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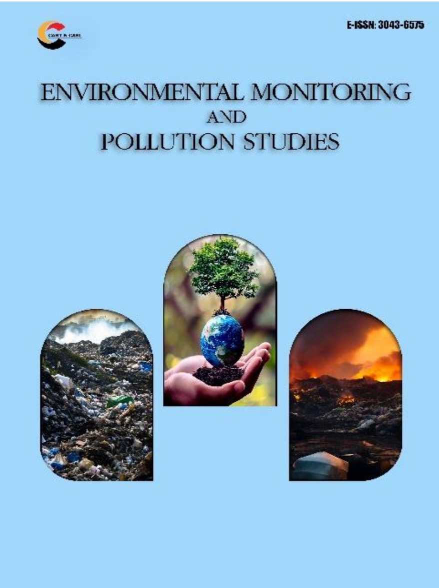


# Heavy Metals Concentration and Pollution Index (HPI) in Drinking Water in Aba Metropolis, Nigeria

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## Abstract

**Groundwater remains the primary source of drinking water in many Nigerian urban centres, yet its quality is increasingly threatened by rapid urbanisation and anthropogenic activities. This study assessed the concentration of selected heavy metals and evaluated the Heavy Metal Pollution Index (HPI) of groundwater sources in Aba metropolis, Abia State, Nigeria. A total of forty (40) borehole water samples were collected across four local government areas: Aba North, Aba South, Osisioma Ngwa, and Obingwa, during both the dry and wet seasons. Samples were analysed for iron (Fe), copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd), chromium (Cd) and cobalt (Co) using Atomic Absorption Spectrophotometry following standard APHA procedures. The results were compared with World Health Organization (WHO) guideline values, and groundwater suitability was evaluated using the HPI model. Findings revealed that Pb, Cu, and Zn concentrations across all sampling points were largely within WHO permissible limits, indicating minimal health risk from these metals. However, elevated iron concentrations exceeding the recommended limit (0.3 mg/L) were recorded in several locations, particularly in Osisioma and Obingwa LGAs, suggesting geogenic influence and possible infrastructure-related contributions. Heavy metals such as Cr, Cd and Co were not detected across all samples. The computed HPI values ranged from 0.001 to 0.10, far below the critical threshold of 100, confirming that groundwater in Aba metropolis is generally unpolluted by heavy metals. The study underscores the relative safety of groundwater in the area while highlighting the need for continuous monitoring to prevent future degradation.**

**Keywords**: Groundwater, Heavy Metal, Heavy Metal Pollution Index, Drinking Water, Urbanization

## Introduction

Groundwater serves as the primary supply of potable water, agriculture, and many domestic activities, including washing and bathing, in numerous regions of Nigeria. Groundwater is abundance and easily accessible in certain regions of Nigeria; however, its quality cannot be visually determined without laboratory analysis and comparison to established standards such as the World Health Organisation (WHO) and the Nigeria Standard for Water Quality (NSDWQ) (Emeka et al., 2020). Human activities can modify subsurface water quality at any step of the hydrologic cycle, which includes precipitation, surface runoff, infiltration, percolation, evaporation, and transpiration (Afolabi et al., 2022). Water infiltration through subterranean rocks and soil can acquire natural pollutants, even in the absence of human activity or pollution (Jeevanandam et al., 2007; Vespasiano et al., 2021).

Water quality has emerged as a significant global concern due to pollution from industrial and urban waste predominantly resulting from human activities (Ojutiku and Okojevoh, 2017). The primary anthropogenic sources of heavy metal contamination in water, sediment, and aquatic organisms include industrial activities, mining, agriculture, and the disposal of untreated or partially treated effluents containing toxic metals (Huang et al., 2020; Desiree et al., 2021; Anyanwu et al., 2022; Afolabi & Adesope, 2022). Heavy metal contamination has emerged as a global issue due to its intrinsic bioaccumulation and biomagnification capabilities, together with its prolonged persistence in environmental compartments, necessitating continuous monitoring. Typically, water utilised in residential, industrial, agricultural, commercial, and other applications is predominantly extracted from subsurface sources. Contemporary human activities, stemming from progress and urbanisation, have resulted in a proliferation of agricultural, biomedical, nuclear, industrial, and domestic waste, causing significant contamination of groundwater and the broader ecosystem (Momodu & Anyakora, 2015; Nwoke and Edori, 2020; Omireh et al., 2025). This poses significant human health risks, making it essential to determine the numerous ways human activities have affected environmental water quality. Research conducted by Nwankwoala and Ekpewerechi (2017), Hassan et al. (2021), Ali et al. (2022), Jonah and Anyanwu (2023), Al-Mayah and Al-Ghasham (2024), and Omireh et al. (2025) has presented diverse methodologies for monitoring pollutants, particularly heavy metals, in relation to water quality assurance.

Aba metropolis is a significant urban centre in Nigeria and Abia State, characterised by urbanisation and economic prospects; yet, the natural resources in the environment are severely impacted by human exploitation. The availability of high-quality ground and surface water is essential for living in urban centres; nevertheless, due to various human activities, regular monitoring of water resources is needed. This study specifically investigates the concentration of heavy metals and the pollution index (HPI) in drinking water inside Aba metropolis, Nigeria.

## 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, Aba South, Osisioma Ngwa and Obingwa and their communities all within Aba metropolis in Abia State). Specifically, forty (40) groundwater samples were collected across the Four (4) Local Government Councils (LGC) on January 15th 2025 (Figure 2-5). 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*

Fourty (40) samples was collected across the Four (4) 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*

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. 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).

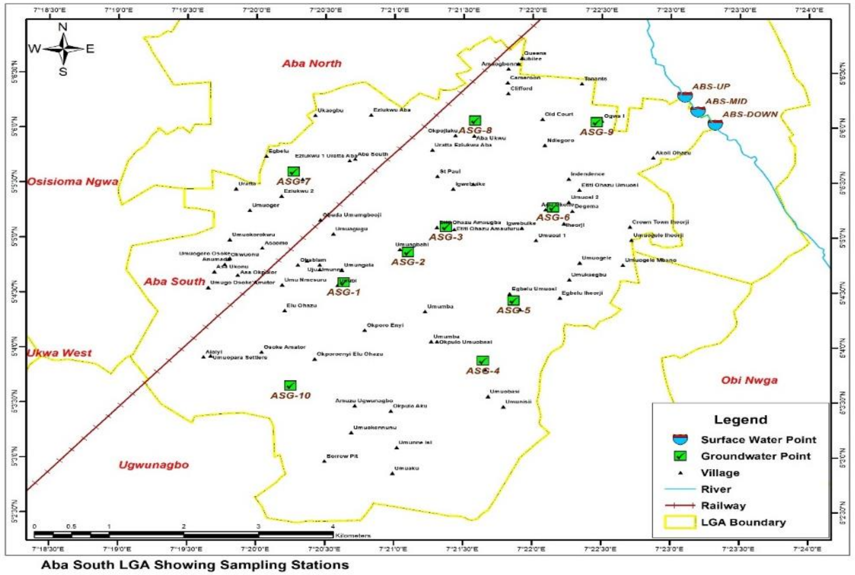


Figure 1: Overview of Sampling Points in Aba South LGC

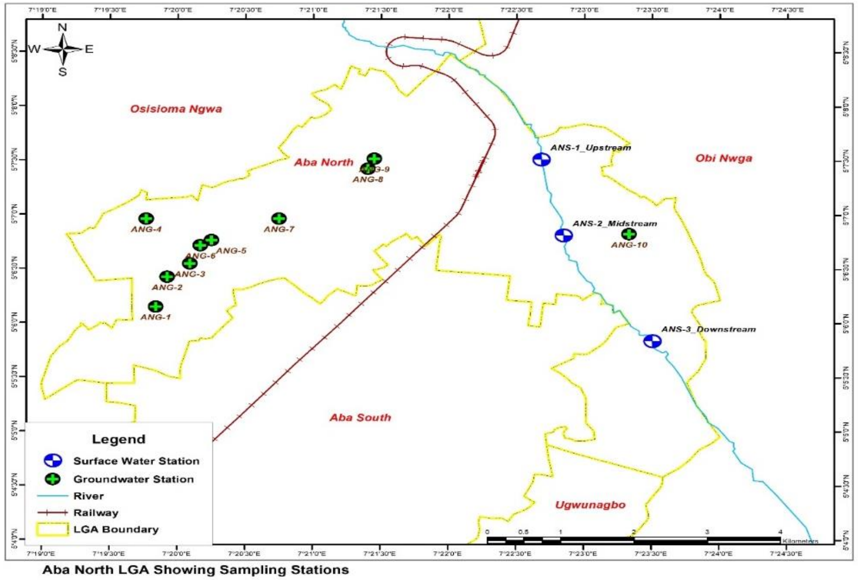


Figure 2: Overview of Sampling Points in Aba North LGC

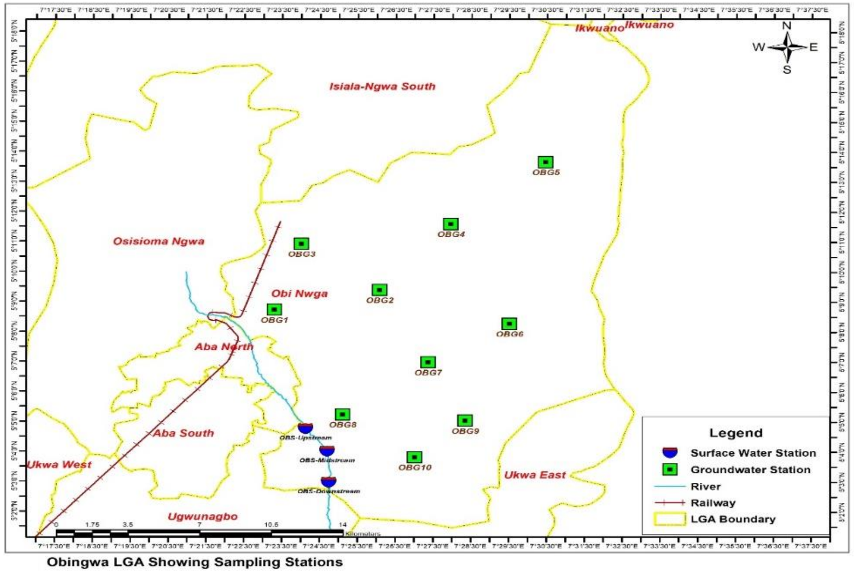


Figure 3: Overview of Sampling Points in Obingwa LGC

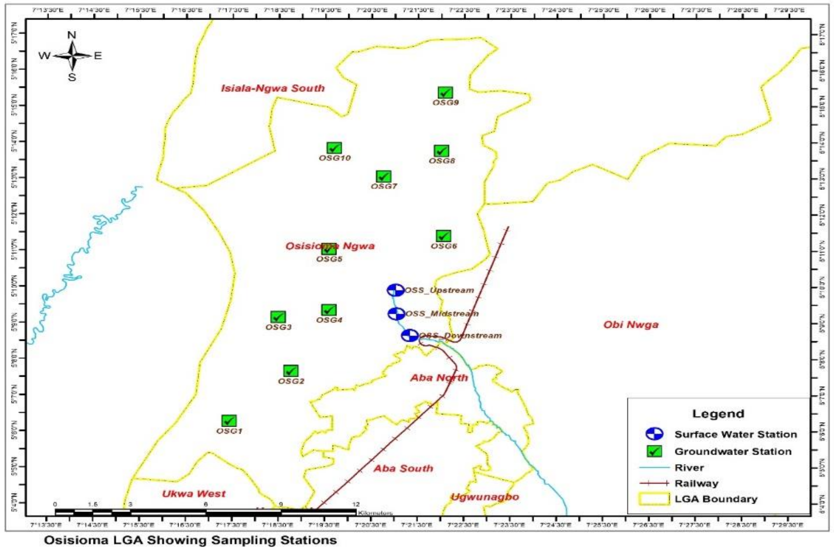


Figure 4: Overview of Sampling Points in Osisioma Ngwa LGC

*Heavy Metal Pollution Index (HPI)*

HPI estimated was based on the procedure proposed by Mohan et al. (1996) which based on the weighted arithmetic mean method which was developed on two basic steps—establishing of a rating scale for each selected quality characteristic giving weight to the selected parameter and selecting of pollution parameters on which the index was to be based on (Rahman et al., 2020). The HPI of the groundwater was expressed as:

$$HPI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i} \qquad (Eq. 1)$$

where *Qi* = the sub-index of the *i*th parameter, *Wi* = the unit weight of the *i*th parameter, and *n* = the number of parameters which was considered in the calculation. *Qi* was calculated as below:

$$Q_i = \sum_{i=I}^{n} \frac{|M_i - I_i|}{S_i - I_i} x\ 100 \qquad (Eq. 2)$$

where *Mi* = the monitored heavy metal, *Ii* and *Si* = the ideal and standard values of the *i*th parameter, respectively. The difference between *Mi* and *Ii* ignored the negative algebraic sign. The Ii values were taken from MAC values of the metals, and *Si* values were from the standard values of WHO (Afolabi et al., 2022). The lower the value of HPI, the lesser the concerns to the health; however, the critical HPI value is 100 (Zakhem & Hafez, 2015). According to Rahman et al. (2020), groundwater with HPI <100 is suitable for drinking purpose while HPI <100 is unsuitable for drinking purposes.

*Statistical Analysis*

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

## Results and Discussion

*Heavy Metal 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 1.

*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.

*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. 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.

*Aba South LGA:* Lead (Pb) was ranged from 0.001 to 0.003 mg/L), with a mean of 0.001 mg/L. Although lower than other LGAs, all detected values were within WHO's 0.01 mg/L. Iron (Fe) levels ranged from 0.025 mg/L to 0.75 mg/L, with values well below the WHO's acceptable limit. Copper (Cu) ranged from 0.85 mg/L to 3.135 mg/L with mean value of 1.72 mg/L. The reported concentration was within the WHO's limit of 2 mg/L except for point 1-3 and 6. Zinc (Zn) ranged from 0.43 mg/L to 2.125 mg/L, with a mean of 1.2 mg/L, which exceeds with values well below the 3 mg/L WHO threshold.

*Obingwa LGA:* The Pb ranged was 0.001 mg/L while it was undetected in many of the sampling points, with mean value of 0.01. all detected values were within WHO's 0.01 mg/L. Iron (Fe) ranged from 0.13 mg/L to 0.705 mg/L, with mean value of 1.07. The reported concentration across the sampling points exceeded the WHO's 0.3 mg/L limit. Copper (Cu) ranged from 0.215 to 0.735 mg/L, with mean value of 0.527. The reported concentration was within the WHO's limit of 2 mg/L. Zinc (Zn) ranged from 0.615 mg/L to 2.38 mg/L, with mean value of 1.339. From the outcome, all values reported across the sampling points are below WHO limits of 3 mg/L, indicating no zinc-related risk.

The concentrations of heavy metals (Cu, Pb, Zn, Fe, Co, Cd, and Cr) in the groundwater are below the permissible limits set by WHO and FMENV, with the exception of Fe, while Co, Cd, and Cr were not discovered at any sampling locations. The increased iron levels were documented in the study by Erhiga et al. (2024), due to enhanced geochemical mobilisation. The reported concentration of Fe was comparable to that documented by Naminata et al. (2018) and Laniyan and Adewumi (2019). The stability of groundwater lead indicates restricted percolation of metallic waste into deeper aquifers, consistent with observations in Ogun State, where shallow wells adjacent to industries exhibited lead spikes, while deeper wells remained uncontaminated (Ojekunle et al., 2020). The lack of cadmium and chromium in the majority of groundwater sites is promising, signifying the absence of detectable contamination from plating, tanning, or mining activities, in contrast to heavily industrialised areas like Onitsha and Port Harcourt, where Cr and Cd are commonly documented (Saheed et al., 2020).

*Heavy Metal Pollution Index (HPI) of the Groundwater*

The HPI of groundwater from many sampling locations was evaluated and given in Table 2. Obingwa exhibited the lowest groundwater HPI value of 0.001, closely succeeded by Aba South, which recorded an HPI of 0.02, both categorised within the realm of very low contamination. Osisioma exhibits a minor rise, with a groundwater HPI of 0.05,indicating a marginally higher yet still acceptable level of metal contamination.

Table 1: Heavy Metal Concentration in Groundwater across Sampling Points and Locations

| Study Area (LGAs) | Sampling Points | Pb | Fe | Cu | Zn |
|---|---|---|---|---|---|
| Osisioma | 1.00 | 0.006±0.01 | 2.41±0.01 | 2.105±0.005 | 0.155±0.005 |
| | 2.00 | 0.05±0.025 | 1.81±0.01 | 1.74±0.04 | 0.81±0.03 |
| | 3.00 | 0.01±0.015 | 0.93±0.02 | 1.6±0 | 1.025±0.025 |
| | 4.00 | ND | 1.555±0.005 | 0.495±0.065 | 0.425±0.015 |
| | 5.00 | ND | 0.67±0 | 2.05±0.02 | ND |
| | 6.00 | ND | 0.855±0.035 | 1.035±0.035 | ND |
| | 7.00 | 0.01±0.025 | 1.245±0.035 | 0.73±0.03 | 0.35±0.02 |
| | 8.00 | ND | 1.495±0.055 | 1.545±0.005 | 0.3±0.02 |
| | 9.00 | 0.005 ± 0.015 | 0.785±0.085 | 0.885±0.015 | 0.2±0.01 |
| | 10.00 | ND | 1.575±0.045 | 1.675±0.055 | ND |
| | **Mean** | 0.01 ± 0.02 | 1.33 ± 0.03 | 1.39 ± 0.03 | 0.467 ± 0.02 |
| Aba North | 1.00 | ND | ND | 0.92±0.02 | 0.34±0.01 |
| | 2.00 | ND | ND | 1.425±0.015 | 2.063±0.01 |
| | 3.00 | ND | 0.35±0.01 | 0.77±0.01 | 1.09±0.02 |
| | 4.00 | ND | 0.25±0.02 | 2.105±0.025 | 0.755±0.01 |
| | 5.00 | ND | 0.63±0.02 | 1.045±0.045 | 1.45±0.02 |
| | 6.00 | ND | ND | 0.63±0.03 | 0.89±0.01 |
| | 7.00 | 0.001 ±0.01 | 0.325±0.005 | 0.88±0.02 | 1.16±0.01 |
| | 8.00 | 0.03 ± 0.01 | ND | 1.595±0.055 | ND |
| | 9.00 | ND | 0.22±0.03 | 0.835±0.065 | ND |
| | 10.00 | ND | ND | 1.575±0.045 | 1.635±0.035 |
| | **Mean** | 0.01 ± 0.01 | 0.345 ± 0.017 | 1.178 ± 0.33 | 1.043 ± 0.13 |
| Aba South | 1.00 | ND | 0.025±0.005 | 3.025±0.015 | 0.615±0.015 |
| | 2.00 | ND | 0.275±0.035 | 2.425±0.035 | 0.83±0.02 |
| | 3.00 | ND | ND | 3.135±0.025 | 1.63±0.02 |
| | 4.00 | ND | 0.75±0.02 | 1.505±0.015 | 2.125±0.015 |
| | 5.00 | 0.001±0.01 | ND | 0.85±0.03 | 0.745±0.025 |
| | 6.00 | 0.001±0.01 | 0.195±0.015 | 2.01±0.01 | 0.43±0.02 |
| | 7.00 | 0.003±0.01 | ND | 1.595±0.045 | 1.545±0.005 |
| | 8.00 | 0.001±0.01 | ND | 0.885±0.015 | 0.885±0.015 |
| | 9.00 | ND | 0.18±0.01 | 1.775±0.045 | 1.675±0.055 |
| | 10.00 | ND | 0.255±0.025 | ND | 1.475±0.045 |
| | **Mean** | 0.001 | 0.28 ± 0.01 | 1.72 ± 0.02 | 1.2 ± 0.02 |
| Obingwa | 1.00 | ND | 0.705±0.015 | ND | 2.38±0.02 |
| | 2.00 | ND | 0.665±0.005 | ND | 1.83±0.03 |
| | 3.00 | ND | 0.2±0.01 | ND | 0.915±0.015 |
| | 4.00 | ND | ND | ND | 1.545±0.005 |
| | 5.00 | 0.001±0.01 | 0.13±0.02 | ND | 0.885±0.015 |
| | 6.00 | ND | 0.745±0.015 | ND | 1.675±0.055 |
| | 7.00 | ND | 0.54±0.01 | 0.63±0.01 | 1.08±0.02 |
| | 8.00 | ND | 0.225±0.045 | 0.735±0.025 | 0.615±0.015 |
| | 9.00 | 0.001±0.01 | ND | 0.215±0.015 | 0.83±0.02 |
| | 10.00 | ND | ND | ND | 1.63±0.02 |
| | **Mean** | 0.001 ± 0.01 | 1.07 ± 0.02 | 0.53 | 1.339 ±0.02 |

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

Table 2: Heavy Metal Pollution Index (HPI) of Groundwater

| Metals | S Standard | Standard value in PPb ($S_i$) | $L_i$ Ideal Value | $M_i$ Monitor Value | $1/S_i$ Unit W1 Weight | $M_i - L_i$ | $S_i - L_i$ | $Q = \frac{Mi-Li}{Si-Li} x \frac{100}{}$ | Wi * Qi | $HPI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **Osisioma** | | | | | | | | | | |
| Pb | 0.01 | 10 | 0 | 0.01 | 0.1 | 0.01 | 10 | 0.1 | 0.1 | |
| Fe | 0.3 | 300 | 0 | 1.33 | 0.0033 | 1.33 | 300 | 0.44 | 0.44 | |
| Cu | 2 | 2000 | 0 | 1.39 | 0.0005 | 1.39 | 2000 | 0.07 | 0.07 | **0.63** |
| Zn | 3.0 | 3000 | 0 | 0.467 | 0.00033 | 0.467 | 3000 | 0.016 | 0.016 | |
| | | | | | | | | | **Σ WiQi = 0.6284** | |
| **Aba North** | | | | | | | | | | |
| Pb | 0.01 | 10 | 0 | 0.001 | 0.1 | 0.001 | 10 | 0.01 | 0.01 | |
| Fe | 0.3 | 300 | 0 | 1.043 | 0.0033 | 1.043 | 300 | 0.35 | 0.35 | |
| Cu | 2 | 2000 | 0 | 1.178 | 0.0005 | 1.178 | 2000 | 0.06 | 0.06 | **0.43** |
| Zn | 3.0 | 3000 | 0 | 0.345 | 0.00033 | 0.345 | 3000 | 0.012 | 0.012 | |
| | | | | | | | | | **Σ WiQi = 0.428** | |
| **Aba South** | | | | | | | | | | |
| Pb | 0.01 | 10 | 0 | 0.001 | 0.1 | 0.001 | 10 | 0.01 | 0.01 | |
| Fe | 0.3 | 300 | 0 | 0.28 | 0.0033 | 0.28 | 300 | 0.09 | 0.09 | |
| Cu | 2 | 2000 | 0 | 1.72 | 0.0005 | 1.72 | 2000 | 0.086 | 0.086 | **0.23** |
| Zn | 3.0 | 3000 | 0 | 1.2 | 0.00033 | 1.2 | 3000 | 0.04 | 0.04 | |
| | | | | | | | | | **Σ WiQi = 0.226** | |
| **Obingwa** | | | | | | | | | | |
| Pb | 0.01 | 10 | 0 | 0.001 | 0.1 | 0.001 | 10 | 0.01 | 0.01 | |
| Fe | 0.3 | 300 | 0 | 1.07 | 0.0033 | 1.07 | 300 | 0.36 | 0.36 | |
| Cu | 2 | 2000 | 0 | 0.527 | 0.0005 | 0.527 | 2000 | 0.026 | 0.026 | **0.44** |
| Zn | 3.0 | 3000 | 0 | 1.339 | 0.00033 | 1.339 | 3000 | 0.045 | 0.045 | |
| | | | | | | | | | **Σ WiQi = 0.441** | |

**Wi= Pb: 0.33, Fe:0.2, Cu:0.27, Zn:0.2, ΣWi = 1**

Aba North exhibits the highest groundwater HPI, recorded at 0.10. The groundwater HPI readings exhibit a development from Obingwa (0.001) to Aba South (0.02), then to Osisioma (0.05), and finally to Aba North (0.10). All readings remain much below the essential HPI threshold. HPI levels in groundwater were minimal (range from 0.001 to 0.10), signifying that all four locations had HPI values beneath the crucial threshold of 100. According to the HPI classification by Rahman et al. (2020), all sample sites with HPI < 100 indicate an absence of heavy metal pollution. The HPI value revealed in the current study is inferior to that reported by Asomaku (2022). The low HPI indicates that groundwater is predominantly safe from heavy-metal contamination; yet, Aba North requires vigilant monitoring to avert further decline.

## Conclusions

This study assessed heavy metal concentrations and the Heavy Metal Pollution Index of groundwater sources in Aba metropolitan to ascertain their suitability for potable use. The findings demonstrate that groundwater in Aba North, Aba South, Osisioma Ngwa, and Obingwa LGAs is predominantly secure about heavy metal contamination. Lead, copper, and zinc concentrations consistently adhered to World Health Organisation allowed limits, however cadmium, chromium, and cobalt were undiscovered at all test locations, indicating negligible industrial metal intrusion into the aquifer system. Iron was the sole element that surpassed guideline limits in multiple locations, notably in Osisioma and Obingwa, indicating the impact of natural geochemical processes, corrosion of borehole infrastructure, or localised human activity. Notwithstanding elevated iron concentrations, the computed Heavy Metal Pollution Index values for all sites were markedly below the critical threshold of 100, hence affirming the lack of heavy metal contamination and demonstrating the general appropriateness of groundwater for household utilisation.

The regional diversity in metal contents underscores the necessity of localised evaluations instead of generalised assumptions regarding groundwater quality. Although present conditions indicate a minimal contamination risk, escalating urbanisation, waste management methods, and industrial growth in Aba metropolitan may jeopardise groundwater quality in the future. Consequently, regular monitoring, enhanced waste management methods, and increased public knowledge are very advisable to maintain groundwater safety. The results offer a crucial foundation for policymakers and environmental managers to enact proactive groundwater preservation measures in metropolitan areas of Nigeria.

**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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