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ORIGINAL RESEARCH ARTICLE

Comparative Physicochemical and Heavy Metal Assessment of Water Sources in Bularafa, Gulani LGA, Yobe State, Nigeria

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ABSTRACT

This study evaluated the physicochemical properties and heavy metal concentrations of the major drinking water sources in Bularafa, Gulani Local Government Area, Yobe State, Nigeria, to determine their suitability for domestic consumption. Nine water samples, including tap, well, and borehole water, were collected from Tsangayan Gabas, Unguwar Sarki, and Unguwar Yamma. Standard APHA analytical methods were used for physicochemical analysis, while heavy metals were determined using Atomic Absorption Spectrophotometry (AAS). The physicochemical analysis revealed substantial deviations from World Health Organization (WHO) drinking water standards. Turbidity values ranged from 45.6–51.9 NTU, exceeding the WHO permissible limit of 5.0 NTU by approximately 9–10 fold. Electrical conductivity ranged from 600 to 710 µS/cm, with most samples exceeding the WHO-recommended range of 50–500 µS/cm. Total dissolved solids (TDS) ranged from 610–680 mg/L, indicating elevated dissolved mineral content above the acceptable limit of 600 mg/L in several samples. Total hardness ranged from 15–110 mg/L, with sample B2 exceeding the WHO limit of 100 mg/L. The pH values ranged from 7.4 to 9.3, with sample C3 exceeding the recommended upper limit of 8.5, indicating strong alkalinity. Heavy metal analysis demonstrated alarming contamination levels in several water sources. Lead (Pb) concentrations ranged from 0.3 to 0.8 mg/L, with 55.6% of the samples exceeding the WHO limit of 0.5 mg/L. Cadmium (Cd) concentrations ranged from 0.004 to 0.042 mg/L, with 88.9% of samples exceeding the WHO guideline value of 0.003 mg/L by up to 14-fold. Chromium (Cr) concentrations ranged from 0.1–0.7 mg/L, exceeding the WHO permissible limit of 0.05 mg/L in all samples, with maximum values approximately 14 times higher than the recommended standard. Iron (Fe) and copper (Cu) concentrations remained within WHO permissible limits, ranging from 0.045–0.111 mg/L and 0.18–0.78 mg/L, respectively. The elevated concentrations of Pb, Cd, and Cr may be associated with artisanal mining activities, agricultural runoff, and poor waste disposal practices within the study area. These contaminants pose significant health risks, including kidney damage, neurological disorders, anemia, and carcinogenic effects. The study concludes that most of the analyzed water sources are unsuitable for direct consumption without proper treatment and recommends urgent water-quality monitoring, environmental controls, and public health interventions.

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INTRODUCTION

Water is an indispensable natural resource required for human survival, agricultural production, industrial activities, and ecological sustainability. The quality of water consumed by a population significantly influences public health outcomes and environmental safety. Water quality assessment therefore remains an important scientific approach for evaluating the physical, chemical, and biological characteristics of water obtained from different environmental sources (Patel et al., 2023). Comparative analysis of water quality provides valuable information for identifying contamination sources, understanding environmental pollution trends, and developing effective public health interventions.

Globally, access to safe and potable water remains a major challenge, particularly in developing countries where rapid population growth, urbanization, poor sanitation, and anthropogenic activities continually threaten water resources. In many rural communities across Nigeria, residents rely heavily on untreated groundwater and surface water sources such as wells, boreholes, ponds, and streams for domestic use (Boso, 2025). These water sources are highly vulnerable to contamination from

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agricultural runoff, open defecation, indiscriminate waste disposal, mining activities, and industrial pollutants (Omokaro et al., 2024). Environmental pollution resulting from these activities has increasingly contributed to deterioration in water quality and elevated public health risks.

Several studies have demonstrated that anthropogenic activities significantly alter the physicochemical properties and heavy metal composition of environmental matrices, including soil and water systems. Adamu et al. (2023) reported elevated pollution indices of heavy metals in agricultural soils in Northwest Nigeria, indicating widespread environmental contamination associated with human activities. Similarly, Aiki et al. (2023) identified heavy metal contamination and associated health risks in aquatic organisms from the River Gashua in Yobe State, suggesting possible contamination of surrounding aquatic ecosystems. Bashir et al. (2023) also reviewed radon concentrations in Nigerian water sources and highlighted the growing concern about the safety of groundwater resources for human consumption. Furthermore, Abubakar et al. (2024) reported detectable levels of Radon-222 in well and borehole water in Kano State, highlighting the vulnerability of groundwater to geogenic and anthropogenic pollutants.

The increasing burden of environmental pollution in northern Nigeria has been linked to climate variability, agricultural intensification, mining operations, and poor waste management practices. Bello et al. (2025) observed that changing rainfall and temperature patterns have important implications for the sustainability of water resources, while Bawale (2024) emphasized the environmental pressures associated with irrigation farming practices in northern Nigeria. Studies by Adepehin et al. (2025) further demonstrated that mining and agricultural activities substantially impact subsurface environmental structures and groundwater systems. In addition, Agboola et al. (2024) highlighted the occurrence of carcinogenic pollutants in the environment and their potential adverse effects on human health. Heavy metal contamination is particularly concerning because metals such as lead, cadmium, and chromium are persistent, non-biodegradable, and capable of bioaccumulation, thereby posing serious toxicological risks even at low concentrations.

Bularafa community in Gulani Local Government Area of Yobe State is among the rural settlements with inadequate access to treated pipe-borne water. Consequently, the population depends largely on wells, boreholes, and other untreated water sources for drinking and domestic activities. The community is also characterized by increasing artisanal mining, particularly of iron and gold, which may significantly contribute to environmental contamination through ore processing, mine tailings, and runoff containing toxic substances. Mining activities have been recognized globally as significant contributors to groundwater and surface water pollution by releasing potentially toxic elements into surrounding ecosystems. However, despite the growing reliance on untreated water sources and increasing environmental pressures in the area, there is limited scientific information on the physicochemical characteristics and heavy metal burden of the water sources consumed by residents of the Bularafa community.

This lack of baseline environmental data represents a major public health concern because prolonged consumption of contaminated water may predispose the population to chronic diseases such as kidney dysfunction, neurological disorders, gastrointestinal illnesses, carcinogenic effects, and developmental abnormalities. Aliyu et al. (2022) demonstrated significant heavy metal contamination around roads and automobile workshops in Kaduna State, while Almustapha (2022) emphasized the toxicological importance of monitoring lead and cadmium contamination in environmental samples. Similarly, Badamasi and Salisu (2025) reported the presence of heavy metal-tolerant bacteria in contaminated dumpsites, indicating persistent environmental exposure to toxic metals. Bilyaminu et al. (2025) further demonstrated the ecological significance of metal contamination through the isolation of metal-tolerant bacteria with bioremediation potential.

Although several studies have investigated water quality and environmental contamination in different parts of Nigeria, there remains a paucity of information on the comparative physicochemical properties and heavy metal concentrations of drinking water sources in the Bularafa community (Saleh et al., 2025). Existing studies in related environments have largely focused on isolated contaminants or different ecological settings, without adequately addressing the combined physicochemical and toxicological status of drinking water sources in this mining-affected rural community. Consequently, residents may continue consuming contaminated water without adequate awareness of associated health risks or access to evidence-based interventions.

Therefore, this study was designed to comparatively assess the physicochemical properties and heavy metal concentrations of selected water sources in Bularafa, Gulani Local Government Area, Yobe State, Nigeria. The study aims to provide baseline environmental health data necessary for effective water quality monitoring, public health risk assessment, and policy formulation. The findings are expected to contribute to sustainable water resource management and support efforts to achieve Sustainable Development Goal 6, which aims to ensure universal access to safe and clean water.

MATERIALS AND METHODS

2.0 Experimentals

Prior to and throughout the experiment, all the tools and equipment utilized in this investigation were calibrated. Volumetric flasks and measuring cylinders were among the equipment carefully cleaned with detergents and tap water, then rinsed with deionized water. To remove any heavy metals from their surfaces, all glassware was cleaned with 10% concentrated nitric acid (HNO3) and then rinsed with deionized water.

2.1 Materials and reagents

All chemicals and reagents used in the lab were of analytical grade. Before analysis, sample and intermediate metal standard solutions were diluted with deionized water, and glassware and sample bottles were rinsed. Nitric acid (HNO_3, 68%) and Hydrogen peroxide (H_2O_2, 35%) were obtained from Loba Chemic.

2.2 Sampling Study Area

The settlement of Bularafa is situated in Yobe State, Nigeria's Gulani Local Government Area, at Latitude: 11° 8' 58" N (11.14957° N) and Longitude: 11° 52' 54" E (11.8818° E) coordinates. It is recognized as a separate settlement inside the Gulani district and is located in the state's southeast, in the North-East geopolitical zone.

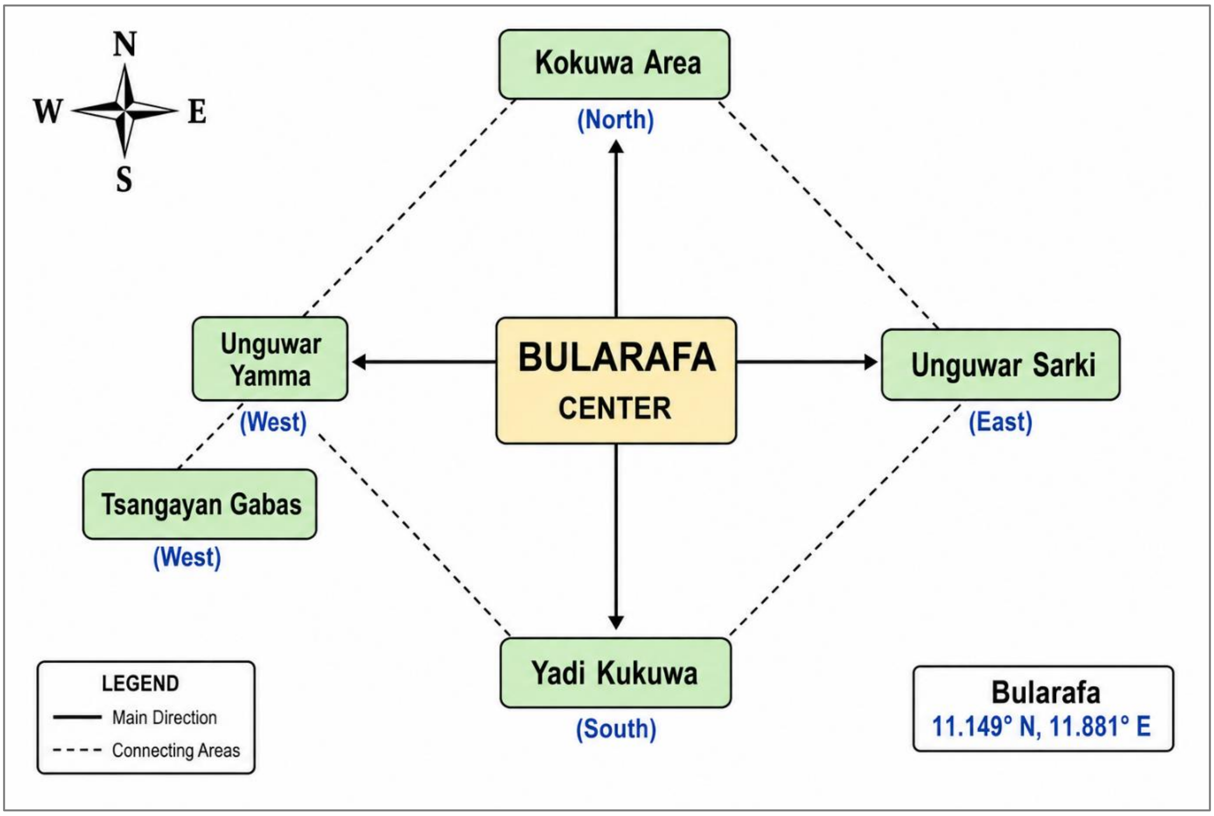

Figure 1 Map of Bularafa showing the sampling sites

Table 1 Water Samples Used and Locations Collected

S/N	Sample Label	Location
1	Tap Water (A1)	Tsangayan Gabas
2	Well Water (A2)	Tsangayan Gabas
3	Bore Hole Water (A3)	Tsangayan Gabas
4	Tap Water (B1)	Unguwar Sarki
5	Well Water (B2)	Unguwar Sarki
6	Bore Hole Water (B3)	Unguwar Sarki
7	Tap Water (C1)	Unguwar Yamma
8	Well Water (C2)	Unguwar Yamma
9	Bore Hole Water (C3)	Unguwar Yamma

2.3 Sample collection

The sample collection was done in October 2025, at the end of the rainy season. Nine water samples were collected from three different locations within Bularafa town (Table 1). The locations were selected systematically to capture the overall characteristics of the town, as shown in Figure 1. The locations include Tsangayan Gabas, Unguwar Sarki, and Unguwar Yamma. Each location had three types of water sources: tap water, well water, and borehole water. All samples were collected in 750 mL plastic bottles that were rinsed three times with the respective sample water before filling. The bottles were tightly closed to avoid contamination and stored at room temperature before analysis.

2.4 Physicochemical Analysis

Water samples from wells, boreholes, and taps in Bularafa were analyzed for pH, temperature, electrical conductivity (EC), turbidity, total dissolved solids (TDS), and total hardness (TH) following APHA (2017) methods. pH and temperature were measured in situ; EC and TDS were measured with a conductivity meter; turbidity was measured with a turbidimeter; and TH was measured by EDTA titration (mg/L $CaCO_3$). All measurements were performed in triplicate, and the mean values were recorded. These analyses provide information on water quality and its suitability for domestic, industrial, and agricultural use.

2.5 Preparation of 1000mg/Litre stock AAS standard solution for selected heavy metals

The manufacturer provided a stock solution containing 1000 ppm of each metal ion, from which a standard working solution of 100 ppm was prepared to plot calibration curves for the different metals.

2.6 Standard working solution and preparation of calibration curve

The volume of the stock solution to be diluted to the new required concentration was determined using the straightforward dilution formula ($C_1V_1 = C_2V_2$). 1 mL of concentrated HNO3 was added to each working standard, which was then diluted to the desired volume with deionized water.

To ascertain the metal concentration in the sample solution, calibration curves were created. A number of operational standards were used to calibrate the equipment. Each metal's working standard solutions were prepared from its standard solution, and the AAS was used to measure their absorbances. Plotting absorbance as a function of metal-ion standard concentration allowed the preparation of calibration curves for each metal ion examined.

2.7 Sample Digestion

The sample is digested using microwave-assisted acid digestion to solubilize metals and destroy organic matter. A SONEO Master 40 Microwave Digester (Hanon, China) equipped with PTFE/TFM digestion vessels and a pressure relief mechanism was used. The digester is also equipped with an integrated fibre-optic/infrared temperature sensor and an online temperature monitoring system. 40.0 ± 0.5 mL of acidified water sample was measured into the cleaned PTFE digestion vessel, followed by the addition of 2.0 mL concentrated HNO_3 (65-70%) and 1.0 mL H_2O_2 (30%). The mixture was allowed to stand for 10-15 minutes in a fume hood to allow initial oxidation. The vessel was allowed to cool to < 40°C before opening. The was then transferred to a 50.0 mL volumetric flask, and the vessel walls were rinsed with ultrapure water (3 × 5 mL), which were added to the flask, followed by dilution to volume and filtering through a 0.45 μm syringe filter.

2.8 Determination of metal contents of each sample

The concentration of the metal ions in the sample was evaluated by measuring their absorbance with a Buck Scientific AAS Model 210VGP (Buck Scientific, East Norwalk, CT, USA) and comparing the absorbance to the relevant standard calibration curve. The machine is equipped with a Hollow Cathode Lamp (HCL) light source for each element and a Deuterium background corrector. It also has titanium burner head with air-acetylene flame type. Three replicate determinations were carried out on each sample. The metals were determined in the absorption/concentration mode, and the instrument readout was recorded manually for each solution.

2.9 AAS Quality Assurance and Quality Control (QA/QC)

2.9.1 Calibration Verification

Initial Calibration Verification (ICV): Independent standard at mid-range, analyzed immediately after calibration. Acceptance: ± 10% of true value

Continuing Calibration Verification (CCV) : Analyzed at 10-15 sample intervals. Acceptance: ±10% . Recalibrate if outside acceptance limits.

2.9.2 Blanks

Method blank: Processed through entire digestion procedure (one per batch of ≤20 samples)

Reagent blank: Prepared with ultrapure water and acids

Acceptance: Metal concentrations below the reporting limit

2.9.3 Accuracy Assessment

Certified Reference Material (CRM) Analysis :

Analyze CRM (e.g., NIST SRM 1643f for trace metals in water) with each batch

Acceptance: Recovery between 80-120% for each analyte

Matrix Spike Recovery:

Spiked a duplicate sample with known concentration (typically 50-100% of expected levels)

Acceptance: Recovery between 85-115%

2.9.4 Precision Assessment

Duplicate Analysis:

Run duplicates for ≥10% of samples

Calculate Relative Percent Difference (RPD) = $|C_1-C_2| / (C_1+C_2)/2 \times 100$

Acceptance: RPD ≤ 20% for concentrations > 5× LOQ

Replicate injections:

Aspirate each sample three times

Calculate %RSD = (SD/mean) × 100

Acceptance: %RSD ≤ 10%

2.9.5 Detection and Quantification Limits

Method Detection Limit (MDL) Determination :

Prepared 7 replicates of low-concentration standard (1-5× estimated MDL)

Processed through full digestion and analysis

Calculate standard deviation (SD)

MDL = 3 × SD

LOQ = 10 × SD (or 3 × MDL)

2.9.6 Carryover Check

Analyzed a reagent blank after the highest standard

Acceptance: Absorbance < 10% of lowest calibration standard

RESULTS AND DISCUSSION

3.1 Total hardness

Water hardness results from calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, usually from the dissolution of minerals like limestone and dolomite (Ameen et al., 2026) The total hardness of the water samples ranged from 15 mg/L (A1) to 110 mg/L (B2) as shown in Figure 2 and Table 2. The WHO (2017) permissible limit for drinking water hardness is 100 mg/L, meaning majority of the samples fall within the safe range. The differences in hardness levels may be due to variations in the geological and mineral composition of the aquifer. Areas rich in carbonate and bicarbonate minerals generally show higher hardness. It can be seen that all the samples collected from Unguwar Sarki (B1, B2, B3) have relatively higher total hardness (80–110 mg/L). This may suggest that the area is rich in carbonate and bicarbonate minerals, which may be affecting the water there. Hard water causes mineral buildup (scale) in pipes and appliances, reducing their lifespan and efficiency. It creates a sticky residue on dishes and fixtures, causes soap scum, and dries up hair and skin, potentially exacerbating eczema and imparting a bitter taste (Godskesen et al., 2012).

3.2 Turbidity

The turbidity of the samples ranged from 45.6 NTU (C1) to 51.9 NTU (B1), far above the WHO limit of 5.0 NTU, as shown in Figure 2 and Table 2. This indicates a high concentration of suspended particles, including clay, silt, and organic matter. Drinking water with high turbidity primarily serves as a barrier for pathogens, allowing bacteria, viruses, and parasites to avoid disinfection. This increases the risk of gastrointestinal problems, raises aesthetic concerns about taste and odour, and signals probable contamination (Kundu et al., 2024). The elevated values may result from surface runoff, erosion, and human activities such as mining, washing, farming, or open defecation near water sources. This is an indicator that proper treatment, such as filtration and coagulation, should be applied to all water before consumption. The samples require adequate purification before they can be considered safe for drinking.

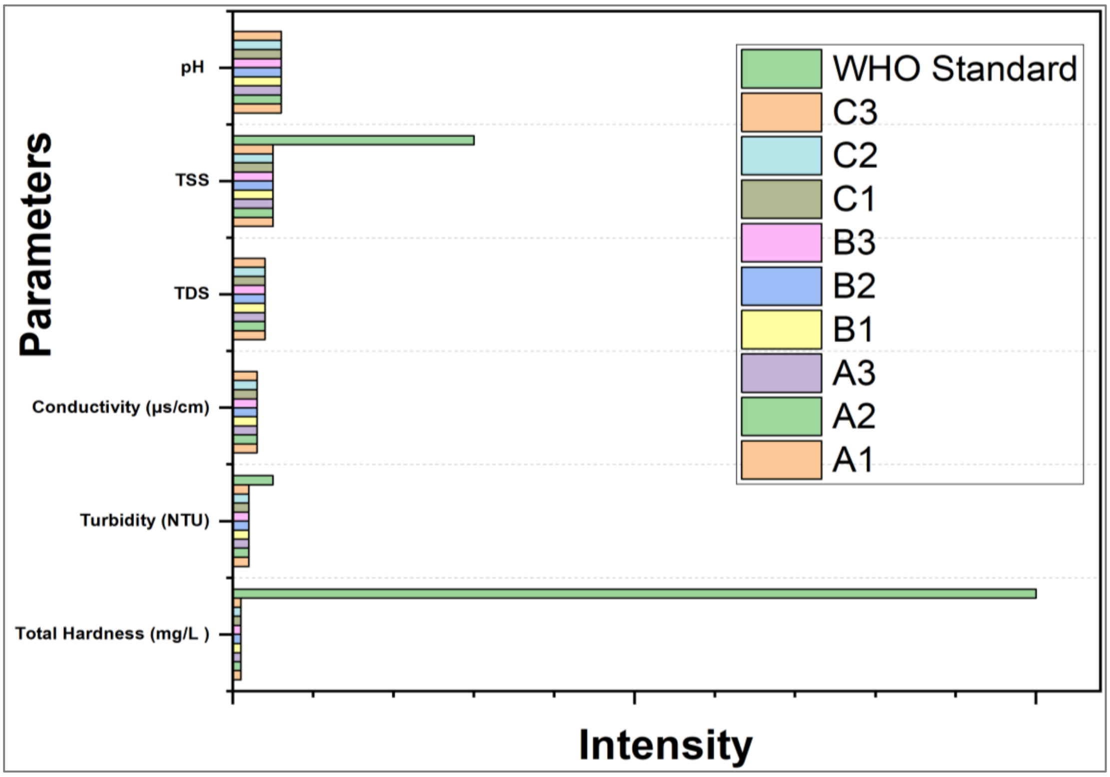

Figure 2 Results of analyzed physiochemical parameters for Tsangayan Gabas, Unguwar Sarki, and Unguwar Yamma

3.5 Total suspended solids

Total Suspended Solids (TSS) in drinking water is the dry weight of organic and inorganic particles larger than 2 microns that are captured by a filter but are not dissolved (Boyd, 2020) It is a physical measure of water quality that degrades the quality of lakes and rivers. TSS is a fractional component of the same sample's "total solids" that has been filtered out. The term "total solids" describes "the material residue left in the vessel after evaporation of a sample and its subsequent drying in an oven at a defined temperature."

Table 2 Result of analyzed physiochemical parameters

Parameters	A1	A2	A3	B1	B2	B3	C1	C2	C3	WHO Standard
Total Hardness (mg/L)	15±2.0	20±3.0	18±2.0	90±2.0	110±2.0	80±3.0	22±3.0	25±2.0	20±2.0	100
Turbidity (NTU)	47.5±2.0	48.7±1.0	46.3±2.0	51.9±1.0	46.5±3.0	50.4±1.0	45.6±2.0	49.9±1.0	48.5±1.0	5
Conductivity (µs/cm)	695±1.0	685±2.0	650±3.0	700±1.0	690±1.0	710±1.0	600±2.0	700±1.0	680±1.0	50-500
Total Dissolved Solids (mg/L)	645±2.0	650±1.0	610±1.0	670±1.0	610±2.0	680±1.0	620±2.0	660±1.0	650±1.0	300-600
Total Suspended Solids (mg/L)	5.89±0.5	6.04±1.0	6.20±1.0	5.94±0.5	6.00±1.0	7.50±0.5	6.88±0.5	6.89±0.5	6.97±0.5	30
pH	7.4±0.2	7.9±0.2	8.0±0.1	8.2±0.1	8.5±0.2	8.6±0.1	8.4±0.2	8.2±0.2	9.3±0.11	6.5-8.5

Table 3 Heavy Metals Concentration obtained for the samples

Heavy metals	A1	A2	A3	B1	B2	B3	C1	C2	C3	WHO Standard
Lead (mg/L)	0.7±0.1	0.5±0.1	0.3±0.2	0.4±0.2	0.5±0.2	0.6±0.2	0.7±0.2	0.5±0.2	0.8±0.1	0.5
Iron (mg/L)	0.11±0.01	0.098±0.01	0.107±0.01	0.088±0.01	0.067±0.02	0.091±0.01	0.045±0.02	0.061±0.02	0.070±0.01	0.3
Copper (mg/L)	0.28±0.01	0.27±0.01	0.41±0.02	0.33±0.03	0.42±0.02	0.18±0.03	0.73±0.01	0.42±0.02	0.78±0.01	1
Cadmium (mg/L)	0.042±0.02	0.008±0.01	0.031±0.01	0.009±0.02	0.007±0.01	0.004±0.01	0.013±0.02	0.011±0.01	0.015±0.01	0.003
Chromium (mg/L)	0.3±0.02	0.4±0.01	0.3±0.02	0.4±0.01	0.2±0.01	0.1±0.01	0.4±0.01	0.6±0.02	0.7±0.02	0.05

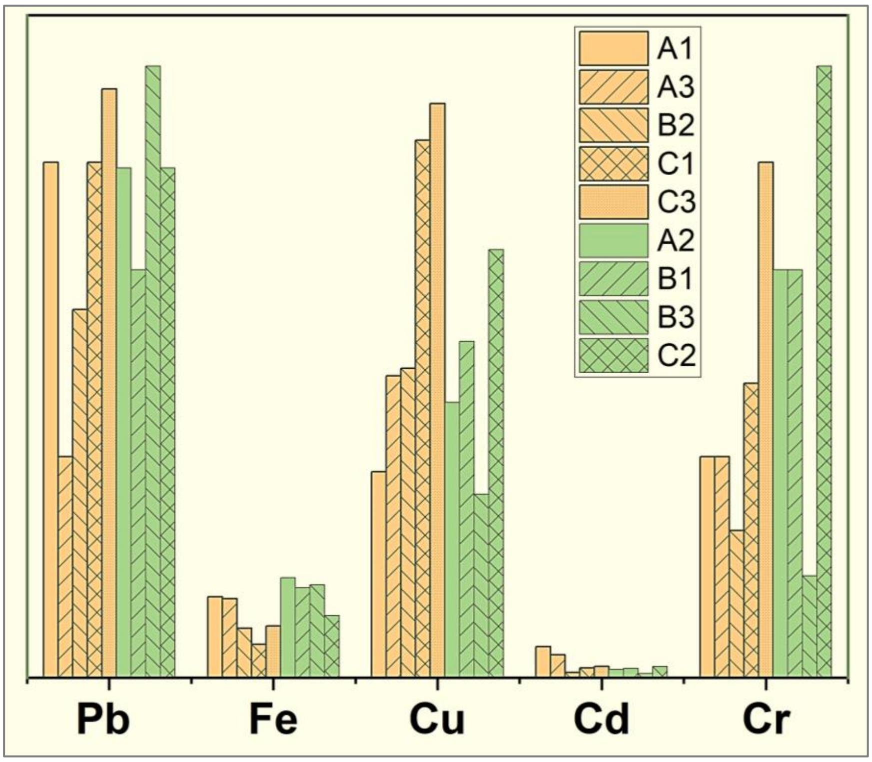

Figure 3 Heavy metals concentration profile for Tsangayan Gabas, Unguwar Sarki, and Unguwar Yamma

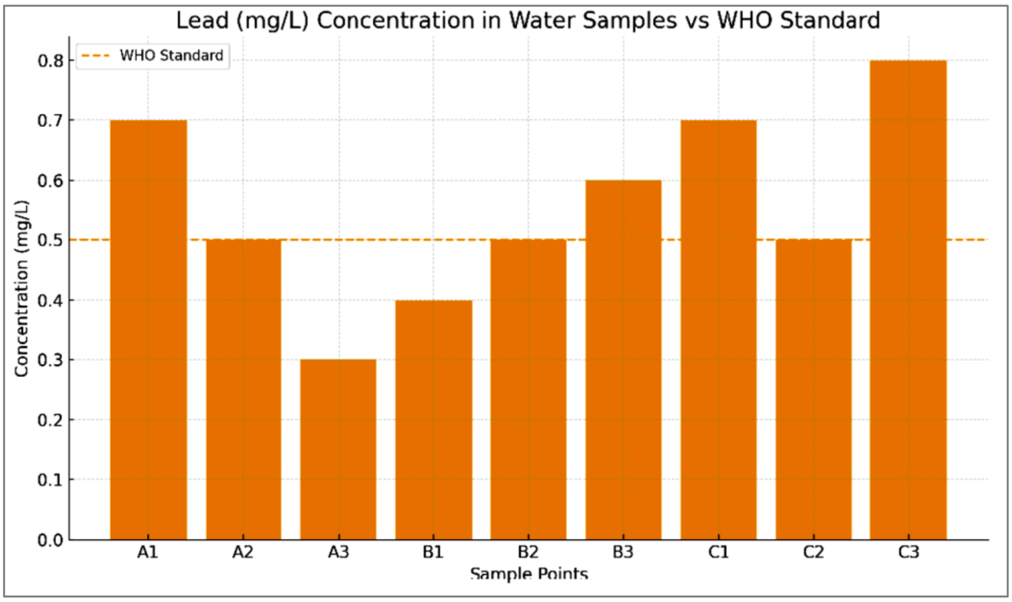

Figure 4 Lead Concentration in Bularafa Water

TSS constituents in water samples are retained by a filter with a pore size of 2 µm or less. The dried residue left on the filter is weighed. TSS constituents include particulate materials like as sediment, silts, and algae, as well as other suspended solid particles (Adjovu et al., 2023) To guarantee clarity and safety, TSS in drinking water should preferably be as close to zero as feasible, with acceptable levels often below 5 mg/L (Butler & Ford, 2017) A TSS value of 5–7.5 mg/L indicates low levels of suspended particles and generally reflects moderate water clarity.

3.6 pH

The pH values ranged from 7.4 (A1) to 9.3 (C2), within the WHO acceptable range of 6.5–8.5, as shown in Figure 2 and Table 2. This indicates that all the samples have relatively high alkalinity. The higher pH reaffirms our earlier result of higher turbidity and high total hardness. This type of water often tastes bitter, feels slippery, and may cause mineral buildup, as discussed earlier. Highly alkaline water can cause eye, skin and gastrointestinal irritations. In terms of water treatment, this type of water usually reduces the effectiveness of chlorine disinfection (Patel et al., 2014). This elongates the treatment process and increases its cost accordingly.

3.7 Results of analyzed heavy metals

Heavy metals significantly affect water quality for domestic and agricultural use, and even trace amounts can pose health risks if above permissible limits. As shown in Table 3, the concentrations of Lead, Iron, Copper, Cadmium, and Chromium in nine water samples from three locations (A, B, C) in Bularafa were compared with WHO (2017) drinking water guidelines to evaluate their safety for human consumption. The heavy metal concentration profile of the three locations is also shown in Figure 3.

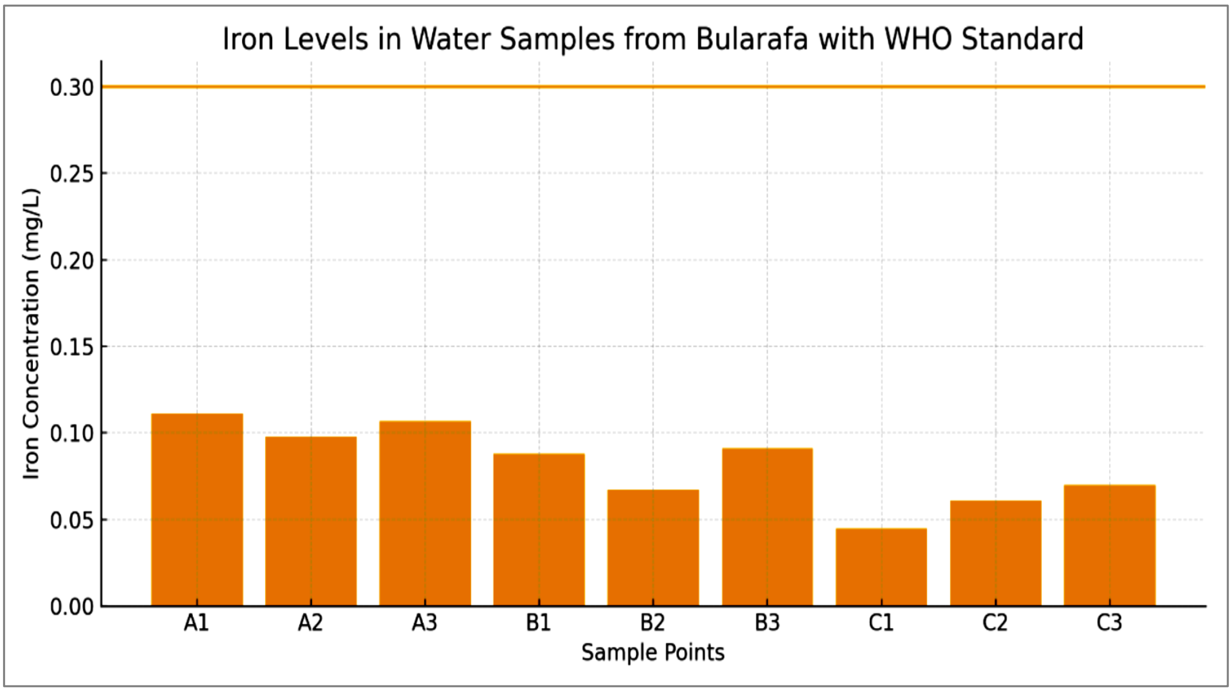

Figure 5 Iron Concentration in Bularafa Water

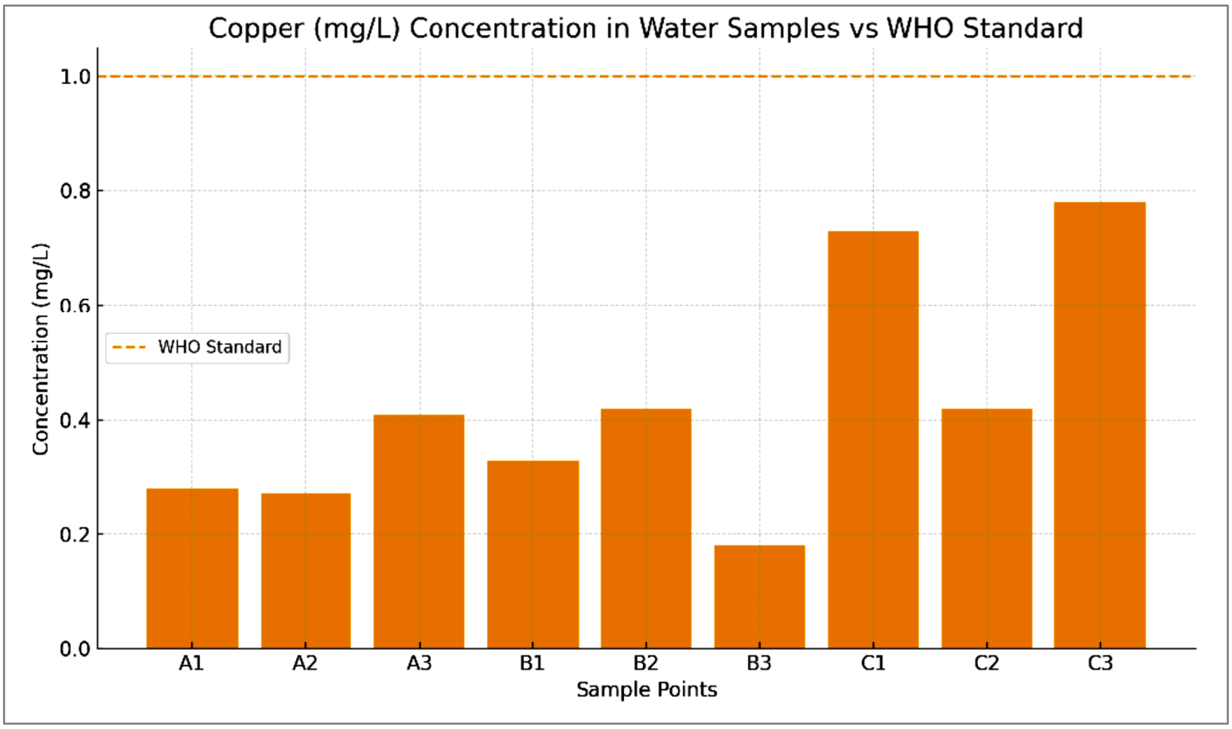

Figure 6 Copper Concentration in Bularafa Water

3.7.1 Lead (Pb)

Lead concentrations in the water samples ranged from 0.3 mg/L (A3) to 0.8 mg/L (C2), with the WHO limit set at 0.5 mg/L (Figure 4). Notably, all the samples, except A3 (0.3 mg/L) and B1 (0.4 mg/L), have relatively high lead content, which is very dangerous. Samples A1 (0.8 mg/L), C1 (0.7 mg/L), and C3 (0.8 mg/L) have extremely high lead content, which is frightening. Those samples were earlier found to also have higher pH, total dissolved solids, turbidity, and conductivity. Elevated lead levels may result from corroded pipes, battery waste, or agricultural runoff. Prolonged exposure can cause neurological disorders, anaemia, and kidney problems, especially in children and pregnant women, making water from the affected sources unsafe for drinking without treatment (Ali et al., 2019; Collin et al., 2022). Such types of water require effective monitoring and treatment before consumption, as most of the residents consume the water directly without any treatment.

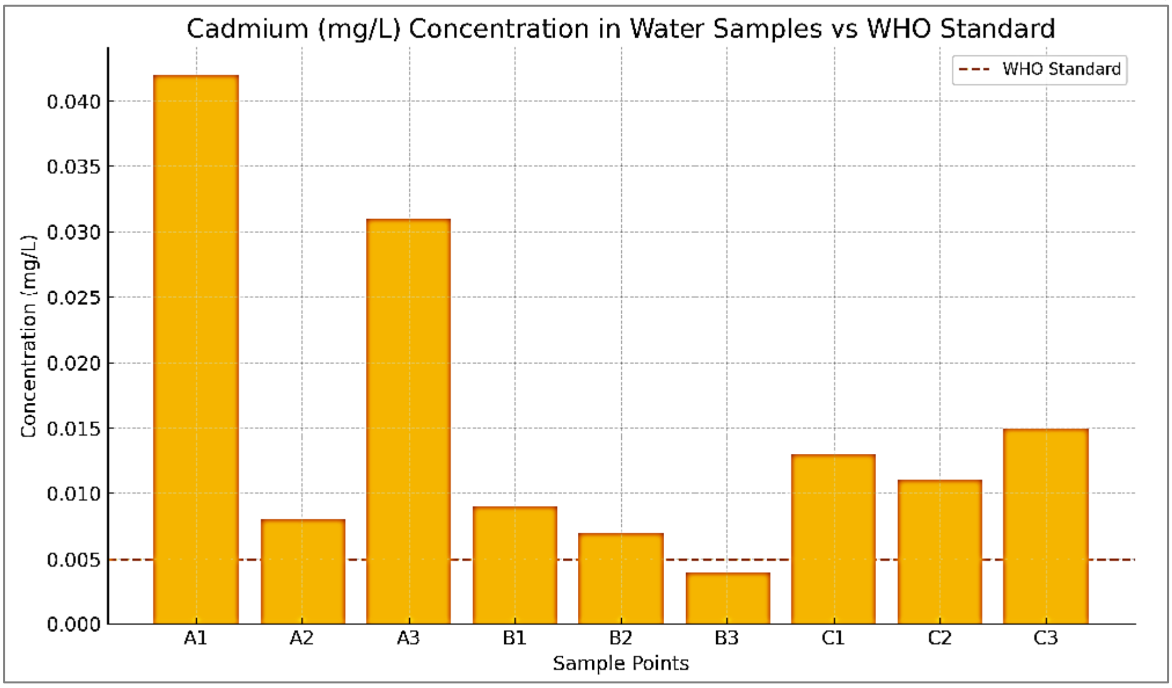

Figure 7 Cadmium Concentrations in Bularafa Water

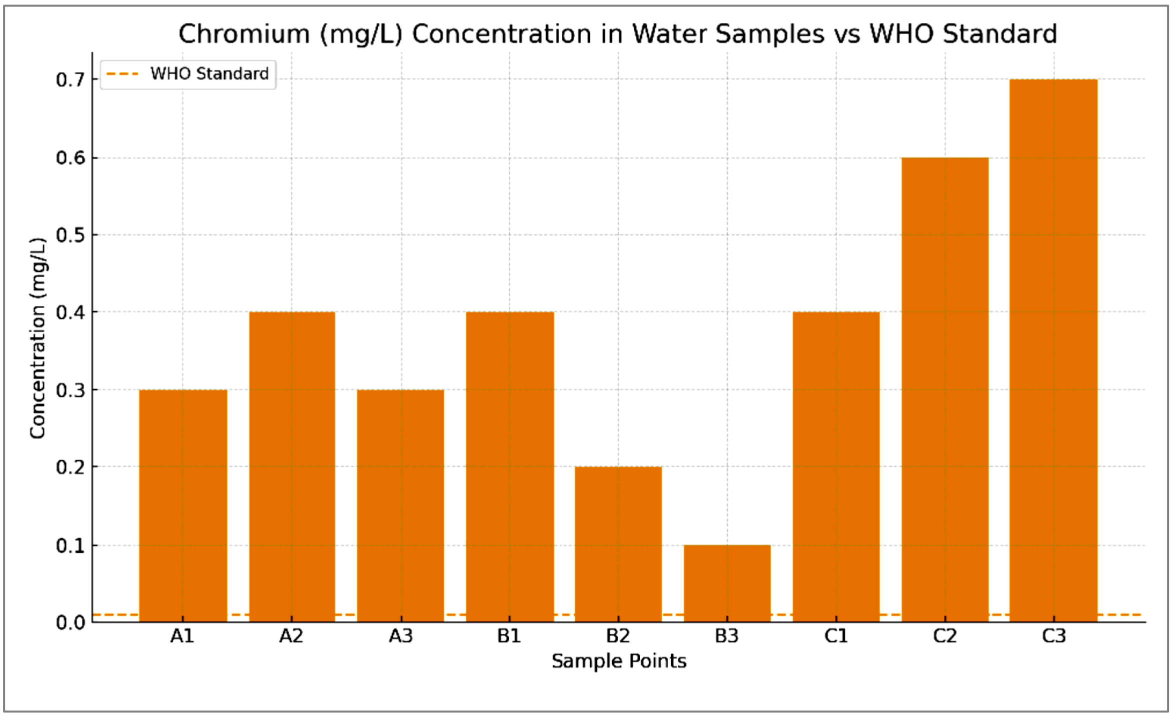

Figure 8 Chromium Concentrations in Bularafa Water

3.7.2 Iron (Fe)

The concentration of iron in the analyzed water samples varied from 0.045 mg/L (C1) to 0.111 mg/L (A1). The WHO permissible limit for iron in drinking water is 0.3 mg/L, meaning that all samples are within the safe range (Figure 5). Although iron is an essential nutrient for human health, excessive levels can cause undesirable taste, discoloration, and staining of laundry and plumbing fixtures (Zairullah et al., 2025) The relatively low concentrations recorded suggest that iron contamination is minimal, possibly due to the absence of industrial discharge or iron-based materials near the sampling points.

3.7.3 Copper (Cu)

The copper concentrations ranged between 0.18 mg/L (B3) and 0.78 mg/L (C2), which are below the WHO permissible limit of 1.0 mg/L (Figure 6). This implies that copper levels in all the sampled water sources are within acceptable limits. Copper may naturally occur from dissolution of copper minerals or corrosion of copper plumbing materials (Vargas et al., 2017) At moderate levels, copper is essential for body metabolism, but excessive intake can lead to gastrointestinal irritation and liver or kidney damage (Taylor et al., 2020) Since all the measured values are within permissible limits, the water samples can be considered safe in terms of copper concentration.

3.7.4 Cadmium (Cd)

The concentration of cadmium in the samples ranged from 0.004 mg/L (B3) to 0.042 mg/L (A1), while the WHO standard for cadmium is 0.005 mg/L (Figure 7). The results show that almost all samples exceeded the WHO permissible limit, except for B3 (0.004 mg/L). The high concentrations indicate possible contaminations from herbicides, inorganic fertilizers, or improper waste disposal. Cadmium is highly toxic even at trace levels and is associated with kidney dysfunction, bone damage, and carcinogenic effects (Charkiewicz et al., 2023. The observed values therefore suggest that the water sources in the studied areas are unsafe due to cadmium contamination.

3.7.5 Chromium (Cr)

Chromium concentrations in the water samples ranged from 0.1 mg/L (B3) to 0.7 mg/L (C3), exceeding the WHO permissible limit of 0.01 mg/L (Figure 8). All the recorded values exceeded the recommended limit, indicating severe chromium contamination. Excess exposure to chromium, particularly hexavalent chromium (Cr^{6+}), is known to cause skin irritation, respiratory issues, and increased cancer risk. Chronic ingestion causes liver and kidney damage, stomach pain, anemia, stomach pain and reproductive issues (Alvarez et al., 2021) The elevated chromium levels make the water unsuitable for human consumption without proper treatment.

CONCLUSIONS

This study was carried out to assess the quality of water from different sources used by the people of Bularafa for domestic and drinking purposes. Nine water samples were collected from three different locations, labeled A1–A3, B1–B3, and C1–C3. The samples were analysed for physicochemical and heavy metal parameters, and the results were compared with the WHO drinking water standards. The findings revealed that most physicochemical parameters, such as pH, turbidity, conductivity, TDS, and TSS, have generally exceeded acceptable limits, making the water unsuitable for direct consumption without proper treatment. Meanwhile, the heavy metal analysis showed that some metals, such as Pb, Cd, and Cr, were present at high concentrations, well above the WHO permissible limits. High concentrations of lead, cadmium, and chromium pose serious health threats such as kidney damage, anemia, bone weakness, and neurological disorders. Bularafa, one of the towns currently engulfed in CKD issues in Yobe State, needs urgent and proper consideration regarding the water consumed by residents, as this revelation may not be unconnected to the problem. Likewise, Bularafa is one of the communities where local mining activities, particularly the mining of iron and gold are commonly practiced. These mining operations can significantly contribute to the presence of heavy metals in nearby water sources through soil disturbance, ore washing, and runoff from mining sites. Therefore, the elevated levels of metals observed in the water may be partly linked to these artisanal mining activities within and around the community It is important to note that although the water samples may appear clear and usable, they are not safe for direct consumption due to the elevated concentrations of those toxic metals and unsuitable physicochemical properties. Hence, regular monitoring, public awareness, environmental control, efficient water treatment, and alternative water sources will help significantly address this tremendous problem. Likewise, as a suggestion for future studies, emphasis should be placed on comprehensive studies of the prevalence of CKD in relation to the mining activities taking place in the area.

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