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Groundwater Quality Assessment in Parts of Igwuruta and Environs, Port Harcourt, Nigeria

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Abstract

The study is based on the water quality assessment of groundwater in selected points in Omunwei community, Igurita, Rivers State Nigeria. Accordingly, 8 water samples were collected from borehole wells (N1-BH, S1-BH, K-BH, AG-BH, IG1-BH, IG2-BH, OM1-BH, OM2-BH). and analysed following standard geochemical procedures. Aquachem software was used to evaluate the hydrogeochemical facies while the concentrations were plotted using simple bar charts. Result of physic-chemical analysis show that the major cations include calcium, magnesium, sodium and potassium. The calcium content ranged from 1.40 to 5.96 mg/l with an average of 2.48 ± 0.53 mg/l. Magnesium ion (mg^{2+}) concentration has average of 0.68 ± 0.20 mg/l. Similarly, the sodium and potassium content on the other hand ranged from 7.72 to 21.56 mg/l and 0.08 to 1.45 mg/l with averages of 16.28 ± 2.15 and 0.68 ± 0.20 mg/l respectively. For the anions, chloride was the dominant anion in the water samples and ranged from 6.00 to 22.00 mg/l with a mean value of 13.13 ± 1.65 mg/l.

Sulphate concentration in all the groundwater samples ranged from 0.48 to 2.48 mg/l with an average of 1.06 ± 0.31mg/l. These values are below the WHO limit. From the piper trilinear diagram as all the samples plotted within sodium and potassium type and chloride type in the cation trilinear plot. On the anion trilinear plot, they indicate a chloride facies. The Durov plot for the studied samples indicates that the samples are dominant in the Na^+K and Cl^- zone. The pH part of the plot reveals that groundwater in study area is acidic. The average ionic composition analysis by stiff diagram signifies dominance of Na+ K and Cl- over the other ions in the order (Na^+K) (Cl^-)>(Ca^{2+}) (HCO_3+CO_3) > (Mg^{2+}) (SO_4). Judging from the results, majority of the Stiff plots have similar shapes which means that they are from the same source. Schoeller diagram was also used to present average chemical composition of the water samples. The relative tendency of ions in mg/l shows $Na^++K^+>Cl^->Ca^{2+}>SO_4>Mg>HCO_3+CO_3$.

One basic measure of water quality is the Total Dissolved Solids (TDS) value indicated a fresh water. The Pollution Index (PI) value of 4.00 shows that the surface water bodies in the area is fit for domestic use as most parameters do not exceed maximum permissible level set by the World Health Organization (WHO) standard. The result of the study shows a mean concentration of the heavy metals as follows: Lead (0.00), zinc (0.37 ± 0112) and iron (0.75 ± 0.198), These values are within the permissible standard for drinking water. However, there is need for periodic groundwater monitoring to ascertain the pollution status of the groundwater system in and around the study area for its protection and sustainable development.

Keywords: Groundwater quality; physicochemistry; Igwuruta; Port Harcourt; Nigeria

Introduction

The supply of clean and uncontaminated water is a great challenge facing developing nations. Water bodies in developing countries are predisposed to pollution. In Nigeria, pollution is a major threat to surface and underground water bodies. This emanates mostly from indiscriminate dumping of refuse, untreated sewage, oil spillage *etc.* [1]. Apart from problem of accessibility of clean water from these contaminated water bodies, it is known that pollution of water could lead to health hazards, sanitary nuisance, severe economic and social consequences [2]. Incidence of diseases like typhoid, giardiasis, infectious hepatitis, paratyphoid, leptospirisis, schistomiasis, shigellosis and amoebiasis could be inherent from consumption of contaminated water. The pathogens associated with these diseases have been directly or indirectly detected as having a link with contaminated water [3]. Aside micro-organisms, water bodies are also known to contain numerous chemical elements at different levels [4].

The citing of boreholes as the source of potable water in this area has become a serious challenge. The challenge is worsened by the fact that there are inadequately trained waste disposal personnel and mechanism, poor waste collection, sorting and disposal methods and location to this disposal site without regards to the local geology and hydrogeology of the area [5]. As a result of the imminent impact of solid waste on the environment, it has become necessary to investigate the potential for the contamination and pollution of the soil and groundwater.

Most Nigerian cities are epitome of urban decay and characterized by poor housing, sanitation and public health infrastructure [6]. The erratic growth of housing units coupled with rapid population explosion has resulted in environmental health hazards [7]. In rural Nigeria today, the volume of waste generated is much lesser than what is obtainable in the urban areas. This is because of the population explosion of people in the urban areas. But Igwurita, the study area, has experienced a steady growth in population over the years due to the presence of the university community. This population growth comes with increased construction of hostels which leads to loss of arable land, more drilling of boreholes which could lead to the lowering of the water table and the problem of waste disposal.

The major means of waste disposal in Igwurita is by dumping and periodic burning of the refuse. Every form of waste is dumped at a particular point. Be it paper, food wastes, clothes, broken furniture, plastics, aerosol cans. This shows that no sorting of waste is carried out, no composting of biodegradable waste is carried and evacuation of waste by authorities for proper disposal is not carried out.

The city lacks surface water sources which could be impounded into dams for portable water supply and therefore, is dependent on groundwater sources for its domestic, industrial and agricultural uses. Groundwater resources in the city are however, highly vulnerable to saltwater intrusion and surface induced contamination from solid waste dump sites. This is primarily due to its proximity to the coast, shallow nature of its aquifers, permeable soil media and flat topography. The aim of this study is to undertake a water quality analysis of the borehole water in parts of Igurita, Port Harcourt, Rivers State Nigeria.

Description of the Study Area

Igwuruta is a town in Ikwerre Local Government Area, Rivers State, Nigeria. The study area is located within latitudes 4° 51'N to 5° 04'N and longitudes 6° 53'E to 7° 09'E. It is made up of 9 villages; Igwuruta-Ali, Omuodukwu, Omunobo, Omuchi, Omuohia, Omueke, Agboga, Omumah and Omuwie. It is located near Omagwa, a community hosting the Port Harcourt International Airport with a population of 50,000 people [8] **(Figure 1)**.

Figure 1: Location map of the study area.

Materials and Methods

Water sample collection

Water samples were collected from private and public boreholes for groundwater quality testing. For each borehole, 1.5 lt of the groundwater samples shall collect in sterilized polyethylene bottles, stored and carried in ice-packed coolers to the laboratory for analysis within 24 hours. The locations of groundwater points measured with the aid of Global Positioning System (GPS).

At each sample location, in-situ measurements for pH, temperature, electrical conductivity and salinity were made with water quality checker.

Chemical parameters tested for are pH, Dissolved Oxygen (DO), Total Dissolved Solids (TDS), total hardness, total irons, nitrite sulphate, biocarbonate, phosphate, total coliform bacteria count, exchangeable cations (such as chloride, sodium, calcium, magnesium and potassium) and heavy metals such as copper, zinc and lead.

Laboratory analysis

The methodologies employed for analyses was carried out in accordance with APHA and the table is given in **Table 1**. The analyses cover physical, chemical and biological parameters of water samples from each borehole. Physical parameters include: Temperature, pH, Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Electrical Conductivity (EC), turbidity, Biochemical Oxygen Demand (BOD) and total hardness (salinity).

Table 1: Physico-chemical characteristics of water samples from the study area.

Parameters	N1-BH	S1-BH	K-BH	AG-BH	IG1-BH	IG2-BH	OM1-BH	OM2-BH	MEAN	WHO Standard (2011)
pH @ 25^{0}C	5	5.01	5.66	5.2	6.5	6.51	5.9	6.7	5.81±0.248	6.50 - 8.50
Electrical conductivity (µS/cm)	38	56	51	49	68	46	31	49	48.50±3.93	1000
Total Dissolved Solids (TDS), mg/l	19	28	22	15	29	28	12	25	22.25±2.26	500
Turbidity (NTU)	0.78	0.39	0.45	0.56	1.28	2.39	0.76	4.56	1.40±0.51	5
Total chloride, mg/l	6	12	15	11	16	22	12	11	13.13±1.65	250
Total alkalinity, mg/l	1.6	1.2	1.8	1.5	1.4	1.23	1.78	2.5	1.63±0.14	-
Total hardness, mg/l	6.01	5.01	6.05	6.1	6.91	7.01	6.05	6.25	6.17±0.21	500
Nitrate, mg/l	1.36	0.83	2.24	0.56	1.36	0.83	0.24	1.5	1.12±0.22	45
Sulphate, mg/l	0.48	0.48	1.67	0.57	2.48	0.48	0.27	2.07	1.06±0.31	200-400
Phosphate, mg	0.04	0.002	0.05	0.07	0.008	0.02	0.15	0.17	0.06±0.02	<5.00
Bicarbonate, mg/l	2.01	2.02	0.05	0.03	1.01	0.12	0.05	0.03	0.67±0.31	-

Chemical parameters include: Total iron, nitrate, nitrite, sulphate, bicarbonate, phosphate, exchangeable cations, (such as chloride, sodium, calcium, magnesium and potassium) and heavy metals such as copper, zinc and lead. Biological parameters are total coliform bacteria count.

Results were compared with World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) values.

Water quality modeling software Aquachem and Microsoft excel were used to analyze data set.

Results

The result of the analyses and the summary of the physico-chemical parameters and metal analysis in mg/L area presented in **(Table 2)** while the various cross plots of showing the distribution of the major cations, anions and trace elements are shown in **Figures 2-4.** The calculated pollution Index for the groundwater water samples in the study area is shown in **Table 3**, while the various cross plots (piper diagram, stiff diagram, Durov and Schoeller plots and ion balance diagram) describing the hydrogeochemical facies are shown in **Figures 5-9.**

Table 2: Result of metal and microbial analysis of water samples from the study area.

Parameters	N1-BH	S1-BH	K-BH	AG-BH	IG1-BH	IG2-BH	OM1-BH	OM2-BH	MEAN	WHO Standard (2011)
Calcium, mg/l	1.4	1.47	2.1	1.96	2.4	1.47	3.1	5.96	2.48 ± 0.53	75
Sodium, mg/l	7.72	10.68	25.45	11.56	17.12	20.68	15.45	21.56	16.28 ± 2.15	100
Potassium, mg/l	0.08	0.62	0.56	0.45	0.09	1.62	0.56	1.45	0.68 ± 0.20	10
Magnesium, mg/l	0.001	0.01	0.001	0.012	0.03	0.01	0.01	0.02	0.01 ± 0.003	30
Zinc, mg/l	0	0.35	0.55	0.45	1	0.35	0.15	0.09	0.37 ± 0.112	2
Lead, mg/l	0	0	0	0	0	0	0	0	0.00 ± 0.00	0.05
Iron mg/l	1.4	0.47	0.1	0.06	0.4	1.47	1.1	0.96	0.75 ± 0.198	0.3
TOTAL coliform (cfu/ml)	0	0	0	0	0	0	0	0	0.00 ± 0.00	

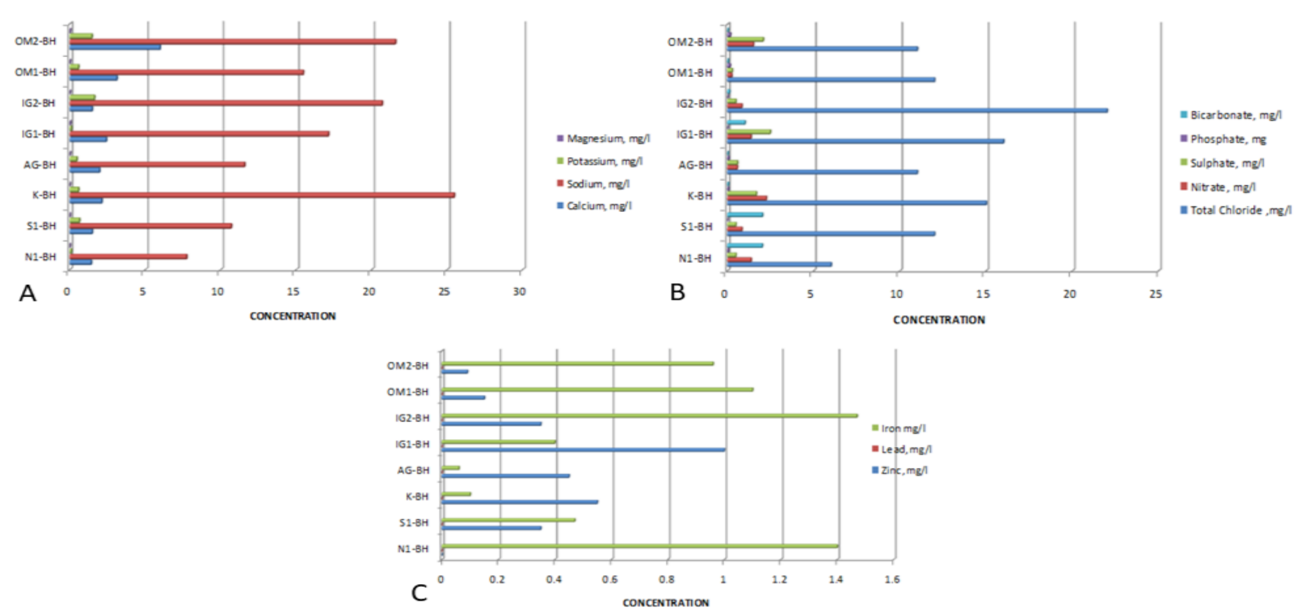

Figure 2: (A) Distribution of major cations in the analyzed samples; (B) Distribution of major anions in the analyzed samples; (C) Trace elements concentration in the analyzed samples.

Table 3: Measured parameter of groundwater in the study area for pollution index determination.

Parameters	N1-BH	S1-BH	K-BH	AG-BH	IG1-BH	IG2-BH	OM1-BH	OM2-BH	Cij	WHO Standard (2011)	Cij/Wij
Electrical Conductivity (µS/cm)	38	56	51	49	68	46	31	49	48.5	1000	0.049
Total Dissolved Solids (TDS), mg/l	19	28	22	15	29	28	12	25	22.3	500	0.045
Turbidity (NTU)	0.78	0.39	0.45	0.56	1.28	2.39	0.76	4.56	1.4	5	0.279
Total chloride, mg/l	6	12	15	11	16	22	12	11	13.1	250	0.053
Total hardness, mg/l	6.01	5.01	6.05	6.1	6.91	7.01	6.05	6.25	6.17	500	0.012
Nitrate, mg/l	1.36	0.83	2.24	0.56	1.36	0.83	0.24	1.5	1.12	45	0.025
Sulphate, mg/l	0.48	0.48	1.67	0.57	2.48	0.48	0.27	2.07	1.06	400	0.003
Phosphate, mg	0.04	0	0.05	0.07	0.01	0.02	0.15	0.17	0.06	4	0.016
Calcium, mg/l	1.4	1.47	2.1	1.96	2.4	1.47	3.1	5.96	2.48	75	0.033
Sodium, mg/l	7.72	10.68	25.5	11.56	17.12	20.68	15.45	21.56	16.3	100	0.163
Potassium, mg/l	0.08	0.62	0.56	0.45	0.09	1.62	0.56	1.45	0.68	10	0.068
Magnesium, mg/l	0	0.01	0	0.01	0.03	0.01	0.01	0.02	0.01	30	4E-04
Zinc, mg/l	0	0.35	0.55	0.45	1	0.35	0.15	0.09	0.37	2	0.184
Lead, mg/l	0	0	0	0	0	0	0	0	0	0.05	0
Iron mg/l	1.4	0.47	0.1	0.06	0.4	1.47	1.1	0.96	0.75	0.3	2.483

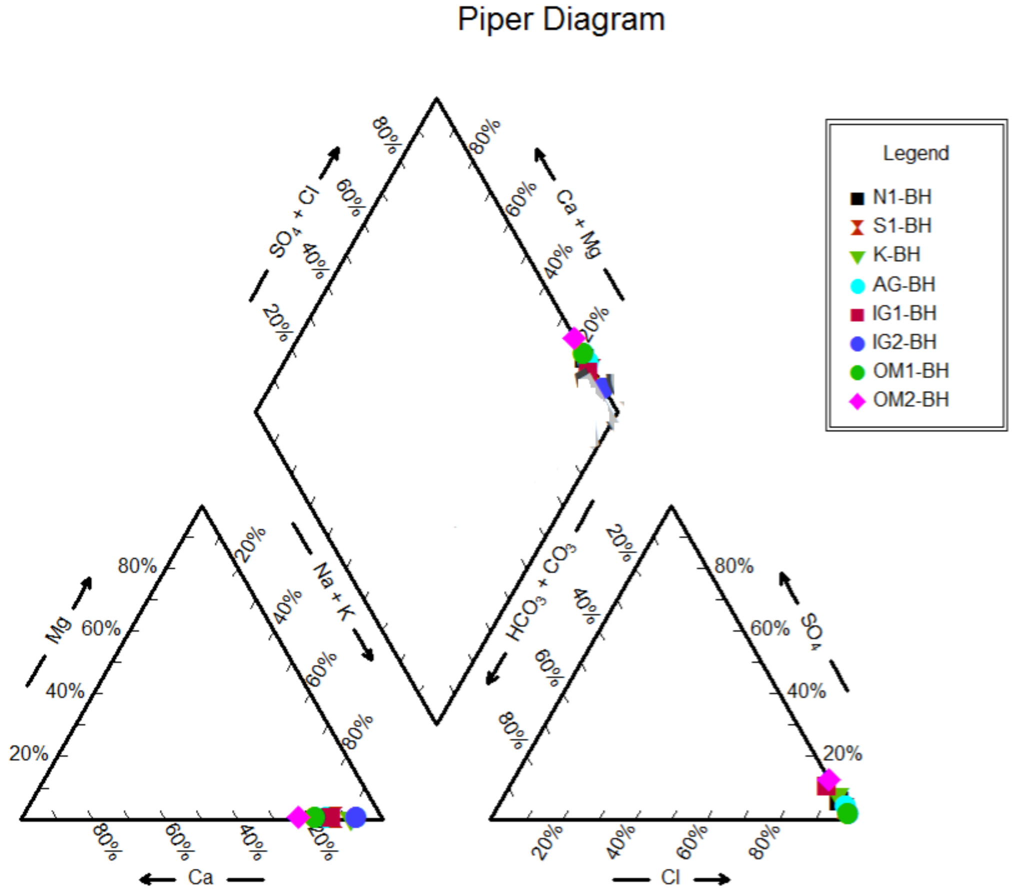

Figure 5: Piper trilinear diagram of the studied groundwater samples.

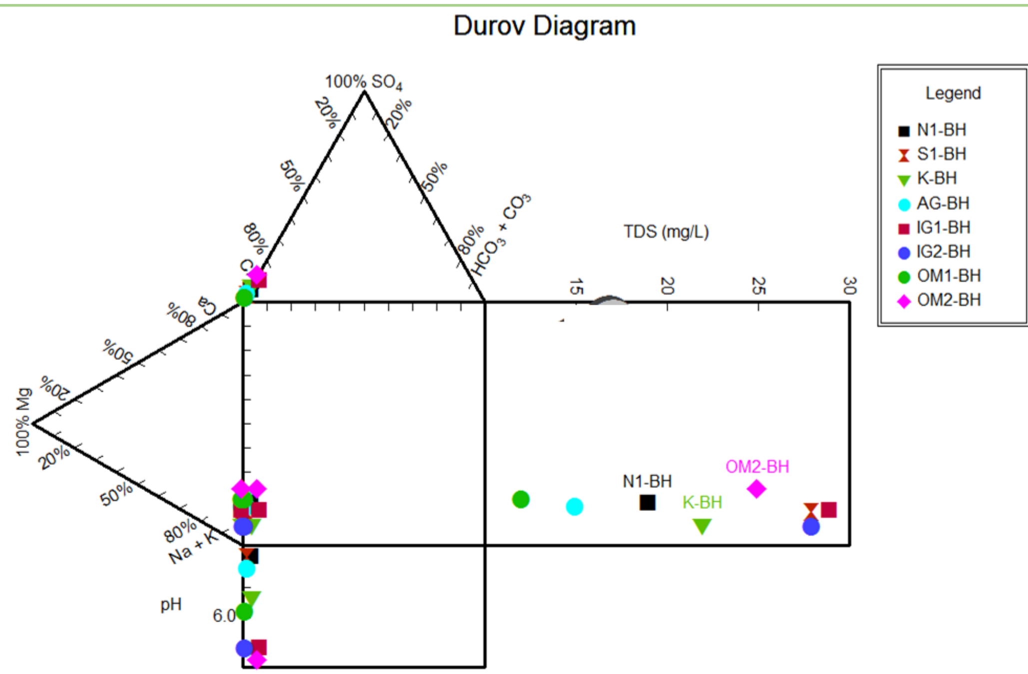

Figure 6: Durov Diagram for the sampled water in the study area.

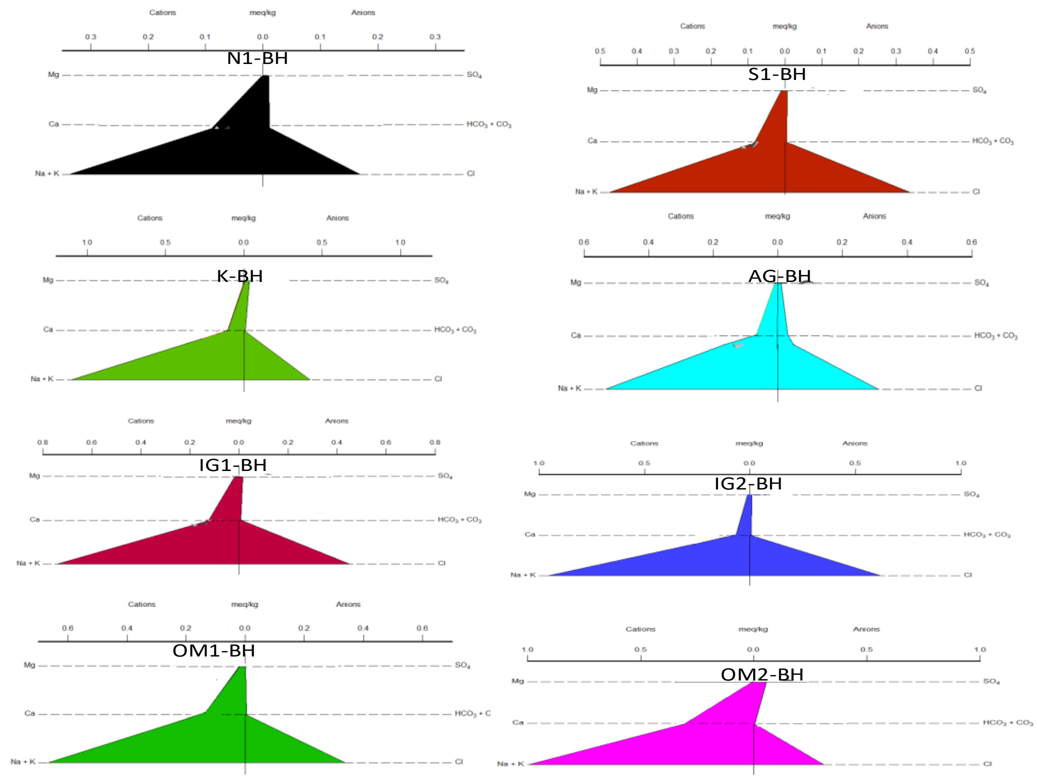

Figure 7: Stiff diagram for water samples.

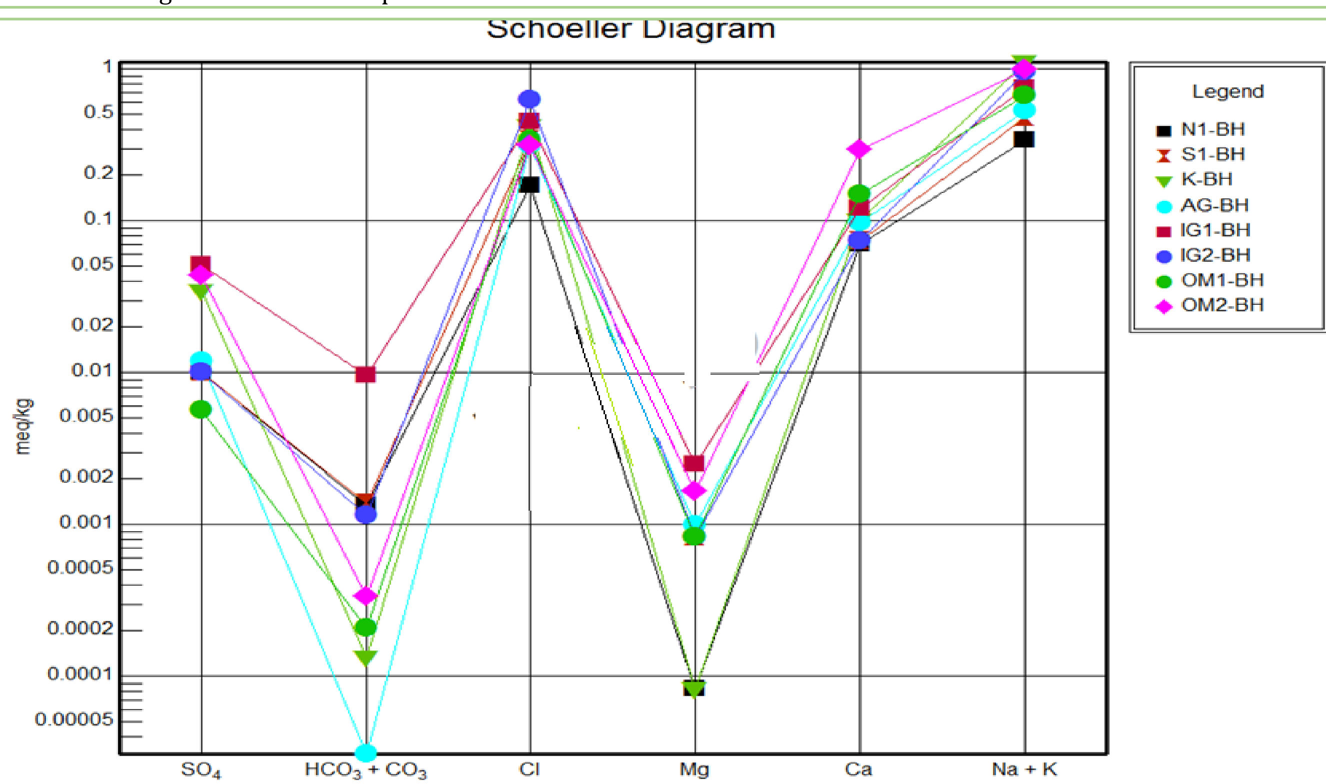

Figure 8: Schoeller plot of water samples in the study area.

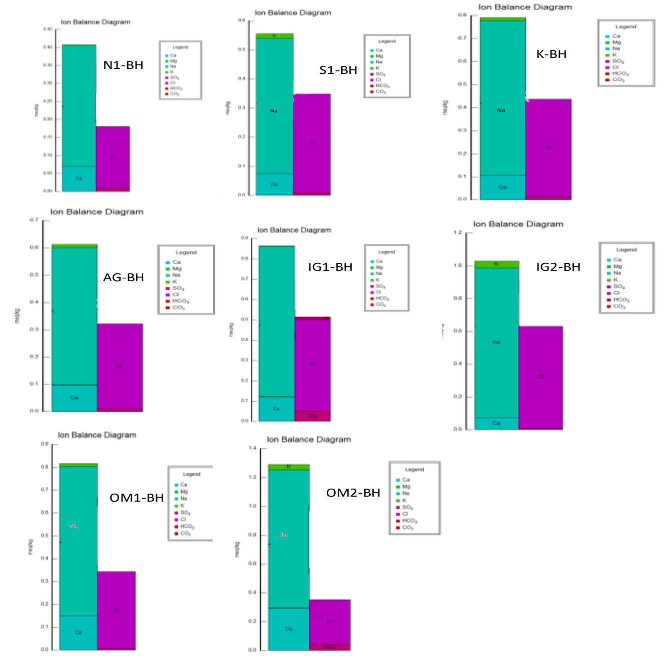

Figure 9: Ion balance diagram for water samples.

Water quality/pollution index

Assessing the water samples suitability for domestication pollution Index computation using the method of Horton et al., was utilized **(Table 3)** [9]. To determine the pollution index of the water samples, the formula below was used expressed as a function of the relative values of Cij/Wij where Cij is mean of the value of the specific parameters and Wij is the WHO permissible standard.

$$PI = \frac{\sqrt{Max\ (Cij/Wij)^2 + (Mean\ (Cij/Wij)^2}}{2}$$

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 [10].

Physicochemistry

The major cations include calcium, magnesium, sodium and potassium **(Figure 2)**. The calcium content ranged from 1.40 to 5.96 mg/l with an average of 2.48 ± 0.53 mg/l. Magnesium ion (mg^{2+}) concentration has average of 0.68 ± 0.20 mg/l. The availability of calcium ion for the groundwater systems of the area could be explained by occurrence of calcium carbonate cement in detrital sedimentary formation.

Carbonate rocks like dolomite and limestone are known as some of the major sources of calcium in groundwater by the action of carbon dioxide [11]. 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 [12].

Similarly, the sodium and potassium content on the other hand ranged from 7.72 to 21.56 mg/l and 0.08 to 1.45 mg/l with averages of 16.28 ± 2.15 and 0.68 ± 0.20 mg/l respectively.

For the anions **(Figure 3)**, chloride was the dominant anion in the water samples and ranged from 6.00 to 22.00 mg/l with a mean value of 13.13 ± 1.65 mg/l.

Sodium must have entered the water system through natural system (that is rainwater). Other natural sources include weathering of feldspars (albite) and leaching of clay minerals [13,14].

The chloride concentrations are comparatively appreciable because of the fact that chloride show correlation with the components of pore water derived from mineral breakdown [14]. The concentration of rain water by evapotranspiration may be an important source of chloride in the area.

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 type. Reports by Essumang et al., Gopalkrushna et al., suggest that chloride level higher than 10 mg/L is a result of anthropogenic source of pollution by sewage, septic systems, landfill or fertilizers [15,16]. The location of the Igurita dumpsite within the vicinity of the sampled groundwater might be a factor in the level of chloride in the water. Higher chloride concentration in water causes laxative effects [17]. 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. A high chloride value above the WHO was reported by Ojukwu and Nwankwoala et al., in Rumuola and Borokiri water stations [18]. Sodium content was equally high at both locations, which could depict presence of intrusion of sea water.

Sulphate concentration in all the groundwater samples ranged from 0.48 to 2.48 mg/l with an average of 1.06 ± 0.31 mg/l. These values are below the WHO limit of 250 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 [19]. Sulphate can also originate in part from non-mineral sources such as sewage, 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.

The pH ranged from 5.00 to 6.70 with a mean value of 5.81 ± 0.28 mg/l which clearly showed the water to be slightly acidic.

The pH measures the level of acidity or alkalinity in a solution or sub- stance. This acidic tendency could still be attributed to human activities such as fertilizer application, leachates from dumpsites. In particular ammonium fertilizers such as urea and ammonium phosphates, such as monoammonium and diammonium phosphate are converted rapidly into nitrate through a nitrification process, releasing acids in the process and thus increasing the acidity of the topsoil [20].

The EC of the samples from the study area ranges from 31 µS/cm-68 µS/cm with mean of 48.5 ± 3.93 µS/cm. The EC of most of the samples were within the WHO recommended limit (1000 µS/cm). This is an indication that the contamination level due to dissolved ions is very low high 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. Water containing more than 1000 mg/L of TDS is considered unhealthy for drinking. The average TDS of the sampled groundwater sources are within the acceptable limit of WHO (15.00 to 25.00mg/l with a mean value of 22.25 ± 2.25 mg/l.).

Hydrogeochemical facies

Piper trilinear diagram **(Figure 5)** shows a close relationship in the chemistry of the sampled waters in the study area. All the samples plotted outside the potable water zone of the diamond portion of the piper diagram.

The sampled water of the study area was found to be sodium chloride type hydrochemical facies from the piper trilinear diagram as all the samples plotted within sodium and potassium type and chloride type in the cation trilinear plot. On the anion trilinear plot, they indicate a chloride facies.

Durov, et al., introduced another diagram which provides more information on the hydrochemical facies by helping to identify the water types and it can display some possible geochemical processes that could help in understanding quality of groundwater and its evaluation. The diagram is a composite plot consisting of 2 ternary diagrams where the cations of interest are plotted against the anions of interest; sides form a binary plot of total cation *vs.* total anion concentrations; expanded version includes electrical conductivity (µS/cm) and pH data added to the sides of the binary plot to allow further comparisons.

The Durov plot for the studied samples indicates that the samples are dominant in the Na^+K and Cl^- zone. The pH part of the plot reveals that groundwater in study area is acidic.

Geochemistry of the water samples is further discussed by means of its major ions. Stiff, et al., diagram is a graphical representation of the different water ions [21]. The average ionic composition analysis by stiff diagram shown in **Figure 6** signifies dominance of Na^+K and Cl^- over the other ions in the order (Na^+K) (Cl^-)>(Ca^{2+})(HCO_3+CO_3)>(Mg^{2+})(SO_4) the stiff diagrams help to identify water samples from the same source by considering the similar shapes. Judging from the results, majority of the Stiff plots have similar shapes which means that they are from the same source.

Schoeller, et al., diagram **(Figure 7)** is also used to present average chemical composition of the water samples

[22]. The relative tendency of ions in mg/l shows $Na^{+}+K^{+} > Cl^{-} > Ca^{2+} > SO_4 > Mg > HCO_3+CO_3$

Water quality

One basic measure of water quality is the Total Dissolved Solids (TDS) which is the total amount of solids, in milligrams per liter that remains when a water sample is evaporated to dryness. With a mean TDS of 22.25 ± 2.26 mg/l, the water under study is classified as excellent and also fresh water.

The Pollution Index (PI) value of 4.00 shows that the groundwater water bodies in the area is fit for domestic use as most parameters do not exceed maximum permissible level set by the WHO standard.

The result of the study shows a mean concentration of the heavy metals as follows: Lead (0.00), zinc (0.37 ± 0.112) and iron (0.75 ± 0.19), These values are within the permissible standard for drinking water.

Conclusion

The assessment of groundwater in selected boreholes in parts of Igurita was carried out using samples collected from 8 boreholes. The study was able to classify the hydrogeochemical facies and evaluated the pollution status of the borehole water. Utilizing the pollution indices, the water resources was certified as adequate for domestic use

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