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Research Paper

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Geophysicochemical Characterization of the Aquifer Systems in Okigwe Local Government Area, South-East, Nigeria

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Abstract— Water is an important resource of the natural environment. It is one of the common substances known and provided for man's usage. In the study area, majority of people do not have access to portable water. The objective of this study is to carry out water sample test of recently developed boreholes so as to assess the groundwater quality in the study area. Groundwater samples from twenty boreholes were collected and analyzed. The groundwater of the study area in terms of mgl^{-1} showed low concentration of major elements ($Ca^{2+} > Mg^{2+} > K^{+} > Pb^{2+} > Fe^{2+} > Cu^{2+}$ and $Cl^{-} > HCO_3^{-} > SO_4^{2-} > NO_3^{-} > PO_4^{3-}$). They were low hardness (Ca^{2+} and Mg^{2+} varies from 0.02 to 5.68mgl^{-1} and 0.03 to 8.222mgl^{-1} respectively), low salt (from 0.001 to 0.008mgl^{-1} of Na^{2+}), low chlorine (from 2.330 to 140.9mgl^{-1} of Cl^{-}) and low sulphate concentration (1.00 to 8.00 mgl^{-1} of SO_4^{2-}). The average values of Potassium, Copper and Iron contents in the groundwater samples are 0.95mgl^{-1}, 0.01mgl^{-1} and 0.11mgl^{-1} respectively. The values of the pH for the study area is from 4.1 to 8.9 with a mean value of 5.44. Their temperature varied from 27.2°C to 30.9°C. The conductivity values within the study area lies between 12 to 725µs/cm with an average value of 141.15µs/cm. The turbidity values within the study area varied from 0.00 to 0.001 NTU. The Total Dissolved Solids (TDS) contents vary from 6 to 310MgL^{-1}. The Total Saturated Solids (TSS) content of the water samples varied from 2 to 8mgl^{-1}. The results reveals that the overall physicochemical values are within the acceptable limits of natural and international standards for drinking, domestic and agricultural purposes when correlated with the World Health Organization (WHO) standard guidelines for water quality.

Keywords— Water quality, groundwater, WHO, physicochemical analysis

I. INTRODUCTION

This study presents a water quality assessment of the aquifer systems in Okigwe Local Government Area, Southeast, Nigeria. Water is an important resource of the natural environment. It is one of the common substances known and provided for man's usage. As a resource of life, people right from the beginning of human civilization have settled close to water sources such as springs along rivers and beside lakes [1].

In the study area, majority of people do not have access to portable water. This problem is compounded by the non-functional Okigwe regional water scheme. In some parts of the area, available records from the Imo State Water Board and Imo State Water Development Agency (IWADA) shows that a number of isolated pre-drilling geophysical surveys have been carried out for siting boreholes. From the records, it was discovered that the problems that militated against the development of both rural and urban water development in the area bother mainly on the complex geological nature of some parts of the study area [2].

Groundwater is never really chemically pure as water invariably dissolves some of the minerals it comes in contact with at any given time [3]. These dissolved minerals are contained in the groundwater which influences its hydrogeochemistry and ultimate quality [4]. The effect of the poor management of these dissolves minerals include: pollution, environmental hazards and aesthetics. These factors put together affect the physicochemical parameters such as PH, turbidity, temperature and conductivity of the water. This research is therefore aimed at determining the hydrogeophysical and hydrogeochemical parameters of the research area in response to the increasing demand of portable water for drinking and agricultural purposes.

The chemical make-up of ground water be dependent on the dissoluble products of rocks and soils that it interacts with as it moves within the porous and permeable media [5]. The potential sources of concentrations of cation and anion contained in the groundwater are the geochemistry of groundwater conduits and the lithology of the vadose zone materials. Also, they could be brought about through seepages of industrial wastewater, unsewered sanitary

facilities, city waste or the use of soil enhancement chemicals. If these are not properly attenuated during the process, leaching may occur and this will adversely make alterations to the physical, chemical and biological property of the groundwater [6].

The majority populate in the study area do not have access to portable water. This problem is attributed to the poor management of the solid waste materials within the area and the gradual increase in the rate of industrial and commercial activities in the area. The major sources of water supply are rain water, surface streams, rivers and very few boreholes. During rainy season, the people rely more on rain water harvest. During the dry season, reliance is more on surface streams and rivers. Some of these spring and streams lie at far distances away from residential areas. Studies show that in and around the study area the quality of drinking water has not been properly assessed. Hence, it is essential to do a proper assessment of the water quality of the area in order to ascertain and assess its quality with regards to the World Health Organization (WHO) benchmark.

The study area which is Okigwe Local Government and its environs, southeast Nigeria, is located approximately between latitudes 5°30' N and 6°00′N and longitude 7°00′E and 7°30′ E. It is about 300m above mean sea level in altitude. Soils of the area are derived from the false bedded sand stones of the Ajali Formation and the maastrichtian geologic era proximal to the upper coal measures called the Nsukka Formation of the Danian geologic era. Okigwe can be accessed through the Enugu-Port Harcourt expressway, Okigwe-Owerri express road, Afikpo-Uturu express roads with other secondary and minor roads. Okigwe area is mainly drained by Imo Rivers. The drainage path is mainly dendritic and the area is made distinctive by slightly undulating topography. This reveals the hilly terrain of the area. The climate of the study area is tropical. It has a mean annual rainfall of 2250 mm and a mean annual temperature range of 27° to 28°C [2]. The Ajali formation overlies the Mamu formation. The Ajali sandstone consist of thick friable medium to fine-grained sand, averagely sorted, typically somewhat white in colour, but sometimes iron stained [7]. Figure 1 shows the map of the study area.

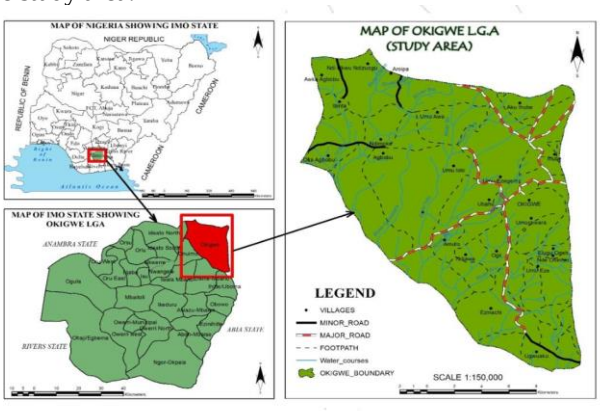

Figure 1: Map of Okigwe and environs [8].

Adequate geochemical investigation is required for a proper assessment of groundwater resources of the area. Hence, a documented result of the analysis will serve as reference materials for further research on the geochemical model of the area. The electrochemical activity of rocks be dependent on their chemical composition, and on the concentration of the electrolytes dissolved in the ground water with which they are in contact.

The assessment of groundwater quality is essential to check its sustainability for designated purpose such as drinking, irrigation and industrial use. The physicochemical parameters assessed such pH, total dissolved solids, conductivity, turbidity and total suspended solids are compared with standard values to determine its acceptability.

The selection of water quality parameters was based on the need to be used for the general purpose of drinking, irrigation and industry. It is based on the WHO standard to determine its sustainability for use. If the value of the physicochemical parameters fall within these standards, then, the water is suitable for use.

The rest of the paper is organized as follows, Section II describes briefly previous research works. Section III contains the methodology, Section IV discusses the analyses of the results with a spot-on table of results while Section V concludes the research findings with succinct recommendations.

II. RELATED WORK

Assessment of physicochemical characteristic of groundwater was carried out by [9] within selected industrial areas to assess the impacts of industrial activities on the selected sites. The study revealed that the industrial processes mainly from anthropogenic activities had negative implication on the physicochemical parameters analyzed. Similar work done by [10] in major industrial and residential locations of Lagos metropolis, showed many measured values of physicochemical parameters of some locations to be below permissible limits for drinking water quality due to residential activities such as waste disposal and industrial activities mainly from heavy discharge of effluents from treatment plants as well as dissolution of ionic heavy metals from the activities of heavy machines. In an analysis done by [11] for ground water used specifically for drinking, the results obtained for the physicochemical parameters were within the accepted range of the recommended WHO guidelines except for some parameters which were at alarming state for which treatment and immediate interventions were suggested.

III. MATERIALS AND METHODS

Groundwater samples from twenty borehole locations were collected in new pre-cleaned polypropylene bottles. The water was pumped out of the boreholes and allowed for 10

minutes to remove stagnant water before collecting the representative samples. The samples were analyzed for eight (8) groundwater quality parameters. These are pH, temperature and conductivity using portable meters which was determined on-site. Others are acidity, turbidity, alkalinity, total dissolved solids (TDS) and total suspended solids (TSS). The pH values were obtained using a HACH sensor 3 pH meter. The turbidity value was obtained using the spectrophotometric technique. All the samples were stored accordingly at 4°C. Chemical analysis for Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Chloride (Cl^{-1}), Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) were analyzed by volumetric titration methods. Measurements of Potassium (K^+) and Sodium (Na^+) were obtained using the flame photometer. The chemical analyses were done within two weeks from the day of the collection of the water samples at IES-ELS-HEPZELAHNIFERIA Limited, Port Harcourt, Rivers State, Nigeria.

The spectrophotometeric technique as outlined by the American Public Health Association [12] was used to determine Chlorine (Cl^-), Sulphate (SO_4^{2-}) and Phosphate (PO_4^{3-}). The obtained values from the water samples were compared with the World Health Organization (WHO) standards.

IV. RESULTS AND DISCUSSION

The overall physicochemical parameters of the twenty water samples analyzed in the research area are shown in table 1. The groundwater in terms of mgl^{-1} is characterized by $Ca^{2+} > Mg^{2+} > K^+ > Pb^{2+} > Fe^{2+} > Cu^{2+}$ and $Cl^- > HCO_3^- > SO_4^{2-} > NO_3^- > PO_4^{3-}$. The average contribution of individual cations to the total cations is 58.75% Ca^{2+}, 40.44% Mg^{2+}, 0.56% K^+, 0.17% Pb, 0.07% Fe^{2+} and 0.006% Ca^{2+}. On the average, anions are made up of 75.05% Cl^-, 13.98% HCO_3^-, 7.96% SO_4^{2-}, 2.47% NO_3^- and 0.54% PO_4^-.

pH

The pH is one vital parameter for assessing water quality. It impacts the physicochemical characteristics of ground water. The solubility of certain substances that are detrimental to water quality is catalyzed by the pH.

The result of the analyses indicates that the pH values for the selected area ranges from 4.1 to 8.9 with a mean value of 5.44 (Table 1). This indicates the slightly acidic nature of the groundwater. The low pH values of the groundwater in the area are connected with the low PH range of the soil. It may also be due to the use of inorganic chemical fertilizers for agricultural activities in the area. The result is that these forms weak acidic solutions as they diffuse through the sandy permeable layers of the formation. They are then washed down into the aquifer which sources the groundwater.

Temperature

For the water samples, their temperature varied from 27.2°C to 30.9°C. This is within the WHO allowable maximum of 30°C. According to [13] this temperature range can be considered to be normal in this environment. The observed temperatures are sufficient for good filtration. They also allow for effective turbid materials extraction. However, microbiological characteristics such as survival and growth of microorganisms are favored by such high temperatures.

Conductivity

Electrical conductivity values is a function of the total amount of dissolved substances in the ground water. Both electrical conductivity and TDS are directly related. The conductivity values within the study area lies between 12 to 725µs/cm with an average value of 141.15µs/cm. This is below the World Health Organization standard not exceeding 400.00µs/cm for drinking water indicating the water is not considerably ionized with small amounts of dissolved substances.

Turbidity

The turbidity values within the study area varied from 0.00 to 0.001 NTU which is well below the maximum permissible limit of the World Health Organization standards of 5.00NTU.

Total Dissolved Solids (TDS)

The TDS contents vary from 6 to $310MgL^{-1}$. This is within the WHO desirable limit of $500.00mgL^{-1}$. Low TDS ($<50mgl^{-1}$) and low conductivity ($2100mgl^{-1}$) values is an indication of zones with high aquifer resistivity. The converse is equally true for low aquifer resistivities. In the study area, results show that most of the VES locations with high aquifer resistivity correspond to zones where the borehole water depicts low TDS and low conductivity. Areas with low aquifer resistivity also correspond to zones with high TDS and conductivity values for the borehole water. The flavor of drinking water is considered as generally good when the TDS content is less than $600.00mgl^{-1}$.

Total Suspended Solids (TSS)

The TSS content of the water samples varied from 2 to $8mgl^{-1}$. This falls far below the WHO maximum value of $500mgl^{-1}$ for drinking water.

Assessment of Trace Elements and Heavy Metals

For water to be fit for drinking and domestic purposes, its hardness must be determined. The contents of Calcium and Magnesium metal cations mainly determines the hardness of water. The concentration of Ca^{2+} and Mg^{2+} in the study area varies from 0.02 to $5.68mgl^{-1}$ and 0.03 to $8.222mgl^{-1}$ respectively. These values are well below the maximum permissible limit as recommended by [14]. This shows that the water in these areas is suitable for drinking.

The average values of Sodium, Potassium, Copper and Iron contents in the groundwater samples are $0.1mgl^{-1}$, $0.95mgl^{-1}$, $0.01mgl^{-1}$ and $0.11mgl^{-1}$ respectively. These values are within the maximum permissible limits of WHO (Table 1). Hence, they pose no threat to the groundwater quality.

The lead (Pb^{2+}) content of all the groundwater samples with an average of 0.29 mgl^{-1} lies above the maximum limit. Lead has no known biological benefit to man. When inhaled or ingested in large quantity, it is harmful and can lead to damage of several systems of body causing high blood pressure and anemia. Further, it can cause convulsions, coma and death in children when present in very large quantities in the body.

The contents of all the anions HCO_3^-, Cl^-, SO_4^{2-}, NO_3^- and PO_4^{3-} analysed in the groundwater sample showed that their values are within the maximum permissible limits of WHO.

(Table 1). Hence, they pose no threat to the quality of groundwater in the area.

Table 1: Statistics of physicochemical parameters.

PARAMETER	MINIMUM	MAXIMUM	MEAN	WHO STANDARD
PH	4.10	8.90	5.44	No guideline
Total Dissolved Solid (TDS) (mg/l)	6.00	310.00	63.25	< 600.00
Total Suspended Solid(TSS) (mg/l)	2.00	8.00	4.20	No guideline
Conductivity (µs/cm)	12.00	725.00	141.15	< 400.00
Temperature (°C)	27.20	30.90	41.47	25.00
Turbidity (NTU)	0.00	0.10	0.10	< 1.00
Ca^{2+}(mg/l)	0.02	5.68	99.23	No guideline
Mg^{2+}(mg/l)	0.03	8.22	68.30	No guideline
Na^{+}(mg/l)	0.001	0.008	0.01	No guideline
K^{+}(mg/l)	0.045	6.289	0.95	No guideline
Fe^{2+}(mg/l)	0.008	0.269	0.11	< 0.3
Pb^{2+}(mg/l)	0.05	0.89	0.29	0.01
Cu^{2+}(mg/l)	0.001	0.015	0.01	2.0
HCO_3^- (mg/l)	4.00	4.80	4.92	No guideline
Cl^{-}(mg/l)	2.33	140.90	26.41	5.0
SO_4^{2-}(mg/l)	1.00	8.00	2.80	< 250
PO_4^{3-}(mg/l)	0.05	0.89	0.19	< 1.0

V. CONCLUSION

Hydrogeochemical characterization of the area was carried out using water samples from twenty wells. Analysis of the groundwater samples revealed results for pH, temperature, conductivity, turbidity, TDS, TSS as well as assessment of trace elements and heavy metals. The alkalis contribution of groundwater of the study area is characterized mostly by Ca^{2+} and Mg^{2+} while that of acids is dominated by Cl^-. Generally, the results showed consistency with the WHO standard for all the water sampling sites. However for proper aquifer management and sustainability of groundwater quality in the study area, we recommend the use of inorganic chemical fertilizers as those enriched with compounds such as nitrogen causes groundwater pollution hence should be discouraged. Also corrosion resistant materials is advised for the distribution systems such as water mains and pipes in household water systems. Furthermore, periodic monitoring of the quality of groundwater in the area should be carried out. This is necessary to check the level of exploration which may increase the values of some of the parameters thereby deteriorating the quality of groundwater in future.

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