Network for Research and Development in Africa
International Journal of Pure and Applied Science Research
ISSN: 2384-5918, Volume 12, Issue 2
PP 1-11 (April, 2025)
OTL: 45727711-11221-1
arcnjournals@gmail.com
https://arcnjournals.org

Heavy Metals in Ground Water Samples of Some Selected Wards of Maiduguri Metropolis and Jere Local Government Area of Borno State

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***Abstract**: This study investigated the quality of borehole water samples in Maiduguri Metropolitan Council (MMC) and Jere Local Government Areas (LGA), with a control sample from Biu LGA. The research aimed to analyze heavy metals (Copper, Mercury, Cobalt, and Nickel) and physicochemical parameters (Colour, Turbidity, pH, Total Dissolved Solids, Electrical Conductivity, and Temperature) in the water samples. The concentration of heavy metals in MMC and Jere LGA water samples followed a similar decreasing order: Cu>Ni>Co>Hg. Hausari Zango (MMC) had the highest Copper concentration (1.3120±0.2160 mg/l), while Mairi Kuwait (Jere LGA) had the highest concentration (1.0240±0.0310 mg/l). Nickel Concentration: Hausari Zango (MMC) had the highest Nickel concentration (0.1020±0.0170 mg/l), while Mairi Kuwait (Jere LGA) had the highest concentration (0.0790±0.0020 mg/l). Fezzan Main (MMC) had the highest turbidity value (14.0670±0.4970 NTU), while Mairi Maimusari Primary School (Jere LGA) had the highest turbidity value (0.5906±0.0099 NTU). The pH values ranged from 6.61±0.0283 to 8.34±0.0636°C in MMC, and 7.04±0.0283 to 8.23±0.0778°C in Jere LGA. TDS values ranged from 133±0.0000 to 1767±4.3647 mg/l in MMC, and 80±4.9497 to 612±2.8284 mg/l in Jere LGA. Electrical conductivity values ranged from 265±4.2426 to 3540±1.4142 µs/cm in MMC, and 160±5.0711 to 1223±3.5355 µs/cm in Jere LGA. The study revealed varying levels of heavy metals and physicochemical parameters in the borehole water samples from MMC and Jere LGA. The results indicate a need for regular monitoring and treatment of borehole water to ensure its safety for consumption.*

Keywords: Anthropogenic, Electrical Conductivity, Concentration, Aquifer Turbidity.

Introduction

Groundwater, apart from drinking is also an essential resource for irrigation, which is a means of alleviating poverty by increasing food production, improving the economic situation of rural households, increasing farmers' incomes, and creating jobs in agriculture and other related sectors (Abate et al., 2022). In addition, the availability of groundwater resources has the potential to boost other income-generating activities such as small industries and micro-enterprises (Akbari et al., 2020; Ghanim et al., 2023; Tiba, 2022).

Health Risks Associated with Radionuclides and Heavy Metals

Human exposure to radionuclides and heavy metals is linked to severe health consequences, including increased risk of cancer and poisoning, highlighting the need for monitoring and mitigation (Mgbukwu, 2023; Nduka et al., 2023), Although low-level exposure to radionuclides and heavy metals occurs naturally, human activities, particularly industrial processes, have significantly elevated exposure levels, increasing the risk of adverse health effects (Mgbukwu, 2023). Prolonged accumulation of heavy metals and radon can lead to detrimental health consequences, including cellular disruption, tissue damage, and organ dysfunction, ultimately resulting in chronic health problems (Bedassa, 2022; Kalip, 2020; Samuel et al., 2022).

Exceeding permissible levels of heavy metals (HMs) can lead to toxicity. As non-biodegradable pollutants, HMs can accumulate in the ecosystem, potentially reaching hazardous levels that pose significant risks to human health (Abdel-Rahman et al., 2019). Ground water accessed through boreholes in the research area can be categorized into three types:

1. Shallow Aquifers: 100-150 meters deep

2. Middle Aquifers: approximately 200 meters deep

3. Deep Aquifers: 250 meters deep or more

All three categories are present in the sampling sites within the research area (Study Area). Numerous studies have investigated heavy metal and radon levels in drinking water, assessing the associated annual effective cancer risk, both within Nigeria and globally. For instance, a recent study by Ajiboye et al. (2022) analyzed radon concentrations in water samples from southwestern Nigeria, contributing to the existing body of research on this critical issue. Besides radon, water can harbor other potentially hazardous elements, including cadmium, lead, chromium, arsenic, and selenium. These contaminants can originate from natural processes such as tectonic activity and erosion, as well as human activities like fossil fuel combustion and industrial processes (Faweya et al., 2018). Notably, even at low levels, these elements can induce the formation of free radicals, leading to oxidative stress and potentially damaging biological molecules and DNA (Jidele et al., 2021). A study by Dankawu et al. (2021) assessed the excess lifetime cancer risk and annual effective dose of borehole and well water samples. The results revealed that the water in the study area poses health risks, rendering it unsuitable for domestic use and human consumption.

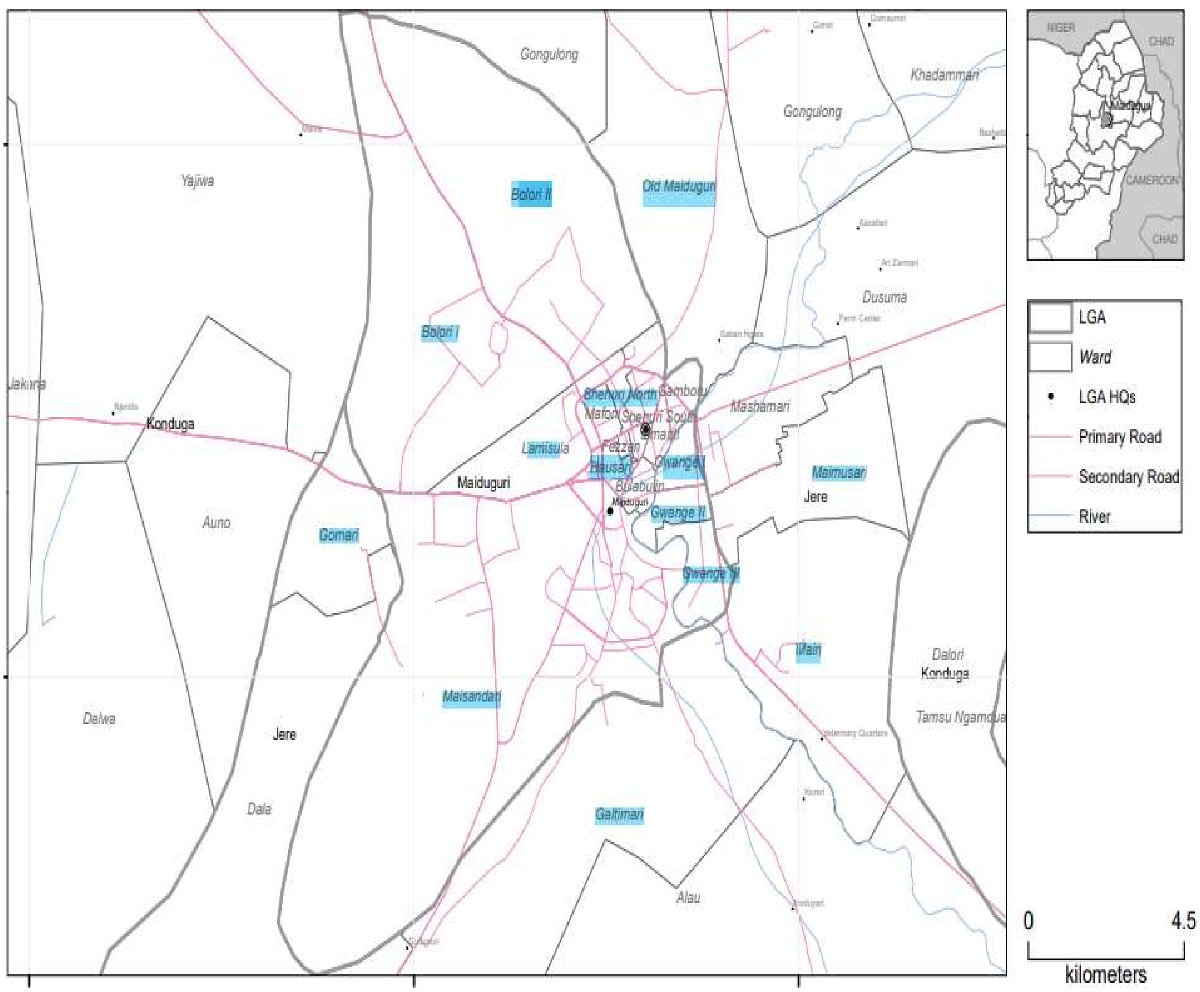
Study Area

Borno State was established on February 3, 1976, from the former North Eastern State, with Maiduguri as its capital. Located within latitudes 10° to 15° E and longitudes 10° to 25° N, it spans 69,436 sq km, making it Nigeria's largest state by land area (BSD, 2007).

Borno State occupies most of the Chad Basin and shares international borders with Niger, Chad, and Cameroon. Domestically, it borders Adamawa, Yobe, and Gombe states. The state's climate is predominantly hot and dry, with a slightly milder south. The rainy season typically runs from June to September, with varying durations and humidity levels across the state.

As of 1991, Borno State's projected population was 2,596,589, with a population density of 38

inhabitants per square kilometer (BSD, 2007). The state features two main vegetation zones: Sahel and arid in the north, and Sudan savannah in the south.



Map of Jere LGA, Borno State Showing Sampling Points (Update on: 05 February 2018 Sources: OSGOF, OpenStreetMap Feedback: ochanigeria@un.org More information: https://www.humanitarianresponse.info/en/operations/nigeriawww.unocha.org/nigeria www.reliefweb.int/country/nga)

Materials and Method

The following instruments, glassware, and reagents were utilized in this project:

1. Atomic Absorption Spectrophotometer (AAS): Buck Scientific Model 210VGP AAS, USA

2. Ultraviolet-Visible Spectrophotometer (UV): DR3900 HACH

3. Distilled Water

4. Turbidity Meter: TL2300

5. pH Meter: Hanna HI9800

Water sampling

A total of 31 borehole water samples were randomly collected in May 2024 from designated locations. To prevent contamination, samples were stored in properly cleaned polyethylene bottles, washed with clean water and rinsed with distilled water. Following established procedures, the samples were swiftly transported to the laboratory for further analysis, (Jones et al., 1999).

Laboratory Analysis

Equipment Calibration and Sample Preparation

To ensure accuracy, all equipment and instruments were calibrated before and during the experiments. Glassware was thoroughly cleaned with 10% concentrated nitric acid (HNO_3) to remove heavy metals, then rinsed with distilled-deionized water.

Digestion tubes were soaked in 1% potassium dichromate and 98% sulfuric acid (H_2SO_4), while volumetric flasks were soaked in 10% nitric acid (HNO_3) for 24 hours. After soaking, the tubes and flasks were rinsed with deionized water and dried in an oven. All apparatus and materials were stored in a dust-free environment until analysis.

Calibration and Analysis

The calibration plot method, as described in the British Pharmacopoeia, was used for metal ion preparation and Atomic Absorption Spectroscopy (AAS) analysis. A stock standard solution (1000 ppm) was prepared, and working solutions (100 ppm) were diluted for analysis. The absorbance of these solutions was measured using AAS at specific wavelengths for cadmium, lead, and mercury. The calibration graph was plotted, and the regression equation was used to determine heavy metal concentrations.

AAS Analysis

Sample solutions were fed into the AAS instrument, where metals were vaporized and subjected to light at precise wavelengths, allowing for accurate detection and quantification of heavy metals. The degree of light absorption by the metal's correlates directly with their concentration in the sample. By employing a calibration curve, the metal concentrations are precisely quantified. Rigorous quality control protocols are applied to guarantee result accuracy. In summary, AAS is a highly sensitive and accurate technique for assessing heavy metal levels across diverse sample types (Usman et al., 2023).

Results/Discussion

Physicochemical Properties

Physicochemical properties of water are characteristic of the climate, geochemical, geomorphological and pollution conditions, prevailing in the drainage basin and the underlining aquifer (Limgis, 2019). Groundwater sources, such as boreholes, are susceptible to contamination by heavy metals through surface water leaching. Proximity to solid waste dumpsites and sewage systems significantly increases the risk of contamination. While some minerals and metals present in water are essential for human health, excessive levels exceeding regulatory standards set by organizations like the Nigerian Standards for Drinking Water and the World Health Organization can pose serious health risks. Colour contamination in drinking water is primarily a concern for aesthetic reasons. The study's findings indicate that both Maiduguri Metropolitan Council (MMC) and Jere Local Government Area (LGA) generally had minimal colour contamination issues, with a few exceptions exhibiting high values. Specifically, MMC samples had a colour value of 6 PtCo or less, except for Maisandari Polo and Fezzan wards, which recorded higher values of 19±0.7071 PtCo. In the case of Jere LGA, only one location (Mashamari Primary School) had a high colour value of 75±2.1213 PtCo, while the remaining wards had colour values of 5 PtCo or less. Turbidity which is the optical clarity of the water is closely related to colour, because most times if the colour of water is high, turbidity likewise becomes high and vice versa. The study found that turbidity values were generally low, consistent with the low colour values observed in most samples. The highest turbidity levels were recorded in Maiduguri Metropolitan Council (MMC): 0.3251±0.028 NTU at Ngomari Delori Ajilari Cross while in Jere Local Government Area (LGA) the highest turbidity was at Fezzan Main 14.067±6.4469 NTU. pH, a measure of acidity or alkalinity which influences the solubility of metals and ions in water. The study found that nearly all locations exhibited pH values ranging from slightly acidic to slightly alkaline. Specifically, in Maiduguri Metropolitan Council (MMC), pH levels varied from as low as 6.61±0.0283 in Hausari Zango to a high of 8.34±0.636 in Bolori 1 Ward.

Total Dissolved Solids (TDS) represent the concentration of soluble substances in water. High TDS levels can render water unsuitable for consumption. The study found that only a few areas exceeded normal TDS levels. Notably, in Maiduguri Metropolitan Council (MMC), three locations had TDS levels above 1000mg/l, indicating potentially high concentrations of dissolved solids., these includes; 1082±2.8284 mg/l in Gwange 2, 1403±2.1213 mg/l in Bulabulin and 1767±4.3640 mg/l in Hausari Zango. Jere LGA recorded the highest value of TDS of 612±8284 mg/l in Mairi Kuwait Ward.

Electrical conductivity measures the ability of water to conduct electricity, facilitated by the presence of ions. This property is directly influenced by the concentration and mobility of ions in the solution. Notably, electrical conductivity values are typically twice the total dissolved solids (TDS) value, providing an indirect indicator of TDS levels. The study found that the highest mean electrical conductivity (EC) values in Maiduguri Metropolitan Council (MMC) were in the following wards; 2163±4.9497µs/cm>2807±3.5355µs/cm>3540±1.4142 µs/cm that is Gwange 2, Bulabulin and Mairi Kuwait Ward respectively. Jere LGA had a high EC of 1132±2.8284 µs/cm and 1223±3.5355 µs/cm in Mairi Distinction Primary School and Mairi Kuwait Ward respectively.

The study recorded temperature variations in water samples from different locations. In Maiduguri Metropolitan Council temperature ranged between; 27.9±0.1414 ^{0}C in Bulabulin Ward and 29.5±0.2121 ^{0}C in Gamboru Community Borehole. Jere recorded lowest temperature of 27.8±0.4243^{0}C with the highest value being 28.9±0.0707^{0}C, in Alau Raw Water Pumping Station.

Heavy Metals

Results of the study on copper revealed that Maiduguri Metropolitan Council have a mean concentration of 0.4311 mg/l, Hausari Zango ward 1.3120±0.2160 mg/l followed by Bulabulin 1.2330±0.3240 mg/l (Table 3). The lowest concentration of copper with 0.0350±0010 mg/l was observed in Maisandari Ajelori of the Metropolis. While results from all locations in Maiduguri falls below the WHO guideline value of 2 mg/l for copper, 3 locations recorded values above the NSDWQ (1 mg/l), these locations include; Hausari Zango, Bulabulin Primary Health Care and Limanti Kariari wards (Table 3). Only Hausari Zango recorded a concentration that is above the US EPA (1.3 mg/l). In Jere Local Government Area, the concentration of 1.0240±0.0310 mg/l was observed in Mairi Kuwait and lowest value of 0.0580±0.0010 mg/l in Dala Zannari (Table 4). Mean concentration of 0.3388 mg/l was obtained across Jere.

Mercury is observed to be very low in both Maiduguri Metropolis and Jere Local Government Area. Hausa Zango of Maiduguri Metropolis have concentration of 0.0014±0.0002 mg/l with Gwange 2 Primary Health Care being closest with a value of 0.0005±0.0000 mg/l (Table 3). Jere LGA have highest concentrations of mercury (0.0002±0.0000 mg/l) in 4 wards, the wards include; Mairi Distinction Primary School, Mashamari Primary School, Mairi Kuwait and Biu Control (Table 4). Mercury was not detected for the following wards of Jere, these includes; Ngomari Delori Ajilari Cross, Dala Zannari, Ngomari Sajeri Ajilari Cross, Dala Abuja Sheraton, Alau Raw Water Pumping Station and Mairi Maimusari Primary School (Table 4).

Results for Cobalt analyzed in Maiduguri Metropolis is shown in Table 3. The result revealed that Hausari Zango had the highest concentration of 0.0340±0.0060 mg/l. Locations that recorded lowest values are; Shehuri North, Maisandari Polo and Maisandari Ajelori, with values of 0.0010±0.0000 mg/l each. The mean concentration of Cobalt in Maiduguri is 0.0065 mg/l.

In Table 4, above the concentration of Cobalt in Jere Local Government is as follows; Galtimari Grave Yard recorded 0.0200±0.0000 mg/l as the highest, 3 locations followed with 0.00500±0.0000 mg/l each, those locations are; Mashamari Primary, Mairi Distinction Primary School and Biu Control. Six locations had least concentration values of 0.0010±0.000 mg/l, the areas include; Ngomari Ajilari Cross, Dala Zannari, Dala Abuja Sheraton, Alau Raw Water Pumping Station, Galtimari Solar and Mairi Maimusari Primary School. Cobalt was not detected in Ngomari. There is no guideline value given for cobalt, by WHO, Nigerian Standard for Drinking Water Quality and US EPA.

Analysis result for Nickel in Maiduguri Metropolis reveal that Hausari Zango had the highest concentration of 0.1020±0.0170 mg/l, while Jere Local recorded 0.0790±0.0020 mg/l in Mairi Kuwait being the highest (Table 3 and Table 4 respectively). Similarly, Maisandari Ajelori and Dala Zannari recorded 0.0030±0.0000 mg/l and 0.0050±0.0000 mg/l (Table 3 and Table 4 respectively) as lowest for both Maiduguri and Jere respectively. Mean concentration of Nickel in Maiduguri was 0.0335 mg/l and Jere had a mean concentration of 0.0262 mg/l. Findings of this studies showed that, seven wards of Maiduguri Metropolitan Council recorded Nickel concentration above that permitted by NSDWQ, while three wards (Table 3) had values above that stipulated by WHO. In the same vein, Jere Local Government Area had six Wards (Table 4), with Nickel concentrations above Nigerian Standard for Drinking Water Quality. Only Mairi Kuwait (Table 4) recorded a value that is above that recommended by WHO.

Results/Discussions

The physicochemical parameters in groundwater samples from Maiduguri Metropolis reveals significant levels of colour and turbidity across all sampled locations, Temperature values within ambient ranges, averaging 28.3°C. There is a relatively stable pH, with a mean value of 7.4.

The most notable observations are Electrical conductivity (EC) peaked at 3540 µs/cm in Hausari Zango Ward, Total dissolved solids (TDS) followed a similar trend, reaching 1767 mg/l in Hausari Zango Ward, roughly half the EC value, while the control location (Biu) showed relatively lower EC (1014 µs/cm) and TDS (507 mg/l) values (Fig. 1).

Physicochemical results for Jere Local Government Area reveal distinct differences compared to Maiduguri Metropolis (Fig. 2); Only one location, Mashamari Primary School, exhibited a notable peak in colour, with a value of 75 PtCo, Turbidity levels were consistently low across all samples, resulting in no visible peak. Temperature values in Jere were similar to those in Maiduguri Metropolis, with a mean value of 28.3°C. The pH had a mean value of 7.6 for almost all the locations under study (Fig. 1 & 2).

Electrical conductivity, Total dissolved solids and Colour are the only parameters that displayed visible peaks. Mairi Kuwait recorded the highest peaks in the chart, with Electrical Conductivity (EC) reaching 1223 µs/cm. Total Dissolved Solids (TDS) had a value 612 mg/l, for the same location.

Heavy Metal Concentration in Maiduguri Metropolitan Council (Fig. 3), showed that; there is a prominent peak for copper in almost all wards, with exceptionally high levels in Biu (control), Limanti Kariari, and Bulabulin Primary Health Care. The highest peak is observed for manganese in Hausari Ward. Hausari Zango Ward exhibits the highest concentration of nearly all heavy metals. The order of concentration peaks is: Copper (Cu) > Nickel (Ni) > Cobalt (Co) > Mercury (Hg). Maisandari Ajelori displays the least peaks, indicating minimal heavy metal concentration.

Heavy Metal Concentration in Jere Local Government Area (Fig. 4), indicate that copper has the most significant presence. The increasing order of copper in the various locations is as follows; Mairi Kuwait>Biu (Control)>Mashamari Primary School. The next highly concentrated heavy metal is manganese and they occurred in this order; Mairi Kuwait>Mairi Distinction Primary School>Biu (Control)>Old Maiduguri>Mashamari Primary School>Old Maiduguri>Farm Centre>Galtimari Grave Yard>Ngomari Ajilari Cross Main>Galtimari Solar Borehole>Ngomari Dala Delori Ajilari Cross>Dala Abuja Sheraton>Alau Raw Water Pumping Station>Mairi Maimusari Primary School. In terms of heavy metal concentration in Jere, Mairi Kuwait recorded the highest, while Dala Zannari showed the lowest concentration.

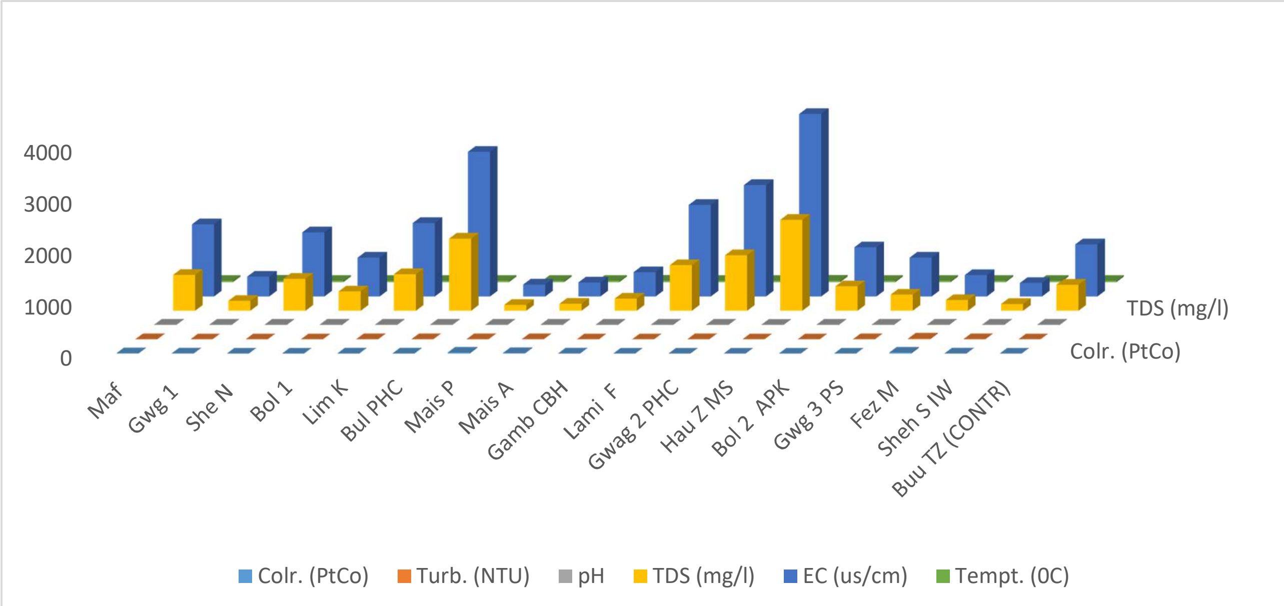


Figure 1: Variation of Physicochemical Parameters in Water Samples of MMC.

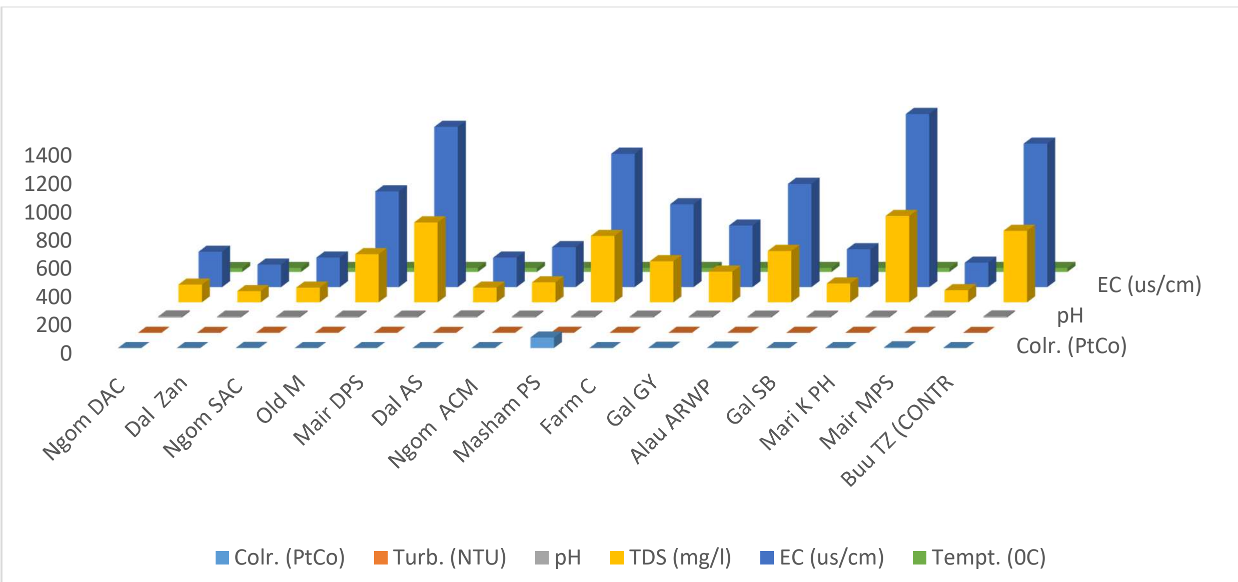


Figure .2: Variation of Physicochemical Parameters in Water Samples of Jere LGA

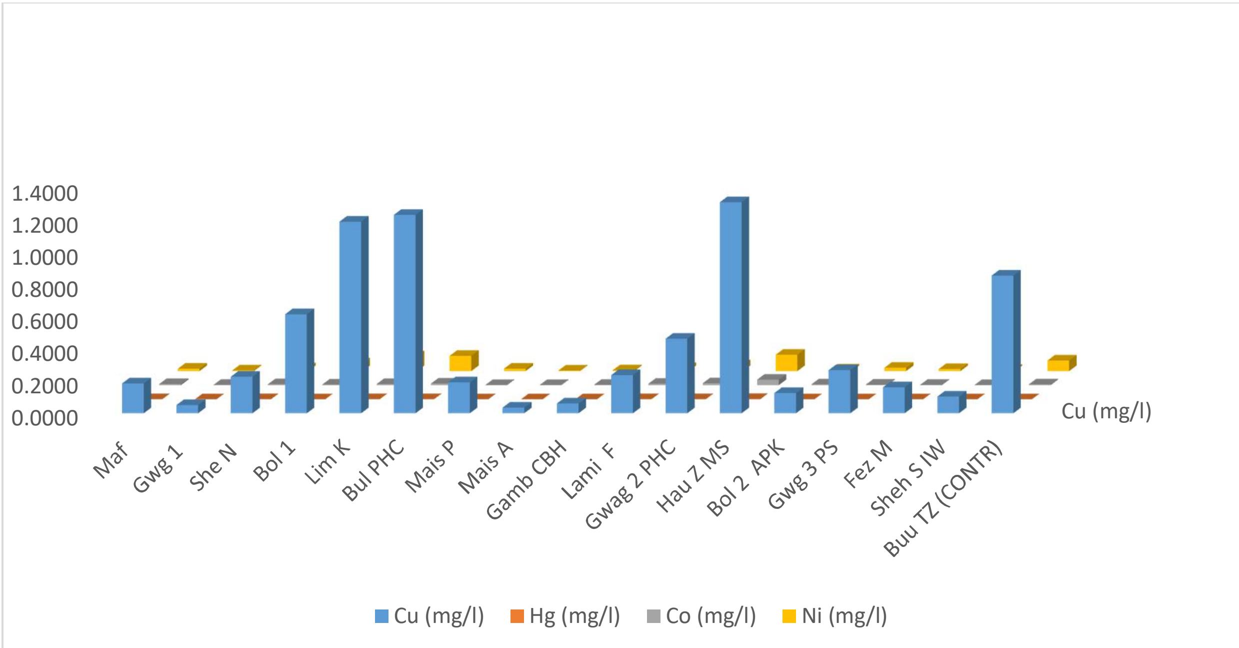


Figure 3: Variation of Heavy Metals in Water Samples of MMC

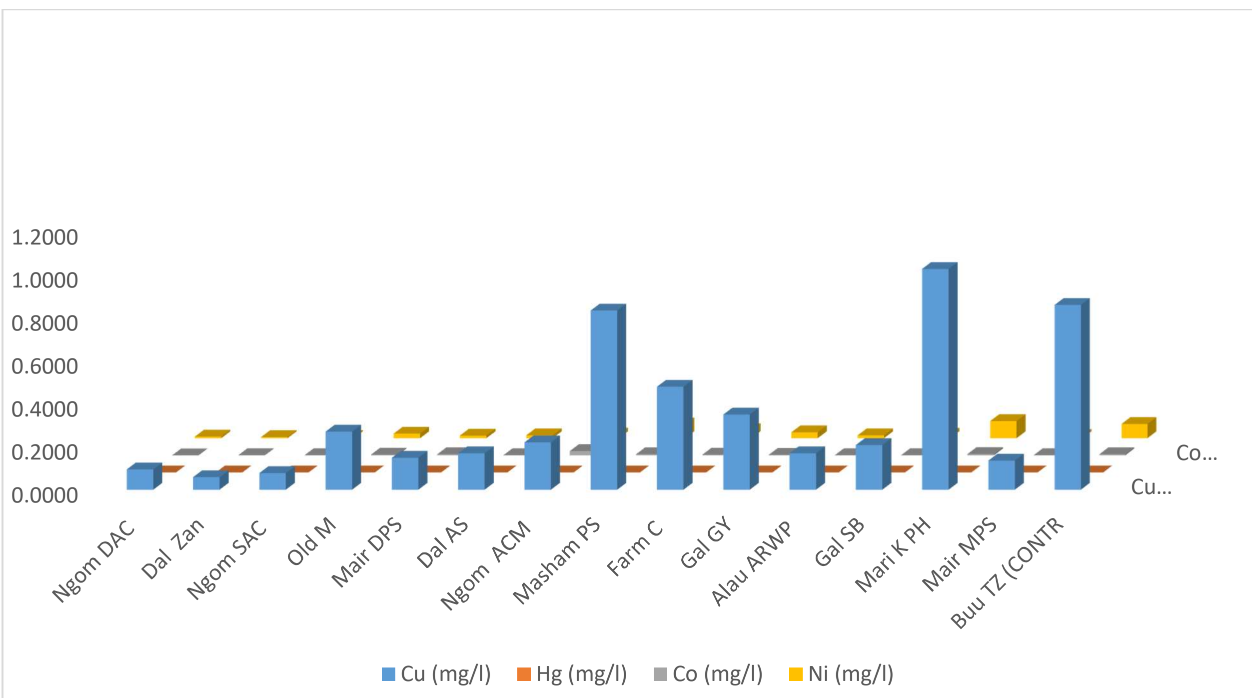


Figure 4: Variation of Heavy Metals in Water Samples of Jere LGA

Conclusion

The investigation of water samples in Maiduguri Metropolis and Jere Local Government Areas of Borno state revealed significant health risks associated with heavy metal contamination in a few locations. Heavy metals like copper were found to be in very high concentration of up to 1.3120±0.2160 ppm in Hausa Zango ward of the Metropolis, while Bul PHC had 1.2330±0.3240 ppm. Biu being the control recorded 0.8570±0.0260 ppm. Jere Local Government Area recorded its highest copper value in Mairi K PH (1.0240±0.0310 ppm), this elevated concentration of copper in those particular locations can make fish breeding to be difficult as copper poses serious threat to fish fingerlings. Another metal worthy of noting is Nickel, the location found to be most concentrated with Nickel in MMC is Hausari Zango with concentration of 0.1020±0.0170 ppm. In the case of Jere LGA, Mair K PH was the location with highest concentration of Nickel (0.0790±0.0020 ppm). The amount of Nickel in this study showed that it exceeded the WHO guideline of 0.02 ppm (WHO, 2006). Nickle in drinking water is associated with skin irritation (dermatitis) and in severe cases of kidney problems or organ damage.

Locations with elevated levels of heavy metals require immediate attention. To mitigate this issue; Effective remediation measures should be implemented to reduce heavy metal concentrations and also an alternative safe drinking water sources should be explored and provided to affected communities.

Taking proactive steps to address heavy metal contamination will help protect public health and prevent potential long-term environmental damage.

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