EVALUATION OF GROUNDWATER CONTAMINATION STATUS IN IGANDO AREA OF LAGOS STATE, NIGERIA

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ABSTRACT

The integrity of groundwater is very important to determine its suitability for drinking. The status groundwater contamination of Igando area of Lagos State was evaluated. Groundwater samples were taken from 16 different locations in Igando using treated 1 litre plastic bottles. The samples were labeled GW 1 to GW 16 and they were analysed for the following parameters: calcium (Ca^{2+}), magnesium (Mg^{2+}), manganese, (Mn^{+}) potassium (K^{+}), sodium (Na^{+}), iron (Fe^{2+}), boron (B^{3+}), total hardness (TH), total dissolved solid (TDS) and chloride (Cl^{-}) using the standard methods for the examination of water and wastewater as prescribed by the American Public Health Association. Analysis of variance (ANOVA) was carried out on the data obtained from groundwater analysis with the aid of an in-built Microsoft excel version 2007. The results of the analysed parameters in groundwater samples investigated from locations 1 – 3, 7 and 9 were below the values stipulated in the guidelines for drinking water by World Health Organisation (WHO). The contamination factors of the analysed parameters in groundwater samples from locations 1 – 3 ranged between 0.02 and 0.36. The modified degree of contamination of groundwater from locations 1 – 3 were 0.09, 0.11 and 0.15 respectively while that of locations 7, 9 and 12 were 17.46, 21.16 and 15.77 respectively. The water quality index of groundwater from locations 1 – 3 were 0.19, 0.62 and 0.14 respectively while that of locations 7, 9 and 12 were 7.08, 8.50 and 6.42 respectively. The pollution load indexes of groundwater from all the locations considered varied between 0.07 and 0.80 except that from location 16 which was 1.05. The ANOVA showed that the mean concentrations of parameters investigated are not different at 5 % significant level while the correlation coefficient matrix revealed the parameters investigated were positively and negatively correlated. It was concluded based on the analysed parameters that only groundwater from locations 1 – 3 were fit for drinking. It was also revealed that using only WHO standard for drinking water to evaluate the status of groundwater can be misleading but also contamination factor, modified degree of contamination and water quality index should also be carried out

***Keywords**: Analysis of variance, contamination, evaluation, groundwater and status.*

1.0 INTRODUCTION

Groundwater is water present below the ground surface that saturates the pore space in the subsurface. It is the major source of potable water in both rural and urban areas of Nigeria (Olatunji *et al*., 2015). The sustenance of life in nature is made possible by water (Edori *et al*., 2016). The availability of safe drinking water is a major problem in the world especially in Africa and Asia (WHO, 2004 and Edori *et al*., 2016).). Most groundwater is cleaned but can be polluted or contaminated (Gibat, 1991). Groundwater is contaminated when concentrations of chemicals, nutrients or elements in water become more than its natural, normal, acceptable or recommended concentrations. It is polluted when the contamination goes on to harm living organisms.

Today, contamination of groundwater is one of the major problems in the world (Hazem and Talaat, 2017). Several works have been carried out on groundwater contamination (Ideriah *et al*., 2007; Longe and Balogun, 2010; Ernest *et al*., 2010; Akoteyan *et al*., 2011; Afolayan *et al*., 2012; Olafisoye *et al*., 2013; Oyedami *et al*., 2013; Idowu and Olubunmi, 2013; Ilaboya *et al*., 2014; Olatunji *et al*., 2015 and Edori *et al*., 2016). Akoteyon (2012) evaluated groundwater quality in Igando area of Lagos State using contamination factor but neglected pollution load index and water quality index as well as the analysis of variance of the metals

analysed The work revealed the groundwater in Igando area was not contaminated. Idowu and Olubunmi (2013) also evaluated groundwater quality in Igando area of Lagos State. However, only TDS, electrical conductivity, chloride, nitrate oxide, zinc and iron were considered. The contamination status of the groundwater was not carried out. Salami and Susu (2015) predicted the groundwater contaminants concentrations in Igando area of Lagos State using two dimensional model. The work did not consider the contamination status of the groundwater.

Therefore the aim of this work is to evaluate the groundwater contamination status in Igando area of Lagos State using contamination factor, modified degree of contamination, water quality index and pollution load index with a view of carrying out the ANOVA and establishing the correlation coefficient matrix for the parameters under consideration. The need for protection and continuous monitoring of groundwater status cannot be overemphasized (Olatunji *et al*., 2015). There are three landfill sites in Igando of Lagos state out of which two are operational and the remaining one is closed. It is imperative that the groundwater in Igando area of Lagos State is evaluated to determine its present status as this will serve for data collection for policy makers and local authorities, tool to sanitise our environment and improve the quality of water consumed by the community.

2. THEORY

2.1 Contamination Factor

Contamination factor (CF) is the level of contamination of water by metals. It can be expressed using Equation (1) (Syed *et al*., 2012).

$$CF = \frac{C_i}{B_i} \tag{1}$$

Where C_i is the measured concentration of a particular element in the groundwater sample and B_i is the concentration of the particular element in the background sample. The background sample is the WHO upper limit standard for concentration of element in drinking water (Edori *et al*., 2016). Table 1 shows the different contamination factor level and class (Hakanson 1980 and Odunlami and Salami, 2017).

Table 1: Different Contamination Factor and Level Class

CF Class	Contamination Factor and Level
$CF \prec 2$	Low contamination factor
$2 \le CF \prec 3$	Moderate contamination factor
$3 \le CF \prec 6$	Considerable contamination factor
$6 \le CF$	Very high contamination factor

2.2 Modified Degree of Contamination

Modified degree of contamination $\left({}_mC_d\right)$ summarises the combined effects of several quality parameters considered harmful to drinking water (Hazeem and Talaat, 2017). The Hakanson modified and generalized form of equation presented by Abrahim and Parker (2008) shown in Equation (2) is used for calculation of the overall degree of contamination at a given sampling site as follows (Syed *et al*., 2012):

(i) The modified degree of contamination is defined as the sum of all the contamination factors for a given set of pollutants divided by the number of analysed pollutants.

(ii) The mean concentration of a pollutant element is based on the analysis of at least three samples.

$$\left({}_mC_d\right) = \frac{\sum_i^n CF}{n} \tag{2}$$

Where n is the number of elements analysed and CF is as defined in Equation (1). The modified degree of contamination allows the incorporation of many metals as possible as there is no upper limit. There are seven graduations for classification and description of modified degree of contamination according to Abrahim and Parker (2008). The different modified degrees of contamination are presented in Table 2.

Table 2: Different modified degree of contamination for groundwater

${}_mC_d$ Class	modified degree of contamination level
${}_mC_d \prec 1.5$	Nil to very low degree of contamination
$1.5 \le {}_mC_d \prec 2$	Low degree of contamination
$2 \le {}_mC_d \prec 4$	Moderate degree of contamination
$4 \le {}_mC_d \prec 8$	High degree of contamination
$8 \le {}_mC_d \prec 16$	Very high degree of contamination
$16 \le {}_mC_d \prec 32$	Extremely high

${}_mC_d$ Class	modified degree of contamination level
	degree of contamination
$32 \leq {}_mC_d$	Ultra - high degree of contamination

2.3 Water Quality Index

The unit weight of a particular element (W_i) is calculated using Equation (3) (Bangalore and Latha, 2008 and Olatunji *et al*., 2015).

$$W_i = \frac{K}{B_i} \tag{3}$$

Where B_i is as defined in Equation (1). *K* is a constant of proportionality which is taken to be unity for simplicity (Olatunji *et al*., 2015). The water quality index (WQI) is calculated using Equation (4).

$$WQI = \frac{\sum (CF \times W_i)}{\sum W_i} \tag{4}$$

Where *CF* is as defined in Equation (1). The numerical value of WQI less than 1 implies that the water is fit for drinking and a numerical value greater than or equal to 1 indicates that the water is unfit for drinking (Bangalor and Latha, 2008).

2.4 Pollution Load Index

The pollution load index (PLI) developed by Thomilson *et al*., (1980) is presented in Equation (5). PLI is aimed at providing a measure of the degree of overall contamination at a sampling site (Mmolawa *et al*., 2011). It is also used for detecting pollution which permits a comparison of pollution levels between sites and at different times (Syed *et al*., 2012). The PLI gives an estimate of the metal contamination status. A PLI value less than 1 denotes the water is not polluted, a PLI value of 1 means only the baseline level of pollution is present and a PLI value greater than 1 indicates the water is polluted.

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \times ... CF_n} \tag{5}$$

3.0 MATERIALS AND METHODS

3.1 Study Area

Igando is situated in Ikoyun/Igando Local Council Development Area of Alimosho Local Government of Lagos State, Nigeria. It is located between latitude 6º 31 0᾽ N to 6º 31 30᾽ N and longitude 3º 15 0᾽ E and 3º 15 30᾽ E (Akoteyon, 2012). The climate of Igando and its environs is a warm tropical type having little seasonal variation and the annual mean temperature is around 30ºC while humidity is about 75 % with a steady vapour pressure (Idowu and Olubunmi, 2013). It occupies an area of about 25.1 sq km. It is bound by Ifako – Ijaye, Agege and Ikeja Local Government in the east and Oshodi/Isolo, Amuwo – Odofin and Ojo Local Government areas in the southern part while river owo demarcates it from Ado – Odo/Ota Local Government of Ogun State (Akoteyon, 2012). There are 3 landfill sites in the area out of which two are operational and the remaining is closed. The major source of drinking water in Igando is groundwater source. There is a presence of a state mini water works which also depend on groundwater source. A state general hospital is also presence in the area which provides health services to the people in Igando and its environ. The soil is red and laterite in nature.

3.2 Location of Position of Sampling Points

The locations of all the sampling points were coordinated using Global Positioning System (GPS) in order to identify the sampling points universally. The coordinate list in Minna data of the sampling points is presented in Table 3.

Table 3: Coordinate List of sampling point in Minna Datum

Location	Eastings (m)	Northings (Meter)	Orthometric Heights (m)
1	528001.270	725659.533	35.173
2	527866.697	725528.750	34.540
3	527874.639	725581.834	34.879
4	527883.005	725600.306	35.035
5	528118.000	725652.000	38.098
6	528192.584	725584.061	34.698

Location	Eastings (m)	Northings (Meter)	Orthometric Heights (m)
7	528110.278	726137.063	37.982
8	528164.000	726145.000	38.269
9	528166.767	726345.164	38.302
10	528032.334	726199.452	37.630
11	528223.586	726344.494	36.393
12	528258.606	726302.929	36.519
13	528023.000	726261.000	37.265
14	527973.288	726202.786	37.435
15	527870.063	726416.404	36.286
16	527780.610	726250.378	34.539

3.3 Sampling and Analysis

Groundwater samples were collected in the month of August, 2017 using 1 litre plastic bottles which had been cleaned by soaking in 10 % nitric acid and rinsed with distilled water in order to avoid contamination and allowed to dry before use. At the sampling locations, the bottles were rinsed three times with water to be sampled prior to filling and they were labeled GW 1 – GW 16. The samples were quickly transferred to the analytical laboratory of University of Lagos for analysis using the standard methods for the examination of water and wastewater as prescribed by American Public Health Association (APHA, 1994). The parameters analysed were Ca^{2+}, Mg^{2+}, Mn^{+}, K^{+}, Na^{+}, Fe^{2+}, B^{3+}, TH, TDS and Cl^{-}. All experiments were carried out in triplicate and the results were found reproducible within $\pm$ 3% error. The data were statistically analysed by setting up and calculating a correlation coefficient matrix and a one way ANOVA using the in-built solver tool in Microsoft Excel version 2007.

4.0 RESULTS AND DISCUSSION

Table 4 presents the numerical values of groundwater samples from Igando of Lagos State. The concentrations of parameters analysed in groundwater samples from locations 1 – 3, 7, 9 and 12 were below the values stipulated by WHO for drinking water. The concentrations of manganese, iron and boron in groundwater sample from location 4 were 0.08, 2.77 and 9.09 mg/L respectively. These values were higher than the WHO standard values of 0.05, 0.3 and 0.5 mg/L for manganese, iron and boron respectively for drinking water. In locations 5 and 6, the values of manganese were 0.09 and 0.1 mg/L respectively which were higher than the value of 0.05 mg/L stipulated by WHO for drinking water. The groundwater sample from location 8 has a value of 0.6 mg/L for boron which exceeded the stipulated value of 0.5 mg/L by WHO for drinking water. The groundwater samples from locations 10 - 11 have iron content of 1.10 and 0.7 mg/L respectively which are above the WHO limit for drinking water. The manganese and iron in groundwater samples from locations 13 – 16 varied between 1.78 and 8.80 mg/L and between 6.03 and 8.04 mg/L respectively. These values were above the WHO values of 0.05 and 0.3 mg/L for manganese and iron respectively. The high values of manganese and iron in groundwater samples from locations 13 – 16 may be attributed to the fact that these location are very close to the dumpsite. Considering the WHO standard for drinking water, groundwater from locations 1 – 3, 7 and 9 were fit for drinking while groundwater in locations 4 – 6, 8, 10 – 11 and 13 – 16 were unfit for drinking based on the parameters analysed. This is an indication that the dumpsites in the area have impacted negatively on the groundwater.

Table 4: Numerical values of groundwater samples from Igando of Lagos state

Locations	Parameters (mg/l)									
	Ca^{2+}	Mg^{2+}	Mn^{+}	K^{+}	Na^{+}	Fe^{2+}	B^{3+}	TH	TDS	Cl^{-}
1	1.80	0.43	0.01	0.36	5.80	0.05	0.01	3.60	29.00	6.90
2	1.73	0.45	0.04	0.09	7.60	0.03	0.02	3.57	27.50	8.94
3	1.79	0.44	0.01	0.14	9.90	0.04	0.03	3.51	30.10	11.70
4	16.07	0.54	0.08	13.97	6.49	2.77	9.09	17.86	23.97	88.06
5	1.79	0.49	0.09	0.03	8.80	0.02	0.05	3.57	29.30	10.32
6	17.70	1.70	0.10	196.60	10.30	0.48	0.12	24.80	44.00	10.32
7	3.50	0.86	0.04	172.60	5.10	0.08	0.10	7.10	66.00	6.70
8	4.30	0.75	0.02	109.50	7.30	0.04	0.60	7.60	70.00	6.70
9	3.50	0.86	0.05	209.90	6.90	0.01	0.02	6.90	37.00	10.70
10	49.60	1.76	0.01	262.00	24.37	1.10	0.16	56.60	121.20	32.95
11	3.50	0.79	0.03	22.00	10.60	0.70	0.06	7.40	69.00	14.70
12	4.78	0.91	0.04	156.00	8.69	0.01	0.03	7.80	41.00	14.89
13	6.41	2.86	2.00	7.53	4.60	7.00	0.01	28.05	23.00	25.00
14	4.81	3.34	1.78	4.02	4.80	7.03	0.01	26.05	49.00	37.50
15	2.41	3.40	2.04	3.02	5.00	8.04	0.10	19.01	98.80	87.50
16	3.21	8.81	8.81	2.51	5.35	6.03	3.60	24.05	42.37	45.00
*WHO	70.00	2.00	0.05	1.00	200	0.30	0.5	100	500	200

*Source: WHO (2004)

Table 5 shows the contamination factors for parameters analysed in groundwater samples from Igando of Lagos State. The contamination factors were obtained using Equation (1). The contamination factor for the parameters analysed in groundwater samples from locations 1 - 3 and 5 were less than 2 which indicates that the groundwater samples from locations 1 – 3 and 5 were of no contamination. Groundwater samples from locations 13 – 16 were of very high contamination in term of manganese and iron because the contamination factors were higher than 6 and this was attributed to the proximate of locations 13 – 16 to the dumpsite. The contamination factor for potassium in groundwater samples from locations 7, 9 and 12 were 172.60, 209 and 156 respectively which indicates the groundwater samples from locations 7, 9 and 12 are of very high contamination. According the WHO standard for drinking water, groundwater samples from locations 7 and 9 may be fit for drinking however, the contamination factor of potassium are 172.60 and 209.90 respectively which showed the groundwater samples were contaminated.

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Table 5: Contamination factor for parameters analysed in groundwater samples from Igando of Lagos State

Locations	Parameters									
	Ca^{2+}	Mg^{2+}	Mn^{+}	K^{+}	Na^{+}	Fe^{2+}	B^{3+}	TH	TDS	Cl^{-}
1	0.03	0.22	0.20	0.36	0.03	0.17	0.02	0.04	0.13	0.03
2	0.02	0.23	0.80	0.09	0.04	0.10	0.04	0.04	0.09	0.07
3	0.03	0.22	0.14	0.14	0.05	0.13	0.06	0.04	0.06	0.05
4	0.23	0.27	1.60	13.97	0.03	9.23	18.18	0.18	0.05	0.44
5	0.03	0.23	1.80	0.03	0.04	0.07	0.10	0.04	0.06	0.06
6	0.26	0.85	2.00	196.00	0.05	1.60	0.24	0.25	0.06	0.07
7	0.05	0.43	0.80	172.60	0.03	0.27	0.20	0.07	0.06	0.03
8	0.06	0.38	0.46	109.56	0.04	0.13	0.12	0.08	0.10	0.08
9	0.05	0.43	0.90	209.90	0.03	0.03	0.04	0.07	0.05	0.05
10	0.71	0.88	0.20	262.00	0.12	3.67	0.32	0.57	0.08	0.16
11	0.05	0.40	0.60	22.00	0.05	2.33	0.12	0.07	0.14	0.07
12	0.06	0.46	0.80	156.00	0.04	0.03	0.06	0.08	0.24	0.07
13	0.09	1.43	40.00	7.53	0.02	23.33	0.02	0.28	0.07	0.13
14	0.07	1.67	35.60	4.02	0.03	23.43	0.02	0.26	0.08	0.19
15	0.03	1.70	40.80	3.02	0.03	26.80	0.20	0.19	0.20	0.44
16	0.05	4.41	176.20	2.51	0.03	20.10	7.20	0.24	0.08	0.23

Table 6 presents the modified degree of contamination, water quality index and pollution load index of the studied groundwater samples. The modified degree of contamination, water quality index and pollution load index were generated using Equations 2, 4 and 5. The modified degree of contamination of groundwater samples from locations 7 and 9 were 11.21 and 21. 16 respectively which indicated that the groundwater samples from location 7 and 9 were of extremely high degree of contamination. The WQI of groundwater samples from locations 1 – 3 were less than 1 while that of locations 7, 9 and 12 were 7.08, 8.50 and 6.42 respectively which implied the groundwater samples from locations 7, 9 and 12 were unfit for drinking since the WQI were greater than 1. The PLI of groundwater samples from locations 1 – 15 were less than 1 while that of location 16 was greater than 1.

Table 6: Modified degree of contamination, water quality index and pollution load index of groundwater samples from Igando of Lagos State

Location	${}_mC_d$	WQI	PLI	Location	${}_mC_d$	WQI	PLI
1	0.11	0.19	0.07	9	21.16	8.50	0.19
2	0.15	0.62	0.07	10	26.89	10.40	0.80

Location	${}_mC_d$	WQI	PLI	Location	${}_mC_d$	WQI	PLI
3	0.09	0.14	0.07	11	2.58	1.57	0.28
4	4.42	4.21	0.70	12	15.77	6.42	0.21
5	0.25	1.36	0.08	13	7.29	32.98	0.48
6	20.20	9.05	0.55	14	6.54	29.59	0.50
7	17.46	7.08	0.26	15	7.34	33.85	0.66
8	11.21	4.53	0.27	16	21.10	134.36	1.05

Considering the WHO standard for drinking water, groundwater samples from locations 1 – 3, 7 and 9 can be deemed fit for drinking based on the parameters analysed in this work. However, in term of contamination factor, modified degree of contamination and water quality index, groundwater samples from locations 7 and 9 were unfit for drinking. This clearly shows that using only WHO standard to determine the status of groundwater for drinking can be misleading. Therefore, the need also for contamination factor, modified degree of contamination and water quality index. Based on the pollution index, groundwater in locations 1 – 3, 7, 9 and 12 can be deemed not polluted. Table 7 shows a one - way ANOVA for parameters investigated in groundwater samples from Igando. The F and F critical in this work were 0.05 and 1.75 respectively at 5% significant level ($\alpha = 5\%$). This implied that the mean concentrations of parameters investigated are not different at 5 % significant level.

Table 7: Analysis of variance of parameters investigated in groundwater samples

Source of variation	Sum of Square	Degree of freedom	Mean Square	F	F critical
Between Treatment	144	15	9.60	0.05	1.75
Residue	262,383.60	144	1,822.11		
Total	262,527.60	159	1,831.71		

Table 8 presents the correlation coefficient matrix for parameters investigated in groundwater samples

Table 8: Correlation coefficient matrix for parameters investigated in groundwater

Parameters	Ca^{2+}	Mg^{2+}	Mn^{+}	K^{+}	Na^{+}	Fe^{2+}	B^{3+}	TH	TDS	Cl^{-}
Ca^{2+}	1.00									
Mg^{2+}	- 0.02	1.00								
Mn^{+}	- 0.15	0.97	1.00							
K^{+}	0.60	- 0.20	- 0.32	1.00						
Na^{+}	0.86	- 0.19	- 0.28	0.56	1.00					
Fe^{2+}	- 0.07	0.71	0.63	- 0.43	- 0.36	1.00				
B^{3+}	0.14	0.18	0.25	- 0.22	- 0.14	0.17	1.00			
TH	0.84	0.42	0.26	0.36	0.58	0.45	0.11	1.00		
TDS	0.56	0.11	- 0.03	0.45	0.57	0.13	- 0.24	0.55	1.00	
Cl^{-}	0.19	0.39	0.34	- 0.12	- 0.12	0.68	0.65	0.39	0.23	1.00

The purpose of the correlation analysis is to measure the intensity of association observed between two variables. In the groundwater investigated, calcium had a weak negative correlation with magnesium, manganese and iron but a strong positive correlation with sodium. Magnesium had a strong positive correlation with manganese but a weak positive correlation with boron and chloride. The correlation observed among the parameters investigated was attributed to the likely reaction among them.

5.0 CONCLUSION

The evaluation of groundwater contamination status in Igando area of Lagos State has been carried out. Based on the guidelines for drinking water by WHO, groundwater samples from locations 1 – 3, 7 and 9 were fit for drinking while groundwater in locations 4 – 6, 8, 10 – 11 and 13 – 16 were unfit for drinking based on the parameters analysed. The contamination factor and the modified degree of contamination revealed the groundwater samples from locations 7 and 9 were of very high contamination and extremely high degree contamination which makes the groundwater samples from locations 7 and 9 unfit for drinking. The water quality index also showed that the groundwater samples from location 7 and 9 were unfit for drinking. This work revealed that using only WHO standard for drinking water to evaluate the status of groundwater can be misleading but also contamination factor, modified degree of contamination and water quality index should also be carried out. The one - way analysis of variance revealed the mean concentrations of parameters investigated are not different at 5 % significant level. The parameters analysed were positively and negatively correlated among themselves.

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