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Assessment of Groundwater Quality in Aba Metropolis, Nigeria: Water Quality Index (WQI) Approach

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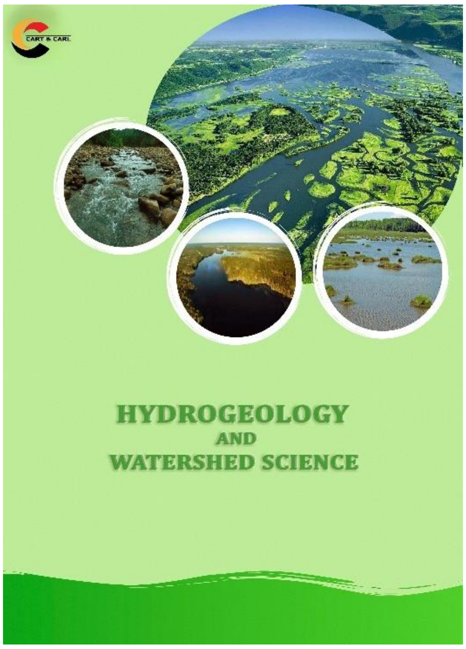

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Abstract

Groundwater constitutes the primary source of potable water for residents of Aba Metropolis, southeastern Nigeria, yet rapid urbanization and industrial expansion pose increasing risks to its quality. This study assessed the groundwater quality in Aba metropolis based on Water Quality Index (WQI) approach. Twenty (20) groundwater samples were collected from various groundwater sources across Aba North and Osisioma Ngwa Local Government Areas in January 2025. In situ measurements of pH, temperature, total dissolved solids (TDS), electrical conductivity (EC), dissolved oxygen (DO), and biochemical oxygen demand (BOD) were conducted, while heavy metals and inorganic elements were analyzed using standard laboratory procedures and Atomic Absorption Spectrophotometry. Results revealed strongly acidic groundwater conditions in both LGAs, with mean pH values (3.90–4.01) far below World Health Organization (WHO) permissible limits. Although TDS (90.3-106.63 mg/L) and EC (117.87-226.83 mg/L) values were within acceptable limits, extremely low DO levels (0.10-0.11 mg/L) indicated poor groundwater aeration and possible chemical oxygen depletion. Iron (Fe) concentrations exceeded WHO guidelines in several locations, while lead (Pb), copper (Cu), zinc (Zn), and other inorganic constituents were generally within permissible limits. WQI analysis classified groundwater in Osisioma as poor (WQI = 78.29) and groundwater in Aba North as unsuitable for drinking (WQI = 448.68), primarily due to acidity and elevated iron levels. The study concludes that groundwater quality in Aba Metropolis is significantly compromised and requires urgent management interventions, routine monitoring, and appropriate treatment before domestic consumption.

Keywords : Groundwater quality, Water Quality Index (WQI), Heavy metal contamination, Physicochemical parameters, Aba Metropolis

Introduction

The predominant component of a living organism is water. The adage that water is life underscores the necessity of prioritising this essential element of existence known as water. Water is vital for sustaining life, and a sufficient (appropriate, safe, and accessible) supply must be accessible to everyone. Enhancing access to potable water can have significant health advantages. All endeavours must be undertaken to get drinking water that is as safe as feasible (WHO, 2022). The availability of potable water is a significant concern in numerous nations, particularly in developing regions. Surface water (rivers, streams, lakes, and reservoirs) and groundwater (boreholes and wells) can provide supplies for potable water. Due to the escalating contamination of surface water, there is a growing dependence on groundwater for drinking and domestic use, as it is perceived to be purified through natural processes (Agwu et al., 2013).

The fast industrialisation and growing human population are intensifying the pressure on natural resources, making their protection a significant problem for humanity (Kauri et al., 2016). Groundwater is an essential resource for millions of individuals for drinking and agricultural purposes. The quality of groundwater is as crucial as its quantity, as it primarily influences its appropriateness for drinking, home usage, irrigation, and industrial applications (Kauri et al., 2016). The quantity of chemical contents, significantly affected by geological formations and human actions, determines groundwater quality. Agricultural and anthropogenic activities have degraded water quality, posing significant dangers to human health (Kauri et al., 2016).

Given the diverse activities of the residents of Aba, including industrialisation, urbanisation, and waste disposal, assessing the quality of groundwater in this region is both pertinent and timely, particularly in light of the recent developmental projects undertaken within and around the Aba metropolis. This project aims to conduct water quality monitoring to evaluate pollution levels in Aba city, Abia State, Nigeria. The quality of water is assessed based on its physical, chemical, and microbiological properties (Agwu et al., 2013). The World Health Organization's 2017 study defines safe drinking water as water that "does not pose any significant health risk over a lifetime of consumption, accounting for varying sensitivities across different life stages" (World Health Organisation, 2017).

Pollutants impacting drinking water sources include heavy metals from manufacturing, metallurgy, paints, chemicals, and similar industrial activities (Omole et al., 2015). Consequently, regular monitoring of water quality is essential to protect public health. Assessments of water quality have been conducted in various environments due to human activities, such as abattoirs (Kenneth et al., 2019), religious centres (Omole et al., 2017), and communities (Nwankwoala & Mzaga, 2017; Mishra et al., 2018; Oboshenure et al., 2019; Emeka et al., 2020; Al-Saffawi et al., 2020; Ram et al., 2021). The findings of these studies either determined the status of water quality or recommended ongoing monitoring or treatment. This study aims to evaluate groundwater quality in Aba metropolis, Nigeria, utilising the water quality index (WQI) model.

Materials and Methods

Study Area

The study was carried out in Aba metropolis in Abia State, located in south-eastern part of Nigeria. Aba metropolis is located approximately between longitude 07° 20' 00'' E to 07° 26' 00' 'E and latitude 05° 2' 30'' N and 5° 08' 00'' N sprawling to an approximate area of 26.7km^2 and cutting across four local government council. The four local government council within the Aba metropolis selected for this study are Aba North, Aba South, Osisioma Ngwa and Obingwa.

Sampling Points/Sites

The water samples for the study was collected from boreholes (as groundwater sources) around the study area (Aba North and Osisioma Ngwa and their communities all within Aba metropolis in Abia State). Specifically, twenty (20) groundwater samples were collected across the two (2) Local Government Councils (LGC) on January 15th 2025 (Figure 1-2). The most common ground water source in Aba is borehole water while the sampled boreholes cut across boreholes in residential buildings and other public places like markets, malls, churches, hotels and schools.

Sample Collection Procedure

Twenty (20) samples was collected across the two (2) Local Government Areas using different containers for different analysis. The 300ml containers was used to collect samples for heavy metal analysis, the 100ml sterile container was used to collect samples for microbiological analysis while beaker will be used for in situ analysis. The 1ml of 10% Nitric acid were initially added into the containers for the heavy metals sampling. All collected samples were stored cooler containing ice packs and transported to the Michael Okpara University of Agriculture, Umudike Abia State for analysis.

Data Analysis

Laboratory Analysis

The pH, temperature, Total Dissolved Solids (TDS) and Electric Conductivity (EC) was determined in situ using Hanna Analyzers (HI 99001 Hanna Instruments). Based on the American Public Health Association (APHA-2012) 3030E, the sample was digested ~1 g with HNO_3, covered and heated to near-boiling (about 95°C) for ~15 minutes and cooled. 5 mL of HNO_3 was added and heated again to near-boiling for 15 min and then cooled.

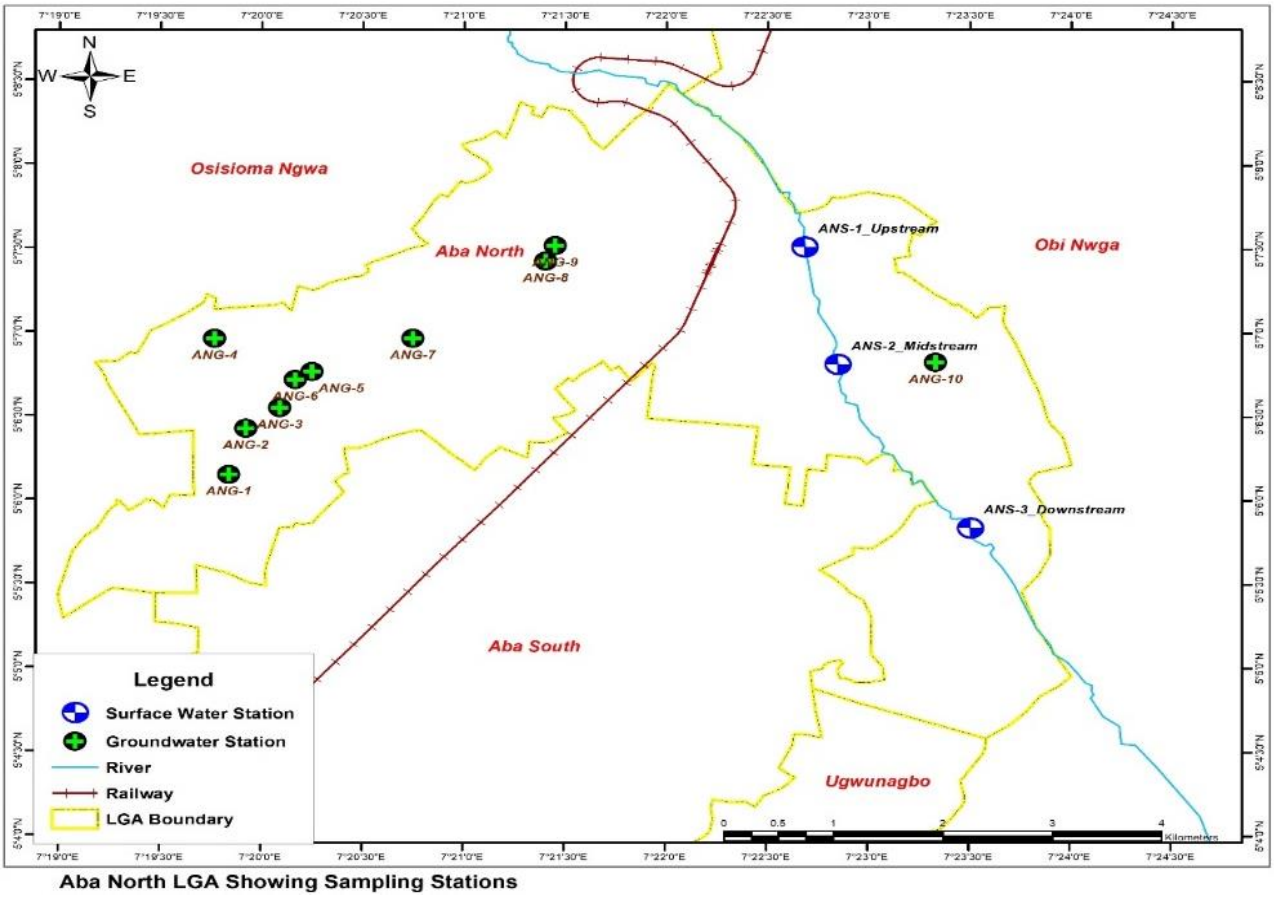

Figure 1: Overview of Sampling Points in Aba North LGC

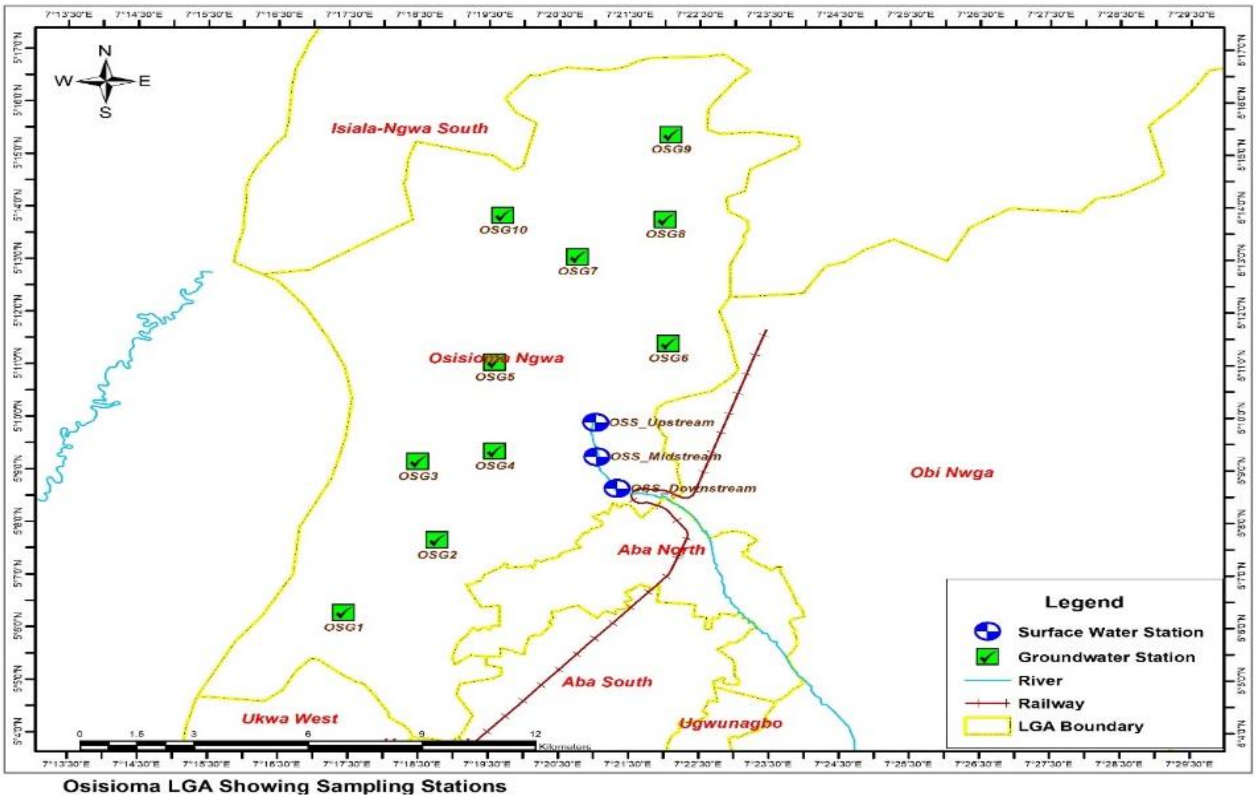

Figure 2: Overview of Sampling Points in Osisioma Ngwa LGC

Slowly, 3–5 mL 30% H_2O_2 was added in small portions, allowing the reaction to subside before heating to ~95°C, then cooled. The acidified water samples were filtered using Whatman ashless filter paper and thereafter analysed with Atomic Absorption Spectrophotometer (AAS) (Shimadzu AA-6650) using standard method (ASTM 4691) to determine the level of heavy metals (Iron (Fe), Copper (Cu), Zinc (Zn), and Lead (Pb)) in the sample (Sokpuwu, 2017; Afolabi & Adesope, 2022).

Water Quality Index (WQI)

In this study, weights (wi) will be assigned to water quality indicators based on the health consequences of those parameters for drinkable water (Chegbeleh et al., 2020). WQI is taken into consideration for human consumption. Weight values (wi = 1–5) for the parameters will be adopted based on similar studies (Ibe et al., 2020; Peterside et al., 2022), and all metals will be assigned weight values of 5 because they are essential factors that affect groundwater quality and are thought to be health-associated. In addition, WQI entails calculating the subindex (SI) (equation (3)), water quality index (WQI) (equation (4)), and relative weights (Wi) (equation (1)) and the quality rating scale (qi) (equations (3.1).

$$W_i = \frac{w_i}{\sum w_i} \quad (3.1)$$

$$q_i = \frac{C_i}{Si} \ x \ 100 \quad (3.2)$$

$$SI = Wi \ x \ qi \quad (3.3)$$

$$WQI = \sum_{n=1}^{n} SI \quad (3.4)$$

Where wi= weight values for parameters, Ci = Concentration of parameters and Si = Standard value of Parameters, qi = Quality rating scale. The standard value of WHO for parameters was adopted for the study (Afolabi *et al.*, 2022). The estimated WQIs were categorized based on Sahu and Sikdar (2008) categorization where <50: Excellent water, 50-100: Good water, 100-200: Poor water, 200-300: Very poor water, and >300: Water unsuitable for drinking.

Statistical Analysis

The laboratory analysis (concentration) of the parameters was analysed using descriptive statistics such as mean and standard deviation while the result will be presented in tabular form.

Results and Discussion

Physicochemical Concentrations

The physicochemical concentration of groundwater samples across the ten sampling points in two (2) LGAs are presented in Table 1.

Osisioma LGA: pH: Groundwater in Osisioma shows strongly acidic conditions, with pH values ranging from 3.59 (lowest) to 4.33 (highest) and a mean of 4.01 ± 0.04. All values fall far below the WHO/FMEnv acceptable range of 6.5–8.5, indicating significant acidification, possibly due to industrial emissions, hydrocarbon leaks, or acidic waste infiltration. Total Dissolved Solids (TDS) exhibit a wide variation, from 12.67 ppm (lowest) to 166.67 ppm (highest), with a mean of 90.03 ppm. Although all values lie within WHO's permissible limit of 1000 mg/L, the increasing TDS toward the commercial and industrial zones suggests moderate mineralization and potential leachate contamination. Electrical Conductivity (EC) of the samples ranged from 23.67 µS/cm to 327 µS/cm, averaging 117.87 µS/cm, indicating relatively high ionic enrichment for shallow wells. Though still within WHO's 1000 µS/cm limit, these values signal increasing dissolved ionic loads, likely from industrial and residential activities. Temperature: The values remained consistent (25.50–27.53°C; mean 27.08°C), suggesting stability of groundwater thermal regime with no major thermal pollution source. Dissolved Oxygen (DO) of the groundwater samples ranged from <0.01 mg/L to 0.14 mg/L, averaging 0.10 mg/L, indicating severe oxygen depletion. WHO recommends DO above 5 mg/L for drinking water. The extremely low DO implies possible anaerobic conditions, high organic load, or poor recharge dynamics. Biochemical Oxygen Demand (BOD) was consistently <0.01 mg/L, indicating low biodegradable organic content, yet the low DO levels point to oxygen depletion from non-organic reactions or stagnant groundwater conditions.

Aba North LGA: pH Groundwater in Aba North is also acidic, with pH values between 3.64 (lowest) and 4.12 (highest) and a mean of 3.90 ± 0.03, all significantly below the WHO's lower limit of 6.5. This confirms widespread acidification, potentially from urban runoff, industrial waste, or leachate infiltration. TDS ranged from 56 ppm to 175.33 ppm, with a mean of 106.63 ppm, all below WHO's maximum limit of 1000 mg/L. However, the spatial rise in TDS toward central urban areas suggests higher ionic loads linked to domestic and commercial activities. EC values ranged from 118.33 µS/cm to 380 µS/cm, averaging 226.83 µS/cm, higher than Osisioma's. This indicates higher mineralization, possibly from sewage infiltration, urban drainage, and densely populated environmental stress. Temperature ranged from 27.23°C to 29.10°C, with a mean of 27.75°C, within normal tropical aquifer conditions, suggesting no external heat influence. DO ranged from 0.03 mg/L to 0.17 mg/L, averaging 0.11 mg/L, far below WHO-recommended 5 mg/L. This extremely low DO indicates poor groundwater aeration, high organic and chemical oxygen demand, and stagnant water conditions. BOD remained <0.01 mg/L across all samples. Although this suggests low decomposable organic matter, the very low DO confirms non-biodegradable pollutants or chemical reactions consuming oxygen.

Table 1: Physicochemical Parameters of Groundwater across Sampling Points and Locations

Study Area (LGAs)	Sampling Points	pH	TDS (ppm)	EC (ms-¹)	Temp. (˚C)	Do	BOD
	1.00	4.26 ± 0.04	12.67 ± 3.06	23.67 ± 3.51	27.53 ± 0.25	0.11 ± 0.01	<0.01
	2.00	3.85 ± 0.05	44.33 ± 2.52	84.67 ± 3.06	25.5 ± 0.2	0.13 ± 0.01	<0.01
	3.00	4.26 ± 0.06	25.67 ± 3.06	50.33 ± 5.51	27.47 ± 0.21	0.12 ± 0.01	<0.01
	4.00	3.99 ± 0.04	49 ± 4.58	98.67 ± 2.52	27.27 ± 0.15	<0.01	<0.01
	5.00	3.59 ± 0.06	144.33 ± 4.04	293.67 ± 4.16	27.07 ± 0.12	<0.01	<0.01
Osisioma	6.00	3.76 ± 0.03	155.67 ± 3.79	305.33 ± 5.03	27.1 ± 0.1	0.11 ± 0.01	<0.01
	7.00	3.92 ± 0.04	166.67 ± 3.06	327 ± 4.36	27.4 ± 0.17	<0.01	<0.01
	8.00	4.33 ± 0.01	144.33 ± 5.13	272.33 ± 3.21	27.07 ± 0.06	0.14 ± 0.02	<0.01
	9.00	4.12 ± 0.02	40.67 ± 4.04	82 ± 2.65	27.27 ± 0.25	<0.01	<0.01
	10.00	3.99 ± 0.03	117 ± 5.57	241 ± 3.61	27.17 ± 0.15	0.09 ± 0.01	<0.01
	Mean	4.01 ± 0.04	90.03 ± 3.89	117.87 ± 3.76	27.08 ± 1.66	0.10 ± 0.01	-
	1.00	3.75 ± 0.07'	126.33 ± 4.04	253.33 ± 3.06	27.47 ± 0.35	0.08 ± 0.02	<0.01
	2.00	3.76 ± 0.03'	115.00 ± 4.58	230.00 ± 3.00	28.23 ± 0.25	0.17 ± 0.01	<0.01
	3.00	3.91 ± 0.03'	93.33 ± 4.51	174.00 ± 5.57	27.50 ± 0.40	0.11 ± 0.02	<0.01
	4.00	3.85 ± 0.01'	114.67 ± 3.51	236.67 ± 2.08	28.13 ± 0.15	0.03 ± 0.02	<0.01
	5.00	3.92 ± 0.02'	66.33 ± 7.77	126.33 ± 4.04	27.47 ± 0.42	0.11 ± 0.01	<0.01
Aba North	6.00	4.04 ± 0.05'	90.00 ± 3.00	174.00 ± 4.58	27.50 ± 0.20	0.08 ± 0.02	<0.01
	7.00	3.64 ± 0.06'	120.00 ± 3.00	235.00 ± 5.00	27.23 ± 0.15	0.13 ± 0.01	<0.01
	8.00	4.07 ± 0.04'	175.33 ± 2.52	380.00 ± 8.89	29.10 ± 0.17	0.14 ± 0.01	<0.01
	9.00	4.00 ± 0.02'	109.33 ± 6.03	214.00 ± 3.46	27.63 ± 0.15	0.11 ± 0.02	<0.01
	10.00	4.12 ± 0.02'	56.00 ± 6.00	118.33 ± 2.52	27.27 ± 0.21	0.16 ± 0.01	<0.01
	Mean	3.90 ± 0.03	106.63 ± 4.50	226.83 ± 4.22	27.75 ± 0.25	0.11 ± 0.02	-

Heavy Metal and Inorganic Concentrations

The outcome of the heavy metal (Pb, Fe, Cu, Co, Zn, Cd, Cr) concentration in groundwater samples across the ten sampling points in four LGAs are presented in Table 2.

Osisioma LGA: Lead (Pb) ranged from ND (not detected) to 0.006 mg/L, with a mean of 0.01 mg/L and all within the WHO's permissible limit of 0.01 mg/L. Iron (Fe) ranged from 0.67 mg/L to 2.41 mg/L, with a mean of 1.33 mg/L. WHO guideline is 0.3 mg/L. All values exceed the limit, indicating high iron loading, consistent with corrosion, industrial discharge, and natural leaching. Copper (Cu) ranged from 0.495 mg/L to 2.105 mg/L, with a mean of 1.39 mg/L. WHO limit is 2.0 mg/L. Many values approach the limit but remain mostly acceptable, though elevated readings indicate possible plumbing corrosion and waste seepage. Zinc (Zn) ranged from ND to 1.025 mg/L, averaging 0.467 mg/L, all below the WHO limit of 3 mg/L, indicating no zinc-related risk.

Calcium (Ca) levels ranged from 0.85 mg/L to 3.135 mg/L, averaging 1.912 mg/L. The reported concentration was below the WHO limit of 200 mg/L. Sodium (Na) ranged from ND to 0.75 mg/L, mean 0.28 mg/L, which is very low and acceptable compared to WHO limit of 200 mg/L. Magnesium (Mg) ranged from ND to 0.575 mg/L, with a mean of 0.286 mg/L, also far below WHO's 50 mg/L limit.

Aba North LGA: Lead (Pb) ranged from ND to 0.03 mg/L, with a mean of 0.01 mg/L and within the WHO limit of 0.01 mg/L. Across the 10 sampling points, Pb was below the detected limit (BDL) in 8 sampling points. Iron (Fe) values ranged from0.22 mg/L to 0.63 mg/L, mean 0.345 mg/L, with WHO's 0.3 mg/L limit indicating groundwater samples are within the standard limit.

Table 2: Heavy Metal and Inorganic Element of Groundwater across Sampling Points and Locations

Study Area (LGAs)	**Sampling Points**	**Pb**	**Fe**	**Cu**	**Zn**	**Ca**	**Na**	**Mg**	**K**
Osisioma	1.00	0.006±0.01	2.41±0.01	2.105±0.005	0.155±0.005	3.025±0.015	0.025±0.05	0.08±0.01	2.38±0.02
	2.00	0.05±0.025	1.81±0.01	1.74±0.04	0.81±0.03	2.425±0.035	0.275±0.035	0.035±0.015	1.83±0.03
	3.00	0.01±0.015	0.93±0.02	1.6±0	1.025±0.025	3.135±0.025	ND	ND	0.915±0.015
	4.00	ND	1.555±0.005	0.495±0.065	0.425±0.015	1.505±0.015	0.75±0.02	ND	1.545±0.005
	5.00	ND	0.67±0	2.05±0.02	ND	0.85±0.03	ND	0.575±0.025	0.885±0.015
	6.00	ND	0.855±0.035	1.035±0.035	ND	2.01±0.01	0.195±0.015	0.425±0.015	1.675±0.055
	7.00	0.01±0.025	1.245±0.035	0.73±0.03	0.35±0.02	1.595±0.045	ND	0.335±0.025	1.08±0.02
	8.00	ND	1.495±0.055	1.545±0.005	0.3±0.02	0.885±0.015	ND	ND	0.615±0.015
	9.00	0.005 ± 0.015	0.785±0.085	0.885±0.015	0.2±0.01	1.775±0.045	0.18±0.01	0.265±0.015	0.83±0.02
	10.00	ND	1.575±0.045	1.675±0.055	ND	ND	0.255±0.025	ND	1.63±0.02
	Mean	0.01 ± 0.02	1.33 ± 0.03	1.39 ± 0.03	0.467 ± 0.02	1.912 ± 0.03	0.28 ± 0.03	0.286 ± 0.02	1.34 ± 0.002
Aba North	1.00	ND	ND	0.92±0.02	0.34±0.01	3.025±0.015	0.025±0.005	ND	0.705±0.015
	2.00	ND	ND	1.425±0.015	2.063±0.01	2.425±0.035	0.275±0.035	1.025±0.025	0.665±0.005
	3.00	ND	0.35±0.01	0.77±0.01	1.09±0.02	3.135±0.025	ND	0.745±0.025	0.2±0.01
	4.00	ND	0.25±0.02	2.105±0.025	0.755±0.01	1.505±0.015	0.75±0.02	ND	ND
	5.00	ND	0.63±0.02	1.045±0.045	1.45±0.02	0.85±0.03	ND	2.02±0.01	0.13±0.02
	6.00	ND	ND	0.63±0.03	0.89±0.01	2.01±0.01	0.195±0.015	1.865±0.025	0.745±0.015
	7.00	0.001 ±0.01	0.325±0.005	0.88±0.02	1.16±0.01	1.595±0.045	ND	0.925±0.055	0.54±0.01
	8.00	0.03 ± 0.01	ND	1.595±0.055	ND	0.885±0.015	ND	ND	0.225±0.045
	9.00	ND	0.22±0.03	0.835±0.065	ND	1.775±0.045	0.18±0.01	1.11±0.02	ND
	10.00	ND	ND	1.575±0.045	1.635±0.035	ND	0.255±0.025	1.485±0.055	ND
	Mean	0.01 ± 0.01	0.345 ± 0.017	1.178 ± 0.33	1.043 ± 0.13	1.912 ± 0.235	0.28 ± 0.03	1.311 ±0.03	0.883 ±0.03

Cr, Cd and Co were undetected (BDL) across all sampling points and locations

Copper (Cu) ranged from 0.63 mg/L to 2.105 mg/L, mean 1.178 mg/L, all within the WHO limit of 2 mg/L. Copper levels therefore pose minimal risk despite moderate elevation. Zinc (Zn) ranged from 0.34 mg/L to 2.063 mg/L with the mean value of 1.043 mg/L and all samples were below the WHO limit of 3 mg/L, indicating no zinc-related risk.
Calcium (Ca) ranged from 0.85 mg/L to 3.135 mg/L, mean 1.912 mg/L. The reported concentration was below the WHO limit of 200 mg/L showing low mineral hardness, acceptable in drinking water. Sodium (Na) ranged from ND to 0.75 mg/L, mean 0.28 mg/L, safely below the WHO limit. Magnesium (Mg) ranged from ND to 2.02 mg/L, mean 1.311 mg/L, well below WHO's limit of 50 mg/L. Potassium (K) ranged from ND to 0.705 mg/L, with a mean of 0.883 mg/L, within safe limits.

Water Quality Index (WQI)

The WQI of groundwater samples (based on mean concentration) was evaluated for the quality for consumption and other purposes and the outcome was presented in Table 3. At Osisioma, the groundwater WQI rises to 78.29, still within the "Poor Water Quality" category but edging closer to the threshold of unsuitability. At Aba North, the groundwater WQI was exceptionally high with WQI of 448.68, which unequivocally classifies the water as "Unsuitable for Drinking." The WQI assessment for groundwater across the four locations reveals distinct gradients of water quality deterioration and varying degrees of suitability for consumption. Groundwater WQI ranged from Good (at WQI of 48) to Unsuitable (at WQI of 448.68). Osisioma and Aba North scored worst, indicating interface between industrialization and water resource deterioration. These findings mirror the WQI-GIS assessment of Aba metropolis by Nwankwo et al. (2023) where spatial clusters of poor-quality boreholes were traced to market clusters, mechanic villages and industrial estates. The reported WQI for this study were higher than those reported by Asomaku (2022) and Etim *et al.,* (2013) for groundwater around dumpsite area.

Table 3: Water Quality Index (WQI) of the Groundwater Sample from the Study Area

Parameters	w_i	Si	Wi	Osisioma			Aba North		
				Ci	Qi	SI	Ci	qi	SI
PH	4	8.5	0.09	4.10	48.24	4.34	3.90	0.46	4.14
TDS	4	50	0.09	90.03	180.06	16.21	106.63	2.13	19.17
EC	4	1000	0.09	117.87	11.79	1.06	226.83	0.23	2.07
Temp	4	40	0.09	27.08	67.7	6.09	27.75	0.69	6.21
DO	4	7.5	0.09	0.10	1.33	0.12	0.11	0.02	0.18
Ca	3	200	0.07	1.912	0.96	0.07	1.912	0.01	0.07
Na	2	200	0.04	0.28	0.14	0.006	0.28	0.0014	0.0056
Mg	2	150	0.04	0.286	0.19	0.008	1.311	0.009	0.036
K	4	12	0.09	1.34	11.17	1.005	0.883	0.07	0.63
Pb	5	0.01	0.11	0.01	100	11	0.345	34.5	379.5
Fe	3	0.3	0.07	1.33	443.33	31.03	1.178	3.93	27.51
Cu	4	2	0.09	1.39	69.5	6.26	1.043	0.52	4.68
Zn	3	3.0	0.07	0.467	15.57	1.09	1.912	0.64	4.48
ΣWi= 46					**WQI = 78.29**			**WQI = 448.68**	

Conclusion

This study provides a comprehensive assessment of groundwater quality in Aba Metropolis using physicochemical parameters, heavy metal analysis, and the Water Quality Index framework. The findings demonstrate widespread groundwater acidification across Aba North and Osisioma Ngwa, with pH values consistently below WHO standards, indicating significant hydrogeochemical disturbance likely linked to industrial activities, urban runoff, and waste infiltration. Although most dissolved solids and major ions remained within permissible limits, the persistently low dissolved oxygen levels suggest stagnant aquifer conditions and possible chemical oxygen depletion processes. Elevated iron concentrations, particularly in Osisioma, further degrade water quality and pose aesthetic and potential health concerns. The WQI results clearly indicate spatial variability in groundwater suitability, ranging from poor quality to outright unsuitability for drinking, with Aba North exhibiting critical deterioration. These outcomes highlight the inadequacy of untreated borehole water for direct consumption in the study area. Consequently, reliance on groundwater without proper treatment presents a tangible public health risk. The study underscores the need for regular groundwater quality monitoring, enforcement of environmental regulations, control of industrial discharges, and the adoption of appropriate water treatment technologies. Implementing integrated groundwater management strategies is essential to safeguard public health and ensure sustainable access to safe drinking water in Aba Metropolis.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Credit Authorship Contribution Statement

Okereke, A. I..: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Visualization, Project administration, Writing - original draft. **Nwankwoala, H. O., Osuji, L. C. and Hart, A.I.**: Supervision, Methodology, Validation, Formal analysis, Data curation, Visualization, Review & Editing.

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