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Evaluating Groundwater Safety: Heavy Metal Contamination of Selected Boreholes across Uyo Metropolis, Akwa Ibom State, Nigeria

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Abstract

In light of growing concerns about water quality and its effects on public Health, this study offers an in-depth analysis of heavy metal concentrations in selected boreholes water within Uyo Metropolis in Akwa Ibom State. The research also emphasizes the potential health risks associated with these heavy metals, particularly as some have been found to exceed the acceptable drinking water limits set by the World Health Organization (WHO). Borehole water samples from ten strategically selected locations were collected and analyzed for heavy metals using Atomic Absorption Spectrophotometry (AAS) to quantify the concentrations of copper, zinc, iron, chromium, and nickel. The results revealed a mean iron concentration of 0.551 mg/L of the composite water samples, surpassing the guidelines set by the World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ), indicating a pervasive risk to consumers. Additionally, elevated levels of nickel (0.298 mg/L) were detected in several samples, further exacerbating the public health implications. The findings underscore the critical need for policy intervention and infrastructure investment to ensure the safety and sustainability of safe water resources for human use.

***Keywords:** Water, boreholes, heavy metal, heavy metal concentrations, Health*

INTRODUCTION

The importance of water to man and his environment cannot be overemphasized. Potable water is necessary for human health and socioeconomic growth (Udongwo et al., 2022). However, some human activities and natural occurrences continuously pollute water sources, affecting water quality. The amount of rainfall, local human activity, and local natural processes significantly impact groundwater quality (boreholes) in a given area. However, this essential commodity is lacking in many societies. Given the importance of clean and safe water, a chemically, physically, and microbiologically safe supply is crucial for the survival and Health of humans and animals alike. Over the years, boreholes have emerged as a primary source of water in rural, semi-urban, and urban areas, underscoring the need for consistent monitoring and maintenance to ensure water quality(Boadi *et al.*, 2020; Imoh *et al.*, 2021). After the colonial era, Nigeria has continued to invest in water drilling technologies and infrastructure. Over time, Nigeria has undertaken several programs and initiatives to enhance access to clean water, particularly in rural regions. As a result, numerous boreholes have been drilled across the country, increasing the availability of safe and reliable water sources for the population. Although borehole water is generally considered safe for consumption due to its drinkable, accessible, and occasionally odorless nature, various studies indicate it can be susceptible to contamination (Boadi *et al.*, 2020; Usoh *et al.*, 2023).

The borehole water quality is influenced by the climate, human activity, and aquifer geology. The use of borehole water sources has grown in many nations due to rapid urbanization and population growth. Hence, due to urbanization, many industries release their wastes directly into the environment without pre-treating it. Thus, toxic substances such as bromates, ammonia, and some heavy metals are referred to as trace elements because they occur in minute quantities in a sample. They are the metallic elements of the periodic table. Heavy metal pollution has received great health and environmental concern among all forms of water pollution because most are toxic and will accumulate and mix with borehole water (Udongwo *et al*., 2022). Urbanization's impact is significantly experienced in areas bordering Uyo Urban, resulting in pollution diffusion from factors such as cut and filled soil, vehicular traffic, earthmoving equipment, wastewater flow, stagnant, polluted wastewater puddles, and solid waste movement. The coastal plain sand geology is mostly flat, causing surface water sources to be relatively scarce and found only in certain isolated locations.

Due to the need to meet the increased demand for water from residential and transiting populations brought about by the urbanization effect, which has also attracted internal migrants from farm households to towns for residence, employment, and job search, groundwater-especially borehole supply the primary source of water for drinking and other purposes(Imoh *et al*., 2021).

In light of the growing need for readily available water sources, the current research aims to assess the levels of heavy metals in borehole waters in selected areas in Uyo Metropolis, Akwa Ibom State. The study evaluates different heavy metal concentrations in borehole water in the urban region, indicating a range of iron, copper, zinc, chromium, and nickel amounts.

MATERIALS AND METHODS

Study area

Uyo, the capital city of Akwa Ibom State in South Nigeria, has an estimated population of 1,265,000. The city is situated at geographic coordinates that lie between 4°30" and 5°30" north latitude and 7°30" and 8°30" east longitude, encompassing a sizable area within the region. (Usoh *et al*., 2023)Located at an altitude of 45 meters above sea level, Uyo has a tropical equatorial climate characterized by two primary seasons: a wet season from March to September and a dry season from October to February. The city maintains a stable temperature throughout the year, with an average monthly temperature of 27°C and relative humidity between 75-90%. The wet season experiences significant rainfall, commencing in March and reaching its peak in June, while the dry season features a short period of dry weather, referred to as the 'August break' by locals. Uyo's equatorial climate creates a verdant tropical environment with consistent precipitation and temperatures (Usoh *et al*., 2023).

Locations and Sampling Methods

Collecting water samples from 10 distinct boreholes involved careful preparation of polyethylene bottles. Initially, the bottles were meticulously washed with distilled water to remove contaminants. The bottles were filled with distilled water and transported to the sampling locations. Once there, the bottles were emptied and rinsed with the borehole water before filling them with the water samples for analysis. This process ensured that the collected samples represented the actual borehole water quality. The collection process was repeated for all 10 designated A-J locations to ensure accurate and consistent data. Polyethylene bottles are common in scientific water sampling, as they are strong, light, and resistant to chemicals.

Five different samples were collected and mixed in each of the sample locations to form a composite sample representing that location. The water samples were collected from 10 different locations, which are listed below with their coordinates. Mbiaobong Ikot Essien: 4.986581 N., 7.97542 E (Sample A), ObioOffot: 5.011866 N., 7.874282 E (Sample B), Itu road: 5.041454 N., 7.921352 E (Sample C), Udo Ekpo Mkpo: 5.026733 N., 7.93655 E (Sample D), MberebeObio: 4.997221 N., 7.900738 E (Sample E), IBB Avenue: 5.017630 N., 7.911793 E (Sample F), Nkemba Street: 5.0374472 N., 7.909296 E (Sample G), Ediene Ikot Obio: 5.024901 N., 7.855056 E (Sample H), IdongesitNtem Isua

Avenue: 5.023369 N., 7.976205 E (Sample I) and Akwa Efak: 5.005892 N., 7.940667 E (Sample J). Each site is located in Uyo, Nigeria, and the coordinates are given to ensure precise location information. The coordinates are based on the Universal Transverse Mercator (UTM).

Methods of Heavy Metal Determination

The analytical process commenced with carefully transferring 100 ml of the water sample into a 250 mL beaker. Then, 10 ml of concentrated nitric acid was introduced into the beaker. The solution was heated on a hot plate for 10 minutes at 100 °C. This vital step aimed to concentrate the solution and reduce its volume, both critical for the ensuing analytical procedures. After the heating phase, the solution was cooled down, and the concentrated solution was meticulously moved to a fresh sample bottle for further analysis. In chemical testing, concentration and volume reduction are standard practices that improve the detectability and measurability of targeted compounds in a solution. To ascertain the metal concentration, the Perkin Elmer Atomic Absorption Spectrophotometer (AAS) Model Optima 8300 series was employed. Each sample was analyzed in triplicates to ensure the accuracy and reproducibility of the results. This approach helps to minimize potential errors and enhance the reliability of the data obtained from the analysis

The study evaluated the concentrations of heavy metals found in borehole water against established safety thresholds determined by the World Health Organization (WHO, 2018) and the Nigerian Standard for Drinking Water Quality (NSDWQ, 2015). By conducting these comparisons, the research aimed to assess the drinkability of the borehole water and the health risks posed by elevated heavy metal concentrations in the water.

RESULTS

This study revealed different concentrations of five heavy metals in borehole water from different parts of Uyo (Mbiaobong Ikot Essien: 4.986581 N., 7.97542 E (Sample A), ObioOffot: 5.011866 N., 7.874282 E (Sample B), Itu road: 5.041454 N., 7.921352 E (Sample C), Udo Ekpo Mkpo: 5.026733 N., 7.93655 E (Sample D), MberebeObio: 4.997221 N., 7.900738 E (Sample E), IBB Avenue: 5.017630 N., 7.911793 E (Sample F), Nkemba Street: 5.0374472 N., 7.909296 E (Sample G), Ediene Ikot Obio: 5.024901 N., 7.855056 E (Sample H), IdongesitNtem Isua Avenue: 5.023369 N., 7.976205 E (Sample I) and Akwa Efak: 5.005892 N., 7.940667 E (Sample J), to compare with the reference (WHO, 2018 and NSDWQ, 2015) standard values for drinking water as depicted in Table 1.

Table 2 compares heavy metal concentrations in borehole water samples from Uyo Metropolis against the World Health Organization (WHO, 2018) and Nigeria Standard for Drinking Water Quality (NSDWQ, 2015) guidelines.

Table 1: Levels of Heavy Metals in Borehole Water Samples collected within Uyo Metropolis, Akwa Ibom State

Sample ID	Cu (mg/L)	Zn (mg/L)	Fe (mg/L)	Cr (mg/L)	Ni (mg/L)
A	0.21 ± 0.1	0.33± 0.2	0.41± 0.5	0.02± 0.1	0.25± 0.2
B	0.18± 0.3	0.19± 0.1	0.53± 0.3	0.12± 0.2	0.26± 0.3
C	0.25± 0.3	0.17± 0.1	0.82± 0.3	0.04± 0.5	0.29± 0.1
D	0.22± 0.2	0.28± 0.1	0.44± 0.4	0.01± 0.6	0.35± 0.1
E	0.16± 0.1	0.19± 0.5	0.39± 0.2	0.01± 0.1	0.38± 0.2
F	0.31± 0.1	0.27± 0.1	0.65± 0.3	0.01± 0.1	0.27± 0.4
G	0.13± 0.3	0.23± 0.2	0.72± 0.1	0.13± 0.1	0.24± 0.2
H	0.29± 0.4	0.14± 0.3	0.58± 0.1	0.02± 0.1	0.41± 0.2
I	0.19± 0.3	0.31± 0.2	0.38± 0.1	0.01± 0.3	0.22± 0.1
J	0.14± 0.2	0.39± 0.2	0.59± 0.1	0.02± 0.2	0.31± 0.3

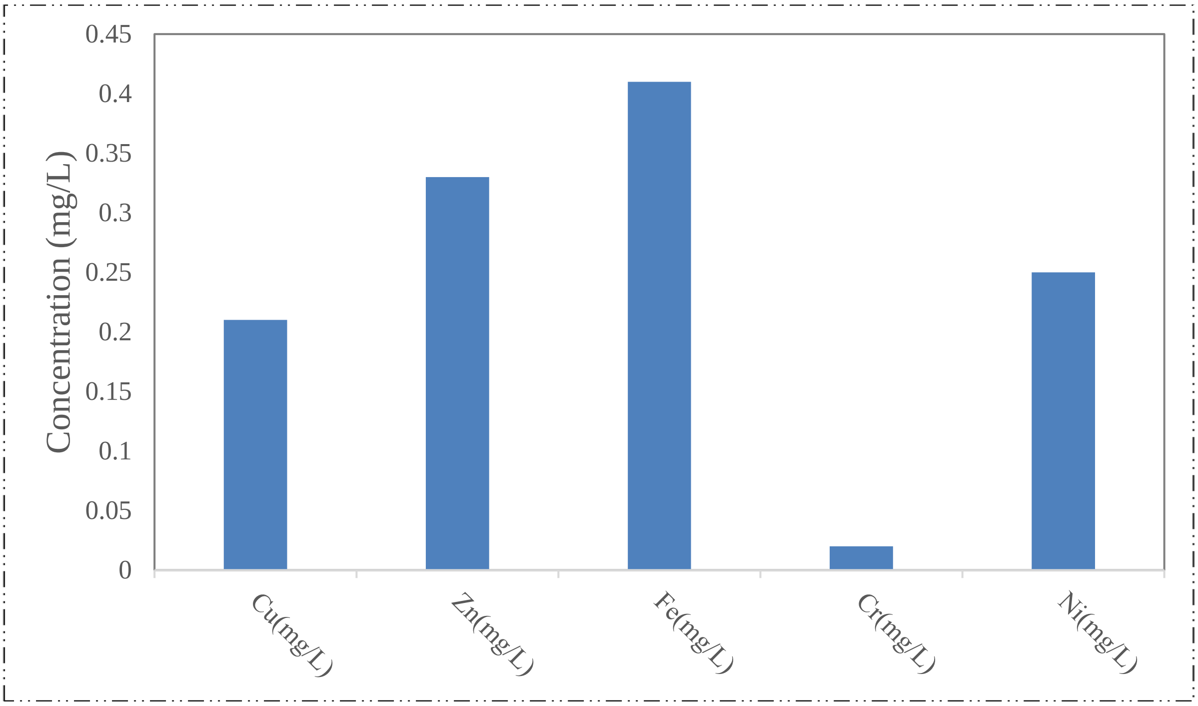

Figure 1: Concentration of metals (mg/l) in water sample A (Mbiaobong Ikot Essien)

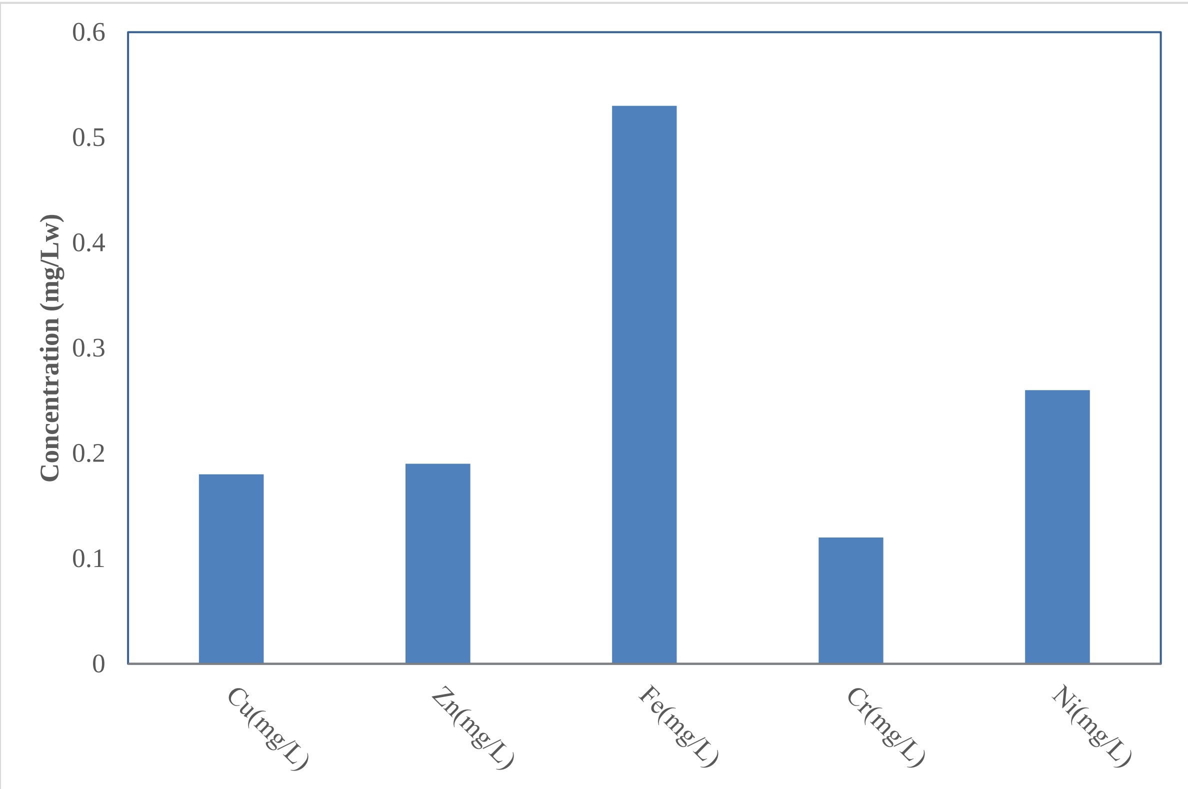

Figure 2: Concentration of metals (mg/l) in water sample B (Obio Offot)

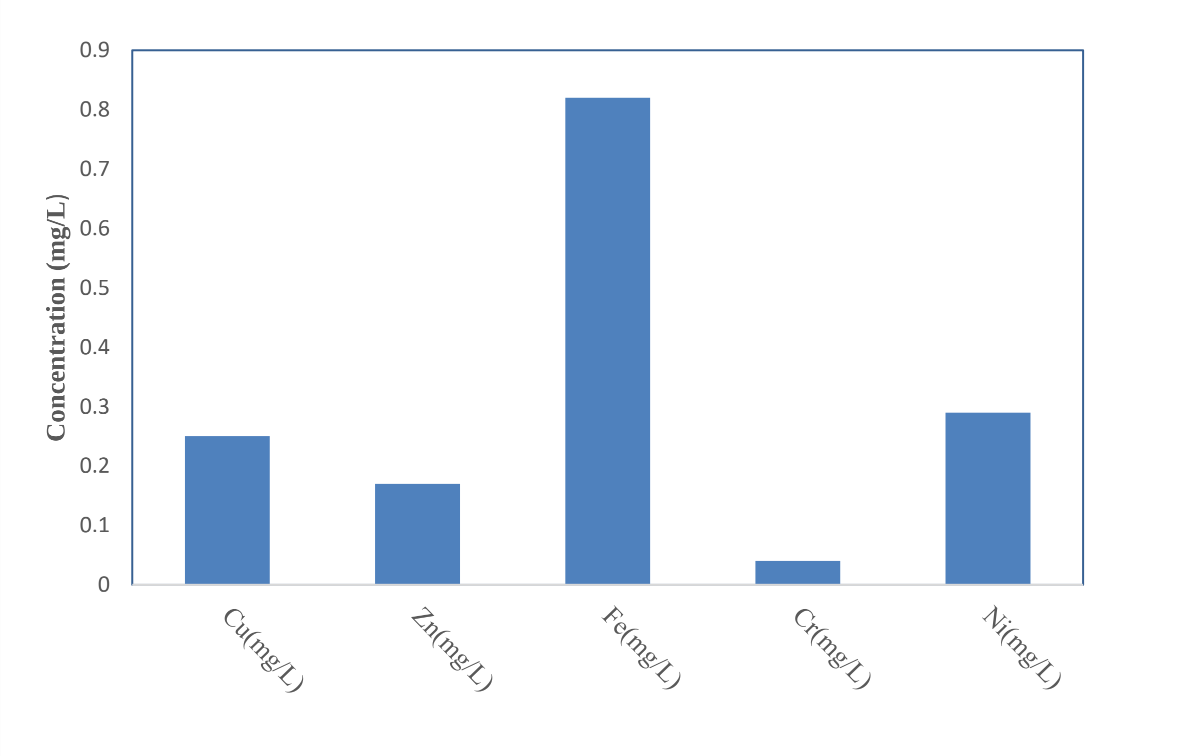

Figure 3: Concentration of metals (mg/l) in water sample C (Itu Road)

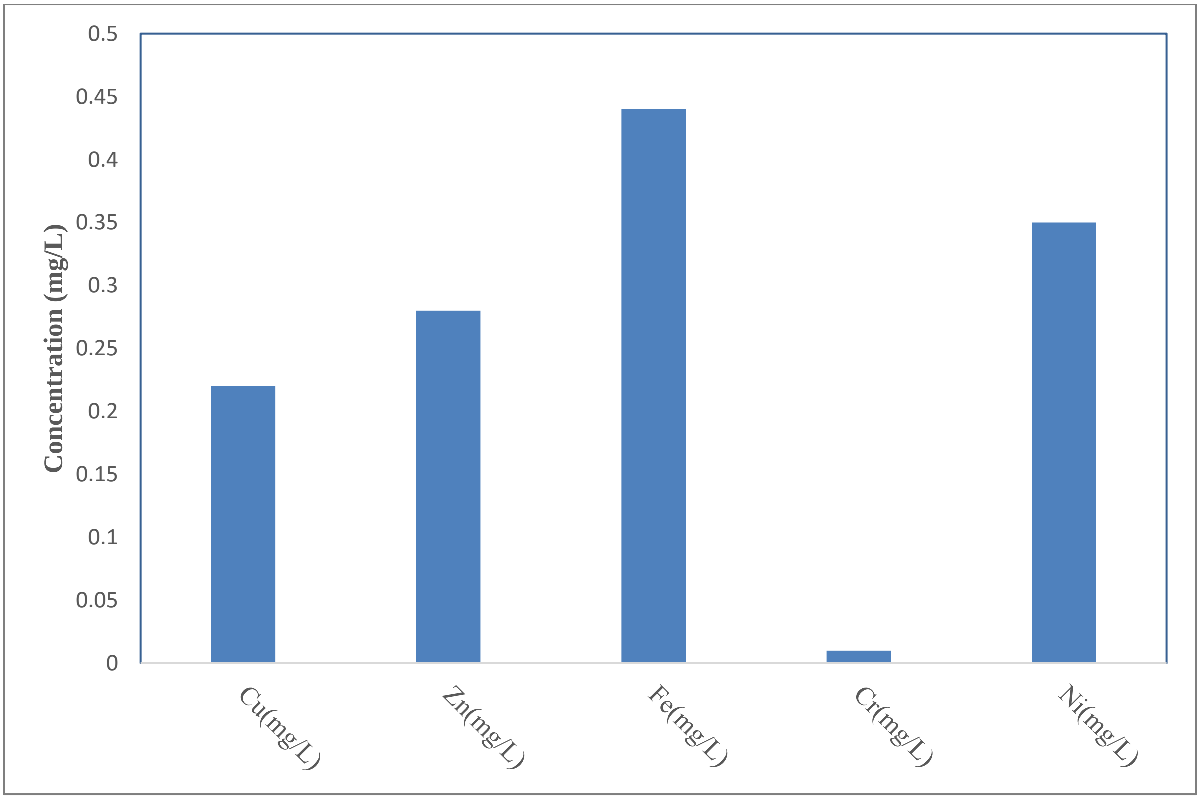

Figure 4: Concentration of metals (mg/l) in water sample D (Udo Ekpo Mkpo)

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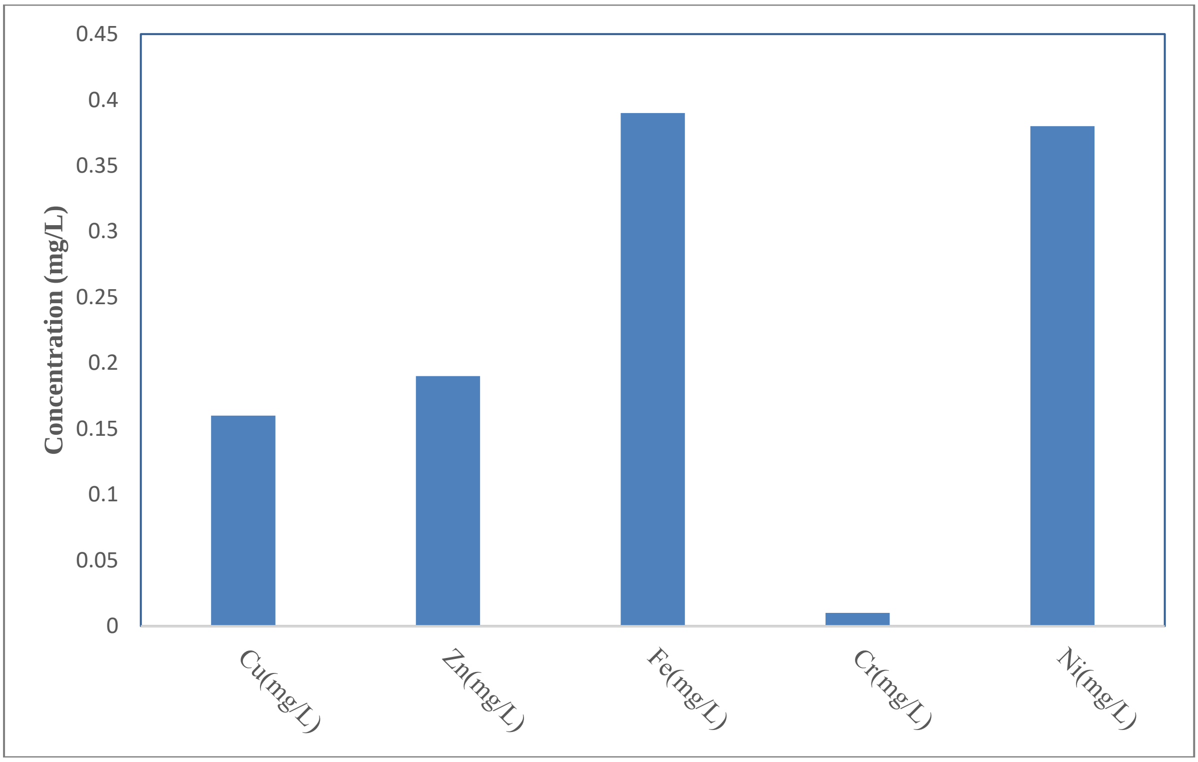

Figure 5: Concentration of metals (mg/l) in water sample E (MberebeObio)

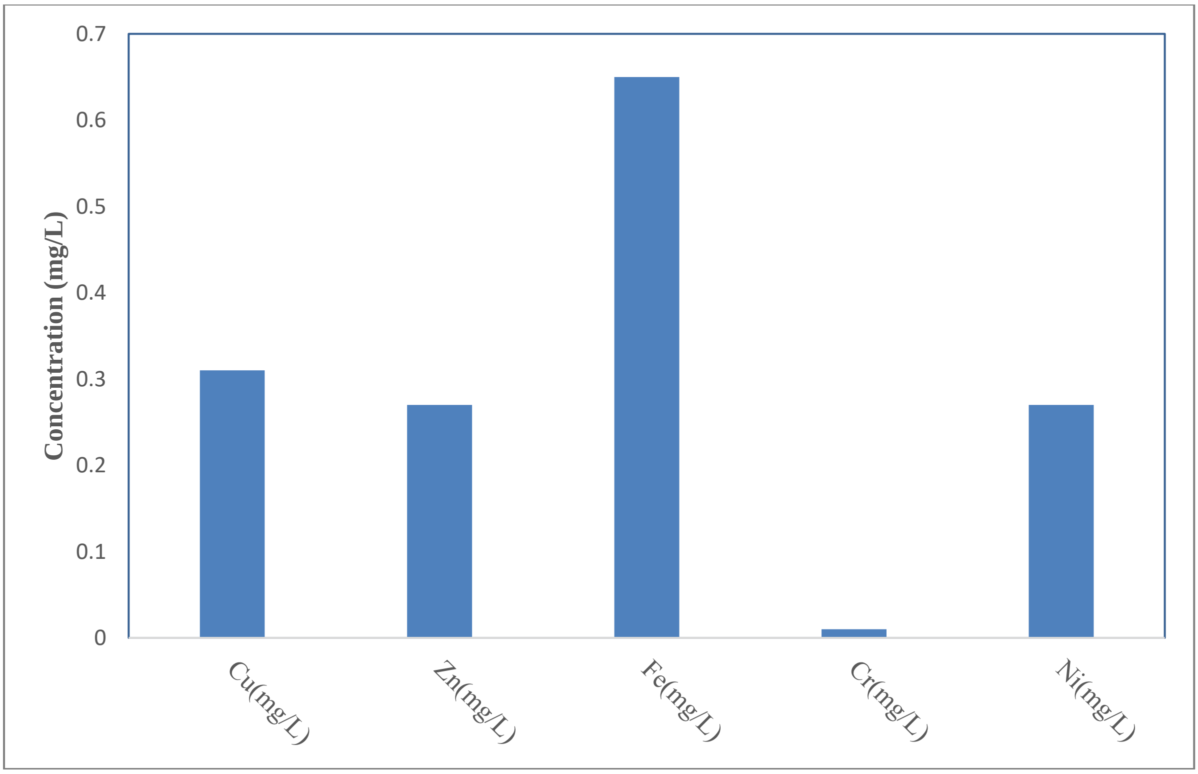

Figure 6:Concentration of Metals (mg/l) in Water Sample F (IBB Avenue)

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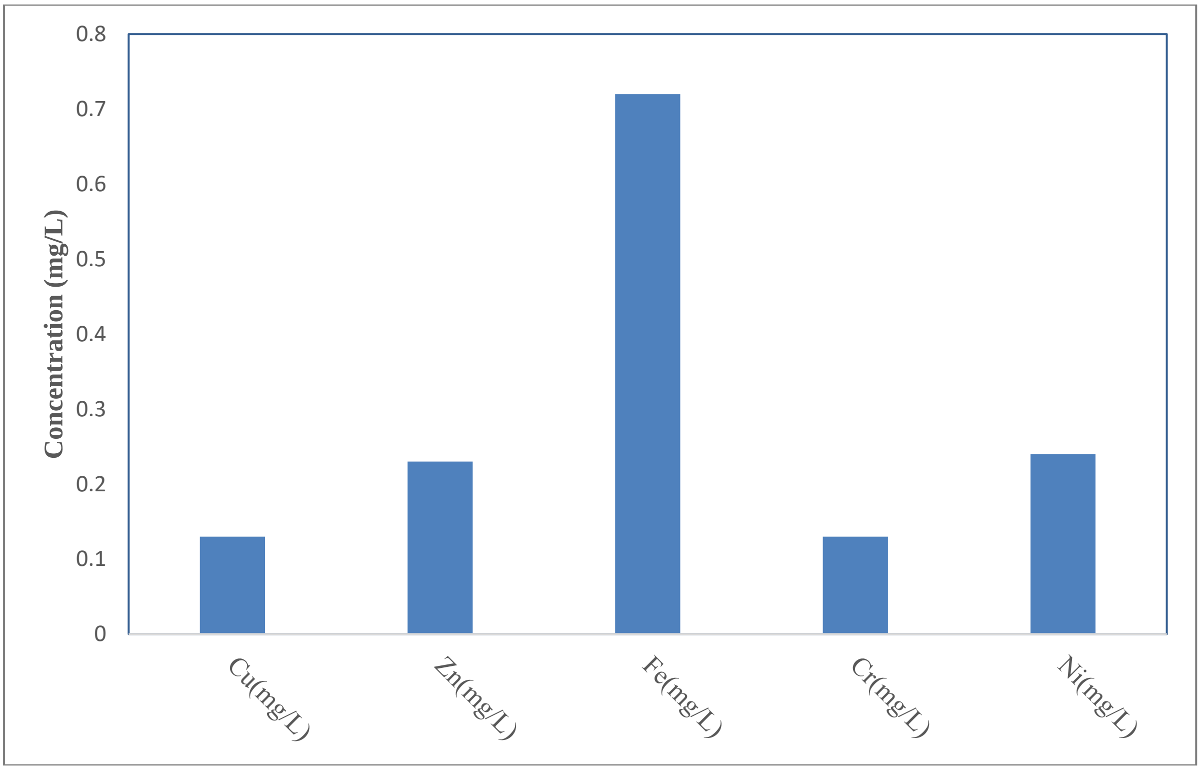

Figure 7: Concentration of metals (mg/l) in water sample G (Nkemba Street)

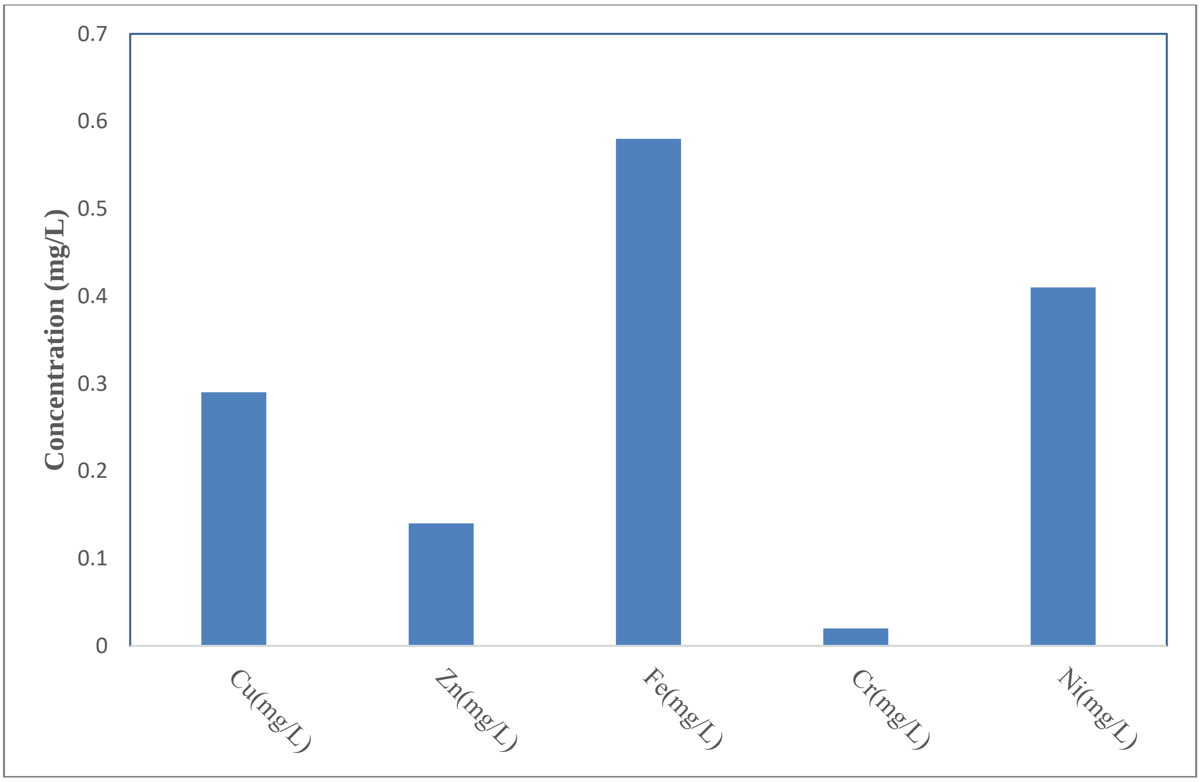

Figure 8: Concentration of metals (mg/l) in water sample H (Ediene Ikot Obio)

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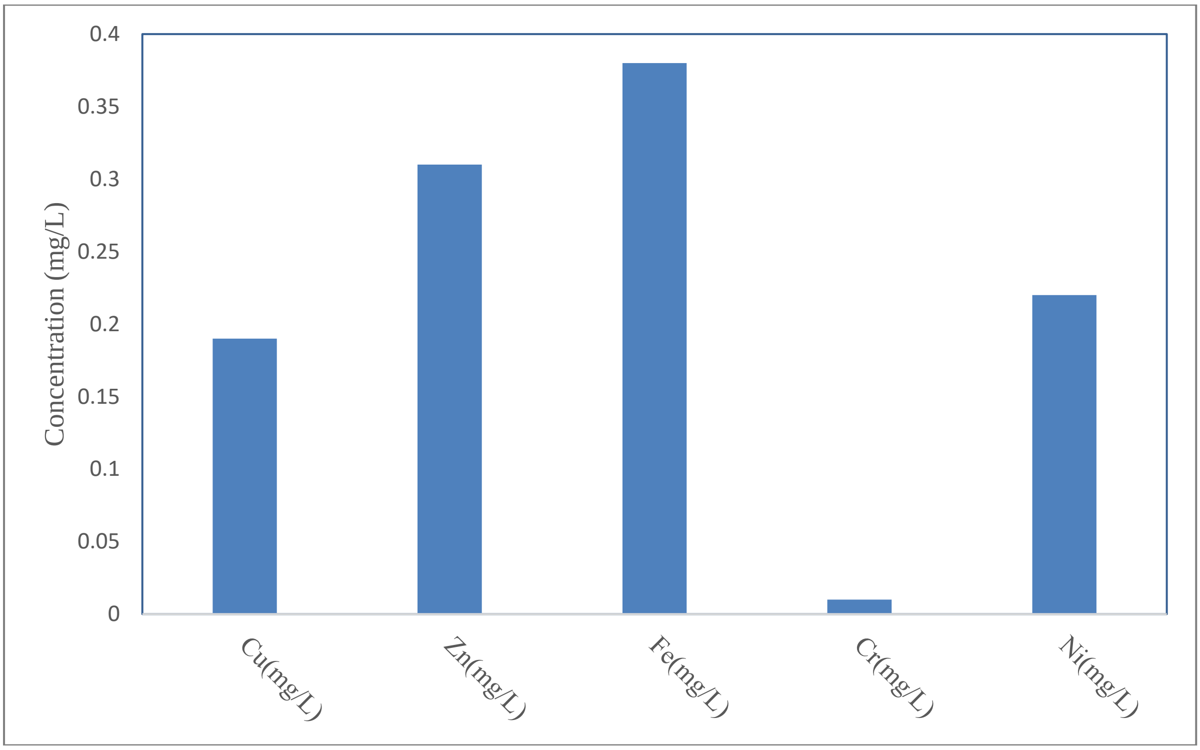

Figure 9: Concentration of metals (mg/l) in water sample I (Idongesit Ntuen Isua Avenue)

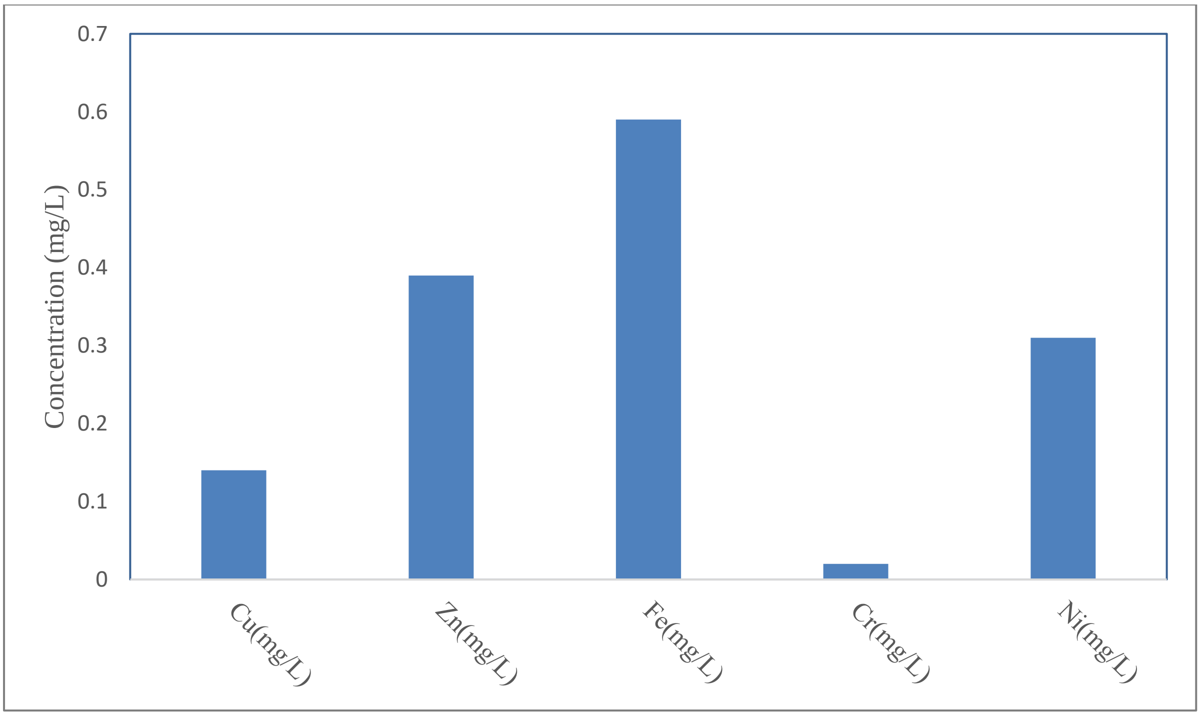

Figure 10: Measured concentration of metals (mg/l) in water sample J (Akwa Ifak)

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Table 2: Comparison of Heavy Metal Concentration in the different samples with WHO and the NSDWQ Standards

Heavy Metals	Mean	Range	WHO Limit (2018)	NSDWQ (2015)
Cu (mg/L)	0.208	0.29-0.13	2.0	1.0
Zn (mg/L)	0.250	0.14-0.39	3.0	3.0
Fe (mg/L)	0.551	0.72-0.38	0.3	0.3
Cr (mg/L)	0.039	0.01-0.13	0.05	0.05
Ni (mg/L)	0.298	0.24-0.41	0.07	0.02

DISCUSSION

As presented in Table 1, the analyzed water samples from ten distinct borehole locations (A-J) exhibited heightened levels of heavy metals, including copper, zinc, iron, chromium, and nickel. The concentrations of these metals varied across the sampled locations, with copper concentrations ranging from 0.14 to 0.21 mg/L, zinc concentrations from 0.33 to 0.39 mg/L, iron concentrations from 0.39 to 0.72 mg/L, chromium concentrations from 0.01 to 0.02 mg/L, and nickel concentrations from 0.21 to 0.41 mg/L. This detailed information provides insight into the heavy metal composition of borehole water sources in the studied area. Notably, the concentrations of heavy metals varied among the boreholes, as depicted in Figure 1. Figure 1 illustrates that copper (Cu) and chromium (Cr) concentrations in all borehole water samples were below the permissible limits set by both the World Health Organization (WHO, 2018) and Nigeria's National Standards for Drinking Water Quality (NSDWQ, 2015). This observation aligns with findings from previous research by Umar *et al.* (2023).

Given that water use for any purpose is governed by standards set by organizations such as the WHO (Kantoma *et al.*, 2018), these results underscore the compliance of the water samples with established guidelines. The analysis also found that Ediene Ikot Obio Imo had the highest copper readings, at 0.29 mg/L, while Nkemba Street had the lowest, at 0.13 mg/L. Still, these values are within allowable bounds, indicating that there might not be a negative effect on the study area's water quality. It is noteworthy that (Umar *et al.*, 2023) reported elevated concentrations of Cd, Cu, and Ni in the industrial effluent of a company in the study area, exceeding permissible limits. However, the copper (Cu) concentrations in the groundwater measured in this study were within the acceptable limits established by standard organizations.

Although zinc (Zn) concentrations were found to be comparatively higher in water samples from locations A, D, I, and J, they remained within the permissible limits set by the World Health Organization (WHO 2018). The observed Zn levels in these samples indicate their toxicity is unlikely to surpass the acceptable limit of 3.00 mg/L, suggesting that the sampled borehole water poses no significant health risks concerning zinc contamination (Nasiru *et al.*, 2022). Zn had the lowest value of 0.14 mg/L in sample H, whereas the highest value of 0.39 mg/L was observed in sample J, with an average value of 0.250 mg/L. Numerous environmental and Health issues have been linked to high zinc concentrations in boreholes. Research indicates that prolonged exposure to elevated zinc levels may harm aquatic organisms, soil fertility, and human well-being (Charity *et al.*, 2018; Okereafor *et al.*, 2020). Therefore, it is crucial to regularly monitor and control zinc concentrations in borehole water to reduce potential hazards (Charity *et al.*, 2018; Okereafor *et al.*, 2020). Nonetheless, drinking water with a low zinc concentration has no negative health effects, as zinc possesses antioxidant qualities that protect people's skin and muscles from premature aging (Ak, 2019). In boreholes, the zinc concentration can be higher due to the leaching of zinc from piping and fittings.

Iron (Fe) exhibited an average value of 0.551 mg/L, surpassing the WHO, (2018) and NSDWQ, (2015) acceptable limits of 0.3 mg/L for all samples A-J. The elevated iron levels may be attributed to clay deposits in the area. As Usoh et al. (2023) reported, iron enters the stream and borehole through sources beyond the dumpsite leachate, including natural weathering of rocks and soils, along with runoff from nearby agricultural activities. The presence of iron in the stream and borehole can impact water quality and ecosystem health, as cited in (Emeka *et al.*, 2020)

Chromium (Cr) ranged from the lowest value of 0.01 mg/L to the highest value of 0.01 mg/L, with an average of 0.039 mg/L. The concentrations of Cr in all borehole water samples remained below the maximum limits set by the WHO (2018) and NSDWQ (2015). Thus, it is unlikely that the chromium levels in these water samples would negatively affect water quality in the study area. However, continuous monitoring of Cr levels is still important to ensure they remain within safe limits.

Among the metals analyzed, nickel (Ni) had the lowest average concentration at 0.298 mg/L. Nevertheless, this value exceeded the WHO (2018) and NSDWQ (2015) standards of 0.7 mg/L and 0.2 mg/L, respectively. Prolonged exposure to elevated Ni levels can lead to cancer and other health issues. Hence, ongoing monitoring of Ni levels in the area is crucial, and steps should be taken to reduce exposure, supported by Genchi *et al*. (2020). These figures illustrate the distribution and levels of metals like copper, zinc, iron, chromium, and nickel, providing visual evidence of the spatial variability in water quality. Iron levels consistently exceeded WHO (2018) and NSDWQ (2015) standards across all samples, indicating a widespread issue of iron contamination. Meanwhile, the concentrations of other metals, such as copper, zinc, and chromium, generally stayed within safe limits, suggesting that, except for iron, the water quality might not pose significant health risks concerning these metals similar to (Genchi *et al*., 2020; Shaibu *et al*., 2023; Shaibu *et al*., 2014). However, nickel levels were also a concern in some samples, exceeding recommended limits and highlighting the need for targeted interventions to mitigate specific contamination sources and utilization of bioindicators for monitoring purposes, as reported (Udousoro & Umoren, 2014).

The mean concentrations of copper (Cu) and zinc (Zn) are well below the permissible limits, as shown in Table 2, indicating no immediate risk from these metals, similar to studies by Shaibu *et al*. (2014) and Moses *et al*. (2020). However, iron (Fe) levels are significantly higher than the recommended limits, suggesting potential health risks and the need for treatment solutions. Chromium (Cr) and nickel (Ni) concentrations are also noteworthy; although Cr levels are within safe limits, Ni exceeds WHO (2018) and NSDWQ (2015) standards, highlighting a concern for long-term exposure and the necessity for continuous monitoring and possible intervention.

CONCLUSION

The study evaluated heavy metal concentrations in borehole waters within Uyo Metropolis, revealing varied levels of heavy metals such as iron, copper, zinc, chromium, and nickel. Iron and nickel levels were above permissible limits in all samples, posing potential health risks. It underscores the need for regular monitoring and remediation efforts to ensure water safety and protect public health against the adverse effects of heavy metal contamination.

REFERENCES

Ak, M. (2019). *International Journal of Clinical Dermatology & Research (IJCDR) ISSN 2332-2977 Skin Aging & Modern Age Anti-Aging Strategies*. *7*(4), 209–240. **[Crossref]**

Boadi, N. O., Saah, S. A., Baa-Poku, F., Mensah, E. A., & Addo, M. (2020). Safety of borehole water as an alternative drinking water source. *Scientific African*, *10*, e00657. **[Crossref]**

Charity, L. K., Wirnkor, V. A., Emeka, A. C., Isioma, A. A., Ebere, E. C., & Ngozi, V. E. (2018). Health Risks Of Consuming Untreated Borehole Water From Uzoubi Umuna Orlu, Imo State Nigeria. *Journal of Environmental Analytical Chemistry*, *05*(04). **[Crossref]**

Udongwo, A. M., & Sambo, D. D. (2022). Assessment of heavy metal contamination in boreholes around mechanic workshops in Uyo Metropolis, Akwa Ibom State, Nigeria. *Journal of Chemical Society of Nigeria*, *47*(4). **[Crossref]**

Emeka, C., Nweke, B., Osere, J., & Ihunwo, C. K. (2020). Water Quality Index for the Assessment of Selected Borehole Water Quality in Rivers State. *European Journal of Environment and Earth Sciences*, *1*(6), 1-4. **[Crossref]**

Genchi, G., Carocci, A., Lauria, G., Sinicropi, M. S., & Catalano, A. (2020). Nickel: Human Health and environmental toxicology. *International Journal of Environmental Research and Public Health*, *17*(3). **[Crossref]**

Imoh, C. B. A., Etuke, U. U., Bassey, J., & John, E. (2021). Physiochemical Assessment on Borehole Water Quality in Uyo Metropolis. *International Journal of Innovative Research in Advanced Engineering*, *8*(9), 222-238. **[Crossref]**

Kantoma, D., Yusuf, J., & Bidam, M. Y. (2018). Assessment of heavy metals concentration in drinking water samples from selected areas of Kauru Local Government Area of Kaduna State, Nigeria. *Bayero Journal of Pure and Applied Sciences*, *10*(1), 509. [**Crossref**]

Moses, E. A., Udosen, E. D., Shaibu, S. E., & Ukpong, M. E. (2020). *Geo-Mapping of Trace Metal Concentrations in Respirable Particulate Matter in South-South , Nigeria*. *4*(6), 56–65.

Nasiru, S., Aliyu, A., Garba, M. H., Dambazau, S. M., Nuraddeen, A., Abba, B., & Murtala, Y. (2022). Determination of some heavy metals in groundwater and table water in Tudun Murtala, Nassarawa Local Government Area, Kano-Nigeria. *Dutse Journal of Pure and Applied Sciences*, *7*(4b), 124–130. [**Crossref**]

Nigerian Standard for Drinking Water Quality (NSDWQ). (2015). africacheck.org. Accessed 26 February 2024

Okereafor, U., Makhatha, M., Mekuto, L., Uche-Okereafor, N., Sebola, T., & Mavumengwana, V. (2020). Toxic metal implications on agricultural soils, plants, animals, aquatic life and human Health. *International Journal of Environmental Research and Public Health*, *17*(7), 1–24. [**Crossref**]

Shaibu, S. E., Adekola, F. A., Adegoke, H. I., & Ayanda, O. S. (2014). A comparative study of the adsorption of methylene blue onto synthesized nanoscale zero-valent iron-bamboo and manganese-bamboo composites. *Materials*, *7*(6), 4493–4507. [**Crossref**]

Shaibu, S., Inam, E., Moses, E., Ofon, U., Fatunla, O., Obadimu, C., Ibuotenang, N., Offiong, N.-A., Ekpo, V., Adeoye, T., Udokang, E., & Fapojuwo, D. (2023). Prospects of nanosorption and photocatalysis in remediation of oil spills. *Journal of the Nigerian Society of Physical Sciences*, *5*, 1043. [**Crossref**]

Udousoro, I., & Umoren, I. (2014). *Assessment of Surface and Ground Water Quality of Uruan in Akwa Ibom State of Nigeria*. *4*(6), 11–27.

Umar, S., Muhammad, A., & Elijah, S. (2023). Assessment of heavy metal contamination in groundwater from motorized boreholes in Maitumbi, Tipa Garage Area, Minna, Niger State. *Science World Journal*, *18*(2), 212–215. [**Crossref**]

Usoh, G. A., Ahaneku, I. E., Ugwu, E. C., Akpan, G. E., Ahuchaogu, I. I., & Ikpe, J. (2023). *Determination of Water Quality Index for Assessment of Stream and Borehole Water Quality around Uyo Waste Dumpsite*. *6*(1), 33–45.

WHO (2018). A global overview of national regulations and standards for drinking-water quality. Geneva: World Health Organization. who.int. Accessed 26 February 2024.