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Groundwater Quality Assessment in Eti-Osa, Lagos-Nigeria using Multivariate Analysis

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ABSTRACT: Groundwater quality in Eti-Osa was assessed**.** 18 water samples were collected from hand dug well and measured for 3 physical (pH, EC and TDS) and 9 chemical parameters (Ca, Cl, Fe, TH, Mg, NO_3, SO_4,TSS and Zn) after standard procedures (APHA).The results show that pH of groundwater samples indicates a neutral condition (7.01).TH was slightly hard (37.11mg/l).TDS, Fe and Mg concentrations were above the NDWQS limit of (500, 0.3 and 0.2mg/l) respectively for drinking water purpose. The Coefficient of variation shows that all the groundwater parameters with the exception of pH, Ca, Cl and Fe are highly heterogeneous. The correlation among the groundwater parameters shows that pH has a negative correlation at $P < 0.05$ with Ca and TSS (r= -0.49).TH and Ca showed a positive correlations with Cl (r=0.51), EC (r=0.58).The factor analysis employed indicates four factors. Factor I, explains 27.73% of the total variance, with a strong positive loading on EC, TDS, Ca and a negative loading on pH. Factor II accounts for 21.35% of the total variance, and was characterized by strong positive loading of Zn and negative loading of Fe and TDS.Factor III was characterized by high positive loading of Cl and TH and accounts for 15.98% of the total variance while factor IV accounts for 14.05% of the total variance and was characterized by a strong positive loading of NO_3.The paper recommended routine monitoring and thorough treatment before consumption. The study demonstrates the effectiveness of factor analysis in assessing the hydrochemical processes of groundwater in the area. @JASEM

Groundwater constitutes an important source of water for drinking, agriculture and industrial production. The use of groundwater has increased significantly in the last decades due to its widespread occurrence and overall good quality. The contribution from groundwater is vital; because about two billion people depend directly upon aquifers for drinking water, and 40 percent of the world's food is produced by irrigated agriculture that relies largely on groundwater (Morris et al., 2003).Despite its importance, contamination from natural, human activities, steady increase in demand for water due to rising population and per capita use, increasing need for irrigation, changes in climates and over-exploitation etc)among others has affected the use of groundwater as source of drinking water. In Nigeria, regulatory agencies (Standard Organization of Nigeria (SON), Federal Ministry of Environment (FME) among others are established for the enforcement of national water quality and emission standards in order to protect human health and aquatic ecosystems. In term of effectiveness of these agencies, the decree that established them can be described as stale judging from the punitive contents which can best be described as a disincentive and invitation to chaos. The penalties for defaulters are cheaper and paying such a pittance as fine saves them more money than the actual objective for which the decree was made.
Access to sources of water in Nigeria shows that 48% (about 67 million Nigerians) depend on surface water for domestic use, 57% (79 million) use hand dug wells, 20% (27.8 million) harvest rain, 14% (19.5 million) have access to pipe borne water, and 14% have access to borehole water sources (FGN,2007).Globally, about 80% of all diseases and death in developing country are water-related as a result of polluted water (Ayeni et al; 2011, Aderibigbe et al; 2008).

Among the multivariate techniques, R-mode factor analysis has been widely employed for understanding hydrogeochemical association and processes controlling them (Briz-kishore and Murali, 1992; Ravi, 1999 and Rao, et al., 2001). As a first step, correlation analysis that reveals the relationship between two variables was calculated for the major ion in groundwater samples in the study area. Though factor analysis reduces the dimensionality of the problem, the meaning of these factors may sometimes be difficult to deduce (Davis, 1986).

In this study, Kaiser varimax rotation was applied for the multivariate analysis of groundwater quality parameters. The final step of the factor analysis projected the data on the rotated significant factors and the scores obtained by this projection (factor scores) are used to understand the nature of variables. According to Dalton and Upchurch (1978) factor scores are related to the intensity of the chemical processes described by each factor. Negative numbers reflect areas unaffected by the process, positive numbers indicate areas most affected and near-zero numbers affect to an average degree (Lawrence and Upchurch, 1982).
This study examined the governing factors of groundwater quality based on multivariate analysis technique in the study area.

The Study Area: Eti-Osa Local Government Area is located between latitude 6^0 15' and 16^0 17' and longitude $3^0$3' east and 3^0 35' east. It is bounded in the south by Atlantic Ocean, in the east by Ojo local government, north by Lagos lagoon and part of Mainland and Island local government and in the

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west by Ibeju- Lekki local government (Odumosu et al., 1999). The study area occupies an area of about 192.3km^2.The population is about 287,785 with density of 1,496 person per km^2 (NPC, 2006). The study area houses the Lagos lagoon and the beaches, which stretch to the Atlantic Ocean. It comprises of nine wards namely; Victoria Island, Ward H_1 and H_2, Ikoyi West, Ward L_1, Ikoyi East, Ward L_2, Obalende, Ward $_M$, Eti-Osa N. E, Ward K_3, Eti-Osa, S. E, Ward K_2, Eti – Osa N.W, Ward K_1, and Eti – Osa S.W, Ward.

The climate is tropical type with an average rainfall of 2500mm and temperature of 30^{0}C. The vegetation pattern reflects its coastal location with mangrove swamp trees being the dominant type. The topography is between 3-15m above sea level. The geology consists of quaternary alluvial deposits such as red-yellow, red-brown, grey and sandy- clays, silt, sand, gravels, and other detrital material. The major source of water provision in the study area includes pipe-borne water and boreholes.

MATERIAL AND METHODS

Reconnaissance survey of the study area was carried out prior to the actual sample collection. The reconnaissance survey facilitated a better understanding of the spatial distribution of wells within the study area. Groundwater samples were collected during the month of June, 2009 at eighteen (18) sampling points using a random sampling technique. Three (3) physical parameters were measured for pH, Electrical Conductivity and Total Dissolved Solids while nine (9) chemical parameters were analyzed for Total Suspended Solids, Total Hardness, Calcium, Magnesium, Chloride, Nitrate, Sulphate, Zinc and Iron using standard methods for water samples examination after American Public Health Association 1998.

The co-ordinates of the sampling points were recorded using Global Positioning System (GPS) Garmin Channel 72 model. Well water samples were collected in clean 1.5 litre plastic jar with screw caps, and packed in cooler containing ice and transported to the laboratory within 24hours from the time of sample collection.

The in situ measurement was carried out using potable digital meter, EXTECH pH-100 and HM digital EC/TDS/Temperature COM-100 respectively. Total Hardness and Chloride were determined using titrimetry method. The concentrations of metals (Iron, Zinc, Magnesium and Calcium) were determined by Atomic Absorption Spectrophotometer (AAS) while Total Suspended Solids, Sulphate and Nitrate were determined using HACH DR/2000 direct reading spectrophotometer.

RESULTS AND DISCUSSION

Table 1 presents the statistics of groundwater parameters in the study area. It was observed that the pH in all the groundwater samples ranges from 6.79 to 7.22 with a mean of 7.01 mg/l, indicating a neutral condition. The pH values are within the prescribed limits of 6.5-8.5 for drinking water standards.

The results show that Total Hardness varied between 27.21- 47.02, with a mean of 37.11mg/l, indicating the groundwater Quality of the study area is slightly hard. The TDS, which is an indicative parameter to assess the degree of water quality, varied between 437.43 - 777.46 with a mean of 607.44mg/l .The TDS values were above the prescribed limits of 500mg/l for drinking water purpose. TDS in groundwater are generally not harmful to human being but high concentration may affect persons, who are suffering from kidney and heart diseases (Gupta, 2004).

Water containing high solids may also cause laxative or constipation effects. The concentration (mg/L) of Calcium, Magnesium, Chloride, Sulfate and Nitrate are in the range of 12.72 -19.50, 1.44-3.97, 178.55 – 265.89, 1.31 -2.29 and 0.52-1.02 with a mean of 16.11, 2.71, 222.22, 1.80 and 0.77 respectively.

Compared to Nigerian Drinking Water Quality Standards (NDWQS), the concentration of Ca, Cl, SO_4 and NO_3 are below the safe limit of 300, 250, 100 and 50 mg/L for drinking, respectively whereas, concentration of Mg (2.71mg/l) was above the permissible limits of 0.2mg/l for drinking purpose.

Since the chloride-rich minerals are not found in the study area, the higher concentrations of chloride in the groundwater could be caused by pollution sources such of domestic wastewater and septic tanks. Iron content varies from 0.56-0.79 mg/l, with a mean of 0.66 mg/l. The concentration of Fe (0.66mg/l) is above the prescribed limits of 0.3mg/l for drinking water standards. On the pattern of relative variation, the result of the Coefficient of variation (C.V) shows that all the examined groundwater variables with the exception of pH, Ca, Cl and Fe are heterogeneous. Considering the high variability of groundwater parameters in the study area, there is need for routine monitoring and thorough boiling before consumption of groundwater quality.

Table 2 presents the correlation among various parameters of groundwater in the study area .pH shows a negative correlation at $p<0.05$, with Ca and TSS (r=-0.49).Similarly, Fe shows a negative correlation with Zn (r=-0.49) while TH and Ca showed a positive correlations with Cl (r=0.51), EC (r=0.58) respectively. Since correlation analysis reveals similarities or differences in the behavior of pairs of ions, and does not conveniently identify groups of ions that behave similarly, factor analysis was carried out for the groundwater parameters to help in hydrogeochemical interpretation of the data.

Result of factor analysis of the groundwater chemistry indicates four factors (Table 3) that can be related to various controlling processes of hydrochemistry. The rotated factor matrix statistics show that the four factors extracted explain 77.11 % of total variance. The communalities of the variables and proportion of their variance explained by the extracted common factors vary from 0.72 to 0.89, suggesting the factor analysis model can be represented adequately based on the overall variance of the data set. Factor I, which explains 27.73% of the total variance, has a strong positive loading on EC, TDS, Ca and a negative loading on pH. It further shows moderate loadings on Mg and Zn while the loading on Cl, NO_3 and Fe depict a very low loadings. The negative loading of pH on factor I confirms that the concentration of pH in the groundwater does not contribute significantly to EC, TDS and Ca values.

Factor II accounts for 21.35% of the total variance, which is characterized by strong positive loading of Zn and negative loading of Fe and TDS. The rest of the variables show low to very low loadings. Factor III is characterized by high positive loading of Cl and TH which accounts for 15.98% of the total variance. Factor IV accounts for 14.05% of the total variance and is characterized by a strong positive loading of NO_3. Nitrate is derived mainly from the non-lithological (Ritzi et al.,), which is caused by anthropogenic activities. For example, the association between NO_3 - and Na^+ reflects the impact of domestic wastewater and septic tank.

The combination of TDS with Cl measures high salinity, TH (Ca and Mg) represents permanent hardness. According to Subba Rao et al (1997) enrichment of TDS and Cl is possible because of the effect of urban wastewaters. According to Hem (1991) water lost alkaline earth elements (Ca and Mg) through the exchange process and may later participate in chemical reactions, which raise the pH.The loadings on Cl and TDS are interpreted as representing the role of weathering of country rocks, climate and anthropogenic sources of groundwater contamination. Similarly, Ca and Mg reflect the weathering of country rocks (Mohan et al., 2000). Nitrate has no known lithologic source and hence it reveals pollution, which is attributed to the urban wastewaters and high density of septic tank (Uma, 1993; Ballukraya and Ravi, 1999).

Table 1: Descriptive Statistics of groundwater sample parameters
All units except pH are SD= standard deviation; LCL=lower confidence limit; UCL=upper confidence limit; CV=coefficient of variation

Parameters	Mean	SD	LCL	UCL	CV (%)
pH	7.01	0.43	6.79	7.22	6.13
TH	37.11	19.92	27.21	47.02	53.68
Ca	16.11	6.82	12.72	19.50	42.33
Mg	2.71	2.54	1.44	3.97	93.73
Cl	222.22	87.82	178.55	265.89	39.52
TDS	607.44	341.88	437.43	777.46	56.28
NO_3	0.77	0.50	0.52	1.02	64.94
Fe	0.66	0.19	0.56	0.76	28.79
SO_4	1.80	0.99	1.31	2.29	55.00
EC	1.32	0.69	0.98	1.67	52.27
TSS	6.78	5.98	3.82	9.74	88.20
Zn	4.44	4.89	2.03	6.89	110.14

Table 2: Correlation Matrix of Groundwater parameter. Correlation is significant at the 0.05 level (2-tailed), in bold

Parameters	pH	TH	Ca	Mg	Cl	TDS	NO3	Fe	SO4	EC	TSS	Zn
pH	1											
TH	0.06	1										
Ca	**-0.49**	0.19	1									
Mg	-0.27	0.04	0.29	1								
Cl	0.25	**0.51**	0.09	0.03	1							
TDS	-0.39	0.18	0.65	0.36	0.23	1						
NO3	-0.19	-0.22	-0.03	0.45	0.18	0.13	1					
Fe	-0.10	-0.21	0.05	-0.39	-0.08	-0.16	0.12	1				
SO4	0.42	0.13	-0.26	-0.08	0.42	-0.09	0.39	0.05	1			
EC	-0.44	0.21	**0.58**	0.40	0.16	0.93	0.16	-0.19	-0.14	1		
TSS	**-0.49**	0.02	0.34	-0.34	-0.13	-0.06	-0.22	0.67	-0.43	-0.05	1	
Zn	-0.19	0.28	0.22	0.74	0.22	0.46	0.27	**-0.49**	0.26	0.45	**-0.48**	1

Table 3: Rotated Factor Matrix Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Variables	Components				
	Factor 1	Factor II	Factor III	Factor IV	Communality
Hydrogen ion Concentration	**-0.73**	0.20	0.39	-0.08	0.74
Total Hardness	0.22	0.12	**0.73**	-0.35	0.72
Calcium	**0.83**	-0.12	0.08	-0.11	0.72
Magnesium	0.47	0.62	-0.16	0.35	0.75
Chloride	0.09	-0.01	**0.86**	0.18	0.79
Total Dissolve Solids	**0.84**	0.21	0.20	0.05	0.79
Nitrate	0.13	0.08	-0.03	**0.92**	0.87
Iron	-0.02	**-0.88**	-0.01	0.29	0.86
Sulfate	-0.35	0.12	0.57	0.57	0.79
Electrical Conductivity	**0.84**	0.23	0.14	0.05	0.79
Total Suspended Solids	0.31	**-0.85**	-0.15	-0.22	0.89
Zinc	0.41	**0.71**	0.19	0.27	0.78
Eigen Values	3.33	2.56	1.92	1.69	
% of Variance	27.73	21.35	15.98	14.05	
Cumulative % of Variance	27.73	49.08	65.06	79.11	

Conclusion: The present study assessed the physico-chemical characteristics of open hand dug well quality in Eti-Osa, Lagos-Nigeria .The NDWQS drinking water quality standards adopted show that TDS, Iron and Magnesium values were above the prescribed limits. Also, TH, Mg, TDS, NO_3, SO_4, EC, TSS and Zn were highly variable. Result of the multivariate statistical analysis, as applied to the chemical data set of groundwater quality in the area provides an insight into the underlying controlling hydrochemical processes in study the area. Four factors including factor 1(EC, TDS, Ca and pH), factor 2 (Zn, Fe and TDS), factor 3 (Cl and TH) and factor 4 (NO_3) extracted from the dataset represent the signatures of weathering of country rock, climate and anthropogenic contamination, salinity and pollution respectively. This study demonstrates the effectiveness of factor analysis in assessing the hydrochemical processes of groundwater and also to provide preliminary assessment of the groundwater quality that will serve as a data base for future investigations and monitoring of groundwater quality in the study area. The paper recommends the need for routine monitoring and thorough boiling before consumption of groundwater quality. The recent drive towards urbanization and industrialization means a greater demand for groundwater and high rate of wastewater released onto the land surface. Hence, groundwater yield and appriopate laws guiding the release of wastewater onto the land should be strictly adhered to.

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