INVESTIGATION OF SALINE WATER INTRUSIONS ALONG THE COASTAL REGIONS OFAKWA IBOM STATE, NIGERIA

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**[*1]EYENAKA, F. D., [2]IGBOEKWE, M. U.,
[3]CHUKWU, G. U. AND [4]AMOS-UHEGBU, C.**

[2,3&4]Department of Physics,
Michael Okpara University of Agriculture, Umuahia, Nigeria
*[*1]Department of Physics, College of Education,*
Afaha Nsit, Akwa Ibom State, Nigeria
franciseyenaka@gmail.com,+2348027038870

ABSTRACT

Saline water intrusions along the coastal regions of Akwa Ibom State was investigated using geochemical and physicochemical analyses. Results of the parameters of groundwater samples investigated showed, pondium Hydronium (pH) values ranged from 4.99 to 7.45; electrical conductivity ranged from 5.41 to 89.90 mho, total dissolved solid from 2.77 to 45.90 mg/L and total alkalinity from 0.99 to 16.10 mg/L. Also from the investigation, the ionic concentrations of groundwater samples were below the minimum permissible standards of the India Standard Institute, European Union and World Health Organization for recommended water consumption. Parameter like sulphate (SO_4^{2-}) with concentration ranging from 115.00 to 333.00 mg/L showed significant intrusion. Both natural and anthropogenic factors are responsible for saline intrusion across the study area. The uniqueness of the technique and investigation through laboratory analysis showed the extent of saltwater intrusion into the freshwater aquifer along the interface. Also, the result of this work will form a baseline geochemical data within the study area and will assist individuals, non-governmental organizations, industries and government on mapping and development of the transition (interface) zones or contamination zones in the shoreline of Akwa Ibom State.

INTRODUCTION

The assessment of groundwater quality is important for socio-economic growth and development. The chemical composition of water is an important factor to be considered before it is used for domestic or irrigation purpose.

As groundwater is isolated from the surface, most people take it for granted that groundwater should be relatively pure and free from pollutants. Although most groundwater are still of high quality at some locations, it is becoming difficult to maintain the purity of groundwater. One of the major sources of pollution of groundwater, regularly confronting continental areas adjoined by oceans is saline water intrusion into the coastal/continental aquifer. This has been reported by several authors (Igboekwe *et al*., 2019; Rahaman and Bhattacharya, 2014).

Seli *et al*., (2019), studied groundwater quality and hydrochemistry of Ganye area, Northeastern Nigeria, using multivariate statistical analysis. Their results revealed that about 30% of the water resources have good quality, 53.3% have poor quality, 10% fall in the range of very poor and 6.7% unsuitable for drinking.

Sadashivaiah *et al*., (2008) studied the hydrochemistry of groundwater quality in Tumkur Tuluk, Karnataka State, India. From their research, they discovered that the type of water that predominates in the study area is Ca-Mg-Hco_3 type during both pre and post-monsoon seasons of the year 2006, based on hydro-chemical facies. Besides, in their study, the suitability of water for irrigation is evaluated based on sodium absorption ratio, residual sodium carbonate, sodium percent and salinity hazard. Their result suggests that the water is safe for domestic, industrial and agricultural purposes.

Magnus *et al*., (2011) evaluated groundwater qualities using hydrochemical methods taking a case study of Michael Okpara University of Agriculture, Umudike and its surrounding areas, Southeastern Nigeria. Their results showed that the groundwater in the area was acidic. The results also show high turbidity exceeding the World Health Organization (WHO) standard. The waters have moderate to high values of total dissolved solids, total suspended solids and conductivity.

Ishaku *et al*., (2015) studied the groundwater quality and hydrochemistry of Toungo area, Northeastern Nigeria. Their findings identified diffused form of contamination, leaching of bed rock geochemistry, salinity, natural mineralization, anthropogenic contamination, silicate weathering and oxidation as the major processes controlling the groundwater geochemistry.

The aquifer structure of Akwa Ibom State falls in the Benin formation where salt water intrusion into the aquifers occurs beneath the freshwater lens (Oteri and Atolagbe, 2003). Most of the boreholes drilled in the study area have been seen to have saltwater intrusions into the aquifer.

The Federal and State water agencies like United Nations Children Emergency Fund (UNICEF), Millennium Development Goals Project (MDGs), European Union (EU), World Bank Water Project and Akwa Ibom State Rural Water Supply and Sanitation Agency (AKRUWATSAN), have initiated several hydro geological evaluation of its groundwater resources. However, the extent of groundwater intrusions and nature of these intrusions still require further investigation (UNESCO, 2006).

The objective of this study is to ascertain the groundwater quality along the coastal zones of Akwa Ibom State, Southeastern Nigeria.

Location and Geology

The study was conducted in coastal parts of Akwa Ibom State, South-eastern part of Nigeria (Fig.1).

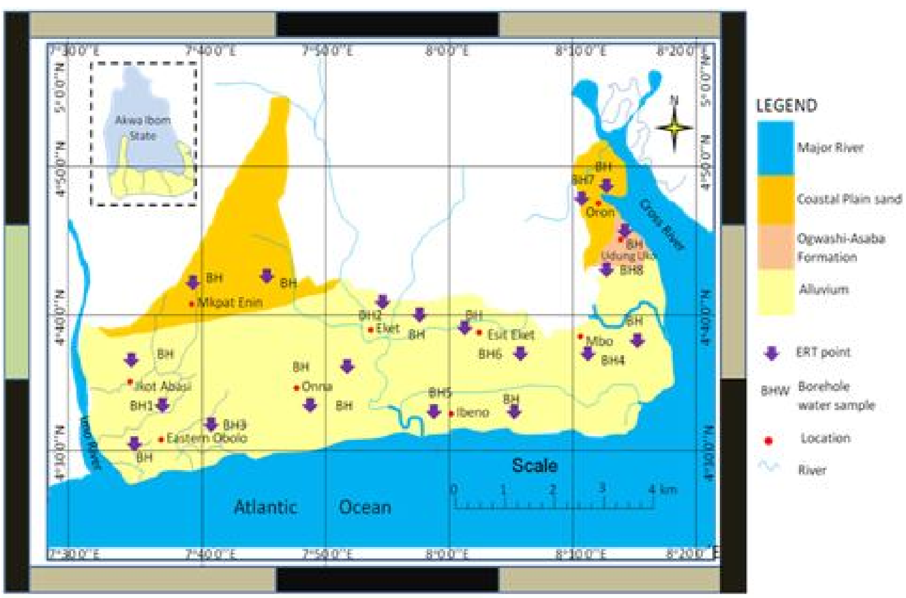

Figure 1: Study location showing the field measurement points

It spreads over the ten Local Government Area (LGAs) comprising Mkpat Enin, Onna, Eastern Obolo, Eket, Mbo, Udung Uko, Esit Eket, Ibeno, Oron and Ikot Abasi. The area lies approximately between latitudes 4^030^1 and 5^000^1N of the equator and between longitudes 7^030^1 and 8^020^1E of the Greenwich Meridian and with a total land area of 8,412 km^2. The terrain of the study area is relatively flat with elevations ranging between less than zero and about 30m above sea level. The area has a humid tropical climate with temperatures (annual mean 26^0C) and high relative humidity (annual mean 85%). Precipitation is also high averaging about 3,855m annually and greatly exceeding the annual evaporation (1,680m) (Evans *et al.,* 2010).

In terms of geology, the survey area falls within the coastal region dominated by the Benin Formation also known as the Coastal Plain sands (CPS). The major aquiferous formations are the deltaic planes and Benin Formation. Both confined and unconfined aquifers are encountered at vary saline and clay groundwater Mbipom *et al.,* (1996).

The Benin Formation consists predominantly of massive highly porous sands and gravels with locally thin shales and clay interbeds to form a multiaquifer system in the delta (Akpabio and Eyenaka, 2008).

Edet and Okereke (2002) posited that in the Benin Formation, the ingress of saltwater into Tertiary aquifer occurs below the freshwater lens extending from the shoreline to about 5,000 m in some locations. The CPS forms the major hydrogeological units in the area. This consists of poorly arranged continental sands (fine-medium-coarse) and gravelly sands which are superimposed with fluctuating thin clay horizons, lenses and lignite streaks at some places. The Formation of a multi aquifer system is caused by thin clay/shale horizons which cut the lateral and vertical extents of the aquifer sands (Evans *et al.,* 2010; George *et al.,* 2010).

METHODOLOGY

Groundwater samples were collected from twenty different sites long the coastal region of Akwa Ibom State. Two borehole samples from each Local Government Area making a total of twenty samples collected. Sample collection, movement, storage, treatment and analysis were done as outlined by the American Public Health Association (APHA, 1992). The location of the sampling sites is shown in Figure 1 while the global positioning coordinates as well as relief features are shown in Table 1.

Table1: Sampling points of borehole water source, code and GPS coordinates

Sampling Point	Code	Elevation (m)	Northing (m)	Easting (m)
1	OW 1	10.00	4.8134	8.2259
2	OW 2	7.00	4.8190	8.2314
3	OW 3	38.00	4.7638	8.2539
4	OW 4	15.00	4.7459	8.2771
5	OW 5	15.00	4.5940	7.7596
6	OW 6	24.00	4.6136	7.7639
7	OW 7	150.00	4.6381	7.9123
8	OW 8	20.00	4.9686	7.8564
9	OW 9	4.00	4.5482	7.5509
10	OW 10	16.00	4.6000	7.6898
11	OW 11	10.00	4.5631	7.7474
12	OW 12	12.00	4.5863	7.7641
13	OW 13	9.00	4.6335	7.9014
14	OW 14	3.00	4.6001	7.958
15	OW 15	38.00	4.6598	8.0554
16	OW 16	17.00	4.6732	8.0554
17	OW 17	20.00	4.6333	8.1873
18	OW 18	36.00	4.6340	8.1831
19	OW 19	6.00	4.5390	8.0015
20	OW 20	7.00	4.5824	7.9878

Several sensitive parameters of water such as pH, temperature, Total Dissolved Solid (TDS), Electrical Conductivity (EC), were determined insitu using digital meters (e.g. Water Treatment Work (WTW) – conductivity meter model L/92 and WTW – pH meter model pH/91). Temperature was measured using a mercury thermometer (range 0 to 100^0C). The analysis of trace elements and cations in water were carried out using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) technique, while unaccidified water samples were analyzed for anions concentrates using the DIONEX DX-120 ION Chromatography techniques. All the analyses was done in triplicates and carried out at the Ministry of Science and Technology, Uyo, Akwa Ibom State where the equipment are standard. The samples were analyzed for thirteen constituents and physical properties. Analytical results for thirteen significant elements were further compared with recommended standards to determine the extent of the pollution and the water quality.

RESULTS AND DISCUSSION

Physicochemical analyses were conducted to determine the concentrations of different water quality parameters such as temperature, pH, EC, TDS, TA, TH, mg^{2+}, Na^{+}, K^{+}, Ca^{2+}, Fe^{2+}, Cl^{-} and SO_4^{2-} using standard method to ascertain quality of water.

A summary of the results of physicochemical analyses of the water samples are presented in Table 2. These results are further presented as contour diagrams [Figs. 2 – 14] displaying the different parameters. The summary of the physicochemical element analysis of the water samples were compared with drinking water standards (WHO, 2006, ISI, 1995 and EU, 1998) in Table 3.

The measured acidity and alkalinity of water samples showed that the pH values is very close to neutral with values varying from 4.99 to 7.45 with average value of 5.92 and standard deviation of 0.79 and was below the maximum permissible limits for all standards considered, UNESCO (2006). The Electrical resistivity values for borehole samples ranged from 5.41 to 89.80 mho with mean value of 27.55.

Total alkalinity value for groundwater sample were found to be very low ranging from 2.77 to 45.90 mg/L with mean value of 14.33. Hence, water with low alkalinity is likely to be corrosive (Table 3).

Total dissolved solid which is a measure of the salinity characteristics of groundwater has values ranging from 2.77 to 45.90 mg/L with average mean value of 14.33 and standard deviation of 49.80. The result in Table 4 show that the water is fresh since the TDS are all below the maximum permissible limit for all standards considered (Table 3).

Total hardness values ranged from a 5.00 mg/L to 25.00 mg/L with an average of 15.51 while 26.66 is the value for the standard deviation. The low mean value of 15.51Mg/L is below the maximum permissible limits for all standard considered (Table 3).However, hardness in water is caused mostly by dissolved Ca^{2+} and Mg^{2+} ions which primarily results from dissolution of limestone or dolomite from the soil and rock materials. Hardness renders water useless in laundry work by causing excessive scale Formation.

The concentrations of Ca^{2+}, Mg^{2+}, $Na^{2+,}$ K^{+} and Fe^{2+} vary from 0.18, 0.49, 2.15, 0.24 and 0.02 mg/L, respectively to 12.50, 6.00, 22.32, 2.50 and 0.21 mg/L, respectively. The enrichment levels of Na^{+}, Ca^{2+} and Mg^{2+} are therefore, higher than that of the other cations. Several factors could be responsible for their observed selective enrichment of some cations over others. A possible source of cations (especially Ca^{2+} and Mg^{2+}) selective enrichment includes rainwater, dissolution of minerals like calcite ($CaCo_3$) and dolomite ($CaMg(CO_3)_2$) in soils and bedrocks and the weathering of anorthitic plagioclase ($CaAl_2Si_2O_8$), diopsidic pyroxene ($CaMgSi_2O_6$) and forsteritic olivine (Mg_2SiO_4).. While rainfall water can contribute only marginal increase to the concentration of these cations in natural waters (Earman*et al.,* 2008). Tijani (2004) observed similar enrichment conditions in the Benue Trough, such enrichment conditions can originate from the interplay of fossil seawater and salt dissolution sources with modifications of the chemistry of the primary source solution through water/rock interactions involving cation exchange with clay minerals, dolomitization of limestone and/or albitization of feldspars.

Table 2: Result of Physicochemical Analysis of Ground Water Samples

CODE	Location of Sample (Borehole) LGA	Elevation (m)	pH	Temp .(^{O}C)	EC (mho)	TDS (mg/L)	TA (mg/L)	TH (mg/L)	SO_4^{2-} (mg/L)	Cl^- (mg/L)	Na^+ (Mg/l)	Mg^{2+} (Mg/l)	Ca^{2+} (Mg/l)	Fe^{2+} (Mg/l)	K^+ (Mg/l)
OW 1	EffiongUsung St., Oron	10.00	5.30	25.70	29.80	17.45	6.10	15.00	301.00	27.05	3.84	0.68	1.46	0.07	1.53
OW 2	Usung Close, Oron	7.00	5.32	27.50	31.30	15.39	8.01	17.50	220.00	24.85	3.46	0.49	1.65	0.03	1.32
OW 3	Usun Road, UdungUko	38.00	5.01	28.00	89.80	45.90	7.80	17.50	201.00	31.95	3.83	0.86	1.34	0.11	1.84
OW 4	Eniong, UdungUko	15.00	5.41	30.20	85.30	43.70	7.90	17.30	202.00	28.65	4.55	0.75	2.68	0.14	1.64
OW 5	Coconut Plantain, MkpatEnin	15.00	6.25	27.00	22.00	11.23	2.40	5.00	205.00	24.85	2.41	0.66	0.18	0.03	1.22
OW 6	IkotOyoro, MkpatEnin	24.00	6.25	29.00	39.90	20.00	5.11	15.00	221.00	14.20	22.32	0.64	0.84	0.15	0.65
OW 7	Onna Head Bridge, Onna	150.00	6.65	28.20	11.93	6.27	5.00	12.20	291.00	17.75	3.42	1.22	0.21	0.15	0.84
OW 8	EdemIdimIshiet, Onna	20.00	5.41	29.04	20.8	10.42	4.80	12.50	200.00	14.20	3.40	1.18	1.42	0.11	0.24
OW 9	UtaEwa Beach, IkotAbasi	4.00	5.45	27.00	16.69	9.63	5.01	15.00	251.00	14.20	4.18	1.61	2.03	0.05	2.41
OW 10	Ette Town Along E-W-Road, IkotAbasi	16.00	6.04	29.50	9.41	4.80	0.90	2.50	115.00	10.65	3.60	1.54	1.68	0.02	2.26
OW 11	Okoroette, Eastern Obolo	10.00	7.30	28.02	38.70	20.00	7.90	20.00	330.00	14.20	2.15	0.88	0.82	0.20	1.41
OW 12	Iko Town, Eastern Obolo	12.00	7.03	28.50	5.41	2.77	11.80	25.50	201.00	14.20	2.55	0.71	1.89	0.09	0.44
OW 13	IkotEbok, Eket	9.00	7.45	29.04	24.65	10.42	9.01	17.50	241.00	12.85	4.60	0.57	2.84	0.21	1.63
OW 14	EsitUrua, Eket	3.00	6.76	28.50	26.80	12.53	10.12	25.00	205.00	14.20	4.10	0.68	2.03	0.09	1.83
OW 15	AbigheAsangUquo, Esit Eket	38.00	5.36	26.80	13.14	7.90	4.70	10.00	200.00	14.10	20.00	2.40	4.00	0.12	0.67
OW 16	Ikpa, EsitEket	17.00	4.99	27.20	11.97	7.17	4.02	11.20	250.00	9.99	2.50	2.20	4.20	0.11	1.13
OW 17	Unyenghe, Mbo	20.00	5.01	26.80	15.16	9.11	4.80	12.50	200.00	18.10	2.41	3.00	5.00	0.08	1.00
OW 18	UdungEjo, Mbo	36.00	5.11	26.80	15.16	9.11	6.82	12.50	242.00	13.10	2.42	3.00	5.00	0.15	1.00
OW 19	Ibeno Beach, Ibeno	6.00	6.63	26.90	18.07	7.80	14.50	24.40	333.00	3.09	3.33	2.20	12.50	0.12	2.50
OW 20	Upenekang, Ibeno	7.00	5.60	26.80	25.10	15.09	16.10	25.00	250.00	9.33	2.50	6.00	10.00	0.08	1.87

Table 3: Descriptive Statistical Summary of Chemical Element Concentrations Compared to the WHO, EU, ISI Drinking Water Standards

	Drinking Water Standards			Water from the study Area			
Measured Parameters	WHO, 2006	ISI, 1995	EU, 1998	Min.	Max.	Mean	STD
pH	7-8.5	6.5-8.5	NA	4.99	7.45	5.92	0.79
Ec (mho)	250	NA	250-500	5.41	89.80	27.55	97.01
TDS (mg/L)	500	500	NA	2.77	45.90	14.33	49.80
TA (mg/L)	300	300	350	0.90	16.10	7.10	17.51
TH (mg/L)	150	300	100- -500	5.00	25.00	15.51	26.66
Ca^{2+} (mg/L)	75	75	NA	0.18	12.50	3.09	13.78
Mg^{2+}(mg/L)	50	50	30 – 250	0.49	6.00	1.56	5.77
K^{+}(mg/L)	12	NA	NA	0.24	2.50	1.37	2.79
Fe^{2+}(mg/L)	0.3	0.3	0.2	0.02	0.15	0.11	4.00
Na^{+}(mg/L)	120	NA	200	2.15	22.32	5.08	24.25
Cl^{-} (mg/L)	250	250	250	3.09	31.95	16.58	31.80
SO_4^{2-}(mg/L)	200	200	250	115.00	333.00	232.95	224.78

Table 4: Assessment of groundwater samples based on the stipulated limits

Location	pH	EC	TDS	TA	TH	Ca^{2+}	Mg^{2+}	K^{+}	Fe^{2+}	Na^{+}	Cl^{-}	SO_4^{2-}
OW1	-	-	-	-	-	-	-	-	-	-	-	-
OW2	-	-	-	-	-	-	-	-	-	-	-	-
OW3	-	-	-	-	-	-	-	-	-	-	-	-
OW4	-	-	-	-	-	-	-	-	-	-	-	-
OW5	-	-	-	-	-	-	-	-	-	-	-	-
OW6	-	-	-	-	-	-	-	-	-	-	-	-
OW7	+	-	-	-	-	-	-	-	-	-	-	-
OW8	-	-	-	-	-	-	-	-	-	-	-	-
OW9	-	-	-	-	-	-	-	-	-	-	-	-
OW10	-	-	-	-	-	-	-	-	-	-	-	-
OW11	+	-	-	-	-	-	-	-	-	-	-	-
OW12	+	-	-	-	-	-	-	-	-	-	-	-
OW13	+	-	-	-	-	-	-	-	-	-	-	-
OW14	+	-	-	-	-	-	-	-	-	-	-	-
OW15	-	-	-	-	-	-	-	-	-	-	-	-
OW16	-	-	-	-	-	-	-	-	-	-	-	-
OW17	-	-	-	-	-	-	-	-	-	-	-	-
OW18	-	-	-	-	-	-	-	-	-	-	-	-
OW19	+	-	-	-	-	-	-	-	-	-	-	-
OW20	-	-	-	-	-	-	-	-	-	-	-	-

\+ meets the stipulated permissible limits - fails to meet the stipulated permissible limits

Hence, the concentrations of cations shows that, there are all below the maximum permissible limit for all standard considered for drinking water (Table 3).

Cl^{-} and SO_4^{2-} were the two major anions detected in this study. Their concentration ranged from 3.09 to 31.95 Mg/L and 115.00 to 333.00Mg/L respectively. SO_4^{2-} anion is the most enriched anion compared to Cl^{-} anion. Chloride concentration values are below the permissible limit for all standard considered for drinking water (Table 3). Higher chloride concentration in seawater samples due to big discharge of sewage near the sea made it exceeds the limits by WHO. Sulphate (SO_4^{2-}) occurs naturally in water as a result of leaching from gypsum and other common minerals. Hence, discharge of industrial waste and domestic sewage tends to increase its concentration as notice in the study area for SO_4^{2-}. Groundwater was found to exceed the prescribed permissible limit for all standards considered (Table 3).

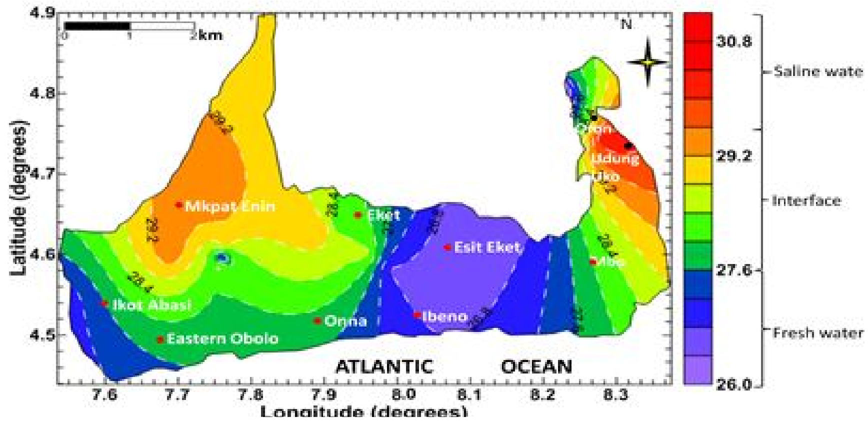

Fig. 2: Contour diagram for temperature distribution for groundwater

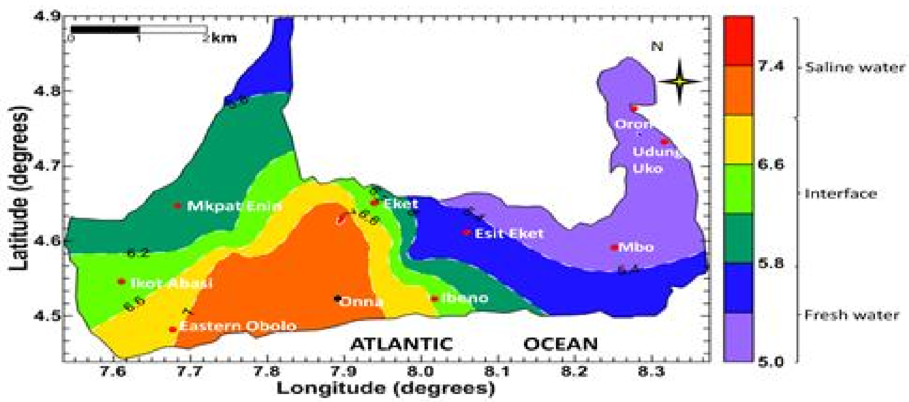

Fig.3: Contour diagram for pH distribution for groundwater

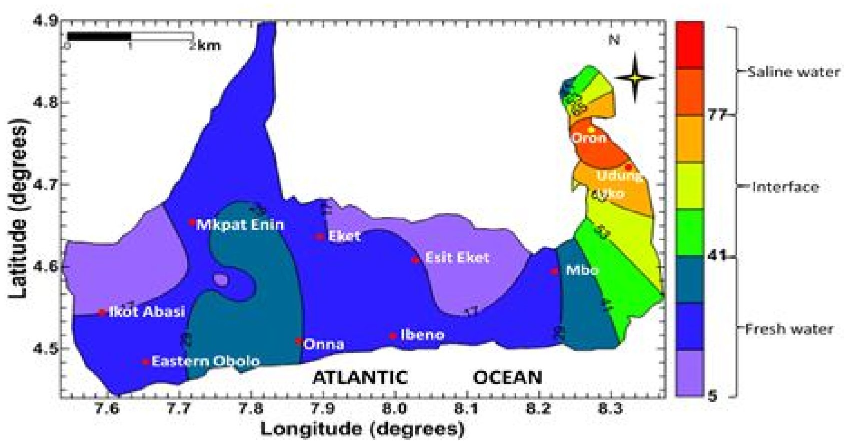

Fig.4: Contour diagram for electrical conductivity distribution for groundwater

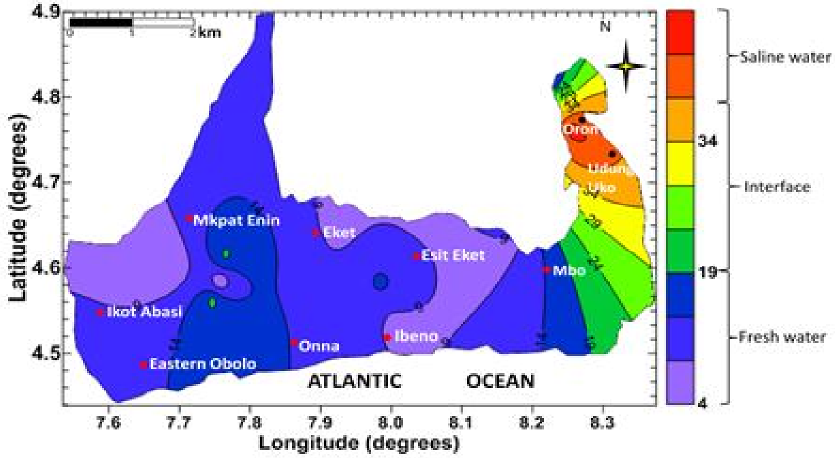

Fig.5: Contour diagram for total dissolved solid distribution for groundwater

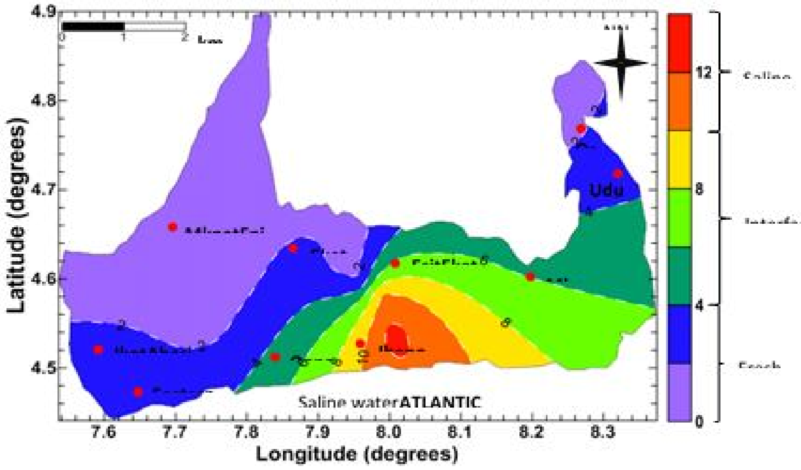

Fig. 6: Contour diagram for calcium ion for groundwater

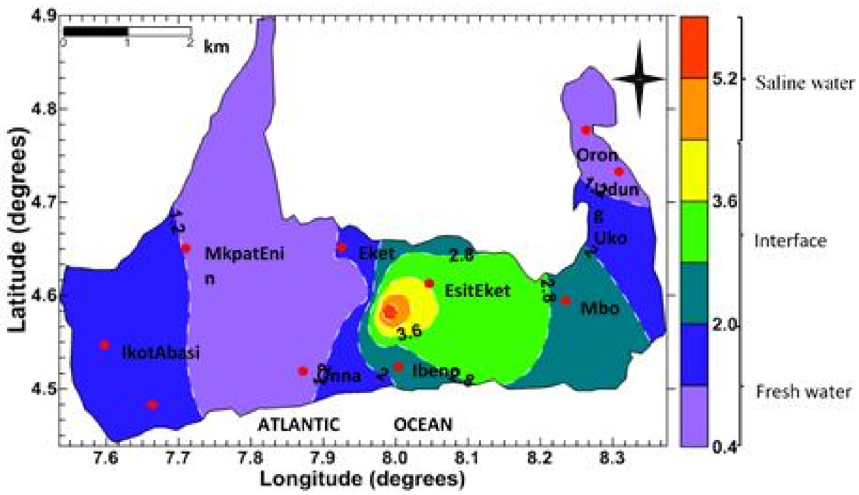

Fig. 7: Contour diagram for magnesium ion distribution for groundwater

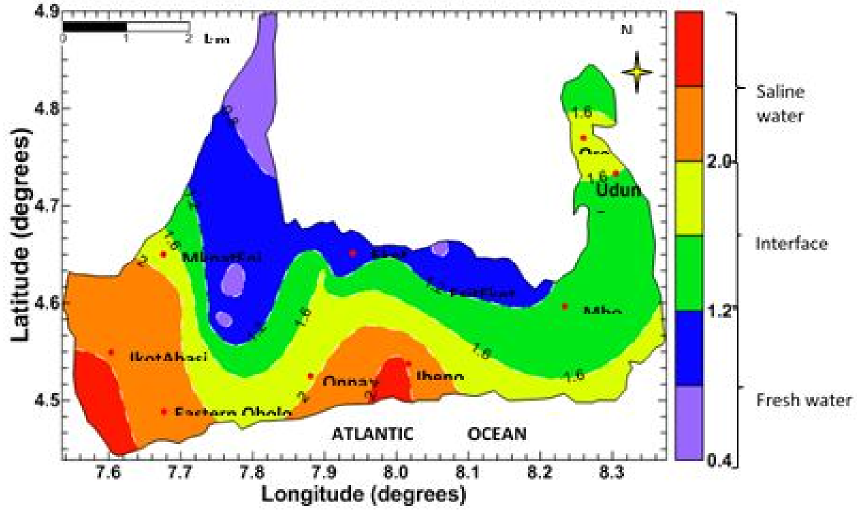

Fig. 8: Contour diagram for potassium ion distribution for groundwater

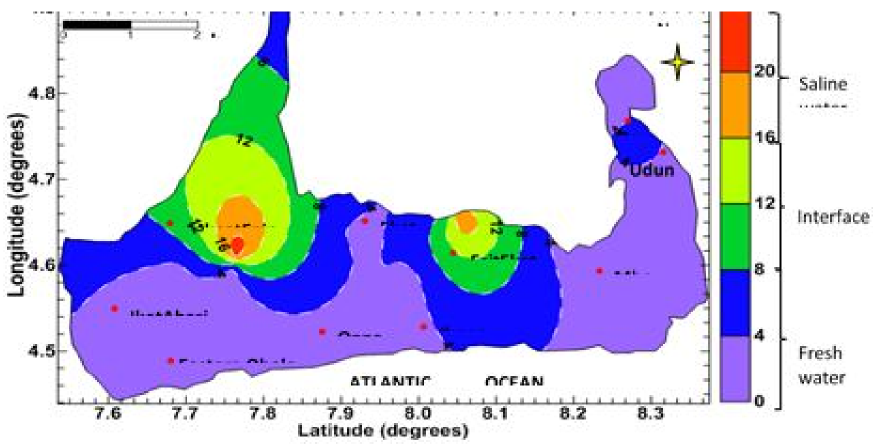

Fig. 9: Contour diagram for sodium ion distribution for groundwater

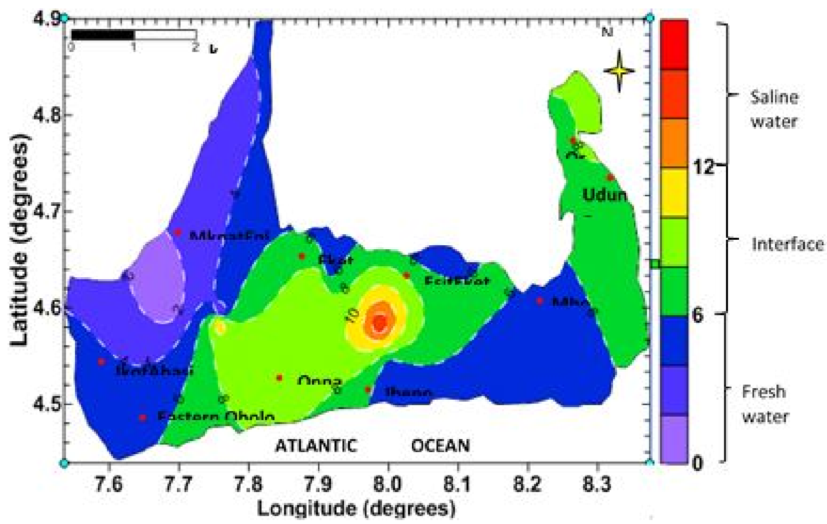

Fig. 10: Contour diagram for Total Alkaline distribution for groundwater

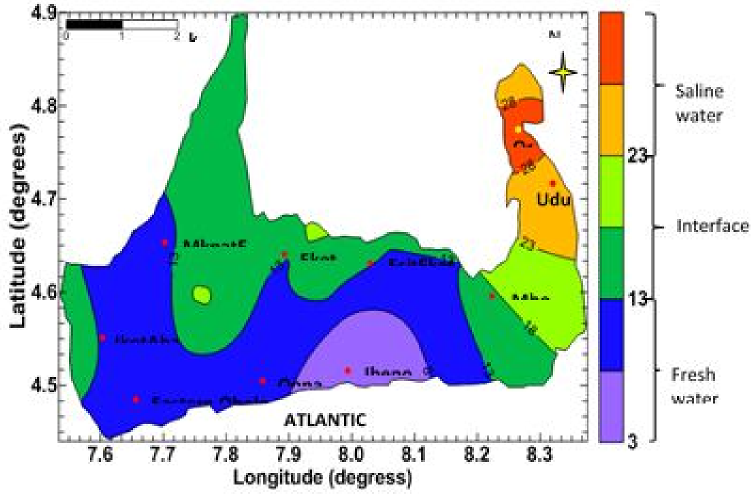

Fig. 11 Contour diagram for Chloride ion distribution for groundwater

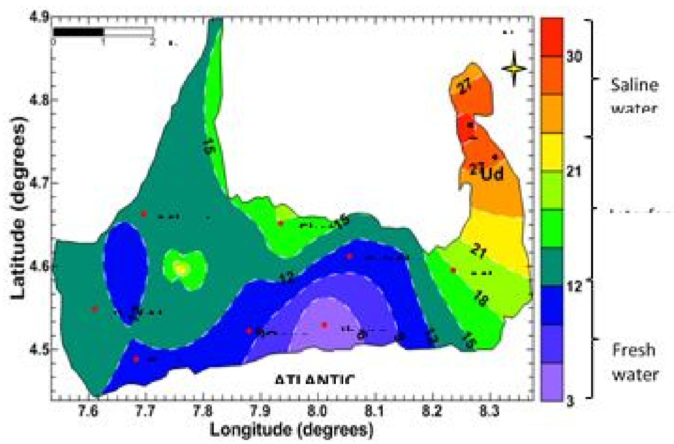

Fig. 12: Contour diagram for Sulphate ion distribution for groundwater

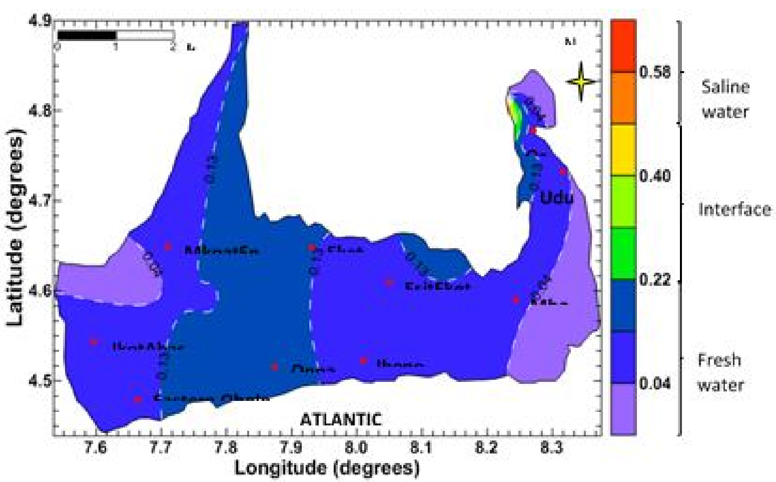

Fig. 13: Contour diagram for Iron distribution for groundwater

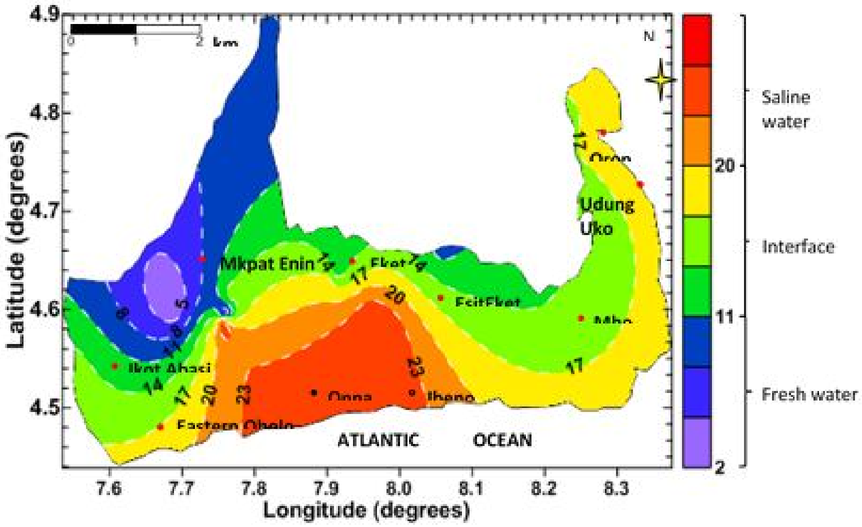

Fig. 14: Contour diagram for Total Hardness distribution for groundwater

CONCLUSION

In this study, geochemical analysis was used to assess the suitability of groundwater for drinking, as well as agricultural and industrial purposes, using physicochemical techniques. The results of the physicochemical parameters of water samples from major boreholes within the area as displaced on the contour diagrams reveal that pH values was closed to neutral and with value ranging between 4.99 and 7.45, EC from 5.41 to 89.90 mho, TDS ranged from 2.77 to 45.90 mg/L, Total alkalinity from 0.90 to 16.0 mg/L, Total Hardness ranged from 5.00 to 25.00 mg/L. The above results from EC and TDS shows that, the water is fresh and belongs to the good-to-excellent class and is, therefore, suitable for domestic, agricultural and industrial use. Also, the ionic concentrates investigations result of groundwater samples were below the permissible limits proposed by (WHO, 2006), (EU, 1998) and (ISI, 1995).

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