ASSESSMENT OF GROUNDWATER QUALITY IN SHALLOW COASTAL AQUIFERS OF OKRIKA ISLAND, EASTERN NIGER DELTA, NIGERIA

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(Received: 6th Sept., 2012; Accepted: 24th Oct., 2012)

ABSTRACT

This paper investigates the aquifer system and groundwater quality of Okrika Island using lithological logs, static water level (SWL) measurements and physico-chemical analyses of sampled waters from ten boreholes. The borehole logs identify three (3) major lithologies within the Benin Formation. These include clayey sand, clay and sand. The clays are silty in places, while the sands are fine to coarse and poorly sorted. In some boreholes, clays occur as topsoil and could be up to 9 m thick. In the other boreholes, the topsoils are either sand or clayey sand. Two main sand aquifer units were delineated. The static water levels are relatively shallow (o.5 7.9 m) making the aquifers in the area vulnerable to pollution from solid wastes and leachates. The pH values vary from 6.6 7.7 with an average of 7.1 which indicate slightly acidic to slightly basic groundwater. The concentrations of chloride are between 10 and 300 mg/L with a mean of 92.28 mg/L. Total alkalinity values are between 81 and 86 mg/L. Iron concentrations range from 0.01 0.1 mg/L with an average of 0.04 mg/L. Sulphate concentration ranges from 0.02 20 mg/L. These values are low when compared with the WHO (2006) standard for potable water. The calcium hardness obtained falls between 10 and 62 mg/L. Magnesium hardness is low in the water and ranges in concentration between 6 and 17 mg/L while total hardness values of the groundwater samples in the area range from 2.5 100 mg/L, indicating that the water is soft to moderately hard. The bicarbonate concentration measured at Isaka II is 81mg/L while the total dissolved solids (TDS) values fall between 10 300 mg/L. Except at few locations where elevated chloride concentrations were recorded, the groundwater is generally potable.

Keywords: Water Quality, Hydrogeology, Saline Water Intrusion, Okrika Island, Niger Delta.

INTRODUCTION

Groundwater plays an important role in the development of human societies. In Okrika Island with a population of about 200,000, the people significantly depend on groundwater for their water supply needs. There are existing boreholes, and during this study, ten (10) more boreholes were drilled in the area to further provide potable water to the populace. However, groundwater quantity is as important as its quality. This is because the health profile of any community is dependent on the quality of the water they use. The consumption of non-potable water could lead to water borne diseases such as typhoid fever, cholera and dysentery. It was in appreciation of this fact that groundwater samples were collected from ten newly drilled boreholes and analysed to assess the potability.

Hydrogeological information on the study area is scarce. However, Udom *et al.* (1999, 2002) carried out study on the hydrogeochemistry of groundwater in Port Harcourt, Tai Eleme, Khana and Gokana Local Government Areas, which adjoin the study area. Udom *et al.* (1999) and Nwankwoala *et al.* (2008) reported that over abstraction of groundwater due to population increase in Port Harcourt and its environs was the major cause of saltwater encroachment. According to these authors, groundwater in the area is potable and suitable for domestic, agricultural, and industrial use.

This study utilizes borehole data to delineate the aquifers in the area, map the static water levels as well as evaluate through analysed water samples the quality status of groundwater in Okrika Island.

Description of the Study Area

Okrika Island is situated between Latitudes $4^{0}35^{1}$ and $4^{0}8^{1}$ N and Longitudes $6^{0}58^{1}$ and $7^{0}15^{1}$ E in the Okrika Local Government Area (Fig. 1) 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 (Iloeje, 1979). The wet season begins in March and ends in October, with a peak in June and July. There is a period of little or no rain in August, popularly called 'August Break'. Annual mean rainfall in the area is over 3000mm (Ojo *et al.,* 1992). 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 (Inyang, 1975), with maximum values in the months of March and April, and the lowest in July and August (Amali *et al.*, 1985). The climatic conditions have an intimate relationship with vegetation type in the area. The high rainfall and humidity promote thick vegetation termed tropical rainforest (lloeje, 1979).

The ground surface in the area slopes from the north towards the Atlantic Ocean in the south. This gentle slope is characteristic of the entire Niger Delta area. Topographic heights rarely exceed 80 m in the area. Okrika area is drained by many rivers and creeks, the major river being the Bonny River.

Geologically, the study area as well as the entire Rivers State, 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). The present knowledge of the geology of the Niger Delta was derived from the works of the following researchers (Reyment, 1965; Short & Stauble, 1967; Murat, 1970; Merki, 1970) 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.

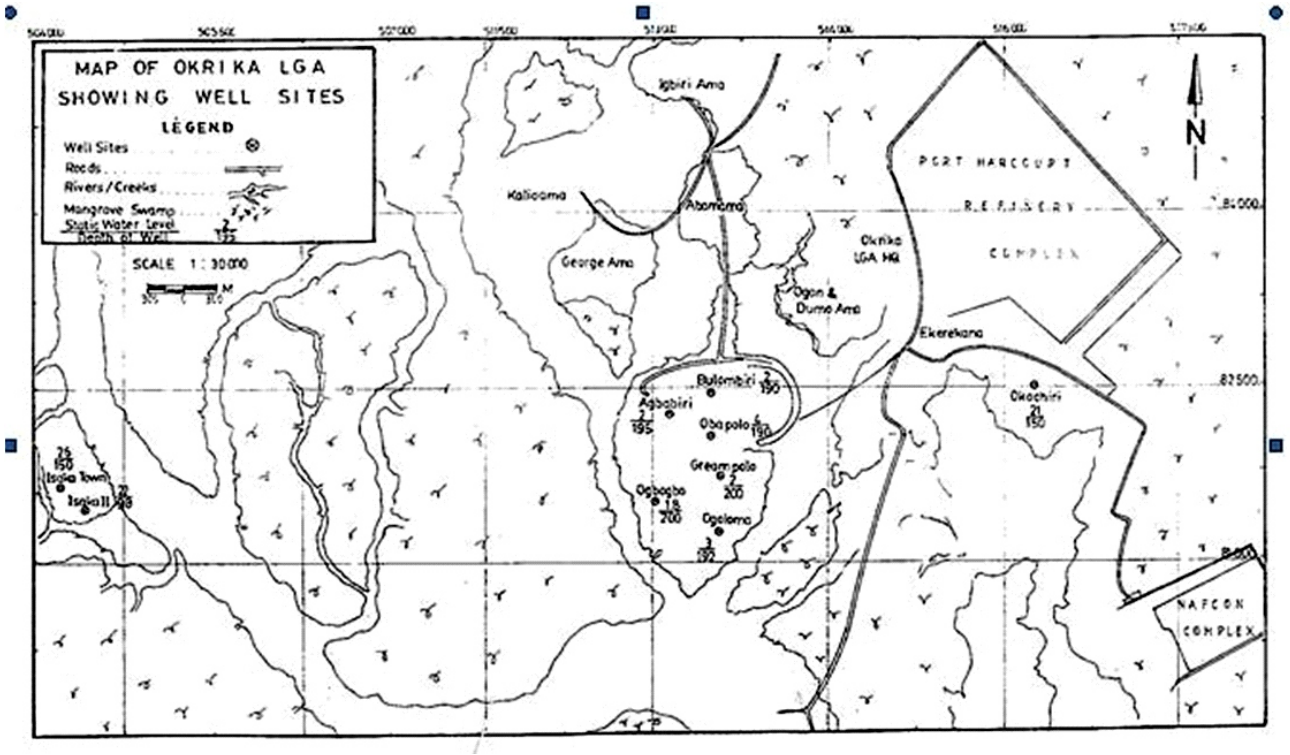

Fig. 1: Map of Okrika Local Government Area Showing Borehole Locations

The geologic sequence of the Niger Delta consists of three main Tertiary subsurface lithostratigraphic units (Short & Stauble, 1967) which are overlain by various types of Quaternary deposits (Table 1)

Table 1: Quaternary Deposits of the Niger Delta (after Etu-Efeotor & Akpokodje, 1990)

Geologic Unit	Lithology	Age
Alluvium	Gravel, Sand, clay, silt	Recent
Freshwater Backswamp, Meander Belt	Sand, clay, some silt, gravel	Quaternary
Saltwater Mangrove Swamp and Backswamp	Medium-fine sands, clay and some silt	Quaternary
Active/Abandoned Beach Ridges	Sand, clay, and some silt	Quaternary
Sombreiro-warri Deltaic Plain	Sand, clay, and some silt	Quaternary

The major aquiferous formation in the study area is the Benin Formation. It is about 2100 m 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 40 150 m thick and comprises of sand and silt/clay with the later becoming increasingly more prominent seawards (Etu-Efeotor & Akpokodje, 1990). The formation consists of predominantly freshwater continental friable sands and gravel that have excellent aquifer properties with occasional intercalations of claystone/shales (Olobaniyi & Oweyemi, 2006). According to Etu-Efeotor (1981), Etu-Efeotor & Akpokodje (1990), Offodile (2002), Udom *et al.* (2002), the Benin Formation is highly permeable, prolific, productive and is the most extensively tapped aquifer in the Niger Delta. All the boreholes in the study area were drilled into it. The Benin Formation consists of fluvial and lacustrine deposits whose thicknesses are variable but generally exceed 1970 meters (Asseez, 1989). 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 2400 mm. 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 (Etu-Efeotor, 1981; Offodile, 2002; Edet, 1993; and Udom, 2004).

METHODS OF STUDY

Ten (10) boreholes were drilled at Cream Ama, Agba-biri, Ogoloma Sandfill, Isaka I, Isaka II, Ogbogbo Sandfill, Bulome-biri, Oba-Polo, ATC Road and Okochiri in Okrika Island and lithologically logged. The boreholes were appropriately screened and static water levels determined. Groundwater samples were collected in clean sterilized 1000 ml plastic bottles with tight fitting caps. The boreholes were allowed to discharge for sometime until the temperature of the water remained constant before samples were taken. This was to ensure collection of representative samples from the aquifer. After each sampling, the bottle was capped immediately to minimize oxygen contamination and the escape of dissolved gases. The samples were then carried in ice-packed coolers to the laboratory for analysis within 24 hours. However, on-site measurements of temperature, pH and colours were made.

RESULTS AND DISCUSSION

The boreholes used for this study were drilled to depths of between 50 and 65 metres. However, screens were located at depths of between 23 and 60 m as follows: Gream-Ama: 46 60 m, Agba-Biri: 57 60 m, Ogoloma: 53 57 m, Isaka: I 38 43 m, Isaka II: 23 27 m, and Ogbogbo Sandfill: 46 50 m. Others are Bulome-Biri: 46 50 m, Oba-Polo: 54 58 m, ATC Road: 54 58 m and Okochiri: 35 40 m. A summary of these borehole parameters is contained in Table 2.

Table 2: Summary of Borehole Parameters in Okrika Island

S/N	Borehole Location	Borehole Depth (m)	Screen Depth (m)	SWL (m)
1	Gream-Ama	60	46 -50	0.6
2	Agba-Biri	60	57 - 60	0.6
3	Ogoloma Sandfill	63	53 - 57	0.9
4	Isaka Town I	50	38 - 43	7.9
5	Isaka Town II	60	23 - 27	6.7
6	Ogbogbo Sandfill	65	46 - 50	0.5
7	Bulome-Polo	60	46 - 50	0.6
8	Ogba-Polo	60	54 - 58	1.2
9	ATC Road	65	54 - 58	0.7
10	Okochiri	50	35 - 40	6.4

Lithologic Logs

The lithologic logs of the ten (10) boreholes in the area are presented in Figs. 2 11. The logs show three (3) major lithologies within the Benin Formation. These lithologies include clayey sand, clay and sand. The clays are silty at some depths, while the sands are fine to coarse and poorly sorted. At Agbabiri, Isaka Town, Oba-Polo and Okochiri boreholes, clays are located at the top and are about 9 m thick. In the other boreholes, the topsoils are either sand or clayey sand.

At Ogoloma, a 3 m thick layer of clay at depth 21 24 m separates the upper sand aquifer from the lower one (Fig. 4). The upper one, which is fine sand, lies between the depths of 9 and 21 metres while the second aquifer is between 24 and 63 metres. This indicates a multi-aquifer system in the area. The same geologic setting is also noticeable in Bulome-Biri borehole (Fig. 8). The clay layer lies between 27 and 43 m depth and is 16 m thick. Two aquifers were also identified. The first one lies between 15 and 27 metres, while the second one is located between 43 and 60 metres. For these two boreholes, the upper aquifers are unconfined, while the lower ones are confined. In the other eight (8) boreholes, only the upper unconfined aquifer could be identified from the lithologic logs. However, there are sandy shale intercalations within the sand aquifer unit.

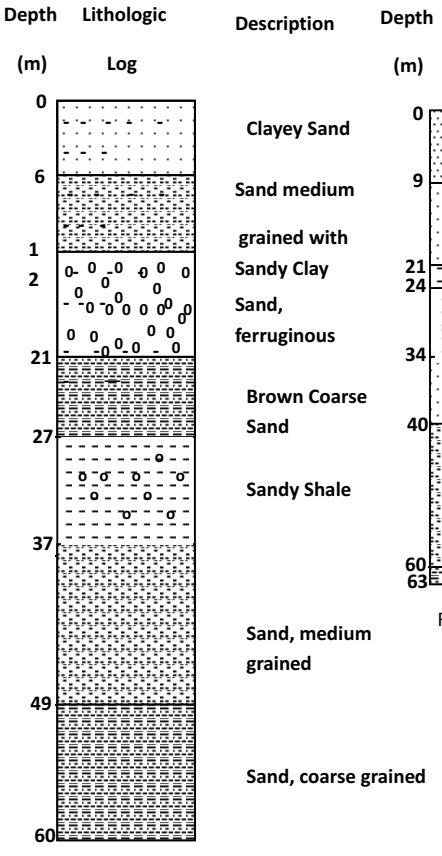

Fig. 2: Cream Ama Borehole Log

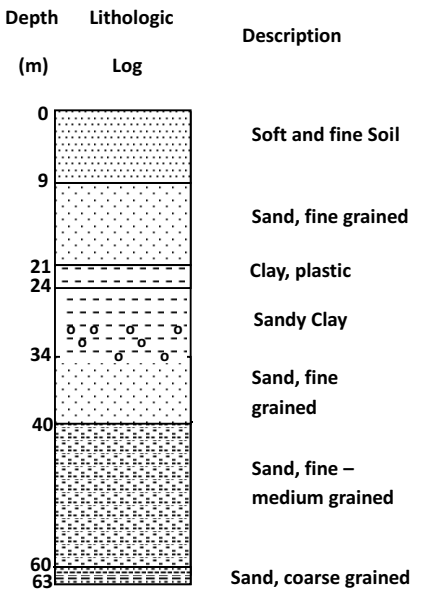

Fig. 3: Agba – Biri Borehole Log

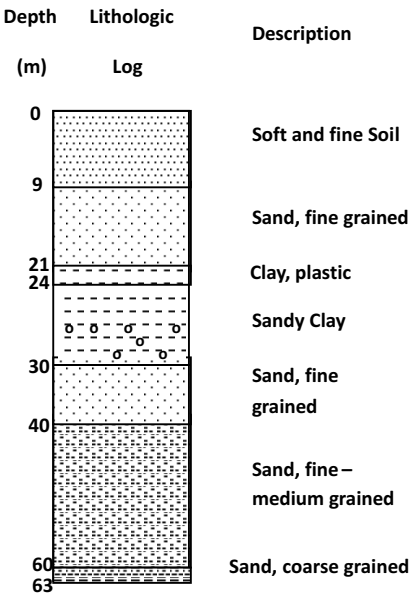

Fig. 4: Ogoloma Sandfill Borehole Log

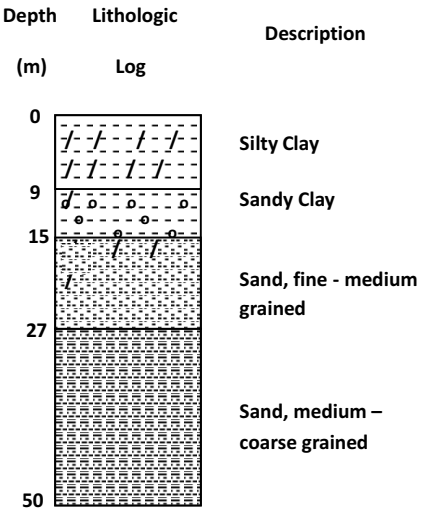

Fig. 5: Isaka Borehole I Log

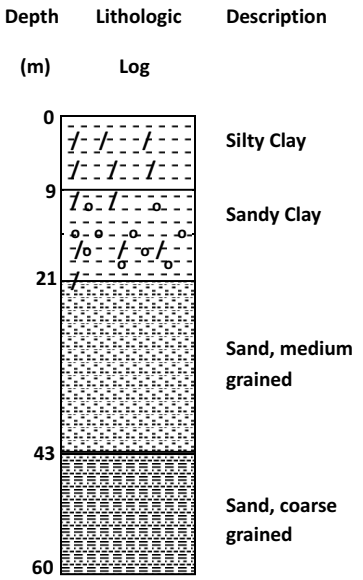

Fig. 6: Isaka Borehole II Log

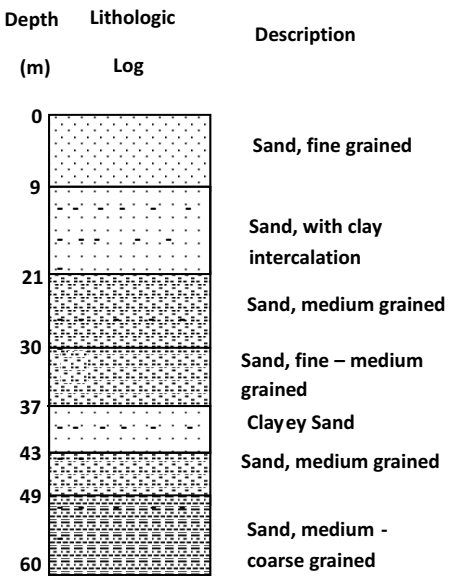

Fig. 7: Ogbogbo Borehole Log

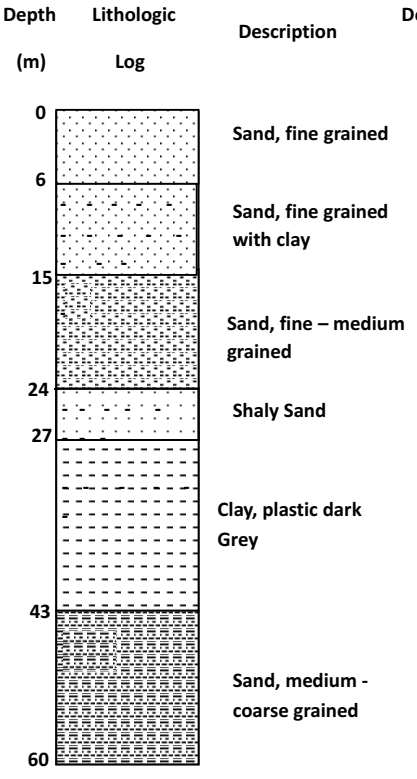

Fig. 8: Bulome - Biri Borehole Log

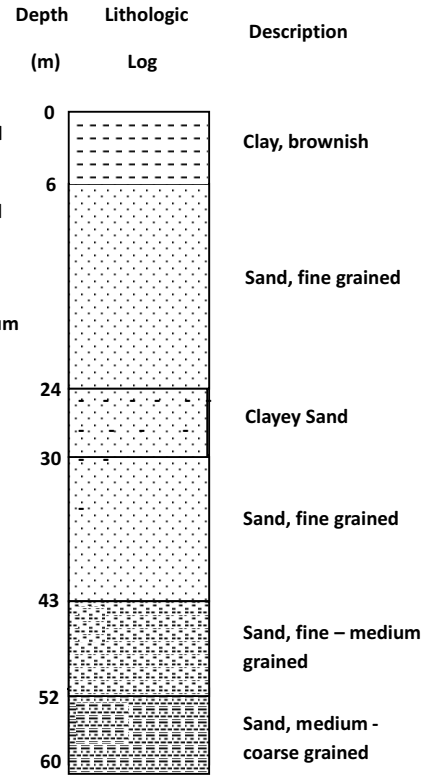

Fig. 9: Oba - Polo Borehole Log

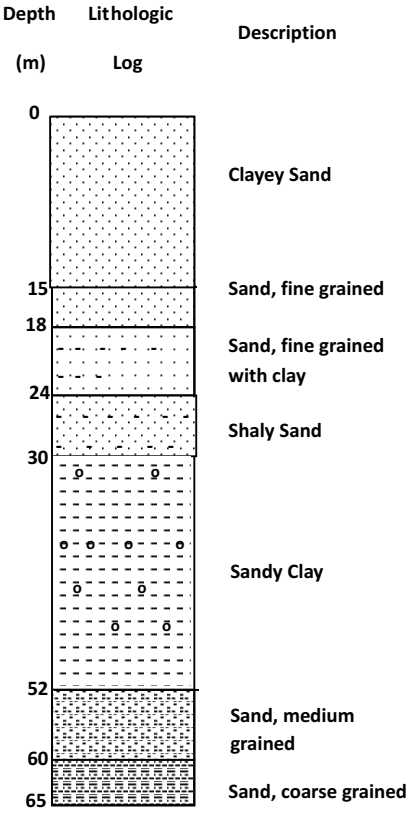

Fig.10: ATC Road Borehole Log

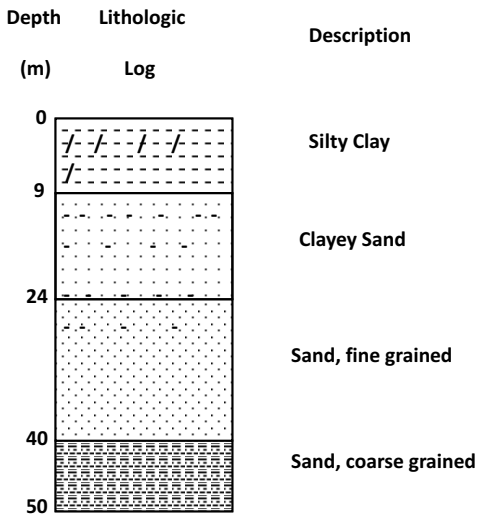

Fig. 11: Okochiri Borehole Log

Static Water Level (SWL)

The static water levels (SWL) in the area range from 0.5 m in Ogbogbo to 7.9 m in Isaka Town (Table 2). These values show shallow water levels in the area which makes the aquifers in the area are vulnerable to pollution from solid wastes and leachates.

Groundwater Quality Assessment

Table 3 shows the physico-chemical properties of groundwater in the study area. The pH values obtained vary from 6.6 7.7 with an average of 7.1. The groundwater is slightly acidic to slightly basic. The acidity could be due to the presence of organic matter in the soil. Also gas flaring in the area generates CO_2 which could have been dissolved in precipitation which percolates into the groundwater to reduce the pH. However, the pH of the groundwater falls within the WHO permissible level.

The concentration of chloride in the water lies between 10 and 300 mg/L, with a mean value of 92.3 mg/L. The relatively high chloride concentrates in four (4) of the boreholes (Gream-Ama, Agba-Biri, Ogoloma and Okochiri) may be indicative of saltwater intrusion. According to Tremblay *et al.* (1973), chloride concentrations above 40 mg/L in groundwater are indicative of saltwater intrusion. These results agree with those of Udom *et al.* (1999) in adjoining Port Harcourt and Tai-Eleme areas. The saltwater intrusion may have been precipitated by excessive abstraction of groundwater in the area.

Table 3: Physical and Chemical Composition of Groundwater Samples in the Study Area

S/No.	Borehole Location	Colour (Hazen Units)	pH	Fe^{2+} (mg/L)	Cl^- (mg/L)	Total Alkalinity (mg/L)	SO_4^{2-} (mg/L)	Ca hardness (mg/L)	Mg hardness (mg/L)	Total hardness (mg/L)	CO_3^{2-} (mg/L)	HCO_3^- (mg/L)	TDS (mg/L)
1	Gream Ama	5	6.8	0.02	300	-	-	-	-	100	-	-	-
2	Agba-Biri	5	-	0.02	46.8	81	0.02	10	-	-	-	-	-
3	Ogoloma	5	7.2	0.10	250	-	-	-	-	100	-	-	300
4	Isaka I	5	7.6	0.01	20	-	20	60	10	70	-	-	10
5	Isaka II	5	6.8	0.01	30	-	-	-	-	-	0.02	81	-
6	Ogbogbo	5	6.8	0.03	20	-	20	60	-	-	-	-	100
7	Bulome -Biri	5	7.4	0.08	10	85	15	-	-	2.5	-	-	120
8	Oba-Polo	5	7.7	0.03	18	86	19.2	62	6	6.8	-	-	122
9	ATC Road	5	7.2	0.06	28	-	-	53	17	70	-	-	80
10	Okochiri	5	6.6	0.04	200	-	0.02	10	-	-	-	-	20
	Minimum	5	6.6	0.01	10	81	0.02	10	6	2.5	0.02	81	10
	Maximum	5	7.7	0.10	300	86	20	62	17	100	0.02	81	300
	Average	5	7.1	0.04	92.28	84	12.4	42.5	11	68.4	0.02	81	107.4
	WHO (2006) Standard	5	6.5-8.5	0.3	250	-	400	-	50	500	-	-	500

Total alkalinity values are between 81 and 86 mg/L. This parameter is related to pH. Since the water is mildly acidic to basic, the alkalinity values in the water are high.

Iron concentrations in the area range from 0.01 0.1 mg/L, with an average of 0.04 mg/L. The iron found in the water owes its source to minerals like hematite, limonite and goethite which occur in the Benin Formation. Leaching of these minerals from the sands would get iron into the groundwater. Sulphate concentration ranges from 0.02 20 mg/L. The values obtained are low when compared with the WHO (2006) standard for drinking water. The calcium hardness obtained falls between 10 and 62 mg/L The slightly high hardness found at some locations are mainly due to calcium hardness, hence it is temporary hardness, and can be removed by boiling the water. Magnesium hardness is low in the water and ranges between 6 and 17 mg/L while total hardness values of groundwater samples in the area range from 2.5 100 mg/L, indicating that the water is soft to moderately hard.

The carbonate concentrations are generally low (0.02 mg/L). The total dissolved solids (TDS) values fall between 10 and 300 mg/L. These levels are within acceptable limit for drinking water.

CONCLUSION

This study evaluates the hydrogeology and groundwater quality in Okrika Island, Eastern Niger Delta, Nigeria using borehole logs and chemical analysis of sampled groundwater. The study shows that the groundwater in the study area is slightly acidic to slightly basic with indication of salt water intrusion in some boreholes. Except at locations where elevated chloride concentrations were recorded, the groundwater is generally potable. However, the shallow groundwater table makes the water susceptible to pollution from surface and near-surface sources.

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