Comparative Analysis of Groundwater Quality under different Land-use Types in Apapa Local Government Area of Lagos, Nigeria

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ABSTRACT

The study examined the differences in physicochemical characteristics of groundwater under varying land uses in Apapa Local Government Area of Lagos State, Nigeria. Samples from 30 hand-dug wells were analysed for six physical and eight chemical parameters. The water samples were from three land use types namely commercial, industrial and residential. Correlation and ANOVA techniques were used to study relationships between elements and differences among land use groups respectively. Parameters such as turbidity, TDS and EC exceeded the WHO standards in some locations. All the chemical parameters under study had significant positive relationships with each other. ANOVA results showed that the observed variations in the occurrence of turbidity, DO, TSS, Cl, Mg, Na and K across land use types were not significant. Significant however at $p< .05$ are variations in pH, EC, TDS, SO_4, NO_3, PO_4 and Ca. The post hoc tests carried out on these seven parameters further indicated a significant difference between residential and industrial land uses. The paper calls for further research.

Keywords: groundwater, water quality, Apapa, water parameters, ANOVA, land-use

1. INTRODUCTION

Just like air and land resources, water is an essential of life. All animals, plant, and human need water in order to live and survive. Water gives life but when not well treated, it leads to loss of lives, the death of plants and animals. As a result, the importance of high-quality drinking water cannot be underestimated. It is true that one of the greatest threats to health remains lack of clean water and sanitation. Globally, about 80% of all diseases and deaths in developing countries are water-related as a result of polluted water (Ayeni et al., 2011; Aderibigbe et al., 2008).

Naturally, water is never pure in a chemical sense. It contains impurities of various kinds dissolved as well as suspended. These include dissolved gases, dissolved minerals, suspended matter and microbes. These are natural impurities derived from the atmosphere, catchment areas and soil. They are very low in amounts and naturally do not pollute water. However, the quality of natural water is influenced by several other factors that have the capacity to make water undesirable. Any physical, biological, or chemical change in water quality that adversely affects living organisms or makes water unsuitable for desired uses might be considered pollution (Wright and Nebel, 2002). In essence, water pollutant is anything that degrades water quality. It includes all of the waste materials that can't be naturally counteracted by water. Anything that is added to the natural taste, look, and colour of water, little above and beyond its capability and to interrupt and degrade it is pollution (Christopherson, 2007).

Water pollution can occur from natural and human sources. The natural sources are from poison springs, oil seeps and sedimentation from erosion while the human sources are from industrial, agricultural, power plants, sewage treatment plants, underground coal mines and oil wells. According to Cunningham and Cunningham (2012), these pollutants from human sources are classified as point source since they discharge pollution from specific locations into the ground. Man is using more materials in his daily activities that are pollutants to the water sources. Najafpour et al., (2008), noted that the outcome of human activities and certain natural phenomena can result in water quality falling below the standard expected for specific purposes.

Groundwater is also prone to the pollution threat. Groundwater is the supposed largest source of freshwater in the hydrological cycle and according to Christopherson (2007), it is more encompassing than all surface lakes and rivers combined. Groundwater constitutes an important source of water for drinking, agriculture and industrial production (Akoteyon & Soladoye, 2011). Over 2 billion people depend on water from underground sources globally. Aderibigbe, Awoyemi and Osagboni (2008), observed a significant increase in the use of groundwater in recent times. According to FGN (2007), 57% of Nigerians (about 79 million) use hand dug wells for domestic purposes while 14% have access to water from boreholes. Despite this volume and its obvious importance, groundwater is widely abused.

According to Ohwo (2010), the groundwater quality of a place is a function of the natural and anthropogenic environments. The physical characteristics of an area such as geology, soil covers, distance from the oceans, climate, and seepages or a combination of the above contaminants and processes affects the quality of groundwater. Anthropogenic activities include the industrial, agricultural and household activities that generate wastes. A semi-pure or natural environment enhances better water quality than an environment choked with human activities. Iqbal (2011) noted that the groundwater is affected by contaminants from point and non-point sources. Point sources include discharges from sewage treatment, landfill leachates, farm effluents and industrial wastes fed into rivers. Non-point sources include runoff, drainage from agricultural land, seepage from septic tanks (soakaways) and seepage of landfill leachate to underground strata and surface water channels. Wright and Boorse (2011) observed that the quality of groundwater can be affected by the presence of chemicals such as lead, hydrocarbons and other volatile organic compounds.

Since anthropogenic activities in each land use category differ from the other, it is expected that the consequent effects on the groundwater quality will also vary. This study is, therefore, focused on establishing variation if any, in groundwater parameters with different land use types. In order to achieve this aim, the study objectives are to:

(i) assess the physicochemical characteristics of groundwater in the study area.
(ii) examine differences in water quality parameters across land use types.
(iii) identify groundwater parameters that are not affected by variation in land use.

2. STUDY AREA

Apapa Local Government Area (LGA) lies approximately between latitude $6^0 22' N$ and $6^0 24' N$ and longitude $3^0 20' E$ and $3^0 40' E$. It shares boundaries to the north and west with Lagos Mainland and Ajeromi-Ifelodun Local Government Areas of Lagos State respectively. To the east and south are water bodies that are parts of the Lagos lagoon and the Atlantic Ocean. It has a total land area of 38.5km^2 of which 13km^2 is water (Lagos Bureau of Statistics, 2011).

Located within a coastal environment, Apapa LGA is on the low-lying coastal plain sand that features sedimentary rocks, sand deposits and accumulated silt materials from the water bodies. The plain formation is a mix of fluviomarine alluvial and juvenile soils. The vegetation cover of the area is the tropical swamp forest of the coastal belt, and the red mangroves and stilt rooted trees with dense undergrowths.

The population figure of the local government is 522,384 giving a density of 13,568.42 persons/km^2. The projections made for 2015, however, signifies an increase in the population to 693,600 (Lagos Bureau of Statistics, 2011).

The study area is a hub of socio-economic activity. It is a vast expanse of manufacturing industries. Various industries, ranging from soap making to plastic, paint and cement production, are within the study area. The reserve tanks of major oil companies are in the area. The two major shipping ports in Nigeria namely the Apapa and Tin Can ports are also located there. There are clusters of petrol stations, shopping malls and several other businesses in the area. Several government establishments, including three military barracks are in Apapa.

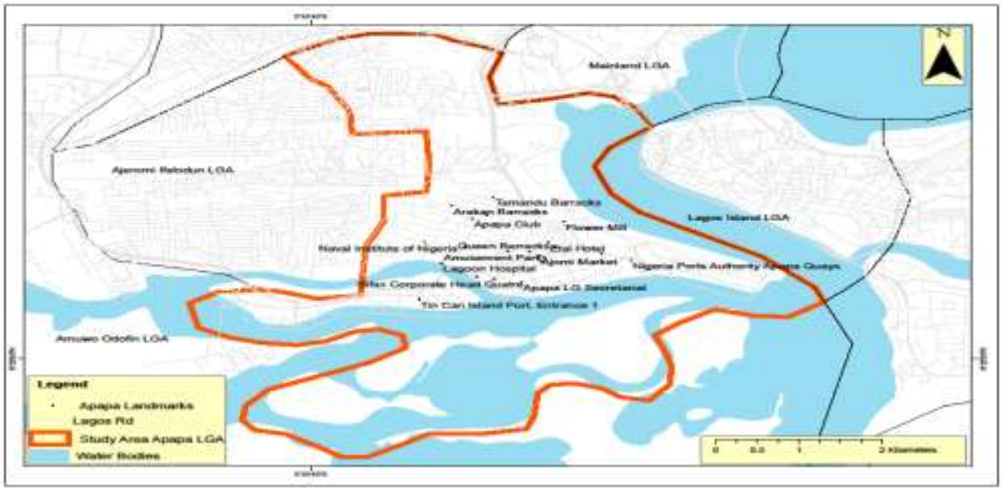

Fig. 1: Map showing the location of the study area

3. METHOD OF STUDY

Water samples used in the study were collected through fieldwork and analysed in the laboratory following APHA (2005) procedure. The thirty (30) hand-dug wells selected for study were from three major land-use types namely commercial, industrial and residential land uses. On the whole, ten of the wells were within the commercial category while twelve and eight were from the industrial and residential respectively. Each well was allocated a number for reference and identification purposes. Figure 2 shows the location and the spread of the wells.

The land use types are indicators of the level of anthropogenic activities in each area. Classifying the study area into strict land use zones was difficult because of the characteristic land use mix feature of the area. The areas designated in this study as commercial are used mainly for commercial purposes such as fuel depots and shopping areas. The industrial areas are distinct and comprise the places where factories are. However, the residential areas are mixed as they include locations that are used largely for administrative but as well as commercial purposes. Included are the military barracks, churches and government offices.

The physical parameters considered include pH, turbidity, dissolved oxygen (DO), total dissolved solid (TDS), total suspended solid (TSS) and electrical conductivity (EC). The chemical parameters tested include major cations such as magnesium (Mg), calcium (Ca), sodium (Na) and potassium (K). Also included are major anions namely nitrate (NO_3), chloride (Cl), sulphate (SO_4^{3-}), and phosphate (PO_4^{3-}). The Global Positioning System (GPS) Garmin Channel 72 model was used to obtain the coordinates of well locations. ArcGIS 9.3 software was used to map the sampling locations. Statistical methods of correlation and one-way analysis of variance (ANOVA) were adopted for use in the study. Correlation analysis was used to identify relationships between water parameters. ANOVA was used to determine significant differences in groundwater parameters across land uses at 0.05% level of significance. The Scheffe post hoc test was conducted to identify the land use groups per parameter that differ. The land use groups were identified as Group 1 (commercial), Group 2 (industrial) and Group 3 (residential).

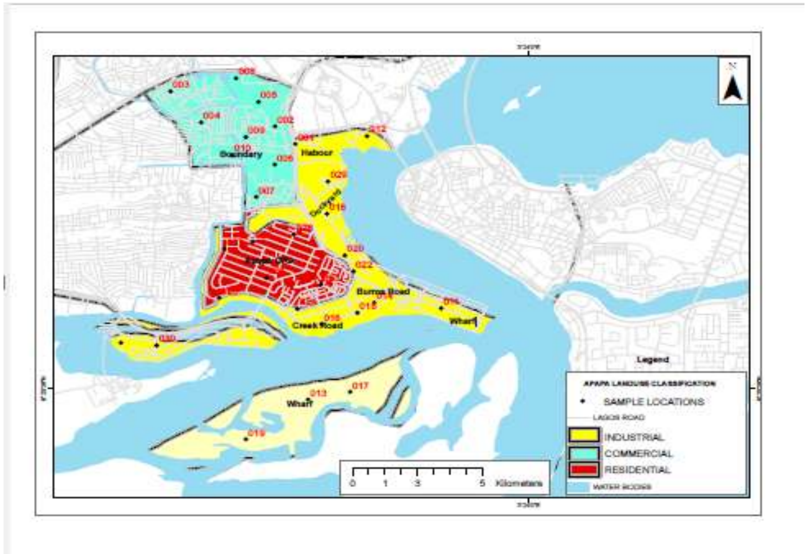

Fig. 2: Map showing the land use pattern and location of sampling wells in Apapa LGA.

4. RESULTS AND FINDINGS

4.1. Physicochemical Characteristics of Groundwater parameters in Apapa LGA

The results of tests carried out on water samples were summarized and presented in Table 1. The table shows the mean concentration of the groundwater parameters in Apapa Local Government Area. Also shown in the table are the minimum, maximum, standard deviation and variance statistics for each parameter under study.

Table 1: Summary of the analysis of groundwater samples for parameters under study

Parameters	No of samples	Minimum	Maximum	Mean	Std. Deviation	Variance
T	30	0	13.0	2.633	3.2851	10.792
DO	30	4.8	6.4	5.917	.4609	.212
TSS	30	0	25.0	3.667	5.4856	30.092
PH	30	6.5	7.4	7.147	.1961	.038
EC	30	203.00	1642.00	702.7333	375.63821	141104.064
TDS	30	136	1100	458.37	256.244	65661.137
Cl	30	8	460	73.07	106.900	11427.513
SO_4	30	6	48	21.40	11.828	139.903
NO_3	30	1.64	12.39	5.5883	2.99347	8.961
PO_4	30	.01	.06	.0317	.01599	.000
Ca	30	10	52	25.33	13.466	181.333
Mg	30	4	16	7.07	3.005	9.030
Na	30	3.86	210.16	36.3030	54.17008	2934.397
K	30	1.06	38.50	7.4877	9.46269	89.543

The laboratory results indicated variation in the concentration of groundwater parameters from one site to the other. For instance, electrical conductivity was above the maximum standard limit of 1000µs/cm in Well 29 (1642µs/cm) and Well 30 (1191µs/cm). Similar cases were observed in Wells 4, 5 and 9 under the commercial land use with 1030µs/cm, 1277µs/cm and 1294µs/cm respectively. Some areas have their TDS higher above the WHO limit of 500mg/l. Under the industrial land use, only Wells 11 and 12 were within the set limit. Wells 29 and 30 have TDS values of 1100mg/l and 797mg/l respectively. Under the commercial land use, Wells 4, 5 and 9 exceeded the limit. In the residential land use type, Wells 24 and 25 were also affected. $P0_4^{3-}$ limit was exceeded in Wells 5 and 10 under commercial land use and also Well 25 under residential land use. Moreover, in the industrial area, only Well 11 was within the set WHO limit.

The Pearson's correlation analysis was carried out on the water sample data using SPSS. From Table 2, there were 64 pairs of water quality parameters which significantly correlated with one another out of a possible 91 pairings. 62 pairs directly correlated, and 2 were inversely correlated. It was observed that all chemical parameters under study had a positive significant relationship with each other. The implication is that an increase in the level of concentration of one will lead to an increase in the other. Some physical parameters which include EC, pH and TDS showed a significant positive relationship with all the chemical parameters under study. The physical parameters were not that significantly correlated either with one another or with the chemical parameters. TSS had a significant correlation with only K, DO and turbidity. The two significant negative relationships observed were between DO and T and DO and TSS. Also, DO significantly correlated with T and $P0_4^{3-}$.

4.2 The relationship between Land uses and Groundwater Quality in Apapa LGA.

In order to verify whether the observed differences are statistically significant, the data was subjected to ANOVA using SPSS software. From the results, turbidity, DO, TSS, Cl, Mg, Na and K were statistically insignificant. The implication is that the observed variations occurred by chance. Therefore, further analysis was not carried out on the parameters. However, seven other parameters were observed to be significant and are presented as follows:

a) pH

A one-way ANOVA was conducted to compare the concentration of pH under the commercial, industrial and residential land uses. The pH concentration differed significantly among the three groups at the $p < .05$ level, [$F (2, 27) = 8.261$, $p = .002$]. pH was highest in the industrial land use (M=7.23) and lowest in the residential land use (M= 6.95). The Scheffe post hoc test indicated that pH under the industrial land use (M=7.23, SD= .096) differed significantly from under residential land use. Also, it was indicated that the mean score of pH under commercial (M= 7.21, SD= .074) and residential (M= 6.95, SD= .278) land uses differed significantly. However, there was no significant difference in the mean score of pH between commercial and industrial land uses.

b) Electrical Conductivity (EC)

There was a significant difference between land use and EC level in groundwater at the $p < .05$ level for the three land use types [$F (2, 27) =4.282$, $p = 0.024$]. To identify the land use types with a significant difference, the Scheffe post hoc test was utilized. A significant difference was indicated between the mean scores of the industrial (M=904.67, SD= 286.036) and residential (M=459.5, SD= 339.445) land uses. No other significant group difference was identified.

c) Total Dissolved Solids (TDS)

The one-way ANOVA test on TDS showed a significant difference at the $p < .05$ level for the land uses [$F (2, 27) = 5.978$, $p= .007$]. Post-hoc comparisons using Scheffe test indicated that the mean score for the industrial (M=607.17, SD=191.46) was

Table 2: Relationship between Groundwater Quality Parameters in Apapa LGA

	T	DO	TSS	pH	EC	TDS	Cl	SO_4	NO_3^-	PO_4^{3-}	Ca	Mg	Na	K
T	1													
DO	-.485**	1												
TSS	.963**	-.487**	1											
PH	.060	.487**	.086	1										
EC	.320	.182	.249	.603**	1									
TDS	.325	.171	.250	.580**	.961**	1								
Cl	.274	-.073	.235	.405*	.785**	.800**	1							
SO_4	.267	.245	.192	.592**	.973**	.921**	.662**	1						
NO_3^-	.259	.234	.187	.604**	.983**	.936**	.749**	.982**	1					
PO_4^{3-}	.170	.366*	.105	.568**	.897**	.859**	.619**	.924**	.934**	1				
Ca	.372*	.076	.299	.545**	.950**	.888**	.691**	.957**	.955**	.873**	1			
Mg	.334	-.028	.282	.463*	.839**	.843**	.882**	.729**	.784**	.636**	.751**	1		
Na	.455*	-.058	.342	.363*	.832**	.847**	.793**	.752**	.750**	.626**	.736**	.845**	1	
K	.505**	-.034	.401*	.389*	.841**	.860**	.717**	.778**	.759**	.655**	.757**	.802**	.979**	1

*significant @ 0.05
**significant @ 0.01

significantly different from the residential (M= 260, SD= 201.58). Again, the commercial mean score (M=438.5, SD= 265.05) did not differ significantly from the industrial mean score.

d) Sulphate (SO_4)

A significant difference was indicated in the ANOVA tests carried out on SO_4 for the land uses at the p< .05 level [F (2, 27) = 6.157, p = .006].The Scheffe test indicated that a significant difference exists in the mean score of SO_4 in the industrial (M= 29, SD= 8.47) and residential (M= 13.5, SD = 11.38) sites. A mean score under commercial (M= 18.6, SD= 11.007) did not differ significantly from either industrial or residential land uses.

e) Nitrate (NO_3)

Another significant difference was observed in the ANOVA result of NO_3 at the p< .05 level [F (2, 27) = 6.003, p = .007]. The Scheffe test indicated that the mean score for the industrial land use (M= 7.48, SD= 2.03) was significantly different from that of the residential (M= 5.59, SD= 2.99). However, the commercial land use (M=4.934, SD= 2.95) did not differ from either of the other land uses.

f) Potassium (PO_4^{3-})

A significant difference at the p< .05 level [F (2, 27) = 11.599, p = .000] was indicated in the ANOVA test on PO_4^{3-}. The Scheffe test further revealed significant differences among two sets of land use groups. First is the comparison of the mean score of the commercial (M= .027, SD= .015) and industrial (M= .044, SD= .008) land uses. Also, the difference in the mean score of industrial and residential (M= .019, SD= .014) was significant. No significant difference was indicated in the comparison of the mean scores of the commercial and residential land uses.

g) Calcium (Ca)

The ANOVA test on Ca indicated a significant difference at the p< .05 level [F (2, 27) = 4.918, p = .015]. The comparison of the different groups of land use indicates that the mean scores of industrial (M= 33.67, SD= 10.646) and residential (M= 18.75, SD= 11.461) groups were statistically significant.

Table 3: Summary of ANOVA results

Parameter	Tests of between-subjects effects				Scheffe Multiple Comparison		
	F	Significance	Partial Eta Squared	Observed Power	Group	Mean difference	Significance
pH	8.26	.002	.38	.94	1 - 3 2 - 3	0.26 0.275	.008 .003
EC	4.28	.024	.241	.697	2 - 3	445.17	.027
TDS	5.98	.007	.307	.84	2 - 3	347.17	.007
SO_4	6.16	.006	.313	.852	2 - 3	15.5	.009
NO_3	6.003	.007	.308	.843	2 - 3	3.918	.01
PO_4^{3-}	11.599	.000	.462	.988	2 - 1 2 - 3	0.17 0.25	.01 .00
Ca	4.918	.015	.267	.76	2 - 3	14.92	.037

5. CONCLUSIONS

This study was carried out to assess the variation in water quality parameters under different land-use types in Apapa local government area of Lagos. The findings from the correlation analysis indicate a close association between the groundwater parameters in the area. The concentration of any of the parameters could be affected by changes in other closely associated parameter. Groundwater under residential land use appears to be distinct from both the commercial and industrial land uses. This observation suggests that differences in anthropogenic activities could explain the variation in the concentration of groundwater elements. It is being suggested that the impact of various forms of anthropogenic activities on groundwater resources should be emphasized particularly in the current drive for industrialization. The paper, therefore, calls for further research.

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