Groundwater Quality Assessment of Ikorodu Local Government Area of Lagos State in Nigeria

ABSTRACT

An assessment of the quality of groundwater in Ikorodu Local Government Area (LGA) was carried out in September 2020 (Late wet season). A total number of 29 samples were collected from different selected locations of the study area. The samples were collected from private and government bore holes. The pH, Total dissolved solids (TDS), Salinity, Turbidity, Hardness, Biochemical oxygen demand (BOD), Chemical oxygen demand (COD), Phosphate, Nitrate, Sulphate, and Total bacterial count (TBC) were determined according to American Public Health Association (APHA) standard techniques. The results showed that the mean pH, TDS, Salinity, Turbidity, Hardness, BOD, COD, Phosphate, Nitrate, Sulphate, and TBC in the water samples were 7.0 ±0.59, 176.0 ±132.2mg/L, 0.14 ±0.11g/kg, 0.32 ±0.05 NTU, 59.58 ±34.89mg/L, 11.59 ±3.41mg/L, 14.90 ±4.18mg/L, 0.97 ±0.46mg/L, 2.62 ±1.27mg/L, 9.44 ±5.94mg/L, and 4.92 ±2.94 x 10^2 cfu/mL, respectively. The calculated Water quality index (WQI) of the different sampling points showed the least WQI was 50.3 and the highest WQI was 66.9. Overall, the WQI indicated “Poor” quality of groundwater in the Ikorodu Local Government Area of Lagos State

Keywords: *Water quality index; Groundwater quality assessment; Physicochemical analysis;* ***B****iological analysis; Ikorodu*

1. INTRODUCTION

Groundwater is an important source of water supply throughout the world. Groundwater occurs almost everywhere beneath the earth surface not in a single widespread aquifer but in thousands of local aquifer systems and compartments that have similar characters (Akoteyon et al., 2018). Knowledge of the occurrence, replenishment and recovery of groundwater has special significance in arid and semi-arid regions due to discrepancy in monsoonal rainfall, insufficient surface waters and over drafting of groundwater resources (Abiola, 2010; Chinenye, 2017; Singh et al., 2013).

It is important to always ensure high quality groundwater so that the consumer’s health is not compromised. Groundwater resources are affected principally by three major activities. These activities are excessive use of fertilizers and pesticides in agricultural area, disposal of untreated/partially treated wastewater to the environment and excessive pumping and improper management of aquifers (Jijingi et al., 2019; Ocheri et al., 2014). The activity of solid waste disposal in open un-engineered landfill sites is one of the factors that cause the groundwater pollution due to lack of pollution control interventions such as water proof layer, leachate treatment pond, and monitoring wells (Abaje et al., 2009; Attahiru et al., 2016; Eo and Io, 2012; Olorunfemi et al., 2015).

According to WHO organization, about 80% of all the diseases in human beings are caused by polluted water. High rates of mortality and morbidity from water borne diseases are well known in Nigeria. Access to safe drinking water remains an urgent necessity, as 30% of urban and 90% of rural households still depend completely on untreated surface or groundwater (Adeola et al., 2015; Nasiru and Balarabe, 2012; Oki and Akana, 2016). The quality of water is defined in terms of its physical, chemical, and biological parameters, its development and management play a vital role in agricultural production, poverty reduction, environmental sustenance and sustainable economic development (Akoteyon et al., 2018; Chandra et al., 2017; Sudarshan et al., 2016). In Nigeria, most of the population is dependent on groundwater as the only source of drinking water supply.

Water quality index (WQI) is defined as a rating reflecting the composite influence of different water quality parameters. It is a mathematical equation used to transform large number of water quality data into a single number. WQI is one of the most effective tools to communicate information on the quality of water to concerned citizens and policymakers (Singh and Hussian, 2016). Hence this study assessed water quality of Ikorodu groundwater by evaluating groundwater sources to generate the WQI of each of the selected Ikorodu water source.

2. MATERIALS AND METHODS

2.1 Study area

This study was carried out in Ikorodu Local Government Area of Lagos State, Nigeria (Figure 1). It has a population of about 836,5100 as reported 2017 by Lagos State population census. Ikorodu is about 26km from Ikeja and 36km from Lagos Island (Eko). Ikorodu is largely bounded at the south by Lagos Lagoon. Its geographical location lies between latitudes 6º 41' 51.13" N and 6º 31' 20.95" N also on longitudes 3ºC 26' 31.82" E and 3º 43' 5.13" E.

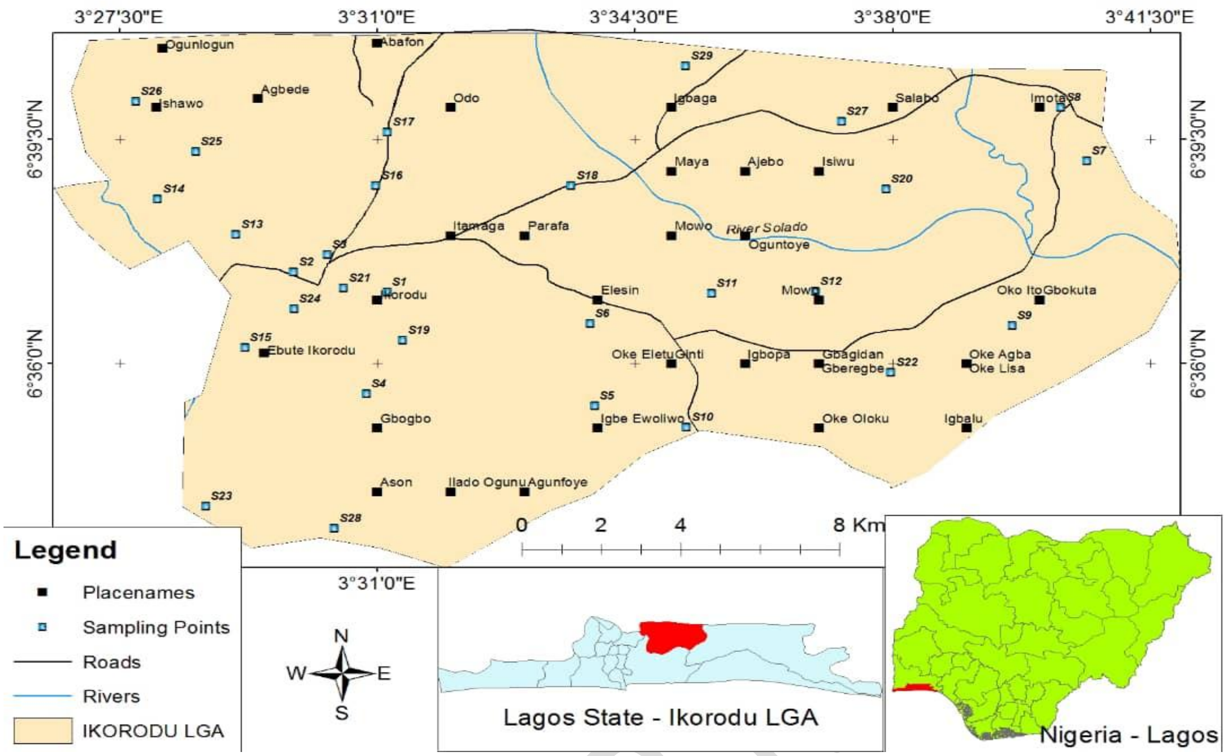

Figure 1: Map of Ikorodu showing sampling points

2.2 Sample collection

Stratified sampling method was adopted for this study, the 29 administrative wards that make up the local government area were taken as strata. A total number of 29 samples were collected from the selected locations in each ward of Ikorodu LGA. The groundwater samples were transferred into sample bottles and carefully labelled with the appropriate identification codes. Prior to collection, and as part of quality control measures, all bottles were washed with non-ionic detergent and rinsed with deionized water before usage. Also, the sample bottles were rinsed three times with the groundwater samples. Table 1 shows all sample points, locations, and the wards they are situated in.

Table 1: Sample locations in their administrative wards of Ikorodu LGA.

Sample Code	Area	Location
S1	Ikorodu Central Ward F	Owode or Grammar school junction
S2	Ikorodu Central Ward B	T.O.S Benson (New Baale) Road
S3	Ikorodu Central Ward A	Eyita Palace
S4	Igbogbo/Baiyeku Ward C1	Jauitu Primary School
S5	Igbogbo/Baiyeku Ward C5	Elepe Secretariat
S6	Igbogbo/Baiyeku Ward C2	Olorunfumi Bashorun Secretariat
S7	Imota Ward C	Ojege House & Itunuobun
S8	Imota Ward B	Anibaba & Owoyele
S9	Imota Ward D	Baale Oko-Oto & Oke Agbo

S10	Ijede Ward D	Abule Eko Secretariat
S11	Ijede Ward C	Okeoyinbo/Obetodun Secretariat
S12	Ijede Ward B	Shitta-Secretariat
S13	Ikorodu West Ward C.	Owuto/Ojokoro Secretariat
S14	Ikorodu West Ward B	Ogolonto/Majidun Secretariat
S15	Ikorodu West Ward A	Ipakodo Secretariat
S16	Ikorodu North Ward E2	Agbala (Abioye House First Gate)
S17	Ikorodu North Ward E1	Odogunyan (No. 1 Ogunlade street)
S18	Ikorodu North Ward E3	Erikorodu (Parafa Myadamo)
S19	Ikorodu Central Ward D	Jauitu Primary School
S20	Imota Ward A	Araromi
S21	Ikorodu Central Ward C	Ituuwolo
S22	Ijede Ward A	Idakan/Egbia Secretariat
S23	Igbogbo/Baiyeku Ward C4	Ibeshe Secretariat
S24	Ikorodu Central Ward E	Jaiyesimi compound Obuu-ale
S25	Ikorodu West Ward D	Ajakuro Secretariat
S26	Ikorodu West Ward E	Isawo Secretariat
S27	Ikorodu North Ward B3	Isiwu Township (Town hall Eweyeroad)
S28	Igbogbo/Baiyeku Ward C	Baiyeku & Offin Irele Secretariat
S29	Ikorodu North Ward E4	Obrunda (Araromi Town Hall)

2.3 Sample analysis

The samples were analyzed for pH, TDS, Turbidity, BOD, Phosphate, Nitrate, Salinity, COD, Coliform count, Bacteria count, Sulphate, Hardness. All the analyses were carried out according to the standard procedures prescribed in American Public Health Association manual (APHA, 2012). Table 2 shows the methods and instrumentation deployed for analysis.

Table 2: Analytical methods and instruments used.

Parameters	**Units**	**Analytical methods/ Instrumentation**
Temperature	^{o}C	Infra-red Temperature gun (Fluke 568)
pH	Nil	Digital pH meter (HANNA 9813-6)
Dissolved Oxygen	mg/L	DO meter (Hach HQ40d)
Hardness	mg/L	Titrimetric Method
Salinity	g/kg	Salinometer (MP 521 multipurpose meter)
Total Dissolved Solids	mg/L	Temperature Controlled Oven
Turbidity	NTU	Digital Turbidity Meter
Biochemical Oxygen Demand	mg/L	Winkler's method (incubation for 5days at 20ºC) used BOD CUM Humidity Chamber
Chemical Oxygen Demand	mg/L	COD by potassium permanganate method using (HANNA HI83099)
Nitrates	mg/L	HACH Spectrophotometer (DR 3900)
Sulphates	mg/L	Spectrophotometer (HANNA HI83099)
Phosphates	mg/L	HACH Spectrophotometer (DR 3900)
Total Bacteria count	cfu/mL	Incubation (BIONICS Vertical Autoclave)

2.4 Water quality index (WQI)

WQI was calculated using the Weighted average water quality index (WAWQI) method, and it was done in three steps. In the first step, each of the 11 parameters (pH, Dissolved solids, Turbidity, BOD, Phosphate, Nitrate, Salinity, COD, TBC, Sulphate, Hardness) were assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes in Table three. The maximum weight of five was assigned to the parameter nitrate due to its major importance in water quality assessment. In the second step, the relative weight (Wi) was computed as shown in Equation (1).

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi} \qquad (1)$$

Where Wi and wi are the relative weight and weight of each parameter, respectively, and n is the number of parameters.

In the third step, a quality rating scale (Qi) for each parameter was assigned by dividing its concentration in each water sample by its respective standard according to the guidelines in the Nigerian industrial standards (NIS), and the result for the same was multiplied by 100 as shown in Equation (2).

$$Qi = \frac{C_i \times 100}{S_i} \qquad (2)$$

where Qi is the quality rating, Ci is the concentration of each chemical parameter in each water

sample in mg/L, and Si is the upper limit of Nigerian drinking water standard for each chemical parameter in mg/L

according to the guidelines of Nigerian Industrial Standard (NIS).

For computing the WQI, the SI was first determined for each chemical parameter, which was then used to determine the WQI using Equations (3) and (4).

$$SI_i = W_i \times Q_i \qquad (3)$$

$$WQI = \sum_{i=1}^{n} SI_i \qquad (4)$$

where SIi is the sub index of ith parameter, Qi is the rating based on concentration of ith parameter, and n is the number of parameters.

Table 3: Details of chemical parameters with their relative weight and assigned weight with drinking water standards as per NIS (2015).

Parameter	**Si**	**Weight**	**Wi**
pH	8.5	4	0.0952
Dissolved solids	500	5	0.0047
Turbidity	1	3	1.5445
BOD	5	3	0.0431
Phosphate	0.1	5	0.8613
Nitrate	50	05	0.3180
Salinity	600	4	4.9320
COD	10	5	0.0559
Coliform count	0	3	0.0000
Bacteria count	10	3	0.1017
Sulphate	100	3	0.0530
Hardness	150	3	0.0084

The computed WQI values are categorized into five types as "excellent water" to "water unsuitable for drinking" using Table 4.

Table 4: Range of WQI for drinking purposes.

Water Quality Index Level	**Water Quality**
0 – 50	Excellent
50 – 50	Good
51 – 75	Poor
76 – 100	Very poor
>100	Unsuitable for drinking

Source: (Chatterjee and Raziuddin, 2002).

2.5 Statistical analysis

The data was presented using descriptive statistics (mean, minimum, maximum, standard deviation). The Pearson's correlation analysis was used to assess the associations of the parameters measured. All analyses were done using the SPSS software version 25.

3. RESULTS

Table 5 shows the variations in the different parameters measured from the 29 sampling points while Table 6 summarizes the data on Table 5 showing the mean value of each parameter measured across the 29 sampling points as well as the standard deviation values obtained for each parameter. From the tables it was observed that minimum pH ranged from 5.65 to 7.88 with a mean of 7.0 ±0.59. Total dissolved solids ranged from 22.40 to 526.80mg/L with a mean of 176.0 ±132.2mg/L. Salinity ranged from 0.01 to 0.49g/kg with a mean of 0.14 ±0.11g/kg. Turbidity ranged from 0.00 to 3.15NTU with a mean of 0.32 ±0.05NTU. Water Hardness ranged from 16.0 to 155.0mg/L with a mean of 59.58 ±34.89mg/L. The BOD was found to range from 4.83 to 21.44mg/L with a mean of 11.59 ±3.41mg/L. The COD ranged from 6.28 to 25.12mg/L with a mean of 14.90 ±4.18mg/L. The Phosphate concentration ranged from 0.15 to 5.81mg/L with a mean of 0.97 ±0.46mg/L. The Nitrate ranged from 0.06 to 5.52mg/L with a mean of 2.62 ±1.27mg/L. Sulphate concentration ranged from 3.02 to 26.20mg/L with a mean of 9.44 ±5.94mg/L. TBC ranged from 1.0 to 11.20 x10^2 cfu/mL with a mean of 4.92 ±2.94 x 10^2 cfu/mL.

Table 5: Variation in parameters from 29 sampling points for September 2020 (Late wet season).

Sample Code	pH	TDS (mg/L)	Salinity (g/kg)	Turbidity (NTU)	Hardness (mg/L)	BOD (mg/L)	COD (mg/L)	PO_4 (mg/L)	NO_3^- (mg/L)	SO_4 (mg/L)	TBC (cfu/mL *10^2)
1	7.55	121.3	0.05	0.686	44.1	10.3	13.38	0.264	3.482	10.2	11.2
2	7.65	218	0.18	1.28	65	14.21	18.23	0.291	3.22	11.5	5.1
3	7.45	332	0.02	3.151	18	21.44	25.12	0.149	2.999	11.8	1.9
4	6.64	400.12	0.21	0.831	128.02	14.06	18.32	0.161	2.952	13.9	8.3
5	6.95	54.07	0.08	0.943	49.21	9.24	12.93	0.327	3.998	5.75	11
6	6.69	158	0.14	0.662	65.2	13.92	18.07	0.493	3.0765	3.018	4.7
7	6.4	370	0.29	0.099	105	5.46	6.28	0.443	1.982	6.81	5.1
8	5.78	276	0.16	0.00	100	9.23	12.09	0.287	2.581	7.83	7.2
9	6.15	36.9	0.29	0.848	107	15.79	20.52	0.675	2.881	8.6	1.1
10	6.21	49.9	0.09	0.121	36	10.79	14.92	0.292	3.691	10.4	2.3
11	5.65	138.3	0.01	0.00	21	12.31	14.02	0.362	3.961	8.4	1
12	6.87	96.3	0.08	0.03	16	9.18	11.93	3.689	2.987	26.2	4
13	7.65	153.2	0.18	0.099	42.9	9.69	12.63	1.195	2.328	22.7	1.4
14	7.88	526.8	0.12	0.019	24	11.19	14.49	5.124	3.784	9.8	9
15	7.48	217	0.19	0.078	56	13.96	15.74	1.991	2.388	9.3	1.5
16	7.42	232	0.16	0.096	64	4.83	6.28	0.881	0.737	4.7	4.5
17	7.1	22.4	0.19	0.03	49	10.19	13.24	0.375	3.785	19.3	9
18	7.09	24.8	0.04	0.02	30.6	8.86	11.39	0.321	1.323	21	5

19	6.97	27.8	0.07	0.05	98.9	9.02	11.85	2.02	0.152	4.07	7
20	6.67	88.1	0.02	0.00	56	12.24	16.2	0.1991	0.056	6.2	6
21	6.89	320.9	0.25	0.069	84.7	10.65	13.21	0.211	2.42	6.1	6
22	6.72	40.2	0.01	0.00	51	13.71	17.81	0.29	1.107	4.2	4.1
23	6.63	125.2	0.13	0.07	52	12.92	17.68	0.252	0.528	5.6	3.2
24	7.49	237	0.08	0.00	25.9	10.99	13.89	0.311	2.076	3.7	4.1
25	7.72	297	0.19	0.07	77	11.58	15.26	0.337	2.282	9.1	1
26	6.77	335	0.49	0.066	155	8.74	11.74	0.322	3.841	5.3	1.3
27	7.23	104	0.06	0.02	48	18.24	23.85	0.774	2.786	5.3	6.02
28	7.66	54.7	0.08	0.02	29	13.19	17.08	0.21	3.082	5.1	6.5
29	7.65	46.9	0.06	0.03	29.2	10.19	13.82	5.812	5.521	7.83	4.02

Table 6: Statistical summary of parameters measured.

	pH	**TDS (mg/L)**	**Salinity (g/kg)**	**Turbidity (NTU)**	**Hardness (mg/L)**	**BOD (mg/L)**	**COD (mg/L)**	**PO_4 (mg/L)**	**NO_3^- (mg/L)**	**SO_4 (mg/L)**	**TBC (cfu/mL $*10^2$)**
Mean	7.00	176.00	0.14	0.32	59.58	11.59	14.90	0.97	2.62	9.44	4.92
Min	5.65	22.40	0.01	0.00	16.00	4.83	6.28	0.15	0.06	3.02	1.00
Max	7.88	526.80	0.49	3.15	155.00	21.44	25.12	5.81	5.52	26.20	11.20

Table 7 shows correlation matrix of the parameters measured in the different collection sites. There were positive correlations of pH with BOD, COD, Phosphate, Nitrate, Sulphate, and TBC, while there were negative correlations with Salinity and Hardness also pH parameter was noticed to generally have weak correlation with other parameters. TDS had negative correlation with COD and Sulphate but had no correlation with TBC and was positively correlated with Salinity, Turbidity, Hardness, BOD, Phosphate, and Nitrate. There were negative correlations of Salinity with Turbidity, BOD, COD, Phosphate, and TBC but was positively correlated with Hardness and Nitrate while no correlation was observed with Sulphate. There were negative correlations of Turbidity with Hardness and Phosphate but no correlation with TBC while positive correlations were observed with BOD, COD, Nitrate and Sulphate. Hardness on the other hand had negative correlations with BOD, COD, Phosphate, Nitrate, Sulphate, and no correlation with TBC. The correlation of BOD with Phosphate, Sulphate and TBC were observed to be negative while there was strong positive correlation with COD and weak positive correlations with Phosphate and TBC were observed. COD was negatively correlated with Phosphate, Sulphate, and TBC but was weakly positively correlated with Nitrate. The correlation of Phosphate with Nitrate and Sulphate were observed to be weakly positive while no correlation was observed with TBC. Similarly, weak positive correlation of Nitrate with Sulphate and TBC were observed also. Sulphate on the other hand had no correlation with TBC.

Table 7: Correlation coefficient matrix of analyzed water quality parameters for all samples.

	pH	TDS	Salinity	Turbidity	Hardness	BOD	COD	PO_4	NO_3^-	SO_4	TBC
pH	1.0										
TDS	0.1	1.0									
Salinity	-0.1	0.4	1.0								
Turbidity	0.1	0.2	-0.1	1.0							
Hardness	-0.3	0.3	0.8	-0.1	1.0						
BOD	0.1	0.0	-0.3	0.6	-0.2	1.0					
COD	0.1	-0.1	-0.2	0.5	-0.2	1.0	1.0				
PO_4	0.4	0.1	-0.1	-0.2	-0.3	-0.2	-0.2	1.0			
NO^{3-}	0.1	0.1	0.1	0.2	-0.1	0.1	0.1	0.3	1.0		
SO_4	0.1	-0.1	0.0	0.1	-0.3	-0.1	-0.1	0.2	0.2	1.0	
TBC	0.1	0.0	-0.2	0.0	0.0	-0.2	-0.2	0.0	0.1	0.0	1.0

A summary of the water quality index of the different samples is presented in Table 8. The table show that the minimum WQI was 50.3 and the highest WQI was 66.9. The table indicated that the quality of water at all sites were poor.

Table 8: Water quality index and category of analyzed samples.

Table 8 show water quality category of the WQI results obtained from the sampled groundwater sources of Ikorodu.

Sample Code	WQI	Quality
1	61.72	Poor
2	66.91	Poor
3	57.12	Poor
4	66.96	Poor
5	66.39	Poor
6	50.30	Poor
7	66.53	Poor
8	55.06	Poor
9	57.01	Poor
10	57.23	Poor
11	63.34	Poor
12	65.90	Poor

13	64.13	Poor
14	59.63	Poor
15	52.65	Poor
16	64.16	Poor
17	56.16	Poor
18	53.45	Poor
19	67.23	Poor
20	53.99	Poor
21	59.91	Poor
22	62.91	Poor
23	67.23	Poor
24	62.47	Poor
25	54.98	Poor
26	53.40	Poor
27	59.68	Poor
28	54.88	Poor
29	62.80	Poor

4. DISCUSSION

Assessing the quality of groundwater gives appropriate information on the quality of water accessible to people in Ikorodu. The quality of ground water is also a good indicator for water treatment in areas with poor water quality and the need to maintain the “status quo” in areas with good and excellent water quality.

The pH of water plays an important role in clarification process and disinfection of drinking water. For effective disinfection with chlorine, the pH should preferably be less than eight, however, lower-pH water (<7) is more likely to be corrosive (Ali et al., 2018; Chinenye, 2017). Failure to minimize corrosion can result in the contamination of drinking water and adverse effect on its taste and appearance (Nasiru and Balarabe, 2012; Oki and Akana, 2016). Nigerian Industrial Standard (NIS) for drinking water as published by the Standards Organization of Nigeria (SON) has prescribed permissible limit of pH to be 6.5 – 8.5. The pH value of groundwater samples ranged from 5.65 to 7.88. Although the average pH of the water samples was 7.0 ±0.59. Four locations (Imota ward B, Imota ward D, Ijede ward C, and Ijede ward D) were found to have pH levels below the lower permissible limit of 6.5.

The presence of dissolved solids in water may affect its taste. The palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent (less than 300 mg/L), good (300–600 mg/L); fair (600–900 mg/L), poor (900–1,200 mg/L) and unacceptable (>1,200 mg/L)(Chandra et al., 2017; Singh and Hussian, 2016). NIS has prescribed ≤500mg/L as the acceptable limit and 2,000 mg/L as the permissible limit for TDS of water to be used for drinking purpose. In the present study, Total dissolved solids ranged from 22.40 to 526.80 mg/L, with a mean of 176.0 ±132.2mg/L. It is inferred that TDS of all Ikorodu groundwater samples were well within the permissible limit prescribed by NIS except sample 14 (Ogolonto/Majidun secretariat), where the TDS concentration was found to be 526.8mg/L.

The requirement for drinking water Turbidity in Nigeria as prescribed by NIS is a maximum of 5NTU with no known health implications for higher Turbidity values (NIS, 2015). The Turbidity of the samples observed were in the range 0.00 – 3.15NTU with a mean of 0.32 ±0.05 NTU. This means all Ikorodu groundwater samples were within the NIS recommended limits of Turbidity for drinking water.

In groundwater sources, Hardness is mainly due to the presence of Calcium and Magnesium salts, and this is known as temporary Hardness. Temporary Hardness of more than 200mg/L as $CaCO_3$ may cause scale deposition in the treatment works, distribution system and pipe work and tanks within buildings (Chandra et al., 2017; Jaji et al., 2007; Singh and Hussian, 2016). Water with Hardness less than 100mg/L may in contrast, have a low buffering capacity and will be more corrosive for water pipes (Akoteyon et al., 2018; Jijingi et al., 2019). The NIS has prescribed ≤150mg/L as the acceptable limit for Hardness in drinking water. However, the Hardness of groundwater samples in Ikorodu ranged from 16.0 to 155mg/L with a mean of 59.58 ±34.89mg/L. Ikorodu groundwater sources were well within NIS permissible limit stipulated at ≤150mg/l except for sample 26 (Isawo secretariat) having high water Hardness of 155mg/L.

BOD test is carried out to determine the presence and concentration of aerobic bacteria in water sample. NIS has no recommended limit for BOD but WHO prescribes ≤5mg/L of BOD as the acceptable limit for drinking water. BOD observed presently in Ikorodu groundwater was within the range of 4.83 to 21.44mg/L with a mean of 11.59 ±3.41mg/L. The groundwater samples from Ikorodu LGA with exception of sample 16 (Agbala area of Ikorodu north) were above WHO permissible limit and sample 16 was at the borderline of the acceptable limit.

COD is a parameter of key concern in wastewater treatment. However, in groundwater it can be used as one of the tools to determine effluence contamination of groundwater. NIS and WHO have no COD permissible limit for drinking water but the Food and Agriculture Organization (FOA) of the United Nations stipulate the permissible limit for COD effluent discharge as ≤120mg/l. COD observed in Ikorodu LGA ranged from 6.28 to 25.12mg/L, with a mean of 14.90 ±4.18mg/L. Ikorodu groundwater COD level was well below the effluent discharge limit indicating it has little or no contact with effluents.

Nitrate is found naturally in the environment and is an important plant nutrient. Some groundwater may also have Nitrate contamination as a consequence of leaching from natural vegetation (Eo and Io, 2012; Olorunfemi et al., 2015). The presence of Nitrate in drinking water is a potential health hazard when present in large quantities, as the combination of Nitrates with amines, amides, or other nitrogenous compounds through the action of bacteria in the digestive tract results in the formation of nitrosamines, which are potentially carcinogenic (Oki and Akana, 2016; Oyelakin et al., 2020). The concentration of Nitrate in Ikorodu groundwater samples ranged from 0.06 to 5.52mg/L with a mean of 2.62 ±1.27mg/L. This was observed to be well within NIS permissible limit stipulated at ≤50mg/L.

Phosphorous occur in an oxygenated environment such as groundwater as Phosphate. NIS has no recommendations on Phosphate in drinking water but WHO sets the permissible limit to be ≤0.1mg/L. Ikorodu groundwater Phosphate concentration ranged from 0.15 to 5.81mg/L with an average of 0.97 ±0.46mg/L. Phosphate levels observed for the entire Ikorodu LGA groundwater were above WHO permissible limits. This could be attributed to the high use of fertilizer to boost farm harvest as farming is the predominant occupation in Ikorodu (Baba and Tayfur, 2011).

The most common form of Sulphur in oxygenated water is Sulphate. The presence of Sulphate in drinking water can cause noticeable taste and very high levels might give a laxative effect in unaccustomed consumers (Singh and Hussian, 2016). Taste thresholds have been found to range from 250mg/L for Sodium sulphate to 1,000mg/L for Calcium sulphate (Akoteyon et al., 2018; Sudarshan et al., 2016). The Sulphate concentration of Ikorodu groundwater ranged from 3.02 to 26.20mg/L with a mean of 9.44 ±5.94mg/L. NIS maximum permissible limit for Sulphate in drinking water is 100mg/L. Sulphate concentration in all the samples were found to be within the acceptable limit prescribed by NIS for drinking water.

Total bacteria count (TBC) is an important parameter to note. It gives the summary of all micro-organisms present in the water sample and referred to as Total plate count. Nigerian standards for drinking water quality states that for every 100ml of drinking water, Total bacteria count should be non-detectable (NIS, 2015). Total bacterial count of Ikorodu groundwater ranged from 1.0 to 11.20 $x10^2$ cfu/mL with a mean of 4.92 ±2.94 x 10^2 cfu/mL. This puts the groundwater sources in Ikorodu LGA above NIS allowable limits for drinking. High TBC levels in drinking water depending on the bacteria present have been linked to many health issues with diarrhea been the most common (Olaleye, 2011).

The correlation coefficients indicates that, the pH of the water samples tend to increase as BOD, COD, Phosphate, Nitrate, Sulphate, and Total bacteria count (TBC) increases. Salinity of the water samples tend to decrease as Turbidity, BOD, COD, Phosphate, and Total bacteria counts increases. The phosphate levels were also observed to increase as Nitrate, Sulphate, and Total bacteria count increases, while the Nitrate concentrations increased as the Sulphate and Total bacteria count increases. The minimum WQI obtained from Ikorodu groundwater sources was 50.3 and the highest WQI was 66.9. This is an indication that the quality of groundwater in the study area is generally poor. The variations in the parameters measured at the different sampling points could be attributed to anthropologic activities or industrial activities that have affected groundwater sources as reported in similar studies carried out in south-west, Nigeria (Abiola, 2010; Akoteyon et al., 2018; Jaji et al., 2007; Jijingi et al., 2019; Oyelakin et al., 2020).

5. CONCLUSION

This study showed that, the quality of groundwater in Ikorodu LGA was generally "Poor". The findings of the study make a case for the treatment of the groundwater in the area before consumption as drinking water. It also calls for a review of anthropological and semi-industrial activities that could affect the quality of water for use among residents in Ikorodu LGA. In addition, it solicits for implementation of public policies regarding the quality of water used by the population, aiming at a better quality of life, which will reduce health problems.

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