Ethiopian Journal of Environmental Studies & Management 18(2): 228 – 239, 2025
ISSN:1998-0507 doi: https://ejesm.org/doi/v18i2.8
Submitted: April 18, 2025 Accepted: June 02, 2025

WATER QUALITY ASSESSMENT OF SELECTED PORTABLE GROUNDWATER SOURCES IN BIU METROPOLIS, BORNO STATE, NIGERIA

***MUSTAFA, I.A., MBURSA, A. AND MALGWI, M.W.**
Department of Geography, Nigerian Army University, Biu, Borno State, Nigeria
*Corresponding author: ibroashly@yahoo.com

Abstract

Accessibility to safe and good quality drinking water is paramount to human survival as such every individual is entitled to good quality water. Thus, in Biu city, Biu Local Government Area, Borno State are facing the problem of water scarcity. The study assesses the quality of a few chosen boreholes. Two samples from each of the five (5) wards that make up the metropolis were sampled. The following physico-chemical variables were analyzed for water quality: pH, EC, turbidity, DO, TSS, sodium, potassium, nitrate, ammonia, sulphate, chloride, salinity, and total alkalinity. The results showed that, in accordance with the World Health Organization's water quality guideline, the water samples' pH ranged from 6.8 to 8.0, making them suitable for drinking and household usage. The value for different physico-chemical parameters on EC, TDS, is within the standard of WHO. The total hardness within the samples varies from samples to another but is still with the range of acceptability. On the area of concentration of heavy metals, Cu exceeded the limit in most of the areas which is set at 0.005. High copper levels in water can have negative impacts on the ecosystem and human health, thus this is reason for concern. The study therefore recommended that there should be periodic boreholes rehabilitation, cleaning of the surroundings, regular assessing of the water samples in order to check the basic physico-chemical characteristics of the water quality, followed by the government and Non-Governmental Organizations (NGOs)can assist and build more boreholes in the study area.

Key Words: *Water quality, Drinking water, Physicochemical characteristics, Biu, Nigeria*

Introduction

The accessibility and availability of portable drinking water is essential to human survival as he depends on water resources as well as the ecosystem (Sadiq *et al.,* 2022). However, access to clean drinking water from better sources has been a problem for developing nations like Nigeria (World Health Organization, 2014). People are still reliant on vulnerable water sources including rivers, streams, springs, and hand-dug wells as a result of this action. The availability of portable water in the environment determines the extent of economic and social development of a community or society. Cutter and Miller (2005) reported that worldwide, an estimated 1.1 billion people do not have access to clean drinking water, and water-diarrheal illnesses are thought to claim the lives of 1.7 million people annually. Therefore, the most important requirement is for water that is safe for human health and adequate for drinking, food preparation, and personal hygiene. Safe, high-quality drinking water is fundamental to public health, environmental sustainability, and socioeconomic development.

It is further observed in the United Nation Sustainable Development Goals (SDGs) particularly Goal 6 highlights how crucial it is to guarantee universal access to and sustainable management of clean water and sanitary facilities. However, in many developing nations, including Nigeria, the quality and availability of drinking water present significant challenges, posing risks to health and well-being. Increased human activity and physical or chemical pollution, which alters the quality of the receiving water body, are the main causes of the exacerbated water quality (Aremu *et al.,* 2011). All around the world, drinking water contains chemical pollutants that may be harmful to human health. In addition, the majority of sources are located close to gullies where open field defecation occurs often, and flood-washed wastes have an impact on the water quality (Messeret, 2012). Recent study has introduced the aspect of anthropogenic chemicals in analyzing quality of water because of the impact it has on health (Kegley and Andrew, 1998).

Studies on water quality are viewed as vital to the health of everyone on the planet. Water quality is a description of the chemical, physical and biological components of water in relation with anticipated use (Aremu *et al.,* 2011). The quality of water sources is affected due to point source and non-point source pollution which can be altered by different pollutant substances such as physical, chemical and biological pollutants among others. Bacteria, viruses, nitrate, salt, and heavy metals are some of the organisms and substances which are found to be making alteration on the water quality in the environment. Pollution occurs when a body of water is negatively impacted by the significant influx of undesired materials (Atta and Razzak, 2008). According to the World Health Organization (2011), assessing the physical and chemical characteristics of drinking water is the most effective method of establishing its quality.

According to Kegley and Andrews, (1998) who pointed out that Just 3% of all water sources on Earth are good (in terms of freshness or quality). Among these are groundwater and surface water, which includes lakes, streams, rivers, and reservoirs (wells and boreholes). That is to say, the increased reliance on ground water as a source of drinking water has resulted from the decrease in the usage of surface water for drinking water supply because of contamination. However, researchers have only shown little attention to drinking water quality issues in the world (Kegley and Andrews, 1998). In Nigeria, the primary source of drinking water in both rural and urban regions is ground water. However, this water has been depleting over time due to increased water demand, climate change, unsustainable extraction, and poor enforcement of drilling standard. These have also caused water scarcity, environmental degradation and water quality issues.

Nigeria's northeast, which includes the states of Adamawa, Bauchi, Borno, Gombe, Taraba, and Yobe heavily, relies on ground water in form of boreholes (Mustafa *et al.,* 2012). With the increase in the availability of boreholes water in the region which is a significant supply of drinking water, and the quality of the water coming from it is a developing problem (Mustafa *et al.,* 2012). Despite the fact that water is essential to life, access to quality drinking water still remains a problem in many parts of Biu metropolis. Majority of households in the study area have to travel a longer distance before getting access to good quality water as against the recommended distance of 1km through the World Health Organization. This context informs the paper's evaluation of the sources of drinking water quality from a few chosen boreholes in the city of Biu.

Materials and Methods

Study Area

The research was carried out in Biu metropolis (Zarawuyaku, Dugja, Galdimari, Yawi, and Silumthla ward) within Biu Local Government Area (LGA) with emphasis on some selected boreholes (Fig 1). The area lays approximately 11.0500° N latitude and 11.8400° E longitude. This location places the area in a strategic position because of the availability of mountains and rocks which usually make the availability of water impossible. Biu LGA covers a total land area of approximately 2,697 square kilometers (or about 1,041 square miles). The terrain is predominantly characterized by rolling hills and plateaus, with fertile plains suitable for agriculture, which is the backbone of the local economy.

The people in the area rely mostly on ground water (boreholes) for drinking and other activities. The absence of government surface water from water bards makes it difficult for people to access portable water. This act has prompted several Non-Governmental Organizations (NGOs) as well as wealthy individuals in providing boreholes in the metropolis.

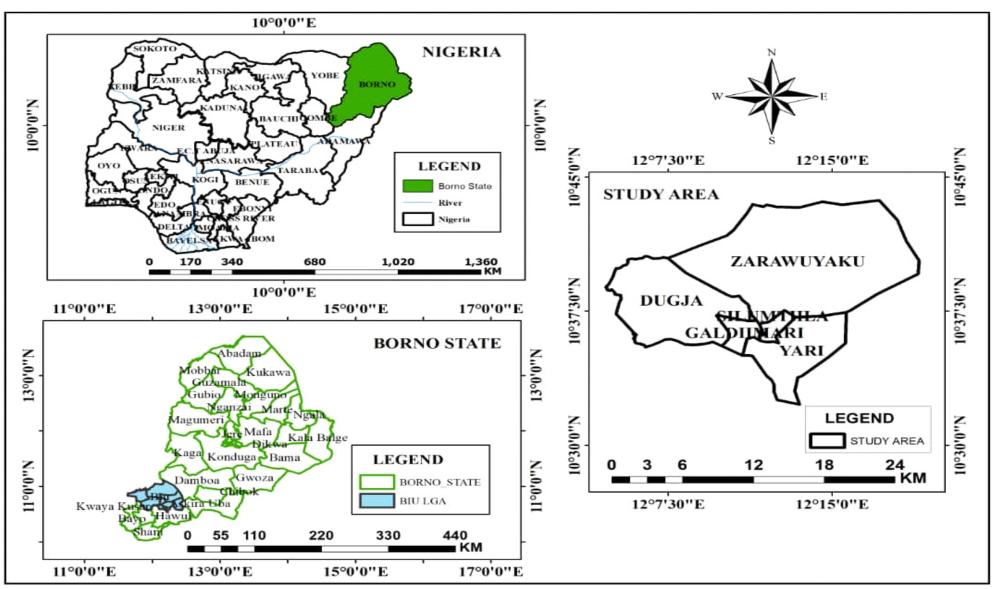

Fig. 1: The research area map

The distribution of water sample point locations within the study region is displayed in Figure 2. This indicates that in each of the wards two sample points were identified which were named with the ward names 1 and 2. The two samples from each of the wards were from North and South of the wards.

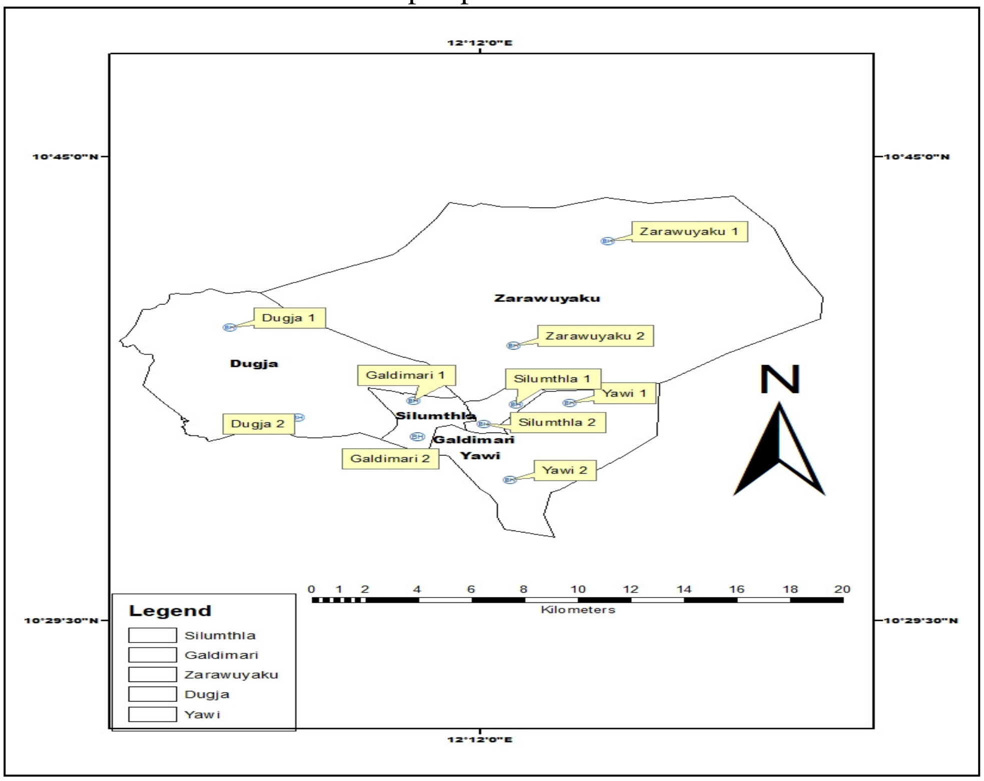

Fig. 2: Water sample points

Table 2: Coordinates of Sample points

S/No	Wards	Sample Points	Latitude	Longitude
1.	Dugja	Dugja 1	12.115	10.655
		Dugja 2	12.138	10.605
2.	Galdimari	Galdimari 1	12.177	10.616
		Galdimari 2	12.179	10.594
3.	Silumthla	Silumthla 1	12.212	10.612
		Silumthla 2	12.201	10.601
4.	Yawi	Yawi 1	12.23	10.613
		Yawi 2	12.21	10.57
5.	Zarawuyaku	Zarawuyaku 1	12.243	10.703
		Zarawuyaku 2	12.211	10.645

Table 3 displays the physical attributes of the water samples. This shows that all the samples are colorless. Sample from Galdimari 2 (Baban line) appears to be white but all the remaining samples from Galdimari remain odourless in terms of smell. Lastly, were the samples collected from Dugja 2 and Yawi 1, high salinity levelwas observed ranging between 5,000-35,000mg/L while the remaining samples fall within the normal pH range.

Samples Collection

Water source sampling locations were specifically chosen to reflect all sources of drinking water. Water samples were collected from boreholes in the five (5) wards that make the metropolis which are Dugja, Galdimari, Silumthla, Yawi, and Zarawuyaku of Biu metropolis. Furthermore, two (2) samples were collected in each of the wards, thereby making the total samples to be ten (10) from the five (5) wards selected taking into consideration the distance from each of the water sources. This action resulted in taking one from the North and another from the south of each ward. The water point samples were randomly collected using sterile sampling bottles, adhering to World Health Organization (WHO) standard protocols to prevent contamination.

In addition, before any sample of water was then collected, cotton wool was used to disinfect the tap's nozzle after being treated in 70% ethanol so that any contaminated substances from the tap will not go into the container. The plastic cans used were thoroughly washed before collecting the water samples from the borehole. The plastic cans were labeled and stored in a sample holding kit after being filled to the brim to prevent air bubbles and securely sealed with a cover so as to avoid contaminants before transporting it to the laboratory for analysis.

Table 1: Sample Locations

S/No	Sampling wards	Sample location	Sample source
1.	Dugja 1	Babban layi	Borehole
2..	Dugja 2	Tabra Fulani	10.605
3.	Galdimari 1	Gidan Makama	10.616
4.	Galdimari 2	Galdimari Babban Layi	10.594
5.	Silumthla 1	Sabon Kwalta	10.612
6.	Silumthla 2	Massalachin Saifullah	10.601
7.	Yawi 1	Usman Pawa	10.613
8.	Yawi 2	20 Housing	10.57
9.	Zarawuyaku 1	Close to Prison Service	10.703
10.	Zarawuyaku 2	Central Primary School Road	10.645

Water Quality Parameters

Lead, zinc, iron, manganese, total dissolved solids, pH, turbidity, temperature, and dissolved oxygen are the water quality characteristics chosen for the study. Using accepted techniques, the water samples' physico-chemical properties were examined. Turbidity, TDS, and TSS were measured *in-situ* using a 214 A turbidity meter, conductivity, and photometric techniques, respectively, whereas unstable pH, temperature, and DO parameters were measured using an ATI-Orion pH meter, thermometer, and probe, respectively. On the other hand, heavy metals like iron (Fe), lead (Pb), and zinc (Zn) were identified using the Atomic Absorption Spectrophotometer (AAS) at wavelengths of 248, 283, and 213.9 nm, respectively.

thresholds for potable water supply.

Identification of Additional Components

Using suitable, approved, and globally recognized protocols described in the Standard Method for the Examination of Water and Wastewater (APHA, 2005), elemental analysis of the water samples was performed. In order to evaluate sodium (Na), magnesium (Mg), and potassium (K), the Atomic Absorption Spectrometer (AAS) Model A. Analyst 400 was used.

Results and Discussion

Properties of the water sampled, both physical and chemical: The water samples underwent physico-chemical examination, which evaluated a total of fourteen parameters within the study area.

pH

When assessing the acid-base balance of water, pH is a crucial metric. The amount of dissolved carbon dioxide (CO_2) that produced carbon acid in the water is what determines this. The result revealed that pH value ranged from 5.85-7.72. This further demonstrates that practically every sample falls inside the World Health Organization's (WHO) guideline range, with the exception ofGaldimari 1 (6.42), Silumthala 1 (6.37), Yawi 2 (6.37), Zarawuyaku 1 (5.85) and Zarawuyaku 2 (6.42). This shows that all those that are below the standard contain some percentage of acidity. The slight variation in the pH values of the boreholes can also be attributed to natural factors or minor contamination. This outcome is consistent with Kolo *et al*. (2009) who reported 6.1 pH value for boreholes in the Bulumkutu ward of Maiduguri. While pH is one of the most crucial operational water quality indicators, it typically has little direct effect on consumers (WHO, 2011).

Electrical Conductivity (EC)

The ionic process in a solution that permits current transmission is measured by electrical conductivity. The result from the analysis shows that the Electrical Conductivity Dugja 1 (207µS/cm), Dugja 2 (295µS/cm), and Silumthla 2 (387µS/cm). This shows that majority of the sample points are below the WHO standard on electricity conductivity in boreholes which should not exceed 400µS/cm. Electrical conductivity is often determined by the concentration of dissolved particles in water. The result from this work is Similar to that of Saminu *et al*. (2020) who took a study of drinking water in part of Kaduna. The result shows that water in the study area was not considerably ionized and has lower level of ionic concentration activity due to small dissolve solids

Total Dissolved Solids (TDS)

Water has the capacity to dissolve a wide range of inorganic and some organic minerals. These different forms of minerals produced unwanted taste and diluted colour in water. The result shows that all the water samples from the area met the requirement of WHO of not more than 600mg/L. However, it still shows a considerable variation among the samples. This is in line with the work of Sasikaran *et al*. (2012) who said that the high values of TDS in ground water are generally not harm full to human beings, but the present of high concentration of these may affect those who are suffering from kidney and heart diseases.

Total Suspended Solids

From the entire sample it clearly shows that most of the samples have low total suspended solids which indicate that the water is clear of solid particles of both organic and inorganicparticles. The areas with clear TSS are found in Dugja 1 (18.00), Galdimari 1(23), Zarawuyaku 1 (13.00), Yawi 1(35), and Zarawuyaku 2(23) are clear. Areas with cloudy are those from 40-80 which are found in areas like Dugja 2(72), Galdimari 2(51), Silumthla 1(45), Silumthla 2(91), Yawi 2(45). Areas with higher TSS values can be associated with the presence of materials that float or suspend in water like sand and sediments.

Total Hardness

Hardness within the samples varies from location to location. Zarawuyaku 1 and Zarawuyaku 2, were seen as areas with the least samples with hardness in water with 168 and 176mg/l respectively. The areas with the highest value of hardness are showed in Dugja 2 (225), Silumthla 2(278). Even with the variation of hardness within the samples it still shows that the water is accepted for drinking since none of them are above the accepted value of WHO which is 500mg/L. The presence of calcium and magnesium compounds as well as other metals can be linked to the hardness. This research is in line with Bashir et al., (2012) which also recorded much lower total hardness than required in Jimeta, Adamawa State Nigeria. However, hard water is known to be undesirable for boilers and laundry.

Alkalinity

The water is safe to drink because the alkalinities found in the tests were quite low. The amount of bicarbonate, carbonate, or hydroxide in water is measured by alkalinity. Alkalinity plays a role in water buffering capacity, which is important for maintaining stable pH. The least were observed in Zarawuyaku 1 (0.11), Zarawuyaku 2 and Galdimari 2 with (0.22), and Silumuthla 1(0.23) while the highest was in Dugja 2 with (0.59).

Table 4: Physico-chemical characteristics of the samples

Parameters	Dugja 1	Dugja 2	Galdimari 1	Galdimari 2	Silumthla 1	SIlumthla 2	Yawi 1	Yawi 2	Zarawuyaku 1	Zarawuyaku 2	WHO
pH	6.98	7.32	6.42	7.72	6.37	7.02	6.94	6.37	5.85	6.42	6.5-8.5
E.CuS/cm	207.00	295.00	139.00	164.00	142.00	387.00	187.00	142.00	123.00	137	200-800 µS/cm
T.D.S mg/dm^3	103.00	141.00	67.00	83.00	71.00	191.00	94.00	71.00	61.00	65.00	300-600 mg/L
T.S.S mg/dm^3	18.00	72.00	23.00	51.00	45.00	91.00	35.00	45.00	13.00	13.00	20-40mg/L
T.Hard mg/dm^3 CaCo^3 eqv	195.00	225.00	176.00	181.00	183.00	278.00	192.00	183.00	168.00	176.00	500mg/L
Alkalinity mg/dm^3	0.31	0.59	0.22	0.65	0.23	0.52	0.28	0.23	0.11	0.22	0.5-24.5g/L

Spatial Variation of Mineral Components in Samples

Significant differences exist between the concentrations at the different sample locations. (Dugja, Silumthla, Galdimari, Zarawuyaku, and Yawi). This suggests that local factors like geology, land use, and pollution sources influence water quality.

Temporal Variability

There was variability in the temporal aspect of the mineral components in the sample water within each location. The variation may be attributed to seasonal fluctuations, rainfall events, or other temporal factors. The result revealed that the entire samples are within the accepted value of the WHO standard of the composition of Nitrate. The lowest was found in Yawi 1 (5.17) while the highest was in Zarawuyaku 2 (28.46). Nitrate presence in water is toxic to health, water containing too much of nitrate is harmful to industrial processes such as dying of wool and silk materials, and it is undesirable in fermentation process Imoisi *et al*. (2012).

In the aspect of phosphate, the result revealed that Zarawuyaku 1 and 2 (0.33 ad 0.77) are the lowest while Silumthla 2 (13.22) is the highest in term of phosphate concentration in the water samples. Further analysis carried out on the sample is Sulfate which revealed that the concentration varies from the samples with Galdimari 2 (1.86) was seen as the least while the highest Zarawuyaku 1 and Dugja 1 with 17.94 and 12.46 respectively. In addition to the analysis is the Chloride which show that the concentration on the samples was high with Silmuthla 2 (53.60) been the highest and Zarawuyaku 1 (10.55) been the lowest in term of the concentration. Lastly, is Fluoride test analysis which shows that the general concentration is low with Dugja 1 and Silmuthla 2 been the samples with the highest concentration with a value of 0.18 and 0.19 respectively.

Table 5 displays the analysis of the heavy metal concentrations in the water samples. Lead (Pb), Cadmium (Cd), Iron (Fe), Nickel (Ni), Chromium (Cr), Cobalt (Co), Manganese (Mn), and Arsenic (AS) are among the heavy metals taken into consideration in the study. All the metals concentration did not exceed the limits of the acceptable values. However, it is important to note that even though the same metals are within their permissible limits, they can still pose potential risk to human health and the environment if their concentration continues to increase over time. Regular monitoring of heavy metal levels in water is crucial to ensure that they remain within safety limits. The results obtained in this study were consistent with the findings of Bitrus and Ibratim (2017) and Saminu *et al*. (2020)

On the other hand, Copper (Cu) has exceeded the limit which is set at 0.005. This is a cause for concern as elevated levels of copper in both the ecosystem and human health may suffer from water pollution. Copper is an essential micronutrient for plants, but excessive amounts can lead to toxicity in plants and animals that consume them. High copper exposure in humans can lead to a number of health concerns, such as neurological disorders, gastrointestinal disorders, and damage to the liver and kidneys.

The exceeded permissible limit for Copper in this particular water sample highlights the importance of proper waste management and pollution control measures. Industrial activities, agricultural practices and improper disposal of waste can all contribute to soil contamination by heavy metals. To reduce the dangers posed by heavy metal contamination, it is essential to implement sustainable practices that minimize pollution and protect water safety. This includes proper waste disposal, reducing the use of pesticide sand.

Table 5: Concentration of major anions in g/dm^3

Parameters	Dugja 1	Dugja 2	Galdimari 1	Galdimari 2	Silumthla 1	SIlumthla 2	Yawi 1	Yawi 2	Zarawuyaku 1	Zarawuyaku 2	WHO
NO_3	8.47	21.71	3.49	16.22	15.78	22.64	5.17	7.83	11.56	28.46	50mg/L
PO_4	2.29	9.34	0.86	5.08	8.46	13.22	1.58	3.34	0.33	0.77	50mg/L
SO_4	12.46	7.55	5.25	1.86	6.23	6.91	11.59	5.84	17.94	9.24	250mg/
CI	25.70	32.53	11.55	17.37	48.70	53.60	19.47	42.67	10.55	21.54	250mg/L
F	0.18	0.45	0.00	0.00	0.03	0.19	0.08	0.14	0.00	0.00	500mg/L

Table: 6 Concentration of Heavy metals in mg/dm^3

Parameters	Dugja 1	Dugja 2	Galdimari 1	Galdimari 2	Silumthla 1	SIlumthla 2	Yawi 1	Yawi 2	Zarawuyaku 1	Zarawuyaku 2
As	0.0000	0.0000	0.0000	0.0000	0.0000	0.0083	0.0000	0.0000	0.0000	0.0000
Cd	0.0000	0.0059	0.0000	0.0000	0.0000	0.0019	0.0000	0.0293	0.0000	0.0000
Pb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ni	0.0064	0.0317	0.0017	0.0824	0.0068	0.0347	0.0026	0.0114	0.0045	0.0563
Cu	0.0126	0.0465	0.0000	0.0000	0.0044	0.0173	0.0528	0.0245	0.0355	0.0814
Fe	0.0345	0.0785	0.0125	0.0154	0.0545	0.0825	0.0115	0.0637	0.0317	0.0384
Co	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0025	0.0000	0.0016
Cr	0.0026	0.0041	0.0015	0.0145	0.0073	0.0227	0.0000	0.0014	0.0056	0.0124
Mn	0.0164	0.0833	0.0067	0.0286	0.0104	0.0167	0.0194	0.0426	0.0145	0.0744
Zn	0.0036	0.0074	0.0000	0.0045	0.0000	0.0000	0.0000	0.0085	0.0015	0.0155

Dugja 1 showed an elevated level of Copper (Cu) at 0.006mg/L exceeding the permissible limit of 0.005mg/L. whereas the safe limits are met by the other metals examined and the presence of elevated copper warrants further investigation into potential sources of contamination and potential health risk. For the Dugja 2 sample which shows no exceedance of permissible limits for any of the analyzed metals (As, Pb, Cu, Cd, Fe, Ni, Cr, Co, Mn). However, it is important to note that this does not guarantee complete safety. To guarantee this water source's long-term safety within the study area, routine monitoring is essential.

In addition, Galdimari 1 exhibited elevated level of Copper (Cu) at 0.007mg/L, exceeding the permissible limit. This indicates potential contamination and necessitates further investigation into the source and potential health implications. This was different in Galdimari2 has this shows no exceedances of permissible limits for any of the analyzed metals. However, consistent monitoring is necessary to not ensure the long-term safety and quality of this water source. Furthermore, the samples from Silumthla 1and 2 and Zarawuyaku 1 and 2 shows no exceedance of permissible limits for any of the analyzed metals.

Lastly, Yawi 1 and 2 shows an elevated level of Copper (Cu) at 0.008mg/L and 0.006 mg/L, respectively, both of which are above the allowable limit. This indicates potential contamination and necessitates further investigation into the source and potential health implications.

Conclusion and Recommendation

The paper evaluated the sources of drinking (boreholes) water quality in Biu metropolis using some selected water quality parameters (pH, EC., TDS, TSS, T. Hardness, Alkaline, NO_3, PO_4, SO_4, CI, F, As, Cd, Pb, Ni, Cu, Fe, Co, Cr, Mn, and Zn). Selected boreholes waters (Baban line, Tabra Fulani, Gidan Makama, Galdimaribaban line, Sabon kulta, MassalachinSaifullah, Usman Pawa, 20 housing, Close to prison service, and central primary school road) were randomly collected from each of the wards. The study revealed the physico-chemical value (pH, temperature, turbidity, colour and odour as well as presence of some chemical components from the ten selected water sample boreholes. In terms of pH, TDS, and alkalinity, the water samples' physico-chemical characteristics satisfied the W.H.O.-recommended criteria for drinking water. However, the electric conductivity recorded in all the sample varies from samples with some exceeding the standard of W.H.O. this may be as a result of salt content in the water which can have implication to man. In term of TSS in samples located in Silmuthla 1 and 2 is not clear due to the presence of materials that float or suspend in water like sand and sediments. It also revealed that in area of hardness of the sample of water in Dugja 2 and silmuthla seem to be very hard. The study therefore recommended that there should be periodic boreholes rehabilitation, cleaning of the surroundings, regular assessing of the water samples in order to assess the water's quality based on fundamental physico-chemical criteria, the government and non-governmental organizations (NGOs) ought to support the construction of more boreholes in the research region.

References

Aremu, M.O., Ozonyia, G.N. and Ikokoh, P.P. (2011). Physico-chemical characteristics of stream, well and borehole water sources in Eggon, Nasarawa State, *Nigeria. Journal Chemical Society of Nigeria,* 36(1): 131–136.

Atta, A.I. and Razzak, B.I.A. (2008). Chemical and physical analysis ofsome ground water sample in Al-Quti wells Hodiedah, Yemen. *Journal of Iran. Chemical Res*., 1: 141-144.

Bashir, A. and Adekola, O. (2012). Assessment of borehold water in Yola- Jimeta Metropolis, Nigeria. *International Journal of water Resources and Environmental Engineering*, 4(1): 287-293.

Bitrus, W.T. and Ibrahim, G.I. (2017). Mineral element in borehole water from Northern and Western geopolitical Zone of Nasarawa State, Nigeria. *International Journal Science World*, 5(1): 1-4.

Cutter, D. and Miller, G. (2005). The Role of Public Health Improvements in Health Advances: The Twentieth Century United States. *Demography*, 42(1): 1- 22.

Imoisi O.B., Ayesanmi A.F. and Uwumarongie-Ilori E.G. (2012). Assessment of groundwater quality in a typical urban settlement of resident close to three dumpsites in South-south, Nigeria. *Journal of Environmental Science and Water Resources*, 1(1): 12 – 17.

Kegley, E.S. and Andrew, J. (1998). The Chemistry of Water. 2nd edition, California: University Science books, 13-162.

Kolo, B., Musa, J.D. and Idris, I.N. (2009). Elemental Analysis of Tap and Borehole Waters in Maiduguri, Semi-Arid Region, Nigeria. *European J. Appl. Sci*., 1(2): 26-29.

Messeret, B. (2012). Assessment of drinking water quality and determination of household potable water consumption in Simada District, Ethiopia

Mustafa, A.I., Ibrahim, A.A., Haruna, Y.I. and Abubakar, S. (2012). Physicochemical and bacteriological analyses of drinking water from wash boreholes in Maiduguri Metropolis, Borno State, Nigeria. *African Journal of Food Science*, 7(1): 9-13.

Sadiq, Q., Ezeamaka, C.K., Daful, M.G. and Mustafa, I.A. (2022). Evaluation of the water quality in river Kaduna, Nigeria using water index. *Environmental Technology and Science Journal*, 13(1): 28:40.

Saminu, A., Maryam, M. and Dadan, G.A. (2020). Assessment of Groundwater Quality in panteka Tudun Nupawa, Kanuna South, Kaduna State, Nigeria. *America J. Engineer. Res*., 9(6): 62-72.

World Health Organization (2006). In water, sanitation and health world health Organization.

World Health Organization (2011). Guidelines for drinking-water quality, 4th edition. Geneva, Switzerland.