Article Number: 2A7A362

A Paper presented at the 39th CSN Annual International Conference, Workshop and Exhibition, Rivers State University of Science and Technology, Port Harcourt, Nigeria.
18th – 23rd September 2016

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Full Length Research Paper

Characterization of beach water and its effect on nearby groundwater quality in Eti-osa and Ibeju-lekki local government areas, of Lagos State, Nigeria

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Groundwater in Eti-Osa and Ibeju-Lekki local government areas of Lagos state were investigated for the effects of beach water influence on adjacent aquifers. Beach water and Borehole samples at distances of 40-50 m and 100-150 m from adjacent beaches in the study areas were taken and analysed for pH, Temperature, Electrical Conductivity, Total Dissolved Solids, Salinity, Ca^{2+}, Mg^{2+}, K^+, Na^+, HCO_3^-, NO_3^-, Cl^- SO_4^{2-}, total hardness and dissolved oxygen. The results were compared with World Health Organisation (WHO) and National Agency for Food and Drug Administration and Control (NAFDAC) standards for water quality. Piper diagram was used to delineate the hydrochemical calfacies of the aquifer and to identify hydrogeochemical changes. The results showed that Cl^- dominated in boreholes of both Ibeju-Lekki and Eti-Osa. Sampled boreholes in Eti-Osa showed prevailing dominance of major seawater ions (Na+> Ca^{2+}> K^+>: Cl^- > SO^-) at levels far beyond permissible limits of potable water quality set by WHO and NAFDAC and showed a Ca-SO_4 and NaCl water type for the boreholes 40-50 m and 100-115 from the coastline line respectively. Water quality requirements of WHO and NAFDAC are within permissible limits for boreholes in Ibeju-Lekki. Analysed Water samples from Ibeju- Lekkiare characterised as Ca-SO_4 water type.Groundwater resources of studied boreholes in Ibeju-Lekki are less influenced by saltwater intrusion from nearby beach, as opposed to Eti-Osa. This is can be attributed to overtly unsustainable exploitation of groundwater resources in Eti-Osa, Which makes groundwater in Eti-Osa unsuitable for domestic purposes.

Key words: Characterization, groundwater, seawater, intrusion, standard.

INTRODUCTION

Water resources permeate every aspect of life, thus requiring utmost attention. . Effective water resource management meets the needs for potable water and domestic usage, agriculture, transport and for other public and industrial usage (UNEP/ROLAC, 2012). It also provides for the natural course of existence of water bodies, as home to many aquatic organisms, plants and animals and a huge ecological capital. Improvement of information in water quality and quantity with the Protection and restoration of the quality and function of ecological systems within the coastal zones are key zones are key policy focus to improve the efficient use of water resources particularly in fragile environments (UNEP/ROLAC, 2012). Lagos state, Nigeria in this

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context can be defined as a fragile environment following recurrent reports of residents in the island areas abandoning boreholes, flooding, building collapses, land encroachment by the ocean (due to ocean water level rise), changing coastal aquifer dynamics etc, which has made these areas vulnerable to climate change hazards. To manage water resources adequately, monitoring and investigative studies are essential; as a noble earth friendly task and responsibility.

Seawater intrusion is part of the changing dynamics with most coastal environments globally, increasing populations in coastal environments which today are highly priced and sought after destinations for habitation comes with disturbance to ecological balance as a consequence. Researchers have lamented on the increasing and excessive abstraction of groundwater resources at rates faster than natural recharge processes, owing to exploding population. Unsustainable withdrawals from non-renewable aquifers, the unreliability of water availability, and the current level of water demand exceeds the sustainable water supply in many places with serious long-term implications and this is detrimental to the ecosystem and as well as the quality of water available. Lagos, located on the southwest coast of Nigeria is made up of island and mainland areas. With an area of 1,341 square miles (3,400 km^2) of which half is water as creeks, lagoons etc and bordered by Atlantic Ocean (Jideonwo, 2014).

Population is estimated at 24.3 million people (Jideonwo, 2014). Average population density is over 20,000 persons / km^2 (LSG Lagos State Government, 2011). The specific study areas; Alpha beach in Eti-Osa Local Government Areas (LGA) and Eleko beach in Ibeju- Lekki LGA of Lagos state are highly vulnerable to climate change hazards (Omenai and Ayodele, 2014). These coastal environments are densely and moderately populated respectively and the natural state of the coastal environment is likely retained in the later unlike the former which some form of reconstructive engineering was ongoing as at the time of this research, to stem the tide of coastal encroachment. Knowledge gaps exists in understanding seawater intrusion (SI) process. In particular associated transient SI processes and timeframes, characterization and prediction of saltwater influences on adjacent groundwaterover regional scales and in highly heterogeneous and dynamic settings [5] like Lagos is a hard nut to crack. Oteri and Atolagber (2003) posited that there is “Lack of adequate knowledge of the nature of salt water intrusion” (Oteri and Atolagbe, 2003). Saline water intrusion has been identified as a major pollution issue, especially in areas that are close to the ocean and lagoon.

Sadly there is no monitoring programme for saline water intrusion in Nigeria

The occasion of excessive extraction of underground water beyond its restorative limit leads to pressure and density variations that cause salt water intrusion in order to maintain ecological equilibrium, as the system of the earth abhors vacuum (Aris Abdullah et al., 2009) have expressed that Intensive exploitation of groundwater aquifer disturbs the natural equilibrium between fresh and saline water and results in the increase of groundwater salinity and the hydrochemical complexities of freshwater-seawater contact. They further observed that the freshwater – seawater mixing creates diversity in the geochemical process, and this manifests in compositional changes away from the groundwater theoretical composition line.

According to Ohwoghere-Asuma (2014) groundwater is an important resource and consequently, its management is only appropriate and necessary for its sustainability (Ohwoghere-Asuma et al., 2014). He suggested that the best way to manage coastal aquifers is dependent on the ability to prevent re-occurrence of saline water intrusion by way of early detection which is achieved by unrelenting monitoring of these aquifers. It is then vital and strategic to understand the groundwater chemistry changes that may have occurred in Eti-Osa and Ibeju-Lekki coastal environment as a result of saline water intrusion.

Hence this study is expected to provide findings to support early warning measures on the migration of the fresh water/sea water intrusion into groundwater and its effects on groundwater quality. These findings will add a voice to the clamour for a saline water intrusion monitoring and assessment plan and policy measures for coastal environments in Nigeria.

MATERIALS AND METHODS

Two borehole were purposively chosen in each study area:Ibeju-Lekki LGA (Eleko beach area) and Eti-Osa LGA (Alpha beach area), following the criteria of (1) heavily/ publicly used borehole, where pumping is carried out daily; (2) boreholes sited at distance of 40-50 m and 100-150 m from the coastline for the first and second boreholes respectively. Groundwater and beach water samples were taken weekly for four weeks in the month of November, 2015. A total of 48 samples were collected and analysed. Triplicate samples were collected per time of sampling at each point after which a mean value was calculated for each parameter measured and a standard deviation (SD) was used as a precision indicator for each measured parameter (Isa et al., 2012). Sample points were marked using a Global positioning system (GPS) instrument. Water samples were collected in plastic bottles that had been washed and cleaned with hydrochloric acid (1:1) and then rinsed severally at the point of sampling with the water to be sampled. Groundwater was pumped and allowed to rush out for 10-15 min before sample fractions were collected (Isa et al., 2012). The beach water was collected with a sterilized bucket rinsed severally with the beach water before sample collection. The water was scooped from three different side points of about 500m apart along the coastline. Water from the bucket was poured into the bottles carefully, avoiding contact with the bottle opening.

These samples after collection were transported in a cooler of ice to the laboratory for analysis within 24 h of sample collection. in-situ measurements, pH and temperature, were carried out using portable digital meter and platinum bulb thermometer respectively. Samples were analysed for physiochemical parameters which included, salinity, Electrical Conductivity (EC), total dissolved solids (TDS), major seawater cations and anions (Ca^{2+}, Mg^{2+}, K^+, Na^+, HCO_3^-, NO_3^-, Cl^-,

Table 1. Location coordinates of sample points and their distance from coastline.

Borehole codes	Area location	Latitiude	Longitude	Distance from the coast
BH 1	ELEKO – IBEJU LEKKI	6.4394° N	3.85423° E	50 m
BH 2	ELEKO – IBEJU LEKKI	6.44113° N	3.85825° E	100-150 m
BH 3	ALPHABEACH – ETI OSA	6.42514° N	3.52306° E	50 m
BH 4	ALPHABEACH – ETI OSA	6.42687 ° N	3.52708 ° E	100-150 m

SO_4^{2-}, total Hardness (TH) and dissolved oxygen (DO) using standard methods (Dano, 2010). The reliability check of the quality of the laboratory analysis and data obtained was done by the Error on ionic balance (%). The analysis is considered as reliable for the error on the ion balance is smaller than 5% (American Public Health Association (APHA), (1998). However, an error of ≤±10 % is within the acceptable range. The statistical package for social sciences (SPSS) Version 16 and piper plot or diagram was employed to analyse laboratory results obtained.

RESULTS AND DISCUSSION

The location of the borehole, and beaches are as shown on Table 1. Table 2 shows the mean values of physicochemical parameters of borehole samples.

DISCUSSION

The pH followed an increasing trend that is, from neutral to more alkaline every other week from the first week to the fourth week for all boreholes. This is indicative of a reduced carbonic acid process
(i.e. a decreased dissolution of CO_2 in water). The coastal aquifer in Eti-Osa showed to have higher mean values of electrical conductivity (EC) at 3282.83 and 2036.340 μScm^{-1}; TDS values of 2307.91 and 1427.1 mg/L for bore holes 50m and 150 m respectively away from the coast, both figures being far above the standard limits. This is indicative of high enrichment of salts inthe aquifer, a pointer to saltwater intrusion (as a result of a pumping operation) (Aris Abdullah et al., 2009) and contamination from industrial activities in that it is densely habited and industrialized. It can be seen in general manner that the high values of electrical conductivity (EC) and TDS are related to saltwater intrusion, as supported by corresponding high levels of Na^+ and Cl^- observed in Eti-Osa, but not in Ibeju-Lekki where no domination of any cation or anion was observed. The high Cl^- and Na^+ ion concentration is indicative of saltwater impact on the groundwater of Eti-Osa (Aris Abdullah et al., 2009) whereas that is not the case in Ibeju-Lekki, where values of measured parameters are within the permissible limits as prescribed by WHO and NAFDAC.

Soluble cations and anions

Generally, the chemical composition of groundwater is primarily dependent on the type of geochemical processes and chemical reactions taking place within the groundwater system. The composition of ions in Eti- Osa and Ibeju-Lekki is dependent on the variant geochemical processes and resultant reactions that take place in both locations. Analytical result presents the abundance of these ions in the following order: Na^+> Ca^{2+}> K+> Mg^{2+} = Cl^- > SO_4^-> NO^-> HCO_3^- for Eti-Osa and Ibeju-Lekki showed relative abundance in the order; Ca^{2+}> Na^+> K^+> Mg^{2+} = Cl- > SO_4^-> NO_3^-> HCO_3^-. Comparing this trend with the compositional make up for seawater (Table 2) and fresh groundwater shows similarities, which is indicative of saltwater intrusion, giving the closeness between the saltwater nature of the beach and the adjacent groundwater.

Sampling points at Eti-Osa had the highest groundwater salinity, the nearest well to the shorelines showed 0.853 measure of salinity and the later which is about 100-150 m had a salinity of 0.875. Although compared to the salinity of the beach, this is only about 4.82% of Alpha beach's (Eti-Osa LGA) salinity. In view of this, consider the assumption of the Environment Canterbury Regional Council (2012), that “If groundwater became contaminated by 2% sea water this would result in chloride concentrations above the guideline values for drinking water” (Environment Canterbury Regional Council (ECRC) (2012). This assumption supports a case for intrusion of saltwater in the groundwater of Eti-Osa as opposed to the situation in Ibeju-Lekki where the percentage of salinity comparable to Eleko beach is 0.004%.

Comparison with WHO and NAFDAC water quality standards

Groundwater from BH1 and BH2 from Ibeju-Lekki were found to meet all WHO and NAFDAC portable water quality requirements, however groundwater samples from Eti-Osa LGA (BH3 and BH4), did not meet all WHO and NAFDAC set standards for water quality. Table 3 shows mean parameter values of groundwater samples investigated in comparison with standards of WHO and NAFDAC as discussed onwards.

Ibeju-Lekki LGA

Based on SPSS analysis it was observed that peculiar

Table 2. Mean values of physiochemical parameters of borehole samples and corresponding beach water.

S/N	Parameter	IBEJU-LEKKI					ETI-OSA				
		BH1		BH2		Elek o beach	BH3		BH4		Alpha beach
		MOV	SD	MOV	SD		MOV	SD	MOV	SD	
1.	pH	7.825	0.377	7.750	0.479	7.0	7.375	0.350	7.525	0.512	7.3
2.	Temperature,° C	31.075	1.719	31.815	0.850	31	30.165	0.579	30.500	0.577	30
3.	EC (μScm^{-1})	267.090	16.074	208.620	9.480	32440	3282.83	261.84	2036.340	231.580	60,520
4.	TDS(mg/l)	186.500	13.127	145.860	6.688	22,720	2307.91	190.786	1427.100	162.830	42623.3
5.	SAL (mg/l)	0.0225	0.005	0.020	.000	6.19	0.832	0.038	0.875	0.246	18.13
6.	Ca^{2+} (mg/l)	11.740	1.788	10.750	0.957	700.0	167.850	11.888	111.680	34.250	1,837.0
7.	Mg^{2+} (mg/l)	4.750	0.957	3.500	1.000	100.0	39.750	8.770	27.500	10.660	470.0
8.	K^{+} (mg/l)	5.000	1.154	6.500	1.000	141.0	37.250	2.629	54.00	13.880	443.3
9.	Na^{+} (mg/l)	9.832	1.373	10.500	1.000	863.3	158.16	13.379	265.92	195.080	6,870
10.	HCO_3^{-} (mg/l)	0.022	0.0170	0.020	0.017	ND	0.022	0.015	0.022	0.017	0.01
11.	NO_3^{-} (mg/l)	2.190	0.181	1.825	0.085	26.51	28.470	2.670	16.747	2.287	62.3
12.	Cl^{-}(mg/l)	13.835	3.627	12.332	1.155	3,523.3	481.580	7.410	524.580	140.745	12,526
13.	SO_4^{2-}(mg/l)	8.665	1.300	6.750	0.500	125.0	33.167	13.989	22.875	11.862	141.0
14.	TH (mg/l)	16.165	1.370	15.000	2.581	803.3	218.330	24.120	152.50	38.622	2,003.3
15.	DO (mg/l)	5.805	0.066	6.007	0.304	5.1	5.150	0.336	5.624	0.309	5.6

Key to Tables 1 and 2:
NAFDAC: National Food Drug Administration and Control SON: Standard Organisation of Nigeria.
STD: standard
MOV: mean of observed values
SD: standard deviation of mean value
SDF WHO: Significance difference from WHO standard
SDF WHO: Significance difference from NAFDAC/SON standard BH1: borehole 1, Ibeju-Lekki LGA, 50m from coastline
BH2: borehole 2, Ibeju-Lekki LGA, 100-150 m from coastline BH3: borehole 3, Eti-Osa LGA, 50m from coastline
BH4: borehole 4, Eti-Osa LGA, 100- 150 m from coastline
UNITS: EC = (μScm^{-1}), Temperature = °C, All other parameters = mg/L.

Table 3. Comparisons with who and nafdac standards for water quality.

Parameter	WHO STD	NAFDAC STD	IBEJU-LEKKI						ETI-0SA					
			BH2			BH2			BH3			BH4		
			MOV	SDF WHO	SDF NAFDAC	MOV	SDF WHO	SDF NAFDAC	MOV	SDF WHO	SDF NAFDAC	MOV	SDF WHO	SDF NAFDAC
pH	7.5 (6.5 –8.5)	7.5 (6.5-8.5)	7.825	0.184	0.184	7.750	0.374	0.374	7.375	0.527	0.527	7.525	0.928	0.928
Temperature,℃	-	-	31.075	-	-	31.815	-	-	30.165	-	-	30.500	-	-
EC (μScm^{-1})	1200	1000	267.090	0.000	0.000	208.620	0.000	0.000	3282.83	0.001	0.000	2,036.340	0.005	0.003
TDS(mg/l)	1500	500	186.500	0.000	0.000	145.860	0.000	0.000	2,307.91	0.003	0.000	1,427.100	0.436	0.001

Table 3. Contd.

SAL (mg/l)	-	-	0.0225	-	-	0.020	-	-	0.832	-	-	0.875	-	-
Ca^{2+} (mg/l)	-	75	11.740	-	0.000	10.750	-	0.000	167.850	-	0.001	111.680	-	0.122
Mg^{2+} (mg/l)	20	20	4.750	0.000	0.000	3.500	0.000	0.000	39.750	0.200	0.200	27.500	0.254	0.245
K^{+} (mg/l)	-	10	5.000	-	0.003	6.500	-	0.006	37.250	-	0.000	54.00	-	0.088
Na^{+} (mg/l)	200	-	9.832	0.000	-	10.500	0.000	-	158.16	0.009	-	265.92	0.548	-
HCO_3^- (mg/l)	-	-	0.022	-	-	0.020	-	-	0.022	-	-	0.022	-	-
NO_3^- (mg/l)	10	10	2.190	0.000	0.000	1.825	0.000	0.000	28.470	0.001	0.001	16.747	0.010	0.010
Cl^- (mg/l)	250	100	13.835	0.000	0.000	12.332	0.000	0.000	481.580	0.000	.000	524.580	0.030	0.009
SO_4^{2-} (mg/l)	500	100	8.665	0.000	0.002	6.750	0.000	0.001	33.167	0.000	.000	22.875	.000	.000
TH (mg/l)	500	100	16.165	0.000	0.000	15.000	0.000	0.000	218.330	0.000	0.002	152.50	.000	0.073
DO (mg/l)	-	-	5.805	-	-	6.007	-	-	5.150	-	-	5.624	-	-

interrelationships exists between the parameters which mirror the groundwater condition in the area. In BH1, pH has very high correlation with HCO_3^- (r = 0.969, p = 0.031). pH indicates the strength of the water reacting as an acid or base, a very strong correlation with HCO_3^- supports the dissolution of CO into carbonic acid characteristic of weathering process involving a calcite substrata. EC has a very high positive correlation with Ca^{2+}, Mg^{2+} and SO_4^{2-} at r values greater than 0.9, p< 0.05. TDS has a very high positive correlations with Mg^{2+} (r = 0.968, p = 0.032). This implies that EC and TDS are controlled by these ions in a linear relationship. Mg^{2+} has a very high positive correlations with NO_3^- (r = 0.960, p = 0.04), whereas TH have a very high positive correlation with Na+ (r = 0.961, p = 0.039) and Cl^- (r = 0.988, p = 0.12).

In BH2, pH has very high correlation with EC, TDS, NO_3^-, Cl^- and TH at values of r ≥9.0, p < 0.05. EC has very high correlations with NO_3^- and TH at values of r = 0.99, p = 0.001. TDS have very high correlations with HCO_3^- (r = 0.971, p = 0. 021), NO_3^- (r = 1.000, p = 0.000) and TH (r = 0.998, 0.002). This implies that EC and TDS are controlled by these ions. K^+ has very high positive correlation with Na^+ (r = 1.000, p = 0.000) and Cl^- (r = 0.962, p = 0.38). Na^+ has very high positive correlation with Cl^- (r = 0.962, p = 0.38). HCO_3^- have very high positive correlations with NO_3^- of (r= 0.979, p = 0.029) and high positive correlation with TH (r = 0.983, p = 0.017).

Eti-OsaLGA

In BH3, EC has a high positive correlation with NO_3^- (r = 0.988, p = 0.012), Cl^- (r = 0.970, p = 0.030). TDS has a high positive correlation with NO_3^- (r = 0.990, p = 0.010), Cl^- (r = 0.971, p = 0.029) and Mg^{2+} (r = 0.966, p = 0.034). This implies that NO_3^- and Cl^- are the controlling factors of the concentration of EC and TDS. Ca^{2+} as well has a high positive correlation with Na^+ (r = 0.994, p = 0.006), NO_3^- (r = 0.979, p = 0.021), and Cl^- (r= 0.971, p = 0.029). Na^+ has a high positive correlation with NO_3^- (r = 0.961, p = 0.039), and Cl^- (r = 0.984, p = 0.016). NO_3^- has a high positive correlation with Cl^- (r = 0.995, p = 0.005) and TH (r = 0.952, p = 0.048). The strong correlations with the major sea water ions with NO_3^- and it suggests impact of contamination from sewage waste and other anthropogenic activities, not neglecting the influence of seawater intrusion into the aquifer. This assertion holds frail as wells built in areas proximate to the coast are often times not built very deep far below the direct impact of sewage pits.

In BH4, salinity has a very high positive correlation with Na+ (r = 0.99, p = 0.02) and has a very high negative correlation with DO (r = - 0.966, p = 0.034). Also K^+ has a very high positive correlation with Cl^- and SO_4^{2-} at r values > 0.9 and p values < 0.05, but has a high negative correlation with HCO_3^- (r = - 0.998, p = 0.02) and DO (r= - 0.993, p = 0.07). Cl^- as well have a high positive correlation with SO_4^{2-} (r = 1.000. p = 0.00). These correlations support the case for saltwater intrusion in the sample point, as salinity is influenced in a linear relationship by sodium ions concentration. This as well is the case between K+, Cl^- and SO_4^{2-}. It can also be deduced that these parameters originate from a common source (Al-Khatib and Al-Najar, 2011). On the other hand, HCO_3^- has high negative correlations with Cl^- and SO_4^{2-}, similarly, it can be deduced that HCO_3^- is not of same source as Cl^- and SO_4^{2}. Figure 1 is a clustered column plot of mean

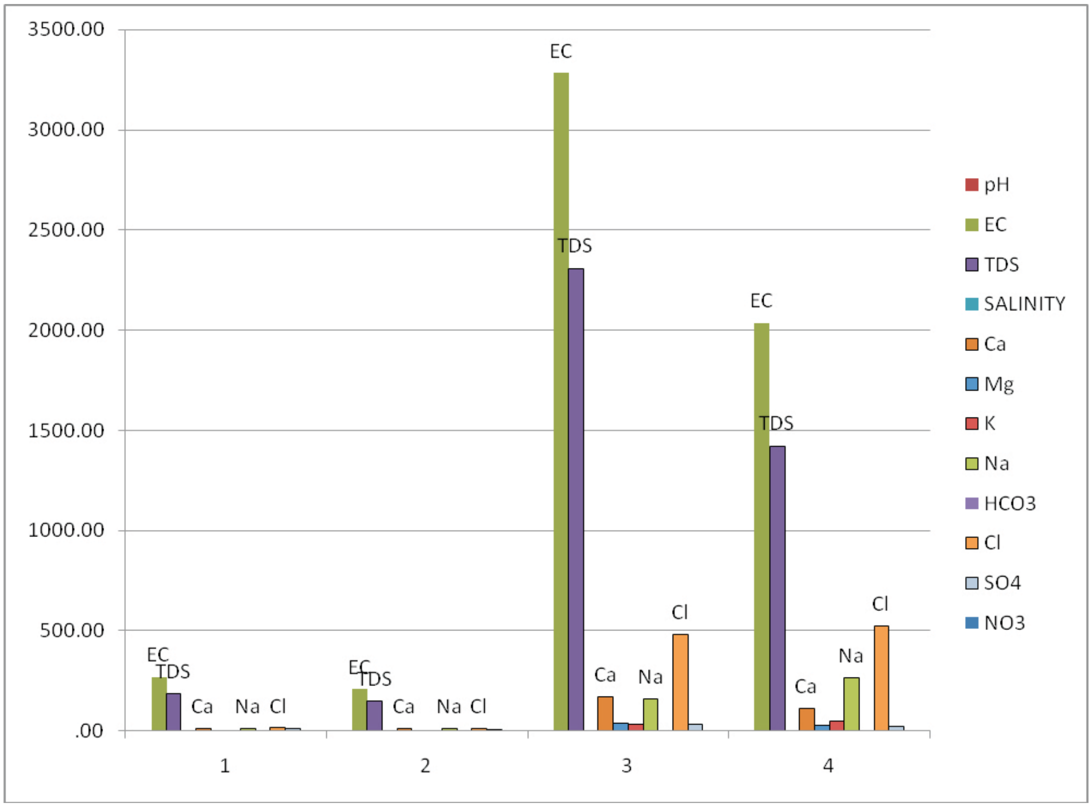

Figure 1. mean values of weekly physiochemical measurements of boreholes in both Ibeju-Lekki (UNEP/ROLAC (2012; Jideonwo,

Interrelationships exists between the parameters which mirror the groundwater condition in the area. In BH1, pH has very high correlation with HCO3- ($r = 0.969$, $p = 0.031$). pH indicates the strength of the water reacting as an acid or base, a very strong correlation with HCO3- supports the dissolution of CO into carbonic acid characteristic of weathering process involving a calcite substrata. EC has a very high positive correlation with Ca2+, Mg2+ and SO42- at r values greater than 0.9, $p < 0.05$. TDS has a very high positive correlations with Mg2+ ($r = 0.968$, $p = 0.032$). This implies that EC and TDS are controlled by these ions in a linear relationship. Mg2+ has a very high positive correlations with NO3- ($r = 0.960$, $p = 0.04$), whereas TH have a very high positive correlation with Na+ ($r = 0.961$, $p = 0.039$) and Cl- ($r = 0.988$, $p = 0.12$).

In BH2, pH has very high correlation with EC, TDS, NO3-, Cl- and TH at values of $r \geq 9.0$, $p < 0.05$. EC has very high correlations with NO3- and TH at values of $r = 0.99$, $p = 0.001$. TDS have very high correlations with HCO3- ($r = 0.971$, $p = 0.021$), NO3- ($r = 1.000$, $p = 0.000$) and TH ($r = 0.998$, 0.002). This implies that EC and TDS are controlled by these ions. K+ has very high positive correlation with Na+ ($r = 1.000$, $p = 0.000$) and Cl- ($r = 0.962$, $p = 0.38$). Na+ has very high positive correlation with Cl- ($r = 0.962$, $p = 0.38$). HCO3- have very high positive correlations with NO3- of ($r = 0.979$, $p = 0.029$) and high positive correlation with TH ($r = 0.983$, $p = 0.017$).

Eti-Osa LGA

In BH3, EC has a high positive correlation with NO3- ($r = 0.988$, $p = 0.012$), Cl- ($r = 0.970$, $p = 0.030$). TDS has a high positive correlation with NO3- ($r = 0.990$, $p = 0.010$), Cl- ($r = 0.971$, $p = 0.029$) and Mg2+ ($r = 0.966$, $p = 0.034$). This implies that NO3- and Cl– are the controlling factors of the concentration of EC and TDS. Ca2+ as well has a high positive correlation with Na+ ($r = 0.994$, $p = 0.006$), NO3- ($r = 0.979$, $p = 0.021$), and Cl- ($r = 0.971$, $p = 0.029$). Na+ has a high positive correlation with NO3- ($r = 0.961$, $p = 0.039$), and Cl- ($r = 0.984$, $p = 0.016$). NO3- has a high positive correlation with Cl- ($r = 0.995$, $p = 0.005$) and TH ($r = 0.952$, $p = 0.048$). The strong correlations with the major sea water ions with NO3- and it suggests impact of contamination from sewage waste and other anthropogenic activities, not neglecting the influence of seawater intrusion into the aquifer. This assertion holds frail as wells built in areas proximate to the coast are often times not built very deep far below the direct impact of sewage pits.

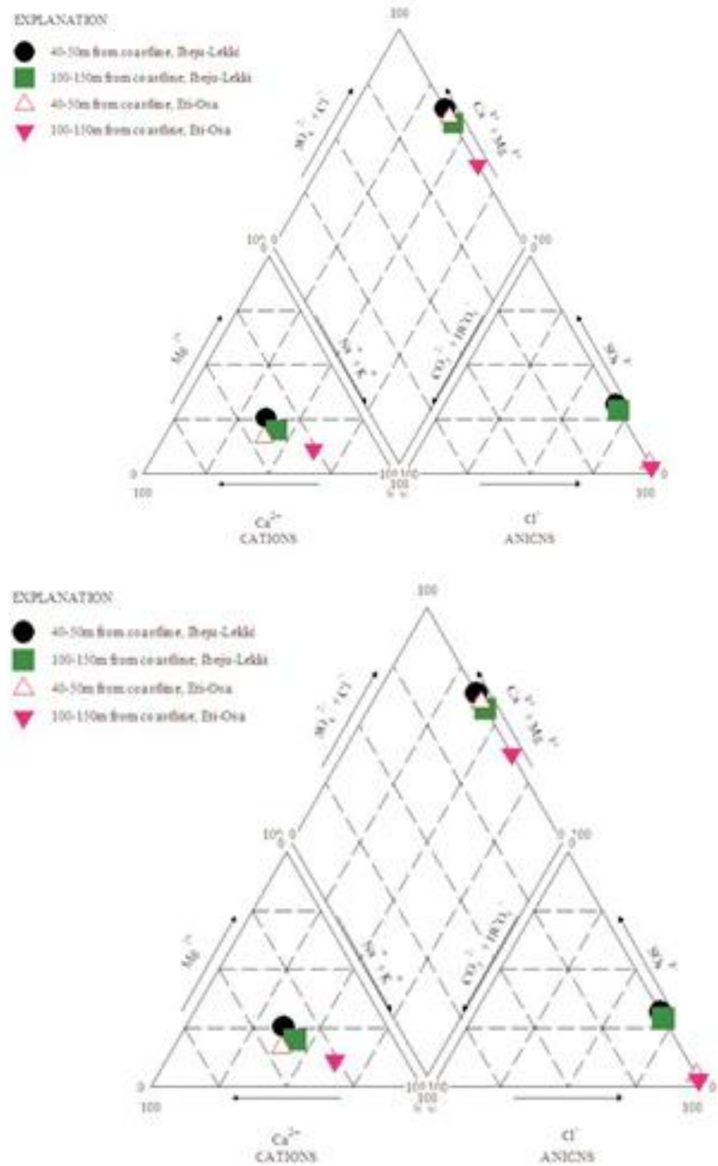

Figure 2. Hydrochemicalfacies of groundwater in Eti-Osa and Ibeju-Lekki LGA.

In BH4, salinity has a very high positive correlation with Na^+ ($r = 0.99$, $p = 0.02$) and has a very high negative correlation with DO ($r = -0.966$, $p = 0.034$). Also K^+ has a very high positive correlation with Cl^- and SO_4^{2-} at r values > 0.9 and p values < 0.05, but has a high negative correlation with HCO_3^- ($r = -0.998$, $p = 0.02$) and DO ($r = -0.993$, $p = 0.07$). Cl^- as well have a high positive correlation with SO_4^{2-} ($r = 1.000$. $p = 0.00$). These correlations support the case for saltwater intrusion in the sample point, as salinity is influenced in a linear relationship by sodium ions concentration. This as well is the case between K^+, Cl^- and SO_4^{2-}. It can also be deduced that these parameters originate from a common source (Al-Khatib and Al-Najar, 2011). On the other hand, HCO_3^- has high negative correlations with Cl^- and SO_4^{2-}, similarly, it can be deduced that HCO_3^- is not of same source as Cl^- and SO_4^{2-}.Figure 1 is a clustered column plot of mean values of water characteristics for the four boreholes under investigation.

Groundwater classification by piper diagram

To follow on the likely conformational changes to the aquifer water that due to saltwater intrusion a plot of chemical data on diamond shaped trilinear diagram (Figure 2) reveals groundwater hydrochemicalfacies classification of BH1 and BH2 from Ibeju-Lekki, which fall

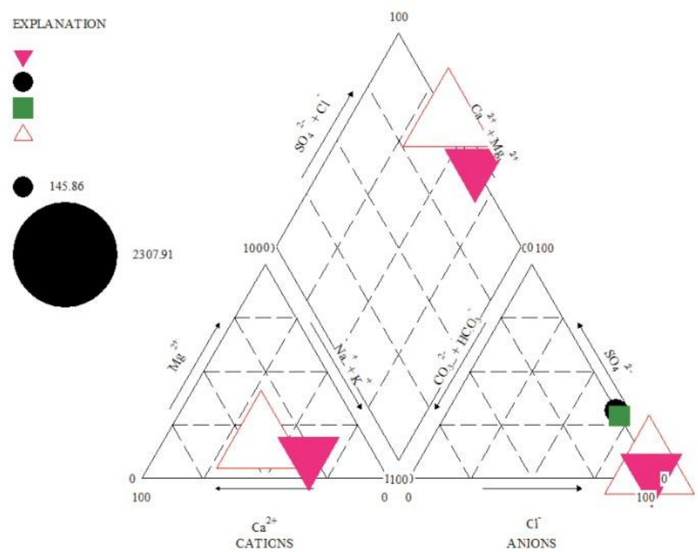

Figure 3. Hydrochemical characteristics in proportion to TDS in Eti-Osa and Ibeju-Lekki LGAs.

in the fields of Ca-Mg-Cl-SO4 and thus characterized as Ca- SO4 waters - typical of gypsum ground waters and mine drainage water type. In Eti-Osa LGA the borehole proximate to the coastline that is, BH3 which is about 50 m to the coastline was found to be of Ca- SO4 water type. It is important to note that it is often times difficult to identify the hydrogeochemical facie of shallow groundwater due to excess infiltration from secondary recharge from irrigation water (Dano, 2010) or precipitation as well as influxes from anthropogenic activities.

However, BH4 in Eti-Osa was found to have Na-Cl water type, characterized by high EC, TDS and salinity, and has been in used for over a year; however the borehole is located 100-150 m from the coastline. This suggests that the continuous exploitation of groundwater has led to saltwater intrusion (Kura et al., 2013). Figure 3 shows the water quality situation or changes in Eti-Osa is characterised by TDS, this depicts influence from a source of dissolvable solids.

Conclusion

Groundwater sample from coastal environments with varying tendencies to climate change hazards were studied, Eti-Osa and Ibeju-LekkiLocal Government coastal communities with different patterns in land usage, population densities and industrial activities having groundwater which are influenced differently by nearby coast were focused. Water samples from two beaches in each Local Government were analysed for physiochemical parameters (pH, Temperature, EC, TDS, Salinity, Ca2+, Mg2+, K+, Na+, HCO3- , NO3-, Cl-, SO42-, TH, DO). The results were used in assessing water quality and the effects of seawater intrusion on groundwater which was analyzed.

Considering hydrochemical changes in groundwater chemistry, Eti-Osa aquifers were compared to Ibeju-Lekki with less pumping pressure. Thus, saltwater intrusion into the aquifer was established in Eti-osa, making water samples from Eti-Osa to be of low quality, as it failed to meet requirements of potable water quality set by WHO and NAFDAC. However water samples from Ibeju-Lekki met all requirements for portable water quality set by WHO and NAFDAC. The groundwaters were characterised using piper diagram. Ibeju-Lekki water samples showed hydrochemicalfacies of Ca-SO_4 water type showing early signs of oncoming intrusion, whereas Eti-Osa aquifers showed Ca-SO_4 and Na-Cl water type, which confirmed salt water intrusion in the area.

RECOMMENDATIONS

Considering the findings from this research it is recommended as follows:

(1) Establishment of an environmental risk assessment network which would initiate a hydrogeological monitoring and management plan to address seawater intrusion issues in Lagos state.
(2) Encouragement of sustainability practices through awareness creation and public environmental health and resource management education is highly recommended.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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