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Assessment of Groundwater Quality in Parts of Port Harcourt Metropolis

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Abstract: The quality of public water supply in Port Harcourt, Rivers State has come under scrutiny owing to the state of the facilities of the Port Harcourt Water Corporation (PHWC). Groundwater they supply were surveyed to determine the fitness for household utilization with respect to chemical quality. Physicochemical parameters were ascertained using standard protocols for water testing. The result disclosed that the values for temperature, electrical conductivity, dissolved oxygen, pH, CI, NO_3^-, Fe, Na, Ca, Mg, HCO_3^-, SO_4^{2-}, total dissolved solid, Zn and turbidity varied from 26.2 - 28.3°C, 200 - 1000 µS/cm, 3.9 - 6.3 mg/L, 4 - 7.15, 7.1 - 710 mg/L, 1.7 - 40.01 mg/L, 0.0001 - 9.6 mg/L, 4.6 - 404 mg/L, 34.5 - 620 mg/L, 22 - 880 mg/L, 12 - 365 mg/L, 5 - 16.16 mg/L, 210 - 684 mg/L, 0.01 - 0.17 mg/L and 0.01 - 0.97 NTU respectively, with all values conforming to WHO and NSDWQ standards, except for pH, magnesium and iron. The water quality index (WQI) is as follows: Rumuola main Water station 28 (D), Eagle Island Water Station 25 (D), Borokiri Sandfill Water Station 34 (D), Diobu Water Station 42 (D), Earnest Ikoli Water Station 46 (D), GRA, Omerelu Street Overhead Tank 42 (D), Moscow Road Water Station 45 (D), Elelenwo Water Station 41 (D), Rumuokwurushi Water Station 40 (D) and Trans Amadi Water Station 51 (C). Improvement in facilities and water treatment ought to be given urgent attention, as the WQI for all but one water station were bad.

Keywords: Groundwater, Water Quality Index, Port Harcourt

1. Introduction

Water quality as the attribute of water in terms of biological, chemical, and physical nature that defines the use to which it will be applied judging from safety consideration [1]. According to Roy [2] water sources must be regularly monitored to establish their fitness for intended purpose, this is because, unsuitable quality portends high risk with economic and environmental implications. Drinking water that does not meet specified standards are burdens for diseases and other physiological impairments [3, 4].

Groundwater is a choice source of potable water for its widespread occurrence, availability, and constituent good quality across varied locale. This has been so for a better half of the last century, as it is in addition, highly dependable during dry seasons and substantially cost-effective during development [5]. The nature of groundwater draws worry as it is straightforwardly connected with wellbeing and human welfare, with its condition impacted by the quality of recharged water, atmospheric precipitation, and surface water and on subsurface geochemical processes. Ranjana [6] unmistakably expressed that the nature of groundwater is nexus to general wellbeing depends. Groundwater has long been valued amongst the purest forms of water available in nature to meet the general demand for rural and semi-rural people [7]. Its desirability for human activities especially in the rural stems from less vulnerability to contamination and requiring less treatment before use [8, 9].

Groundwater is the favoured source of consumable water in Niger Delta and Port Harcourt in particular. There is a swell in environmental pollution via industrial activities (anthropogenic) and natural sources in Port Harcourt and environs. Gas flare, oil spills, black soot are linked to industrial activities while, flooding and saltwater encroachment are natural sources all contributing to pollute water forms [10, 11].

Accordingly, groundwater should be scrutinized to establish that it meets the regulatory standards and has not been abused by these anthropogenic and natural activities.

The aim of the study is to ascertain the physicochemical attributes of groundwater supplied by the Port Harcourt Water Corporation (PHWC), in order to help in the elaboration of strategies for efficient, reduction and remediation of polluted groundwater.

2. Material and Methods

2.1. Study Area

Port Harcourt is the oil capital of Nigeria and the capital city of Rivers State lying at the South-South fringe. Port-Harcourt's urban area for 2021 population is now an estimated at 3,171,076 inhabitants, up from 302,023,2 as of 2020, having a 5.11% growth rate [12]. The locale that became Port Harcourt was before that time a cluster of fishing settlements, which later became the export route for imperialist trade.

Port Harcourt is featured by the Dockyard creek in the Southern part in a loop-like manner, while the Ntawogba River at the Western flank of the Amadi creek drains Rumuokwuta; GRA I-III; Ikwerre Road and Amadi flats. The hydrogeology of the state consists principally of freshwater continental friable sands and gravel with superlative aquifer features, recharged via precipitation (2000 – 2400mm) [13]. This area is abundant in biodiversity, with one familiar and distinctiveness being a distributary system with intertidal mud flat with assemblage animals (Clams, crustaceans, crabs, mollusc, burrowing worms, fish fry and juveniles, shrimp larvae etc.) present.

2.2. Sample Collection

Water samples were collected from the 10 locations (Figure 1) suppling water to residents within Port Harcourt metropolis. The Water stations are: 1) Rumuola Main Water station, 2) Eagle Island Water Station, 3) Borikiri Water Station, 4) Diobu Water Station, 5) Earnest Ikoli Water Station, 6) GRA, Omerelu Street Overhead Tank, 7) Moscow Road Water Station, 8) Elelenwo Water Station, 9) Rumuokwurushi Water Station and 10) Trans Amadi Water Station.

At each borehole, water samples were collected in sterilized sample bottles by first allowing the water to flow freely for about 5 minutes to clear all dissolved solids possibly stuck to the walls of the pipes and tap before allowing to fill to the brim and corked straight away, adopting National Standards for Drinking Water Quality [14] sampling guidelines. All samples were collected in duplicates.

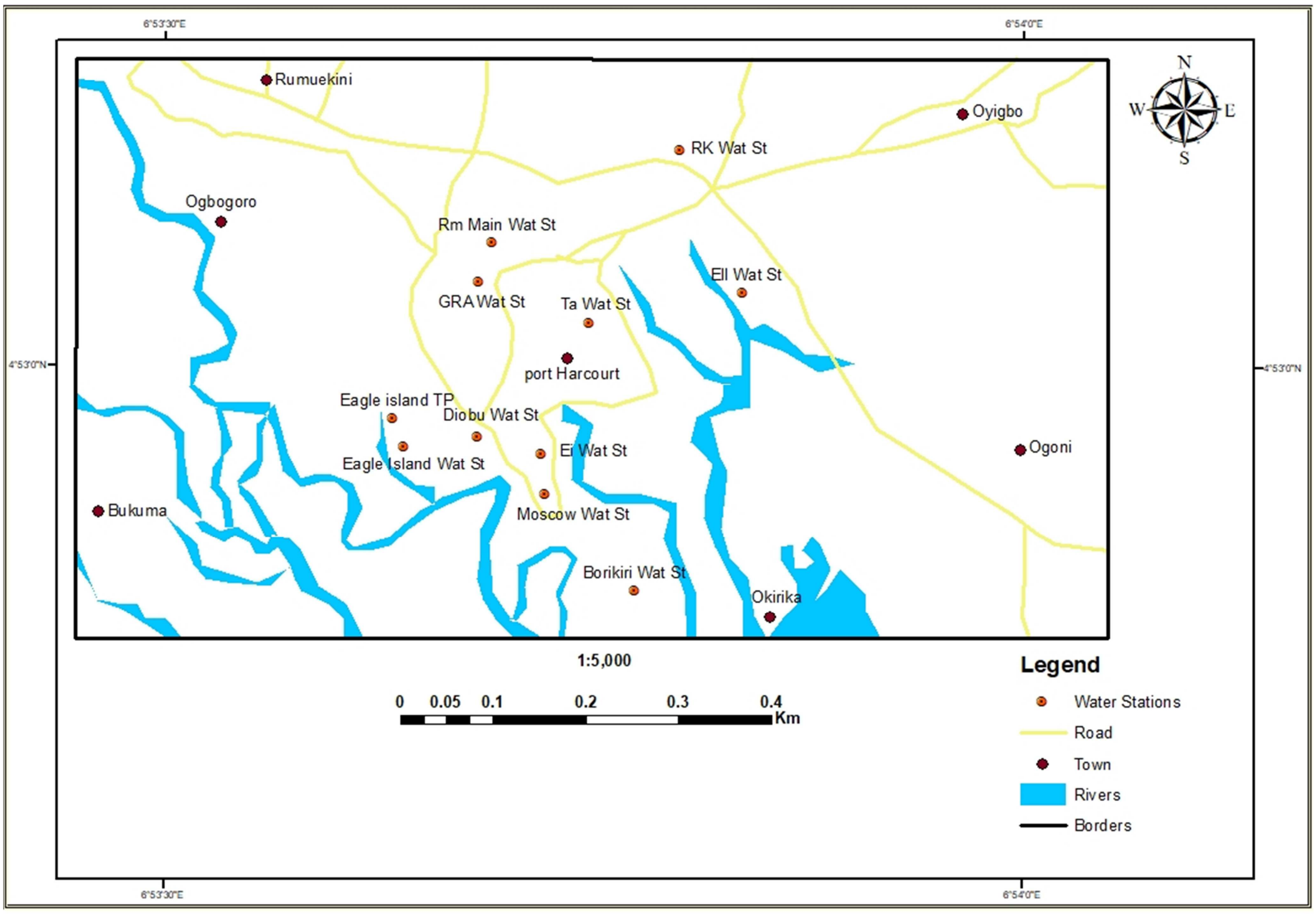

Figure 1. *Map of Port Harcourt showing the Sampling Points.*

2.3. Laboratory Analyses of Samples

Once the samples arrived at the laboratory, the physico-chemical parameters for the water quality were analyzed. Physico-chemical parameters that were analyzed include: Temperature, pH, electrical conductivity, turbidity, dissolved oxygen, total dissolved solids (using portable in-situ instruments), cation metals (iron, calcium, sodium, zinc, and magnesium), anion (chloride, nitrate, bicarbonate, and sulphate) in accordance with the American public health association specifications [15].

2.4. Water Quality Index

The water quality index (WQI) was determined using six parameters: Dissolved oxygen, pH, temperature, nitrate, turbidity and total dissolved solids using the Water Research Centre, National Sanitation Foundation, WQI calculator.

2.5. Data Analysis

Generated data were analyzed using the descriptive statistics, One-way ANOVA and correlation analysis by means of SPSS V20.

3. Results

3.1. Physico-chemical Parameters

Table 1 shows ranges of parameters compared with the NSDWQ [14] and WHO [16] Standards for Drinking Water. Table 2 shows an overview of physico-chemical parameters of groundwater samples from the various stations. Table 3 show the correlation matrix of the various physico-chemical parameters with relationship varying from (-1 to 1) as weakly negative to strongly positive relationship.

Table 1. *Range of parameters compared with the NSDWQ (2007) and WHO (2011) Standards for Drinking Water.*

Parameters	Range	NSDWQ [14]	WHO [16]
pH	4.00 – 7.15	6.5 - 8.5	6.5 - 8.5
EC (µS/cm)	200 - 1000	1000	500
Temperature (°C)	26.2 – 28.3	Ambient	Ambient
DO (mg/L)	3.9 – 6.3	5	4 -6
TDS (mg/L)	200-684	500	<300-900
Turbidity (NTU)	0.01-0.97	5	5
Cl (mg/L)	7.10 - 710	250	250
Ca (mg/L)	34.5 -620	200	75
Na (mg/L)	4.60 - 404	200	200
Mg (mg/L)	22 -880	0.2	50
NO_3 (mg/L)	1.7 – 40.01	50	50
HCO_3 ((mg/L)	12 - 365	100	200
SO_4 (mg/L)	5.00- 16.16	100	250
Fe (mg/L)	0.0001- 9.6	0.3	0.3
Zn (mg/L)	0.01-0.17	3	5

Table 2. *Physico-chemical composition of groundwater samples from the various stations.*

Stations	Temp. °C	EC (µS/cm)	DO mg/L	pH	CI mg/L	NO_3^- mg/L	Fe mg/L	Na mg/L
Rumuola	26.6	389	6.2	4	710	40.01	2.4	404
Eagle Island	27.1	573	5.3	4.2	243	28.04	1.8	138
Borikiri	26.2	521	6.3	5.8	566	32.47	7.15	303.6
Diobu	27.3	717	6.1	7.1	86.8	17.27	0.000	36.8
Earnest Ikoli	26.5	236	5.2	7.15	75.1	15.66	9.6	46
GRA, Omerelu Street Overhead Tank	26.4	200	5.4	7	71	10.86	0.02	46
Moscow Road Water	28.1	250	5.1	6.4	12.2	2.7	0.6	9.2
Elelenwo	27.6	230	4.8	5	14.1	2.9	0.02	9.2
Rumuokwurushi	26.3	1000	4.7	5	21.3	3.3	0.02	13.8
Trans Amadi	28.3	300	3.9	6.8	7.1	1.7	0.02	4.6
Total	270.4	4416	53	58.45	1806.6	154.91	21.63	1011.2
Average	27.04	441.6	5.3	5.845	180.66	15.491	2.163	101.12
Range	26.2-28.3	200-1000	3.9-6.3	4-7.15	7.1-710	1.7-40.01	0.0001-9.6	4.6-404

Table 2. *Continued.*

Stations	Ca mg/L	Mg mg/L	HCO_3- mg/L	SO_4^{2-} mg/L	TDS mg/L	Zinc mg/L	Turbidity NTU
Rumuola	620	880	12.5	7.5	220	0.13	0.019
Eagle Island	60	90	18.5	6.83	684	0.06	0.027
Borikiri	60	50	35	8.2	346	0.14	0.91
Diobu	150	70	365	6.74	450	0.02	0.01
Earnest Ikoli	120	40	38	8.55	210	0.17	0.97
GRA, Omerelu Street Overhead Tank	280	120	110	6.16	530	0.01	0.35
Moscow Road Water	70	40	55.5	5	573	0.02	0.025

Stations	Ca mg/L	Mg mg/L	HCO_3- mg/L	SO_4^{2-} mg/L	TDS mg/L	Zinc mg/L	Turbidity NTU
Elelenwo	38	22	12	5.04	312	0.01	0.057
Rumuokwurushi	34.5	25.7	13	5	341	0.04	0.071
Trans Amadi	48	42.4	14.5	16.16	370	0.02	0.06
Total	1480.5	1380.1	674	75.18	4036	0.62	2.499
Average	148.05	138.01	67.4	7.518	403.6	0.062	0.2499
Range	34.5 - 620	22 - 880	12 - 365	5 - 16.16	210 - 684	0.01 -0.17	0.01-0.97

Table 3. *Correlation matrix of parameters across locations.*

	Temp °C	EC (µS/cm)	DO mg/L	pH	CI mg/L	NO_3^- mg/L	Fe mg/L	Na mg/L
Temp °C	1							
EC (µS/cm)	-0.34	1						
DO mg/L	-0.55	0.14	1					
pH	0.19	-0.29	-0.15	1				
CI mg/L	-0.47	0.06	0.73	0.53	1			
NO_3^- mg/L	-0.52	0.11	0.80	0.45	0.92	1		
Fe mg/L	-0.49	-0.17	0.35	0.14	0.39	0.46	1	
Na mg/L	-0.47	0.04	0.71	0.54	0.99	0.92	0.38	1
Ca mg/L	-0.32	-0.19	0.51	0.28	0.64	0.59	0.01	0.66
Mg mg/L	-0.23	-0.08	0.46	0.51	0.74	0.65	0.01	0.77
HCO_3^- mg/L	0.06	0.24	0.41	0.51	0.18	0.01	0.22	0.21
SO_4^{2}- mg/L	0.36	-0.22	0.41	0.30	0.01	0.04	0.12	0.01
TDS mg/L	0.30	0.06	-0.06	0.01	0.28	0.12	0.44	0.28
Zn mg/L	-0.58	-0.04	0.47	0.15	0.65	0.68	0.92	0.65
Turbidity NTU	-0.55	-0.22	0.27	0.37	0.22	0.26	0.90	0.21

Table 3. *Continue.*

	Ca mg/L	Mg mg/L	HCO_3^- mg/L	SO_4^{2-} mg/L	TDS mg/L	Zn mg/L	Turbidity NTU
Temp °C							
EC (µS/cm)							
DO mg/L							
pH							
CI mg/L							
NO_3^- mg/L							
Fe mg/L							
Na mg/L							
Ca mg/L	1						
Mg mg/L	0.94	1					
HCO_3^- mg/L	0.01	0.14	1				
SO_4^{2}- mg/L	0.06	0.01	-0.14	1			
TDS mg/L	0.30	0.35	0.21	0.21	1		
Zn mg/L	0.31	0.37	-0.29	0.11	0.55	1	
Turbidity NTU	0.12	0.22	-0.14	0.11	0.38	0.72	1

Table 4. *Water Quality Index for each Water Sample.*

S/No.	Station	WQI Value	Classification
1	Rumuola main Water station	28	D
2	Eagle Island Water Station	25	D
3	Borikiri Water Station	34	D
4	Diobu Water Station	42	D
5	Earnest Ikoli Water Station	46	D
6	GRA, Omerelu Street Overhead Tank	42	D
7	Moscow Road Water Station	45	D
8	Elelenwo Water Station	41	D
9	Rumuokwurushi Water Station	40	D
10	Trans Amadi Water Station	51	C

Water Quality Index Legend ·
90 - 100: Excellent Quality – A
70 - 89: Good Quality - B ·
50 - 69: Medium Quality - C
25 - 49: Bad Quality - D
0 - 24: Very Bad Quality – E

3.2. Water Quality Index

The water quality index (WQI) is as shown in Table 4: Rumuola main Water station 28 (D), Eagle Island Water Station 25 (D), Borokiri Sandfill Water Station 34 (D), Diobu Water Station 42 (D), Earnest Ikoli Water Station 46 (D), GRA, Omerelu Street Overhead Tank 42 (D), Moscow Road Water Station 45 (D), Elelenwo Water Station 41 (D), Rumuokwurushi Water Station 40 (D) and Trans Amadi Water Station 51 (C).

4. Discussion

Utmost satisfaction is attained from water utilization when it is within the accepted quality standards; however, where there are deviations away from the set standards in the physiochemical and heavy metals parameters, it is of the essence that it goes through the required processes to boost the water quality preceding utilization, especially for drinking, household, and agricultural purposes.

Water pollution is defined to have occurred when harmful, hazardous substances – such as chemicals or microorganisms, taint water forms such as a river, stream, lake, ocean, aquifer, or other body of water degrading water quality. Pollutants render water bodies toxic and harmful for utilization and deteriorate the environment. Water is deemed to be polluted when its quality is diminished by contaminants to the extent that it mostly does not support the domestic use such as drinking, household activities as swimming, agricultural activities amongst others. For instance, water is considered polluted when critical property like the dissolved oxygen (DO) concentration dropped below the level that mark a shift in its capability to support its biotic communities, which is principally an upshot of human activities [17].

In the present study, turbidity values, Dissolved Oxygen (DO) and Total Dissolved Solids (TDS) and Zinc values were within stipulated values by the WHO while others were outside the limits. In disagreement with Nwankwoala and Udom [18] in their study of groundwater in Port Harcourt City pH values, Electrical Conductivity (EC) and Total Dissolved Solids (TDS) were higher than the limits set by WHO, while other physico-chemical parameters analyzed fall within the limit. In the present study there was statistically significant difference ($p<0.05$) in all parameters measures except temperature. For heavy metals, in this study, iron and magnesium concentrations were outside the permissible limits set by WHO, which agrees to the findings Nwankwoala and Udom [18].

The EC of the samples from the study area ranges from 200µS/cm – 1000µS/cm. The EC of most of the samples were within the WHO recommended limit (500 µS/cm), nevertheless, EC of higher values than the WHO limits were recorded at Borokiri Sandfill, Eagle Island, Diobu and Rumuokorushi Water Stations, but the values are within NSDWQ of (1000 µS/cm). This is an indication of a high levels of contamination due to dissolved ions [19]. Higher conductivity value indicates that there are more chemicals dissolved in the water. This also mirrors the amount of total dissolved salts (TDS) present in the water, as conductivity is directly proportional to TDS, which increases generally as corrosivity of water increases. TDS content of water derives from both natural and anthropogenic sources [20]. Water containing more than 1000 mg/L of TDS is considered unhealthy for drinking [14]. The average TDS of the sampled groundwater sources are within the acceptable limit of WHO (403.6 mg/L).

The analytical results present the overall abundance of the ions in the following order: $Cl>Ca>Mg>Na>HCO_3^->NO_3^->SO_4^{2-}>Fe>Zn$, with cations in this order $Ca>Mg>Na>Fe>Zn$ and anions in this order $Cl > HCO_3^- > NO_3^- > SO_4^{2-}$. Chloride being the dominant anion found in the groundwater of the study area indicates that groundwater in the area is mainly made up of mixtures of earth alkaline and alkaline metals and predominantly Cl/SO_4 type. Reports by Essumang et al. [19]; Gopalkrushna [20]; Mahananda et al. [21]; suggest that chloride level higher than 10 mg/L is a result of anthropogenic source of pollution by sewage, septic systems, landfill, or fertilizers. Higher chloride concentration in water causes laxative effects [22]. The mean chloride content in water from all the sampled groundwater sources is less than the limit (250 mg/L) set by WHO for drinking water, however Rumuola and Borokiri water stations had values exceeding this limit. Sodium content was equally high at both locations, which could depict presence of intrusion of sea water [19].

The mean values for calcium the most abundant cation was above the WHO limit (75 mg/L). The Minimum value of the calcium for the 10 groundwater samples collected was observed at Rumuokwurushi (34.5 mg/L) while the maximum value was recorded at Rumuola (620 mg/L). The average values are above the WHO (2011) limit for calcium as 75 mg/L. Carbonate contents for all but one sample (Diobu) were within WHO limit (200 mg/L). Carbonate rocks like dolomite and limestone are known as some of the major sources of calcium in groundwater by the action of carbon dioxide [23]. The ability of detergent to form a lathering effect can be diminished by proportionately high concentration of calcium in water. Hard water can result in deposits of calcium carbonate, calcium sulphate and magnesium hydroxide inside pipes and boilers, which can result to lower water flows and making for inefficient heating. The ions in hard water can also corrode metal pipes through galvanic corrosion. If the calcium concentration surpasses 100 mg/L, the water taste will be unpleasant. However, neither of these presents a health impact but consumers prefer water that is tasteless and non-cloudy. Essentially, while hard water can be hard on appliances and pipes, it is not hard on the body, and can improve the daily intake of calcium and magnesium [24].

Sulphate concentration in all the groundwater samples ranged from 5.00 – 16.10 mg/L. These values are below the WHO [16] limit of 250 mg/L. Sulphate in the area has an average value of 7.518 mg/L. Sulphate in combination with calcium and magnesium can make water hard. Sulphate is a major constituent of groundwater. It is relatively mobile in groundwater because it is hardly affected by sorption. The limiting phase can again be gypsum if the dissolution equilibrium is exceeded. A possible source for sulphate could be gypsum ($CaSO_4.2H_2O$), bassanite ($CaSO_4 \cdot 0.5H_2O$) and anhydrite ($CaSO_4$) from the aquifer matrix [1, 25]. Sulphate can also originate in part from non-mineral sources such as sewage. Sulphate in the rainwater as originating from traffic fumes, industrial activities and oil exploration and production activities (as in gas flaring) going on within the Niger Delta, the study area inclusive.

Rumuola water samples had the highest level of Nitrate (40.01 mg/L) and the water samples average for nitrate is 15.491 mg/L, all within the WHO limit of 50 mg/L for nitrate in potable water. Nitrates are the final product of the biochemical oxidation of ammonia [21]. Nitrate in water can indicate the degree of organic pollution of the water source [20]. High nitrate concentration in drinking water has deleterious health impacts on pregnant women and infants less than six months old [26]. Nitrate reduces to nitrite which can oxidize haemoglobin (Hb) to methaemoglobin (metHb), thereby inhibiting the transportation of oxygen around the body [27].

Iron levels ranged from 0.0001 to 9/6 mg/L in the sampled water, with 50% of samples having values exceeding the WHO permissible level of iron (0.3 mg/L), in congruence with this study, Ngah and Nwankwoala [28] reported that the groundwater in Niger-Delta was generally high in iron content, with values ranging from 0 – 10 mg/L. For Magnesium, the range is from 22 mg/L to 880 mg/L with a mean value of 138.01 mg/L and 40% of samples having values exceeding.

WHO limit of 50 mg/L. High iron level noticed in the groundwater sources is characteristic of the Niger Delta environs which is probably due to the local geology and history of the Niger Delta [28]. Excessive dissolved iron and magnesium concentrations result in taste and precipitation problems.

The water quality index (WQI) in this study is generally bad as seen in this result: Rumuola main Water station 28 (D), Eagle Island Water Station 25 (D), Borokiri Sandfill Water Station 34 (D), Diobu Water Station 42 (D), Earnest Ikoli Water Station 46 (D), GRA, Omerelu Street Overhead Tank 42 (D), Moscow Road Water Station 45 (D), Elelenwo Water Station 41 (D), Rumuokwurushi Water Station 40 (F) and Trans Amadi Water Station 51 (C). Thus, the groundwater in the study area is not chemically acceptable for human consumption and domestic utilization.

5. Conclusion

Groundwater quality in the study area shows considerable variation with sampling locations and is generally bad with respect to WQI, as pH, electrical conductivity, dissolve oxygen, chloride carbonate, sodium, iron and magnesium exceeded WHO limits for drinking water. To make the groundwater in the study area suitable for human consumption and domestic use, the water must be treated to meet acceptable standards for drinking water.

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