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Assessment of Groundwater Quality and Suitability for Drinking purpose in Imo State, Nigeria

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ABSTRACT

***Background*:** Groundwater serves as a primary source of freshwater supply, especially in areas where surface water availability is limited or unreliable**,** which brings about a rising need to provide improved water supply for drinking purposes. This study assessed the quality and suitability of groundwater for drinking purposes in Imo state, Nigeria

Methods: A total of 19 groundwater samples from boreholes within the study area were collected for the groundwater quality and suitability assessment. Calibration of pH meter, EC/TDS meter, and turbidity meter were carried out by using the standard buffer solutions, sample bottles were washed and rinsed with distilled water. In-situ measurements of parameters such as pH and EC were taken on the site so as to avoid change during transportation and over time. Samples from the borehole were collected into the sampling bottles, which were preserved in an ice box and taken to the lab where other parameters and heavy metals were analysed.

Results: The pH values of groundwater range from 5.4 to 7.1. Values of Electrical conductivity across the study area range between 27.30 µS/cm and 97.00 µS/cm, indicating very low mineralization. The Water Quality Index (WQI) was computed using selected physicochemical parameters which show that the WQI values across the study area range from 30 to 74.

***Conclusions*:** The study revealed that the relatively low WQI values across most locations indicate that groundwater resources within the study area are generally suitable for drinking purposes with minimal treatment.

***Keywords*:** Groundwater, Heavy metals, Imo State, Physicochemical parameters, Water Quality Index

1. INTRODUCTION

One of the most important natural resources is water which can exist either as a surface or groundwater. Life will not exist without water, because it plays an important role in meeting our agricultural, domestic and industrial water demands in the whole world. Unfortunately, it is becoming increasingly scarce because of the increasing demand and deteriorating quality due to pollution, [1]. Quality of groundwater comprises of its physical, chemical and biological qualities. Some of the physical water quality parameters include color, taste and odour. While the chemical water quality parameters include pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), turbidity and temperature. Groundwater is naturally made-up of mineral ions, [2] which slowly dissolves from the particles of the soil, sediments and rocks as the water travels along the surface of the mineral within the pores or fracture of the unsaturated zone and aquifer. Compared with surface water sources, groundwater reserves are available in large quantities and are hardly exaggerated by seasonal changes such as constant temperature, etc. [3] For the above reasons, groundwater is a good substitute for surface water resources. Groundwater quality assessment involves determining the concentrations of ions which decides its suitability for household use (consumption), industrial and agricultural uses. Groundwater pollution does not only affect the water quality but also threatens human health, economic development and social prosperity. These resources cannot be used optimally unless their quality has been assessed. This makes it of prime importance to have prior information on the quality of water resources available. According to WHO organization, about 80% of all the diseases in human beings are caused by water. Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from the source. [4]. Imo state is one of such regions where groundwater resources are of paramount importance for sustaining various water-dependent activities. However, the sustainable management of these resources is facing significant challenges due to increasing population, urbanization, and

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potential impacts of climate change. The study area covers parts of Imo state. Some parts of the area are underlain by Formations that are difficult for groundwater prospecting. These Formations include the Ogwashi Asaba Formation, the Imo shale Formation, the Nsukka Formation and Bende-Ameki Formation. There is water crisis in areas underline by Benin Formation such as the Northern parts of Owerri, this is as a result of government inability to provide water for the citizen. This has resulted in proliferation of shallow substandard water wells predominantly producing water of poor quality with associated health hazards. It is imperative to conduct physicochemical analysis to ensure that water obtained for use is free of contamination. Sustainable groundwater supply development requires an understanding of the subsurface geology, aquifer characteristics and groundwater quality. This can be achieved by integrating geophysical investigation, physico-chemical analysis and hydrogeological. There are lots of indices which have been developed for use in evaluating groundwater suitability for domestic and agricultural use. One of them is the Water Quality Index (WQI) which is widely used for classifying water for drinking purposes, which is based on multiple physicochemical parameters. While for agricultural use, indices such as Sodium Adsorption Ration (SAR), Percent Sodium (%Na) and Residual Sodium Carbonate (RSC) are recommended by the Food and Agriculture Organization (FAO) to assess sodicity and infiltration hazards. In Imo state, previous studies have documented that there is a spike in nitrate, iron, and lead in groundwater, with the Benin Formation contributing to contaminant transport due to high porosity. There are limited studies in Imo state which integrated Water Quality Index for drinking suitability assessment. Therefore, this study aimed to evaluate groundwater quality and determine its suitability for drinking purpose in Imo State by using physicochemical parameters, heavy metals and Water Quality Index.

2.0 MATERIALS AND METHODS

2.1 Materials

2.1.1 Biological materials

Not applicable.

2.1.2 Chemicals and Reagents

Water samples, Buffer solutions, distilled water, formazin standard solution, Ethylenediaminetetraacetic acid (EDTA), Eriochrome black T indicator (EBT), concentrated HNO_3, Zinc standard solution, phenol disulfonic acid and nitrate standard solution.

2.1.3 Equipment and Other Materials

Portable pH meter, EC meter, Turbidimeter, Multiparameter probe, Submersible pump, Cooler box, Samples bottles, Bucket, Bailers, Lab coat, Gloves and GPS.

2.2 Methods

2.2.1 Study Area

The study area is situated between latitudes 4° 38'N and 6° 01'N and longitudes 6° 53'E and 7° 32'E, which is located in the mid south-eastern region of Nigeria as seen in figure 1 below. The climate in Imo state is humid and partially hot.

2.2.2 Sample Collection

Before samples of groundwater were taken pre-sampling preparation was first carried out, which involves calibration of all field instruments such as (pH meter, EC/TDS meter, and turbidity meter) by using the standard buffer solutions, washing and rinsing of sampling bottles (glass) with distilled water so as to remove impurities and also well purging in order to remove stagnant water from the sampling well and to ensure that parameters such as temperature, pH, Electrical Conductivity (EC) had normalized before a fresh sample is taken for reading. A total of 19 groundwater samples from boreholes within the study area were collected over a period of time into the sampling bottles.

2.2.3 Sample Preservation

Samples of groundwater collected from the sampling wells were preserved immediately in a cooler containing ice pack, this is to control the temperature of the samples. Nitric acid (HNO_3) and Sulfuric acid (H_2SO_4) were added to some samples in order to keep the metals dissolved and to stop loss of gas respectively. These samples of groundwater were then transported to the laboratory within 6 hours.

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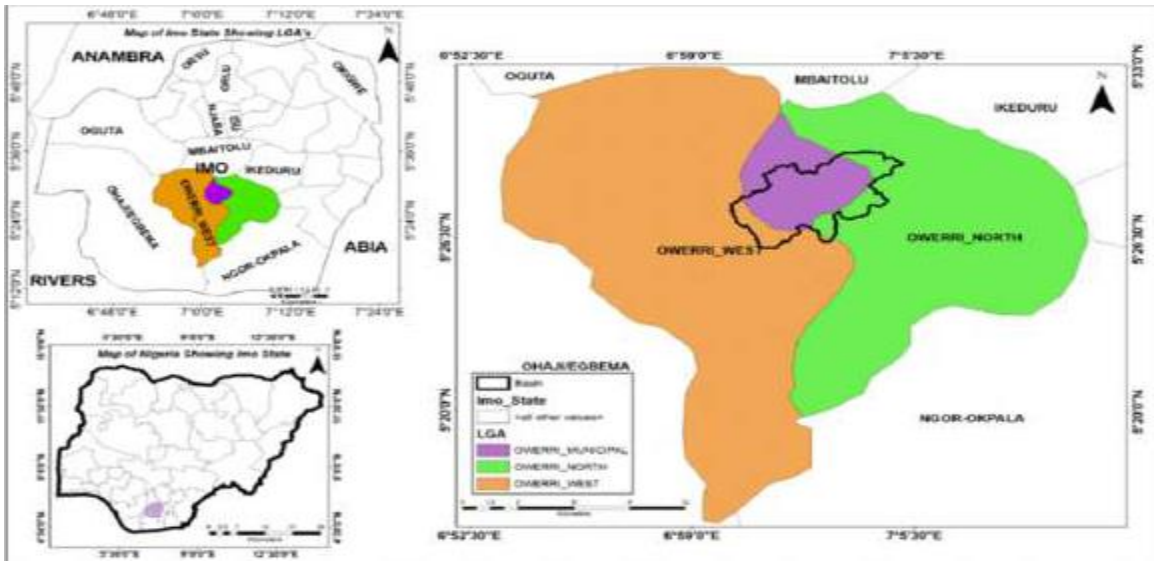

Fig 1. Map of the study Area

2.2.4 Laboratory Analysis

In-situ measurements of parameters such as temperature, pH, Electrical Conductivity (EC) were taken on the site using a calibrated Hanna H198129 pH/conductivity/TDS meter. This is because they are highly unstable and easily be changed during transportation and over time. TDS were also measured using the Hanna H198129 meter. Portable turbidimeter was used to determine the turbidity using the attenuation method at 860nm following APHA 2130B which was measured in Formazin Attenuation Unit and had a detection limit of 1 FAU. Heavy metals such as iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu) were determined by using Flame Atomic Absorption Spectrophotometer, FAAS (buck scientific 210VGP). Air-acetylene flame was used for the operating condition. The wavelengths for Fe, Zn, Mn and Cu were 248.3nm, 213.9nm, 279.5nm and 324.8nm respectively following APHA 3111B. Calibration standards of 0.1, 0.5, 1.0, 2.0 and 5.0mg/L were prepared from 1000mg/L Merck Certipur multi-element stock solution. The detection limits for Fe, Zn, Mn and Cu were given as 0.005mg/L, 0.002mg/L, 0.001mg/L and 0.00mg/L respectively. Nitrate (NO_3) was determined by using UV spectrophotometric screening method by following the APHA 4500-NO_3 B. calibration of 0.5, 1.0, 2.0, 5.0 and 10mg/L NO_3-N was prepared from 1000mg/L KNO_3 stock solution. The detection limit was 0.1mg/L NO_3-N. All samples were run in triplicates.

2.2.5 Quality Assurance and Quality control

In order to ensure reliability of the analytical data, QA/QC measures were adopted in order to validate the results. During sampling, field duplicates were collected and preserved at 4^{o}C. in the laboratory, method blank which consist of deionized water was subjected to the full digestion and analytical procedure with each batch of samples to monitor background contamination. Freshly prepared multi-element standards from 1000mg/L Merck CertiPUR stock were used for the calibration of the FAAS and UV-Vis instruments. The calibration curves had R^2 values greater than 0.995. Continuing Calibration Verification standards were employed after every 10 samples. Methods detection limits (MDL) were estimated from 7 replicate analyses of method blanks and calculated as 3 times the standard deviation. The detection limits obtained were, Fe 0.005mg/L, Zn 0.002mg/L, Mn 0.001mg/L, Cu 0.001mg/L, NO_3-N 0.1mg/L and Turbidity 1 FAU. Uncertainty in the analytical data was evaluated using duplicate precision, MDL, Spike recovery. Duplicate analyses gave RPD values of less than 10% for all parameters. MDLs were derived from replicate blanks. Spike recoveries were between 92% and 108%. Calibration was verified every 10 samples with $R^2 > 0.995$. the conventional propagation of uncertainty was not done but the QA/QC data show the results are sufficiently precise and accurate.

2.2.6 Water Quality Index Calculation

Water quality index was calculated by selecting some parameters and incorporating it into weighted arithmetic index method as given below

$$WQI=\frac{\sum WiQi}{\sum Wi} \quad 1$$

Where WQI is the water quality index which has a value between 0 and 100, Wi is the relative weight of the parameter, Qi is the quality rating of the water quality parameter, i represent number of parameters taken into consideration.

The Quality rating (Qi) is calculated with the formular below

$$Qi= 100 \times \frac{V_i-V_0}{S_i-V_0} \quad 2$$

Where V_i is the actual measured value, V_0 is the ideal value and S_i is the standard permissible value.

$$Wi= \frac{K}{Si} \quad 3$$

Where K is a constant which is given as

$$k= \frac{1}{\sum\frac{1}{Si}} \quad 4$$

2.3 Statistical Analysis

Data were analysed using IBM SPSS Statistics version 25. Descriptive statistics were expressed as mean ± standard deviation. Pearson correlation analysis was used to examine relationships among physicochemical parameters and heavy metals. Statistical significance was considered at $p < 0.05$.

3. RESULTS

The results of the physicochemical analysis obtained are presented in Table 1below and were compared with guideline values established by the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDQW) by the Standard Organization of Nigeria.

Table 1. Physico-chemical and Heavy Metal Characteristics of Groundwater with Water Quality Index (WQI)

S/N	Location	pH	EC (µS/cm)	TDS (mg/L)	Hardness (mg/L)	Turbidity (FAU)	Fe (mg/L)	Zn (mg/L)	Mn (mg/L)	Cu (mg/L)	NO_3 (mg/L)	TSS (mg/L)	Colour (Pt-Co)	WQI
1	Enyiogugu	5.50	37.64	36.32	3.80	3.00	0.00	0.50	0.40	ND	3.52	ND	2.00	42.00
2	Lorji	6.50	27.30	29.02	2.20	1.00	0.00	0.30	ND	ND	0.00	ND	2.00	36.00
3	Mbutu	6.60	29.82	70.43	2.50	3.00	0.00	0.20	ND	ND	0.00	ND	2.00	41.00
4	Nguru Nweke	6.50	79.90	44.70	1.70	2.00	0.00	0.20	ND	ND	0.00	ND	2.00	44.00
5	Nekede	6.40	37.64	24.22	2.60	2.00	3.60	0.80	ND	ND	3.52	ND	2.00	74.00
6	Eziobodo	6.10	27.30	18.70	2.90	1.00	0.80	0.40	0.01	ND	1.43	ND	2.00	56.00
7	Ihiagwa	5.40	29.82	33.43	1.60	3.00	1.60	0.60	ND	ND	0.94	ND	2.00	68.00
8	Obinze	6.10	29.90	38.70	3.30	1.00	0.60	2.00	0.01	ND	0.00	ND	2.00	58.00
9	Egbu	6.20	71.01	11.60	2.20	1.00	0.60	0.40	0.01	ND	3.01	ND	2.00	52.00
10	Orji	5.40	38.01	97.70	2.90	3.00	0.10	0.50	ND	ND	0.94	ND	2.00	47.00
11	Emekuku	6.10	29.90	38.70	3.30	1.00	0.70	0.30	0.01	ND	0.00	ND	2.00	53.00
12	Umuaka orlu	5.50	55.00	26.00	3.40	7.00	0.70	0.80	0.01	0.37	0.91	ND	2.00	64.00
13	Eziachi Orlu	5.90	95.00	47.50	2.10	1.00	0.40	2.10	0.01	0.48	13.00	ND	2.00	71.00
14	Ogberuru	6.10	38.01	36.00	2.90	0.00	0.30	1.90	ND	0.06	8.00	ND	2.00	63.00
15	Ndiuche Okigwe	5.90	95.00	47.00	3.10	1.00	0.40	2.50	0.01	ND	10.00	ND	2.00	69.00
16	Ogbaku Mbaitoli	7.00	70.50	75.50	1.40	1.00	0.00	0.00	0.01	ND	2.91	ND	2.00	32.00
17	Eziama Obiato	6.90	97.00	47.50	2.10	1.00	0.00	0.00	ND	0.00	6.00	ND	2.00	34.00
18	Umunoha Mbaitoli	6.80	42.01	46.40	1.90	1.00	0.00	0.00	0.01	ND	8.00	ND	2.00	37.00
19	Atta Ikeduru	7.10	94.00	39.30	1.10	1.00	0.00	0.00	ND	ND	0.00	ND	2.00	30.00
	WHO	6.50-8.50	500.00	1000.00	500.00	5.00	0.30	2.00	NS	2.00	50.00	NS	15.00	
	NSDQW	6.50-8.50	500.00	1000.00	500.00	5.00	0.30	3.00	NS	1.00	50.00	30.00	15.00	

ND means Not detected; NS means Not Specified

Table 2. WQI classification [10]

WQI Range	Water Quality
< 50	Excellent water
50–100	Good water
100–200	Poor water
200–300	Very poor water
> 300	Water unsuitable for drinking purpose

4. DISCUSSION

Different studies on groundwater quality within the study area has been evaluated by using selected physico-chemical parameters and heavy metals obtained from borehole samples across several communities in Imo State ([5]; [6]; [7]; [8]; [9]). Some of the physico-chemical parameters that were evaluated from the borehole samples obtained from the study area include pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), hardness, turbidity, colour, iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), and nitrate (NO_3). The pH values of groundwater across the sampled locations range from 5.40 to 7.10, indicating slightly acidic to neutral groundwater conditions. Slightly acidic conditions were observed in several locations including Ihiagwa, Orji, and Umuaka Orlu. Acidic groundwater is typical of aquifers hosted within the Coastal Plain Sands of the Benin Formation, where silica-rich sediments dominate and carbonate buffering minerals are scarce. Such acidity may also result from carbon dioxide dissolution in recharge water and organic matter decomposition. From a sustainable groundwater development perspective, slightly acidic groundwater can enhance the mobilization of certain metals, particularly iron and manganese, which may lead to aesthetic and operational problems in water supply systems. Treatment measures such as pH adjustment may therefore be required in communities where acidity persists. Electrical conductivity values across the study area range between 27.30 µS/cm and 97.00 µS/cm, indicating very low mineralization. Low EC values are characteristic of groundwater systems experiencing rapid recharge and minimal residence within the rock. The porous and highly permeable sandy lithology of the Benin Formation allows quick infiltration of rainfall, preventing prolonged mineral dissolution. Low EC values are generally favourable for sustainable water supply, as they indicate minimal salinity risk and reduced treatment requirements. The TDS concentrations range from 11.60 mg/L to 97.70 mg/L, far below the recommended limit of 500 mg/L by the World Health Organization. These low concentrations confirm that groundwater within the study area is fresh and weakly mineralized. From a sustainability perspective, low TDS groundwater indicates high recharge rates and limited anthropogenic contamination, suggesting that the aquifer system still maintains relatively natural hydrochemical conditions. Hardness values across the study area range between 1.10 mg/L and 3.76 mg/L $CaCO_3$, indicating extremely soft water conditions. Soft water is typical of sandstone aquifers where calcium and magnesium-bearing minerals are limited. Although soft water poses minimal health risk, it may lead to corrosion in distribution pipelines, which could increase trace metal concentrations over time. Total suspended solids were absent in all sampled boreholes, while turbidity values range between 0 and 7 FAU. Colour remained constant at 2 PtCo units across all locations. These results indicate that groundwater is generally clear and well filtered through the aquifer matrix, reflecting the natural filtration capacity of the sandy subsurface formations. Iron concentrations show notable variability, ranging from 0.00 mg/L to 3.60 mg/L, with the highest concentration recorded at Nekede. Values exceeding 0.30 mg/L may cause staining and taste problems. Elevated iron concentrations are likely associated with the weathering of ferruginous sediments common in the Benin Formation.

Zinc concentrations range from 0.00 mg/L to 2.50 mg/L, remaining within permissible limits. Manganese concentrations are generally very low, while copper was mostly undetected except in a few locations such as Umuaka Orlu and Eziachi Orlu. Nitrate concentrations vary between 0.00 mg/L and 13 mg/L, with relatively higher concentrations observed in Eziachi Orlu, Ndiuche Okigwe, and Ogberuru. Elevated nitrate levels may indicate agricultural runoff, septic leakage, or organic waste infiltration. For sustainable groundwater development, nitrate monitoring is critical because increasing nitrate concentrations may indicate growing anthropogenic pressure on groundwater resources. Water Quality Index (WQI) was computed using selected physicochemical parameters, which is to provide an integrated assessment of groundwater quality. WQI provides a simplified representation of overall water quality by combining multiple parameters into a single numerical value representing the suitability of water for drinking purposes. Water Quality Index values across the study area range from 30 to 74. Based on the results shown in Table 1 and the classification on Table 2 below: Excellent water quality (<50) occurs in several locations including Atta Ikeduru, Ogbaku Mbaitoli, Lorji, and Eziama Obiato. While good water quality (50–100) occurs in locations

such as Nekede, Ihiagwa, Ndiuche Okigwe, Eziachi Orlu, and Umuaka Orlu. The relatively low WQI values across most locations indicate that groundwater resources within the study area are generally suitable for drinking and domestic purposes with minimal treatment. The higher WQI values observed in locations such as Nekede, Ndiuche Okigwe, and Eziachi Orlu reflect the influence of elevated iron and nitrate concentrations, suggesting localized anthropogenic impacts. While this study provides a valuable data on groundwater quality assessment, some limitations include: the samples were collected over a period of time without assessing seasonal variation between dry and wet seasons; groundwater samples were limited to only 19 samples from boreholes within the study area (Imo state); The assessment was limited to physicochemical parameters and heavy metals; irrigation indices such as Sodium Adsorption Ratio (SAR), Sodium Percentage (%Na), Residual Sodium Carbonate (RSC), Kelly Ratio (KR), Magnesium Hazard (MH), Permeability Index (PI) were not assessed; the certified reference materials were not available.

6. CONCLUSION

Water quality index (WQI) assessment together with the physicochemical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), hardness, turbidity, colour, iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), and nitrate (NO_3) were used to evaluate the groundwater quality. The pH values range from 5.4 at Orji to 7.1 at Atta Ikeduru indicating slightly acidic to neutral groundwater conditions. The electrical conductivity values range between 27.30 µS/cm at Lorji and Eziobodo and 97.00 µS/cm at Eziama Obiata, indicating low mineralization. The TDS concentrations range from 11.6 mg/L at Egbu to 97.7 mg/L at Orji, which is below the recommended limit of 500 mg/L by the World Health Organization. These low concentrations confirm that groundwater resources across much of Imo State remain hydrochemically stable and has generally a good water quality for drinking purposes. Continuous monitoring and proper environmental management are recommended to maintain water quality.

Declaration

The authors declare that this is an original work and is not being considered for publication elsewhere.

Conflict of interest

The authors have no conflict of interest to declare

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Contribution of Authors

Adanna N Adigwe carried out the research and analysis, Leonard I. Nwosu reviewed and edited the paper while Sonny Inichinbia carried out the statistical analysis.

Ethical approval

Ethical approval was not needed as the research involved only collection of water samples. No human participants and no animal experimentation. Permission was obtained from the owners of the sampling borehole.

AI Disclosure

The authors declare that no generative AI tools were used in preparing this manuscript**.**

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