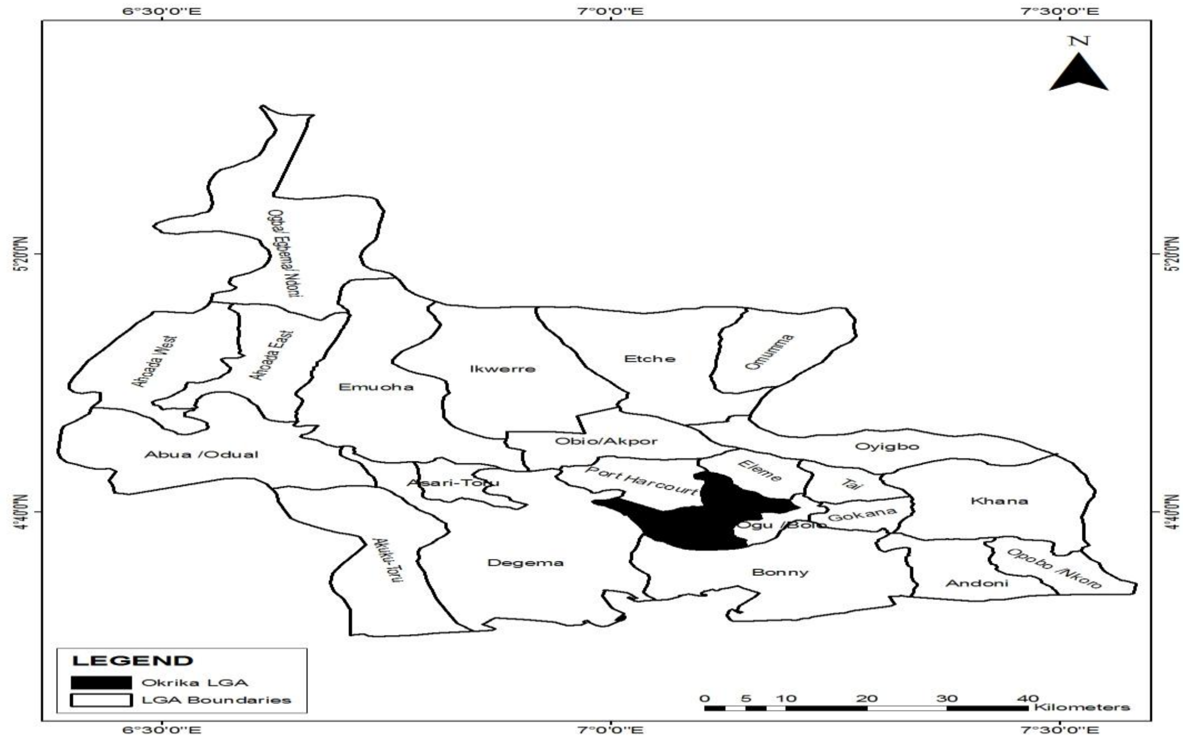

Figure 1: Map of Rivers State Showing the Okrika Local Government Area

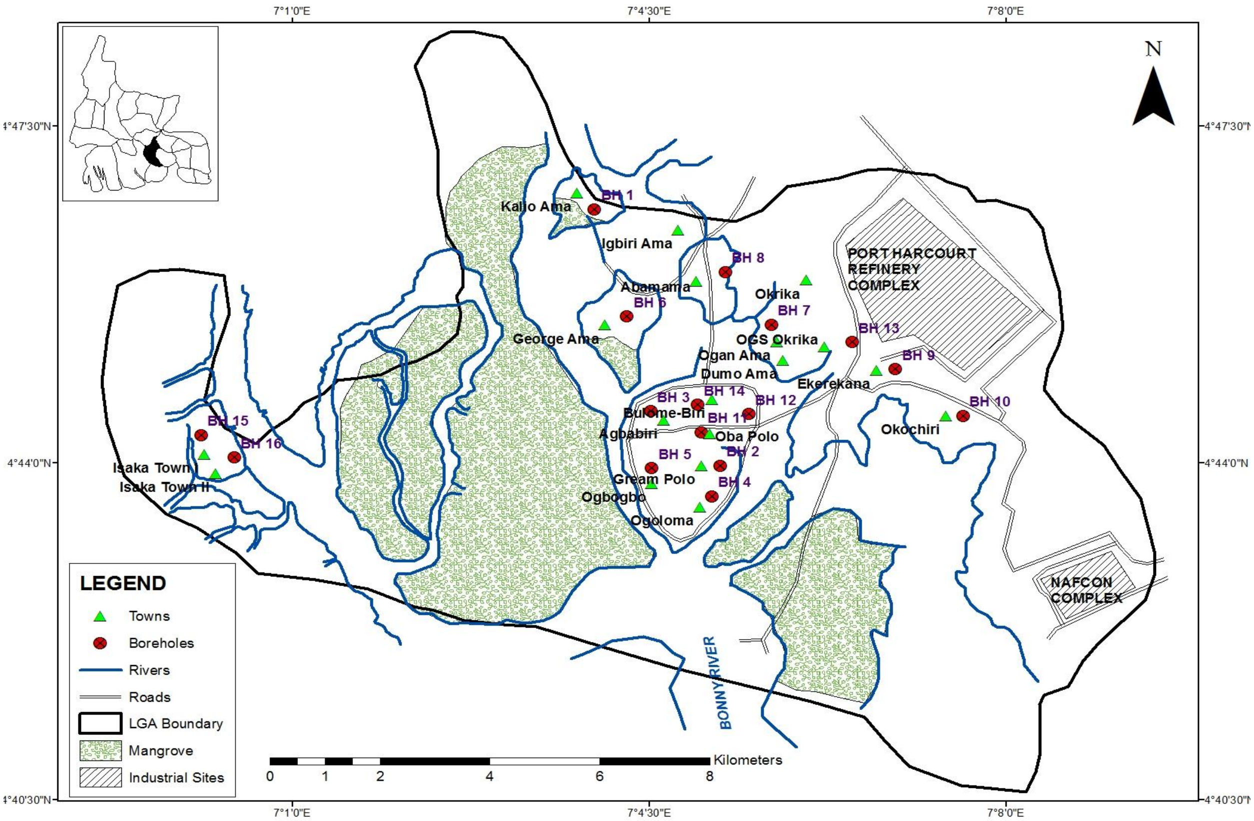

Figure 2: Map of Study Area showing the Study Areas and Positions of the Boreholes (Inset: Map of Rivers State Showing Okrika Local Government Area)

MATERIALS AND METHODS

Groundwater samples were collected from boreholes after 5 minutes of pumping to ensure the samples were true representative from the aquifer. The samples were stored in sterilized two-litre containers with tightly fitting covers wrapped in a black polyethylene plastic bag and put in a cooler to ensure constant temperature. The containers were first washed with de-ionized water, and then several times with the sample water before collection in order to avoid any contamination.

Parameters like pH and temperature and electrical conductivity were determined in the field due to their unstable nature. The pH of the water sample was measured with a pH-meter. The glass tube in the kit was sterilized before been filled to its mark with water sample. The tube was then placed in the space provided in the equipment and a knob adjusted for colour matching, the pH was then read and recorded. The temperature was read using a mercury thermometer. The electrical conductivity was measured using a Mark electronic switchgear conductivity meter. After sampling, the lids of the containers were immediately replaced to minimize contamination and escape of gases. The samples were then stored in an ice-packed cooler for analysis within 24 hours.

All analyses were carried out at a standardized laboratory using national and international regulatory methods. The evaluation of water quality was in accordance with regulatory standard. The approach ensures that the samples collected were tested in accordance with agreed requirements using competent personnel as well as appropriate equipment and materials.

RESULT AND DISCUSSIONS

The results of the groundwater quality analysis in the area are shown in Table 1 below while Table 2 shows the descriptive statistical analysis of the data. The average temperature of groundwater within the study area is 27.42^{o}C. The p^{H} values as recorded in the area range from 6.2 – 7.7 with a mean of 6.9, indicating that the groundwater is weakly acidic to alkaline. Weak acids normally tend to buffer solutions to lower pH changes [24]. This implies that the weakly acidic to alkaline groundwater in the study area has the capacity to reduce any pH within natural waters.The electrical conductivity values ranges from 12.25 – 92.7 (µS/cm) with an exception at George-Ama (Location 6) with 486.0µS/cm. Apart from this location all others fall within the WHO [25] stipulated range of 150µS/cm (Table 1).

BH No.	Borehole location	Colour (Hazen Unit)	pH	Temp°C	EC (µ S/cm	TDS (mg/l	TSS (mg/l)	Cl^- (mg/l)	Fe^{2+} (mg/l)	Total Alkalinity (mg/l)	SO_4^{2-} (mg/l)	Ca^+ (mg/l)	Mg^{2+} (mg/l)	Total hardness (mg/l)	CO_3^{2-} (mg/l)	HCO_3^- (mg/l)	Salinity (mg/l)
BH1	Kalio-Ama	5	6.5	27°c	72.1	100.33	0.00	45.60	0.12	81	56.65	3.53	2.13	6.55	0.02	81	0.03
BH2	Grean-Ama	5	6.8	27°c	58.4	10.70	1.00	300	0.02	85	0.03	54.00	10.00	100	0.02	80	0.02
BH3	Agbabiri	5	6.7	28°c	47.9	94.0	7.00	18.60	0.22	84	92.60	8.00	6.00	14.00	0.03	84	0.10
BH4	Ogoloma	5	7.2	26.7°c	28.7	16.5	0.00	19.00	2.05	NA	60.00	13.40	48.30	5.00	0.02	81	17.10
BH5	Ogbogbo	5	7.5	27°c	92.7	46.35	58.00	40.00	0.3	14.0	69.12	12.00	8.00	20.00	NA	NA	0.05
BH6	George-Ama	5	6.7	28°c	486.0	237.0	0.00	118.00	0.22	11.0	80.60	16.00	6.00	68.00	NA	NA	0.2
BH7	Ogan-Ama	5	5.7	26°c	25.0	11.5	0.00	19.00	0.08	3.0	20.00	1.00	5.80	6.80	NA	NA	00.0
BH8	Abau Okrika	5	6.5	27°c	64.2	80.55	44.2	57.06	0.14	NA	48.70	3.07	1.53	4.44	NA	NA	0.02
BH9	Ekerekana	5	6.8	28°c	46.2	23.1	0.00	18.00	0.01	18.0	96.00	20.00	8.00	28.00	NA	NA	0.05
BH10	Okochiri	5	7.2	27°c	122.3	6.12	0.00	20.00	0.00	12.0	98.00	10.00	0.00	0.00	NA	NA	0.05
BH11	Oba-Polo	5	7.7	29°c	583.1	122	10.6	18.00	0.03	86.0	19.20	62.00	6.00	6.80	0.02	81	0.20
BH12	ATC Road	5	7.2	28°c	49.6	80.0	9.00	27.00	0.06	NA	NA	53.00	17.00	70.00	0.02	80	0.10
BH13	OGS Okrika	5	6.2	27°c	58.2	10.6	1-0	123.0	0.01	8.0	96.0	14.00	12.00	26.00	NA	NA	0.20
BH14	Bulome-Biri	5	7.4	28°c	83.5	120	9.4	20.0	0.08	85.0	15	NA	NA	2.50	NA	NA	NA
BH15	Isaka I	5	7.6	27°c	40.2	10.8	0.00	20.00	0.01	NA	20.0	60.00	10.00	70.00	0.02	81	NA
BH16	Isaka II	5	6.8	28°c	48.0	14.0	2.0	30.00	0.01	NA	NA	49.00	NA	68.00	NA	80	NA

Table 1: Results of Analysis of Groundwater Samples in the Area

Total Dissolved Solids (TDS) ranges between 6.12 – 237.0mg/l against the WHO [25] standard of 250mg/l. BH 1, BH 3, BH 5, BH 6, BH 8, BH 11, BH 12, BH 14 and BH 16, all exceed 250mg/l as shown in Table 2. The high concentration is also reflected in the conductivity of the area with BH 1, BH 3, BH 5, BH 6, and BH 11, all showing increasing conductivity with increasing TDS. Total suspended solids (TSS) ranges from 0.00mg/l – 58.00mg/l. Chloride concentration ranges between 18.00mg/l – 300mg/l. According to Tremblay *et al.,* (1973), chloride concentration above 40mg/l in groundwater is an indication of saltwater intrusion (Fig. 3). BH 1, BH 2, BH 6, BH 8 and BH 13 (Table 1) show values higher than 40mg/l with BH 2 (Gream-Ama) having 300mg/l. Apart from BH 2, all other areas fall within the WHO [25] standards of 250mg/l (Table 2).

Iron values ranges from 0.01 to 2.50mg/l in the area. This falls below the WHO [25] standard of 0.3mg/l, except in Ogoloma (BH 4) and Ogbogbo (BH 5) with 2.50mg/l and 0.3mg/l, respectively. Iron is relatively immobile and that it is generally present in groundwater in small proportions [26]. This situation can therefore account for the low levels recorded in the majority of the samples. Total alkalinity ranges from 0.00mg/l – 86mg/l while Bicarbonate (HCO_3^-) concentration ranges from 80mg/l – 84mg/l. This parameter is not listed in WHO Standards, but according to [27] bicarbonate rarely exceeds 40 – 400mg/l in groundwater. Calcium ranges from 1.00mg/l – 62.00mg/l while magnesium ranges from 0.00 – 48mg/l. Total hardness values range from 0.00 – 700mg/l with the highest concentration value at ATC Road (BH 12). Hardness range of 0 – 60mg/l is not likely to cause any health hazard in water [28]. Carbonate (CO_3^{2-}) ranges from 0.00mg/l – 0.02mg/l.Sulphate (SO_4^{2-}) concentrations in the area ranges from 0.03mg/l – 98mg/l which does not exceed the WHO [25] standard of 250mg/l. Salinity values range from 0.00mg/l – 17.10mg/. Table 2 shows the descriptive statistical summary of the major ions in groundwater in the area while Fig. 2 shows the map of the Static Water Levels (SWL) in the area. Fig. 3 also shows the contours in the study area. Fig. 4 shows the distribution of pH and Temperature while Fig. 5 shows the pH distribution using a bar chart in the study area. The relationship between electrical conductivity (EC) and total dissolved solids (TDS) is shown in Fig. 6 while the variation plot of TDS and EC is depicted in Fig.7. Chloride (Cl^-) distribution is shown on a pie chart (Fig. 8) while the correlation matrix which points out the relationships between the parameters is shown in Table 3.

Parameter	Unit	Mean	Median	Min	Max.	S D	WHO (2008)
Temp.	^0C	27.42	27.00	26.00	29.00	74316	
Ph		6.91	6.8000	5.70	7.70	53977	6.5-8.5
EC	µS/cm	79.45	53.9000	12.23	486.00	110.35807	1500
TDS	mg/l	61.44	34.7250	6.12	237.00	32.50660	1000
T. Hardness	mg/l	31.01	17.0000	0.00	100.00	32.56661	500
Total Alkalinity	mg/l	30.44	11.5000	0.00	86.00	37.85757	NS
Salinity	mg/l	1.13	.0500	0.00	17.10	4.23363	NS
Chloride	mg/l	55.83	23.5000	18.00	300.00	73.33193	250
Fe	mg/l	2.10	0.0700	0.00	2.05	49905	0.3
SO_4^{2-}	mg/l	48.24	52.6750	0.00	98.00	37.61196	400
HCO_3^-	mg/l	40.50	40.000	0.00	84.00	41.83778	380
Ca^{2+}	mg/l	23.69	13.7000	0.00	62.00	23.02880	200
Mg^{2+}	mg/l	8.79	6.0000	0.00	48.30	11.55875	15
CO_3^{2-}	mg/l	0.0094	0.0000	0.00	0.02	0.01124	NS

Table 2: Statistical Summary of Major Ions Data for Groundwater in the Study Area

Note: NS = Not Stated

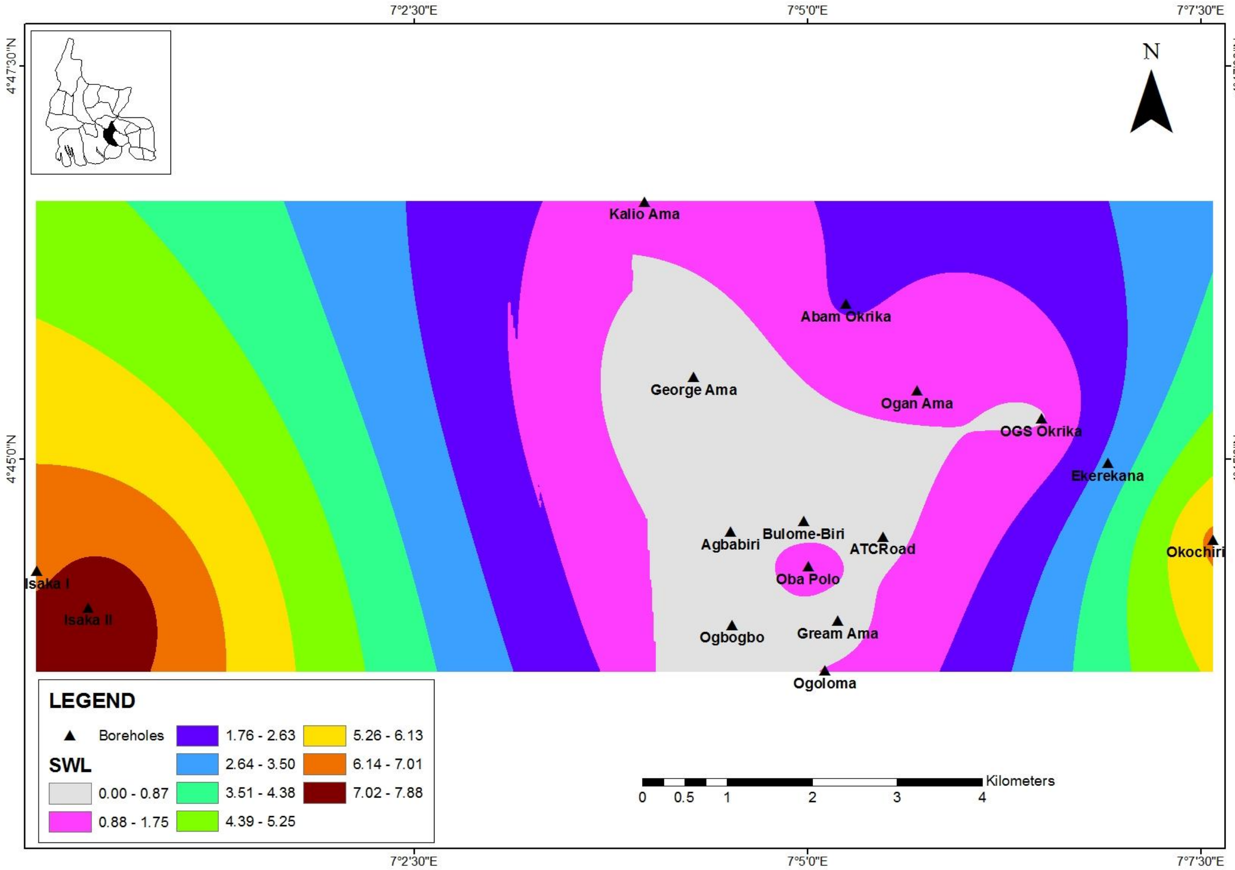

Figure 2: Map of the Study Area showing the Static Water Levels (SWL) (Inset: Map of Rivers State Showing Okrika Island

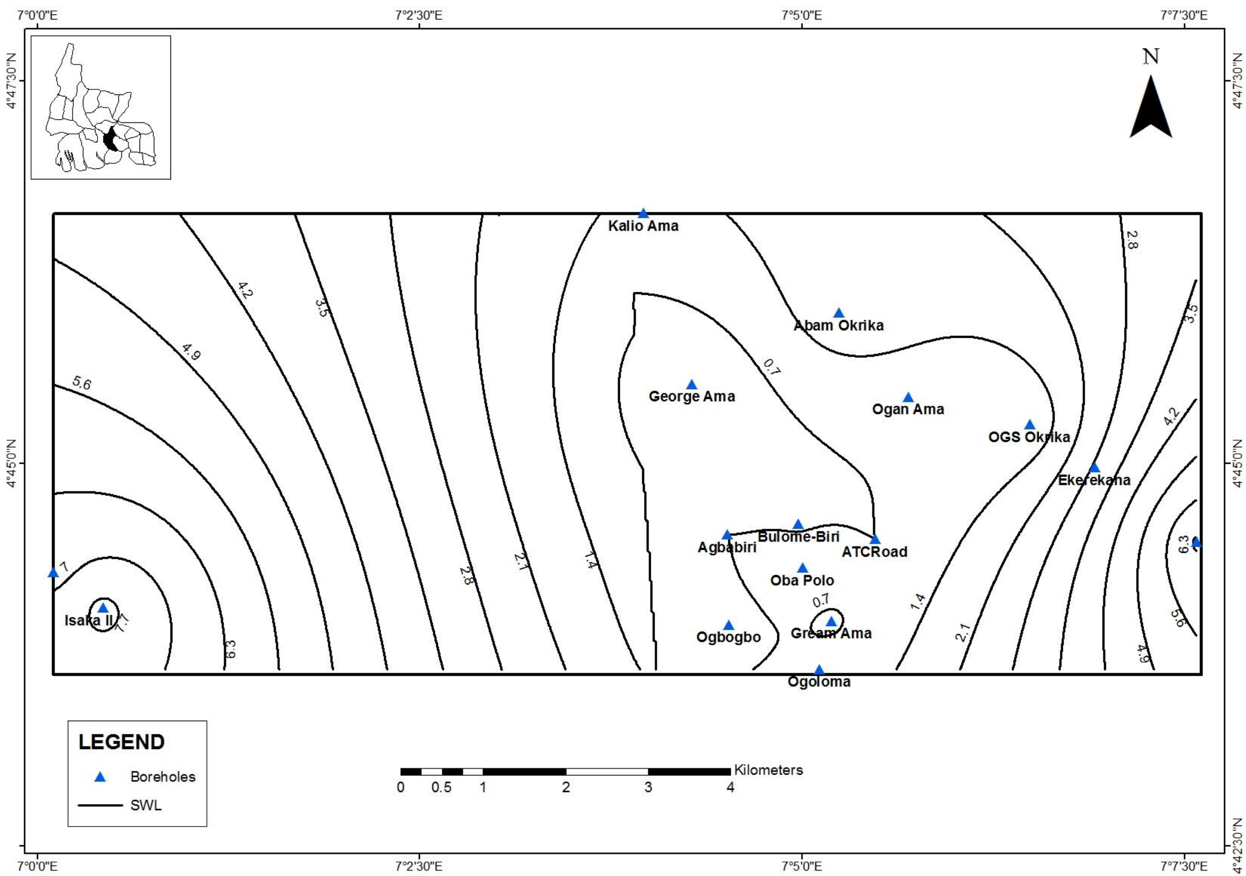

Figure 3: Map of the Study Area showing the Contours (Inset: Map of Rivers State Showing Okrika Local Government Area)

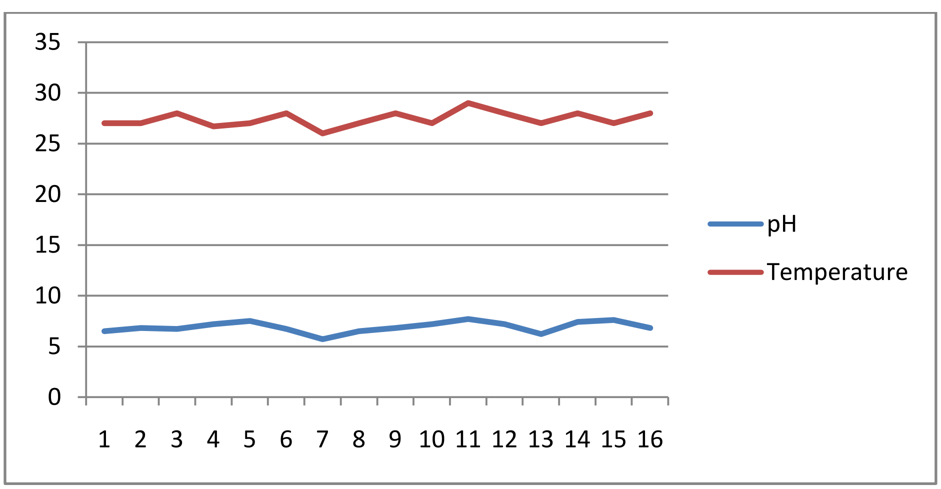

Figure 4: Plot showing distribution of pH and Temperature

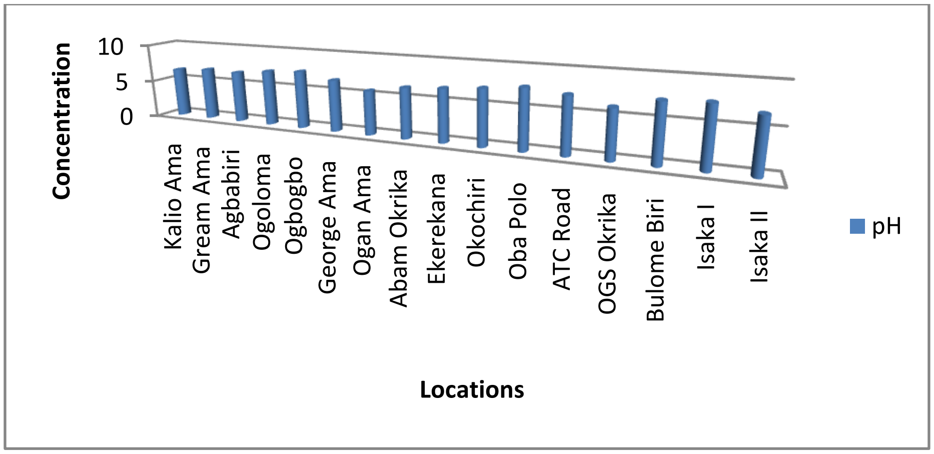

Figure 5: P^H distribution using a Bar

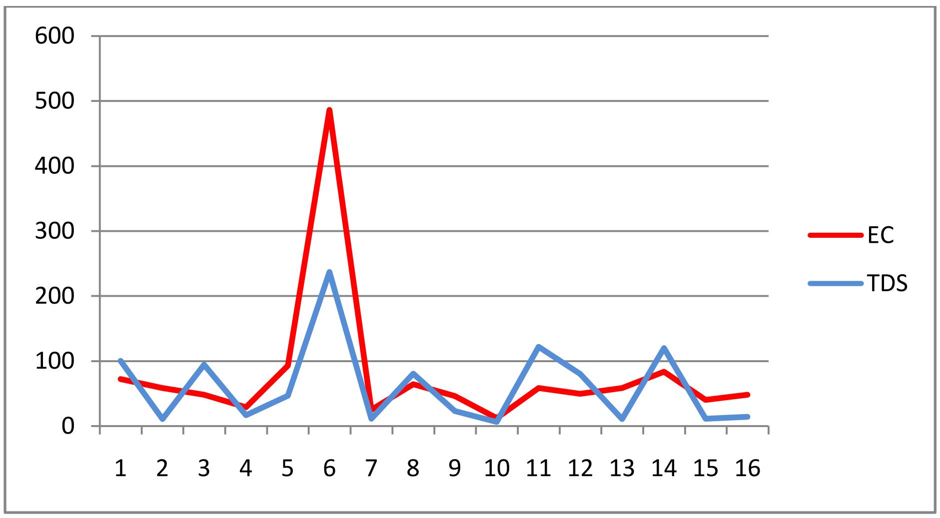

Figure 6: Plot showing EC and TDS Relationships

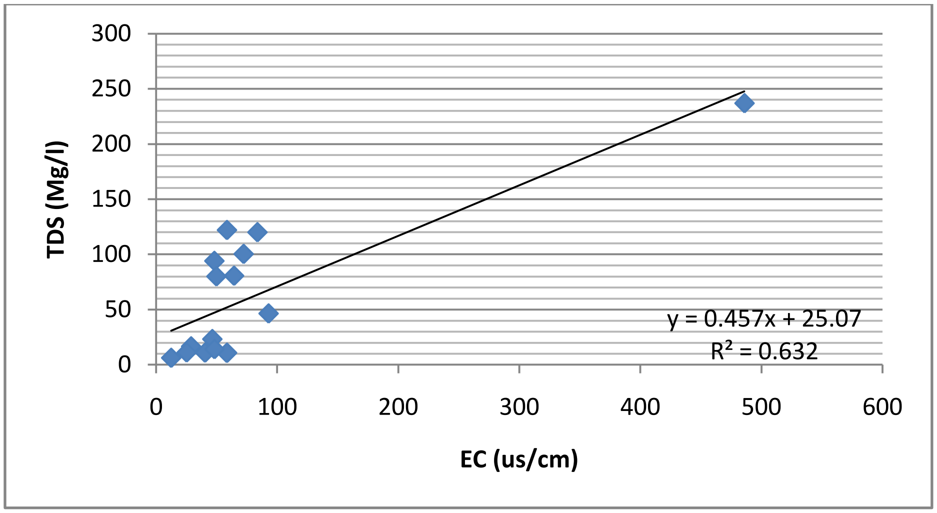

Figure 7: Plot showing variation of TDS and EC

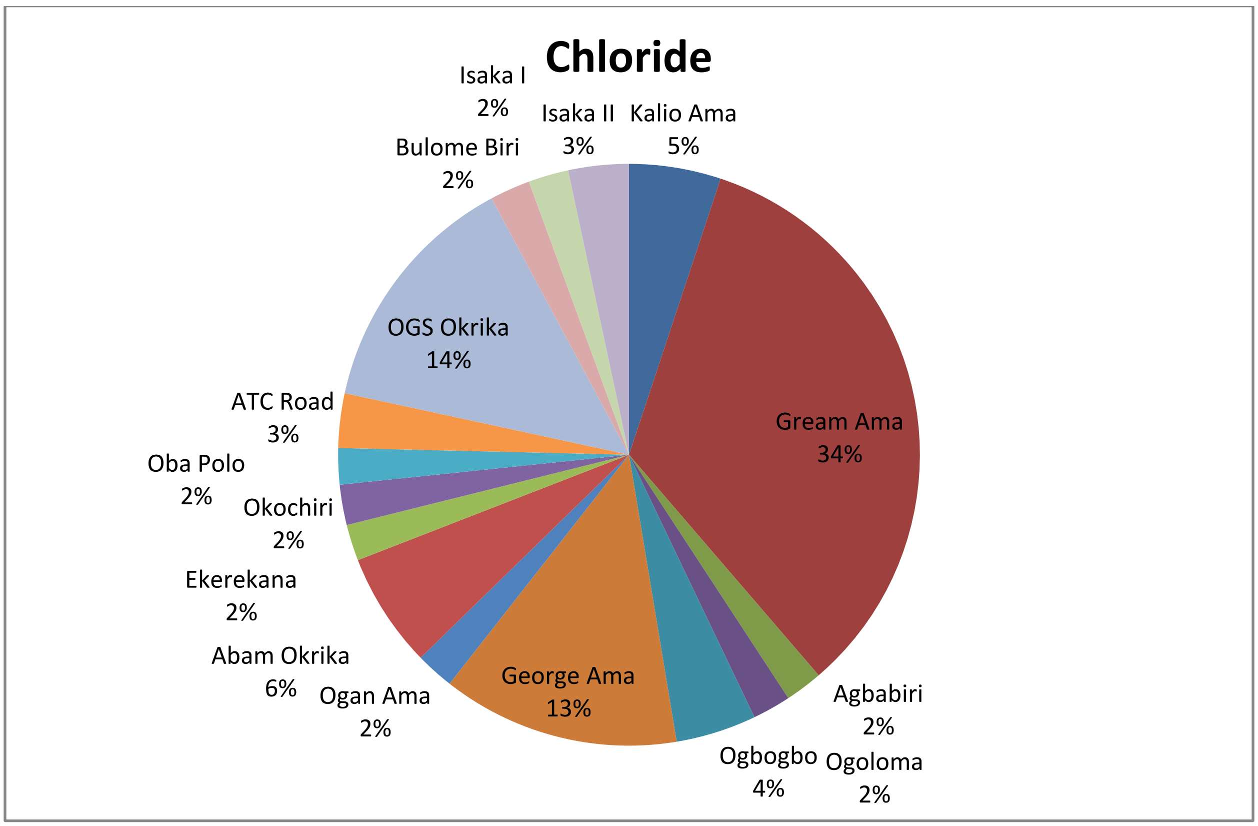

Figure 8: Pie Chart Showing the Chloride Distribution

Parameters	Ph	Temp.	EC	TDS	TSS	Cl^-	$Fe^{2=}$	Total Alkalinity	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Total Hardness	CO_3^-	HCO_3^-	Salinity
pH	1.00														
Temperature	.477	1.00													
EC	-.063	.254	1.00												
TDS	.104	.543(*)	.795(**)	1.00											
TSS	.215	-.057	-.024	.083	1.00										
Chloride	-.228	-.160	.255	-.017	-.099	1.00									
Fe	.140	-.259	-.035	-.090	-.024	-.146	1.00								
Total Alkalinity	.161	.386	-.057	.321	-.116	.247	-.197	1.00							
Sulphate	-.186	-.092	.201	.072	.040	-.137	.138	-.122	1.00						
Calcium	.475	.414	-.104	-.135	-.200	.224	-.202	.022	-.586(*)	1.00					
Magnessium	.153	-.235	-.115	-.225	-.148	-.009	.891(**)	-.275	.038	.078	1.00				
Total Hardness	.077	.132	.297	-.017	-.235	.597(*)	-.244	-.126	-.435	.692(**)	.010	1.00			
Carbonate	.276	.169	-.233	.038	-.247	.063	.248	.469	-.212	.414	.374	.171	1.00		
HCO_3	.297	.237	-.272	-.083	-.312	.049	.219	.322	-.460	.627(**)	.323	.356	.869(**)	1.00	
Salinity	.146	-.250	-.114	-.180	-.140	-.132	.983(**)	-.213	.090	-.117	.914(**)	-.213	.254	.257	1.00

Table 3: Correlation Coefficient Matrix

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Hydrochemical Facies:

Hydrochemical facies are distinct zones that have anion and cation concentrations describable within defined composition categories, and the definition of a composition category, according to [29] is commonly based on [30] trilinear diagram. Hydrochemical facies can be studied in terms of anions, or cations, or both [26]. To define the facies in the groundwater, results of the chemical analysis in milligrams per litre (Table 1) were converted to values in milliequivalents per litre. From the Piper's trilinear diagram [30] of the concentrations of the major cations and anions in groundwater samples (Fig. 9), the hydrochemical facies has been delineated as Sulphate – Chloride - Calcium – Biocarbonate (Cl-Ca-HCO_3^-).

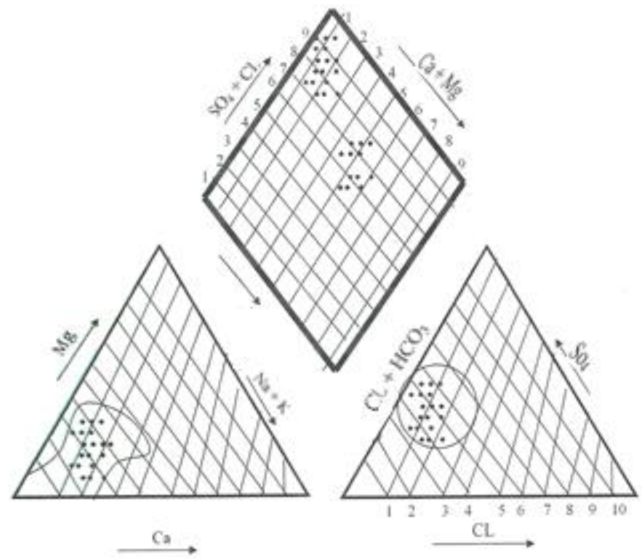

Figure 9: Piper trilinear plots of the water analysis of the study area

CONCLUSION

This study reveals p^H values ranging from 6.2 – 7.7 with a mean of 6.9, indicating that the groundwater is weakly acidic to alkaline. The low acidity of groundwater in the area probably results from industrial wastewaters. The electrical conductivity values ranges from 12.25 – 92.7 (µS/cm) with an exception at George-Ama (Location 6) with 486.0µS/cm. Apart from this location all others fall within the WHO stipulated range of 150µS/cm. Total Dissolved Solids (TDS) ranges between 6.12 – 237.0mg/l against the WHO standard of 250mg/l. BH 1, BH 3, BH 5, BH 6, BH 8, BH 11, BH 12, BH 14 and BH 16, all exceed 250mg/l. The high concentration is also reflected in the conductivity of the area with BH 1, BH 3, BH 5, BH 6, and BH 11, all showing increasing conductivity with increasing TDS. Total suspended solids (TSS) ranges from 0.00mg/l – 58.00mg/l.

This study also reveals that Chloride concentration ranges between 18.00mg/l – 300mg/l. Chloride concentration above 40mg/l in groundwater is an indication of saltwater intrusion BH 1, BH 2, BH 6, BH 8 and BH 13 show values higher than 40mg/l with BH 2 (Gream-Ama) having 300mg/l. Apart from BH 2, all other areas fall within the WHO standards of 250mg/lIron values ranges from 0.01 to 2.50mg/l in the area. This falls below the standard of 0.3mg/l, except in Ogoloma (BH 4) and Ogbogbo (BH 5) with 2.50mg/l and 0.3mg/l, respectively. The average total hardness recorded in the area is 31mg/l, this is indicative of soft groundwater in the area. The area has a low static water level and minor records of salinity, which does not render the water unsuitable. A comparison of the results with internationally accepted standards shows that the water is suitable for drinking and other domestic purposes and for agricultural and industrial purposes. From the Piper's trilinear diagram of the concentrations of the major cations and anions in groundwater samples, the hydrochemical facies has been delineated as Sulphate – Chloride - Calcium – Biocarbonate (Cl-Ca-HCO_3^-). The high water table and porous soils of the area could aid contamination of aquifers. It is therefore, suggested that the aquifers should be protected against pollution and monitoring of groundwater quality on a regular basis to identify any future degradation of the water in the area.

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