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An Assessment of Groundwater Quality in Tudun Fulani, Niger State, Nigeria

Muhammad Taoheed Bisiriyu[1]*, Mustapha Adekomi Ganiyu[2], Lawal Idris Audu[3], AbdulHakam Safiu Abdullahi[4] and Iyanda Murtala Animashaun[5]

[1]*Department of Chemistry, Federal University of Technology, Minna, Nigeria, m.bisiriyu@futminna.edu.ng
[2]Department of Chemistry, Federal University of Technology, Minna, Nigeria. mustaphaadekomi@gmail.com
[3]Department of Chemistry, Federal University of Technology, Minna, Nigeria. lawalidris1357@gmail.com
[4]Department of Chemistry, Federal University of Technology, Minna, Nigeria. ubaydallah144@gmail.com
[5]Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Nigeria.
ai.iyanda@futminna.edu.ng

*Corresponding author: Email address: m.bisiriyu@futminna.edu.ng, Tel: 08034986072

Abstract

Background: *groundwater is the main source of drinking water in Tudun Fulani community in Bosso, Niger State, Nigeria.* ***Objective***: *this study was conducted to assess the physicochemical and heavy metal characteristics of groundwater used for drinking and other domestic purposes in the area with a view to determining its suitability for these purposes.* ***Method***: *twelve water samples comprising of seven hand-dug wells and five boreholes were collected from different locations in the area. Physicochemical parameters (pH, turbidity, electrical conductivity, total dissolved solids (TDS), total suspended solids (TSS), total solids (TS), alkalinity, total hardness, chloride) and heavy metals (lead, manganese, copper and iron) contents were determined using standard methods.* ***Results***: *the results showed that the pH, electrical conductivity, TDS, TSS, TS turbidity, alkalinity, total hardness and chloride ranged between 5.72 – 7.32, 252.5 – 1098 µS/cm, 58 – 11.35 mg/L, 0.001 – 0.108 mg/L, 1.05 – 7.33 NTU, 10.60 - 104.20 mg/L, 26.6 – 170.2 mg/L, and 28.17 – 86.9 mg/L, respectively. The heavy metal analysis revealed lead, manganese copper, and iron to range between 0.001-0.009 mg/L, 0.01-0.28 mg/L, 0.010 - 0.050 mg/L and 0.100 – 0.430 mg/L, while manganese and lead not detected in one and six of the samples, respectively.* ***Conclusion***: *the values of the parameters analyzed in this study were below and within the permissible limits set by the World Health Organization (WHO) for most of the water samples investigated; hence the groundwater is suitable for drinking and for other life supporting activities. However, only four samples (*$W_{1,}W_5$ $W_{6,}$ *and* W_7*) were within the range of 100 - 300 mg/L set by WHO for total hardness. In addition, the pH values of water samples* W_4*,* W_5*,* B_4*, and* B_5 *were below the recommended standard, while the electrical conductivity of* W_5*, turbidity of* W_3*,* W_5 *and iron contents of* W_2 *and* W_7 *were above the maximum limit set by WHO. Therefore, it is recommended that indiscriminate discharge of wastes be checked in locations of* W_2 *and* W_7 *as high iron content in drinking water poses serious health risks to the consumers.*

Keywords: *Groundwater, well, borehole, physicochemical parameter, heavy metals.*

1. Introduction

Water is a fundamental necessities for life and a determinant of the state of health of a nation (Chinedu *et al*., 2011). While good quality water promotes the state of wellbeing of individuals and socio-economic development of nations, poor quality water serves as the causative agent of most deadly diseases in the world (Ince *et al*., 2010). Inaccessibility and unavailability of safe drinking water are still one of the pressing issues in Nigeria and other developing nations (Kassie, 2018). Despite the Nigerian government efforts to revitalize the supply of quality water to the entire citicenry to meet the 2030 vision for water, sanitation, and hygiene, the public pipe-borne water supply is still unevenly distributed and grossly inadequate. As a result, philanthropists, non-governmental organizations, corporate bodies, and individuals provide alternative water sources to complement the erratic municipal water distribution (Kassie, 2018; Chinedu *et al*., 2011).

Groundwater occupy central position in the water supply chain. It remains the largest available source of freshwater as it constitutes 97% of global freshwater (Olatunji *et al.,* 2015; Bharti *et al.,* 2011; Mlipano *et al.*, 2018). It represents 88% of potable water in most semi-urban and rural areas of Nigeria (Alexander, 2008; Adgidzi, 2016) and about 2.5 billion people worldwide rely mainly on groundwater resources to meet their basic daily water needs (UNESCO, 2012). Unlike surface water, groundwater is less susceptible to pollution and seasonal fluctuation, requires minimum treatment, and naturally possesses good quality (Okoro *et al*., 2012; Olatunji *et al.,* 2015; Likambo, 2014). However, indiscriminate wastes disposal and other anthropogenic activities have been reported to interfere with groundwater quality in Nigeria and other parts of the world (Odukoya and Abimbola, 2010; Adefemi and Awokunmi, 2010; Adeyemi *et al.,* 2007; Meena and Bhargava, 2012). Niger State, and some other states in Nigeria are faced with the challege of inadequate potable water. The supply of public pipe-borne water is grossly inadequate due to increased population and human activities. Consequently, many households sought for alternative sources (boreholes, hand-dug wells, ponds, water vendors and packaged water) to meet their domestic water needs (Emigilati *et al*., 2014; Adeleye *et al*., 2014; Yisa, *et al*., 2012; Adegbehin *et al*., 2016). The quality of water obtained from these sources in Niger State has been evaluated by different researchers (Amadi *et al*., 2016; Gimba, 2011; Yisa, *et al*., 2012;). For instance, studies on water quality in Suleja, Niger State revealed that the analyzed water samples; hand-dug wells, boreholes, and surface water in the area were poor for domestic purposes (Amadi *et al*., 2016). Yisa *et al.* (2012) carried out a quality assessment of underground water in Doko community in Niger State, Nigeria, and reported that the chemical oxygen demand and nitrate values of the water samples exceeded the permissible limit of WHO, while chloride and iron contents were below the WHO limits. Gimba (2011) assessed the quality of drinking water in Bosso Town, Niger State. The result of the analysis on forty water samples obtained from the pond, wells, borehole, tap and sachet water in the study area; revealed that 11.10% and 33.30% of well water samples had nitrite (NO_2^-) and nitrate (NO_3^-) contents higher than the recommended values, while residual chlorine for tap and sachet water was below 0.50 mg/L WHO recommendation. The study also revealed that the only sample from borehole failed to meet the guideline value for both iron and fluoride.

Groundwater (well and borehole) is the major source of water available to Tudun Fulani community in Bosso Local Government, Niger State, Nigeria. The nature of the anthroprogenic activities such as farming, indiscriminate disposal and burning of wastes been carried out in the community called for concerned to evaluate the groundwater quality using physicochemical parameters assessment for insight on the portability of water sources available to the inhabitants. Thus, this study aimed to assess the physicochemical and heavy metal characteristics of boreholes and hand-dug wells used for drinking and other domestic purposes in the area to determine its suitability for these purposes.

2. Materials and Method

2.1 Study Area

The area under study is Tudun Fulani community located in Bosso Local Government Area (Figure 1). Bosso is a Local Government Area in Niger State, Nigeria. It occupied a total land mass area of 1,592 km^2 and a population of 203,134 according to the National Population Commission projection in 2019 based on 2006 population census with annual growth rate of 2.5%. Its administrative headquarters is located in Maikunkele (Chawaza Foundation Worldwide, 2020). Its climatic conditions are basically wet and dry seasons and the rainfall pattern usually is conventional with total annual average of around 1,100 mm. The prevailing temperature usually varies between 32 and 20 °C during dry and wet seasons, respectively and an average temperature of 27 °C (Ehigiator and Jimoh, 2015).

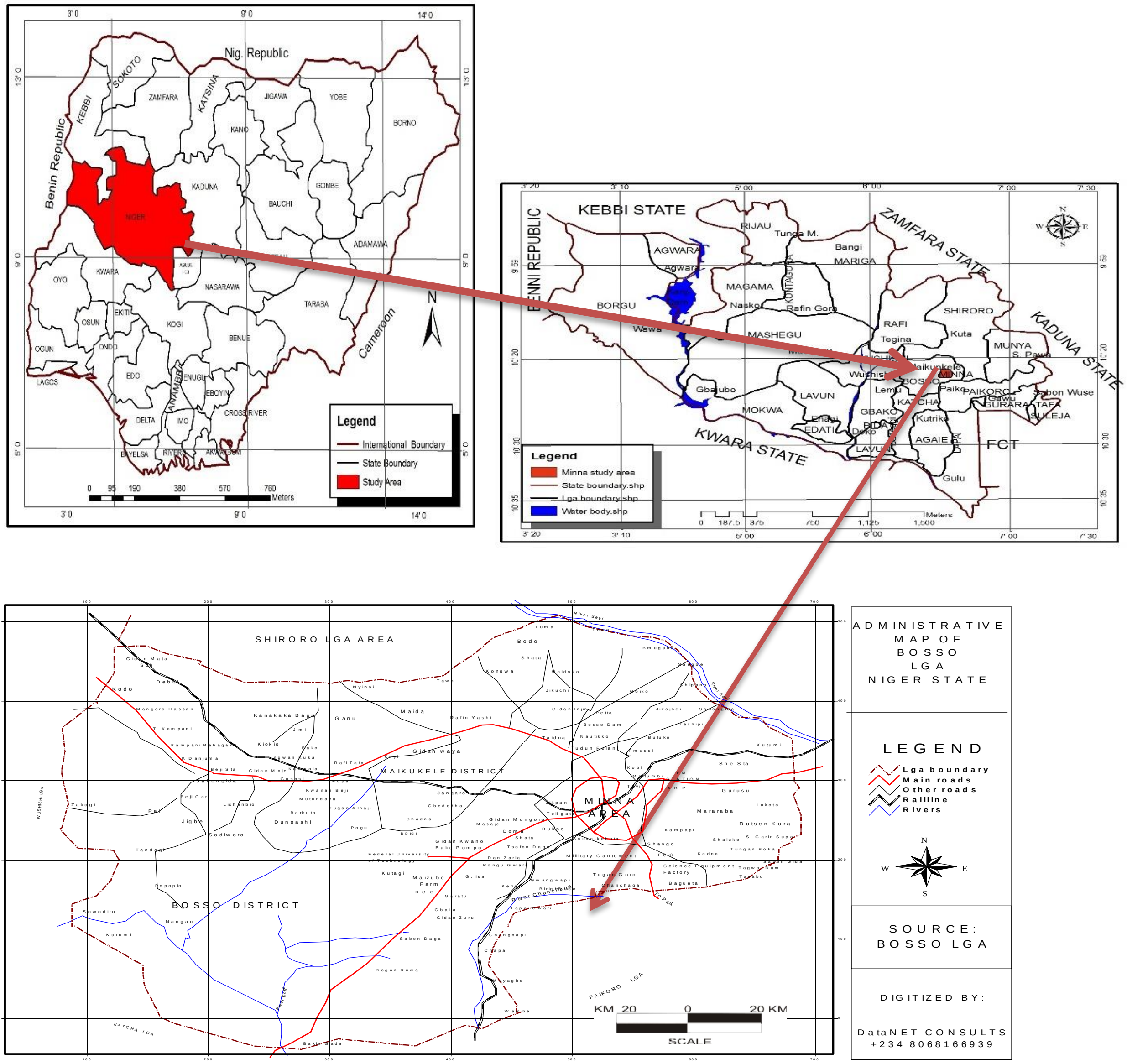

Fig. 1. Map of Nigeria showing the sampling site

2.2 Sampling

A total of twelve water samples comprising of seven hand-dug wells and five boreholes were collected from twelve different locations in Tudun Fulani. They were collected with new plastic bottles from the sites just ones at the end of September (around the end of wet season). The plastic containers were first washed and then rinsed with distilled water. Thereafter, each of the properly labeled bottles was rinsed with respective samples to be collected. After sample collection, it was immediately transported to the laboratory for analyses at the Department of Chemistry, Federal University of Technology, Minna.

2.3 Determination of Physicochemical Parameters

2.3.1 Physical parameters

The pH, turbidity and electrical conductivity of the water samples were determined immediately after collection in the laboratory with pH meter (Model: PHS-25), turbidity meter (Model: WT3020) and electrical conductivity meter (Model: DDS-307), respectively by following the procedures in the manufacturers manual. Total dissolved solids and total suspended solids were determined using gravimetric method (APHA, 1998).

2.3.2 Chemical parameters

2.3.2.1 Chloride ion

Water sample (50.00 cm^3) was measured into conical flask (250.00 cm^3) and potassium dichromate (1.00 cm^3, 5%) was added as an indicator. The resulting mixture was then titrated against silver nitrate ($AgNO_3$) solution (0.014 N) until a reddish-brown colouration was observed. The procedure was repeated two more times to obtain at least two consistent values (Reda, 2016). The chloride ion concentration in each water sanmples was calculated as follows:

$$\text{Chloride ion concentration (mg/L)} = \frac{(A-B)\times N \times 35.5 \times 1000}{V(\text{cm}^3)}$$

Where: A = Volume of $AgNO_3$ used for titrating sample (cm^3), B = Volume of $AgNO_3$ used for titrating blank (cm^3), N = Normality of $AgNO_3$ solution (0.014 N), and V = Volume of water sample (cm^3).

2.3.2.2 Total hardness

Water sample (50.00 cm^3) was measured into Erlenmeyer flask (250.00 cm^3) using a measuring cylinder. NH_4Cl buffer solution (pH 10.00, 2.00 cm^3) and Erichrome black T (2 drops) were added and then titrated with ethylenediaminetetraacetate, EDTA solution (0.01 M) with stirring continuously until the colour changed from wine red to blue. The procedure was repeated two more times to obtain at at least two consistent values (Regional Water Quality Laboratory Minna, 2011). The total hardness in each water sanmples was calculated as follows:

$$\text{Total hardness (as } CaCO_{3,}\text{ mg/L)} = \frac{(A-B)\times M \times 100 \times 1000}{V(\text{cm}^3)}$$

Where: A = Volume of EDTA used for titrating sample (cm^3), B = Volume of EDTA used for titrating blank (cm^3), M = Molar concentration of EDTA solution (mol/dm^3), and V = Volume of sample used for analysis (cm^3)

2.3.2.3 Alkalinity due to methyl orange

Water sample (50.00 cm^3) was measured into conical flask (250.00 cm^3) and methyl orange (2 drops) were added. The mixture was then titrated with H_2SO_4 (0.02 N) until the colour changed from pink to yellow which marked the endpoint. The values were recorded, and the titration was repeated until two concordant values were obtained (Reda, 2016). The methyl orange alkalinity in each water sanmples was calculated as follows:

$$\text{Methyl orange alkalinity (mg/L, as } CaCO_3) = \frac{(A-B)\times N \times 50 \times 1000}{V(\text{cm}^3)}$$

Where: A = Volume acid used for titrating sample, B = Volume acid used for titrating blank, N = Normality of acid used (N) and and V = Volume of sample used for analysis (cm^3)

2.4 Determination of Heavy Metals

The heavy metals (Fe, Mn, Pb, and Cu) contents in the water samples were determined with an Atomic Absorption Spectrophotometer (Model: AA500) following the procedure described by (Chinedu *et al.*, 2011).

3. Results

The results of the mean physical parameters of the groundwater samples analyzed are presented in Table 1.

Table1. Mean physical parameters of groundwater samples

S/N	**Sample/Parameters**	**pH**	**Turbidity (NTU)**	**TSS (mg/L)**	**TDS (mg/L)**	**TS (mg/L)**	**EC (µS/cm)**
1	W_1	6.63±0.005	4.51±0.01	0.014±0.001	0.67±0.000	0.684±0.001	565±5.00
2	W_2	7.32±0.025	3.22±0.00	0.012±0.000	11.35±0.030	11.36±0.030	979±1.00
3	W_3	7.27±0.015	7.33±0.13	0.092±0.001	0.86±0.010	0.952±0.011	830±9.50
4	W_4	5.87±0.025	2.29±0.02	0.036±0.001	0.92±0.005	0.956±0.006	589±0.00
5	W_5	5.72±0.005	6.78±0.02	0.108±0.002	1.51±0.010	1.618±0.012	1098±0.50
6	W_6	6.67±0.015	2.33±0.02	0.025±0.002	1.42±0.005	1.445±0.007	963±1.50
7	W_7	6.55±0.05	4.15±0.03	0.092±0.000	0.58±0.001	0.672±0.001	326±1.00
8	B_1	7.00±0.00	1.75±0.05	0.002±0.000	1.06±0.01	1.062±0.01	747.5±9.50
9	B_2	6.57±0.005	1.40±0.10	0.001±0.000	0.89±0.00	0.891±0.000	252.5±2.50
10	B_3	6.62±0.005	1.16±0.01	0.006±0.002	0.95±0.00	0.956±0.002	739±0.50
11	B_4	6.38±0.00	1.10±0.10	0.011±0.002	1.11±0.01	1.121±0.012	655±5.00
12	B_5	6.19±0.005	1.05±0.02	0.011±0.001	1.24±0.005	1.251±0.006	892.5±2.50
Ref.	WHO Guidelines	6.5 – 6.8	5.0	25	500-1000	-	1000

WHO standard guideline for drinking water (2011), values are presented as mean ± standard deviation of duplicate measurement. The results of the mean chemical parameters of the groundwater samples analyzed are presented in Table 2.

Table 2. Mean chemical parameters of groundwater samples

S/N	**Samples/Parameters**	**Alkalinity (mg/L)**	**Chloride (mg/L)**	**Total hardness (mg/L)**
1	W_1	14.20±0.141	82.90±0.000	100.60±0.019
2	W_2	12.60±0.000	86.90±0.000	38.40±0.022
3	W_3	10.60±0.14	66.60±0.140	82.60±0.016
4	W_4	16.40±0.141	53.16±0.085	79.60±0.012
5	W_5	36.40±0.000	63.97±0.021	170.20±0.024
6	W_6	40.80±0.000	64.83±0.042	140.60±0.008
7	W_7	62.00±0.141	76.32±0.007	112.00±0.071
8	B_1	93.60±0.000	42.45±0.071	28.40±0.005
9	B_2	104.20±0.000	36.76±0.028	40.60±0.020
10	B_3	102.00±0.000	32.90±0.071	26.60±0.000
11	B_4	52.20±0.000	38.88±0.240	42.80±0.030
12	B_5	76.00±0.0141	28.17±0.007	37.60±0.010
Ref.	WHO guideline	120-600	200-300	100-300

WHO standard guideline for drinking water (2011), values are presented as mean ± standard deviation of duplicate measurement. The results of mean heavy metals analysis of the groundwater samples analyzed are presented in Table 3.

Table 3. Heavy metal content of groundwater samples

S/N	Sample/Parameters	Fe (mg/L)	Mn (mg/L)	Pb (mg/L)	Cu (mg/L)
1	W_1	0.100±0.0014	0.16±0.007	0.002±0.000	0.020±0.0028
2	W_2	0.380±0.0028	0.23±0.000	0.004±0.0000	0.012±0.0007
3	W_3	0.200±0.0099	0.18±0.000	0.001±0.0000	0.010±0.0014
4	W_4	0.100±0.0014	0.02±0.000	0.003±0.0007	0.041±0.0035
5	W_5	0.230±0.0021	0.14±0.0007	BDL	0.030±0.0000
6	W_6	0.180±0.0000	0.28±0.001	0.009±0.0007	0.010±0.0007
7	W_7	0.430±0.0014	0.24±0.003	BDL	0.021±0.0014
8	B_1	0.120±0.0000	0.15±0.010	0.001±0.000	0.050±0.0028
9	B_2	0.181±0.0007	0.17±0.000	BDL	0.031±0.0000
10	B_3	0.170±0.0028	0.11±0.010	BDL	0.022±0.0000
11	B_4	0.101±0.0007	BDL	BDL	0.032±0.0007
12	B_5	0.130±0.0000	0.10	BDL	0.040±0.0021
Ref.	WHO	0.300	0.400	0.01	2.00
Ref.	SON	0.300	0	0.01	1.50

WHO standard guideline for drinking water (2011), SON standard guideline for drinking water (2007), values are presented as mean ± standard deviation of duplicate measurement, BDL: below detection limit.

4. Discussion

4.1 Physical Parameters

The mean pH values recorded for all the water samples were found to be in the range of 5.72 – 7.32 as shown in Table 1. However, water samples W_4 (5.87 ± 0.025), W_5 (5.72 ± 0.005), B_4 (6.38 ± 0.00) and B_5 (6.19 ± 0.005) had mean pH values below the set limit, which implies corrosivity. This might be due to surface water runoff and such water could lead to deterioration of metals and other materials (Taiwo *et al*., 2011). Drinking water with a pH value between 6.5 -8.5 is generally considered satisfactory (WHO, 2011). Most of the values obtained are comparable to an average of 6.70 reported by Ojutiku *et al*. (2014) for borehole water in Bosso, Niger State. More so, our results are also similar to 6.52 – 7.37 obtained by Amadi *et al.* (2017) on the analysis of hand-dug well in Lapai, Niger State.

Turbidity indicates the extent to which water has lost its transparency owing to the presence of suspended particles. In this study, the turbidity ranged between 1.05 – 7.33 NTU as depicted in Table 1. Most of the water samples fell within the limit of 5 NTU stipulated by WHO (2011) standard for drinking water except W_3 (7.33 ± 0.13 NTU) and W_5 (6.78 ± 0.02 NTU) that had their turbidity values above the limit. The values obtained were lower than 0.00 – 52.00 NTU for hand-dug well water in Lapai, Niger State (Amadi *et al.*, 2017). The higher values obtained for W_3 and W_5 in this study can be attributed to the presence of particulate matter in the wells as most well are often left uncovered. Although no direct health effect is associated with turbidity it may indicate the presence of disease-causing organisms (Nemade *et al.*, 2009; Akoto and Adiyiah, 2007; Payment *et al.*, 2003; Adekola *et al.*, 2015). It was observed that the mean electrical conductivity obtained for all the water samples ranged between 252.5 – 1098 µS/cm as presented in Table 1. All the water samples, except W_5 (1095 ± 0.50 µS/cm), had a mean value above the maximum limit of 1000 µS/cm set by WHO (2011). These values are similar to 176.00 – 1193.00 µS/cm reported for hand-dug well water in Lapai, Niger State (Amadi *et al.*, 2017), but higher than 280.00 µS/cm mean value reported for borehole water in Bosso, Niger State (Ojutiku *et al*., 2014).

The mean total dissolved solids (TDS), total suspended solids (TSS) and the total solids (TS) of the water samples analyzed were found to range between 0.58 – 11.35 mg/L, 0.001 – 0.108 mg/L, and 0.672 – 11.36 mg/L, respectively as shown in Table 1. These values are below the acceptable limit set by WHO (2011). However, the result is lower compared to 118.00 – 800.00 mg/L for total dissolved solid reported for hand-dug well water in Lapai, Niger State (Amadi *et al.*, 2017) and 618-1060 mg/L total dissolved solid reported for borehole water around Dala Hills, Northwestern Nigeria (Bataiya *et al.,* 2017). Though no health implication has so far been linked to the level of total dissolved solids in drinking water high content makes water unpleasant for drinking. Nevertheless, suspended solids in water serve as points of adherence to pathogenic organisms, thereby reducing the water quality (WHO, 2011).

3.2 Chemical Parameters

Chloride ions do occur naturally in groundwater, but it could be found in greater concentration in a situation where seawater, runoff from rock salt, agricultural wastes, industrial wastes, effluents and wastes from water treatment plants find their way into water source (Venkateswara, 2011; Igwemmar *et al.,* 2013). The concentrations of chloride in the water samples were found to range from 28.17 – 86.90 mg/L as presented in Table 2. This means that all the water samples had chloride below the limit of 200 - 300 mg/L set by WHO (2011). It also implies that the water samples had no salty taste. Small amounts of chlorides are required for normal cell functions in plant and animal life (Igwemmar *et al.,* 2013). However, higher concentrations of chloride ions in water add to its taste, affect metallic pipes and structure of growing plants, increase concentrations of other metals, and could lead to hypertension in animal (Barati *et al.*, 2010; WHO, 2008; Ndamitso *et al.*, 2013). The values in this study are comparable to 12.10 – 95.60 mg/L reported for hand-dug well water in Lapai, Niger State (Amadi *et al.,* 2017) but higher than an average value of 7.00 mg/L recorded for borehole water in Bosso, Niger State. The mean results of alkalinity obtained for all water samples as shown in Table 2 ranged between 10.60 - 104.20 mg/L. These data are below the WHO specification of 120 - 600 mg/L for drinking water. High alkalinity in water may contribute to scale build-up in plumbing. The results obtained in this study are lower compared to 240.00 mg/L average value reported for borehole water in Bosso, Niger State but higher than 9.00 – 74.00 mg/L for hand-dug well water in Lapai, Niger State (Amadi *et al.,* 2017).

The total hardness of the water samples analyzed was found to range between 26.60 – 170.20 mg/L as depicted in Table 2. Most of the water samples had mean hardness below the set standard except W_1 (100.60 ± 0.019 mg/L), W_5 (170.20 ± 0.020 mg/L), W_6 (140.60 ± 0.008) and W_7 (112.00 ± 0.071 mg/L) fell within the range of 100 - 300 mg/L set by WHO (2011) for total hardness. Water samples with high values of total hardness indicate a maximum amount of carbonate and bicarbonate that do not form lather and cause scales in boilers. The values obtained in this study are comparable to the mean value of 140.00 mg/L reported for borehole water in Bosso, Niger State, but lower than 66.00 – 261.00 mg/L reported for hand-dug well water in Lapai, Niger State (Amadi *et al.,* 2017).

3.3 Heavy Metals Concentration

Table 3 shows the mean results of the analysis for the heavy metals (Pb, Cu, Fe, and Mn) in the groundwater samples. The results revealed that lead was not detected in six samples W_5, W_7, B_2, B_3, B_4, B_5 while manganese was detected in one sample B_4. The detectable levels of lead and manganese ranged between 0.001-0.009 mg/L and 0.01- 0.28 mg/L, respectively. These values are below the WHO (2011) stipulated limit for drinking water.

The minima concentration of lead indicates that the water samples were not exposed to indiscriminate disposal of lead batteries and soil containing lead. The results obtained in this study agreed with the mean values of 0.00 mg/L for lead and 0.10 mg/L for Mn reported for borehole water in Bosso, Niger State (Ojutiku *et al*., 2014). The mean concentration of iron in the water samples was found to range between 0.100 – 0.430 mg/L. This signifies that the concentrations are bearable, with most of the samples falling within the WHO (2011) stipulated limit of 0.30 mg/L. But W2 (0.380 ± 0.0028 mg/L) and W7 (0.430 ± 0.0014 mg/L) had a high amount of iron above the recommended standard. This high concentration might be due to deteriorated metal scraps, weathering of rocks containing iron and run-off of urban surfaces (Ranjana, 2009; Olasehinde *et al*., 2015; Amadi *et al.*, 2017) and could allow iron-dependent bacteria to flourish and thus result in further deterioration in the quality of water through the advancement of sludges The results obtained were far below the mean average of 0.50 mg/L reported by Ojutiku *et al.* (2014) for borehole water in Bosso, Niger State and 0.07 – 0.65 mg/L obtained by Amadi *et al*. (2017) for hand-dug well water in Lapai, Niger State.

The mean concentration of copper in the water samples analyzed ranged from 0.010 - 0.050 mg/L which is below the WHO (2011) recommendation standard for drinking water. These results are comparable to mean average of 0.06 mg/L reported for boreholes water in Bosso, Niger State (Ojutiku *et al.*, 2014) but lower compared to 0.12 – 1.48 mg/L obtained by Amadi *et al.* (2017) for hand-dug well water in Lapai, Niger State. Copper is an essential metal that plays an important role in enzymatic activities such as the proper growth, development, and maintenance of both plants and animals (Kangpe *et al.*, 2014). However, if high in domestic water it could cause aluminum utensils and galvanized steels fittings to deteriorate (Chinedu *et al*., 2011).

4. Conclusions

The results of this study have shown that all the physicochemical parameters were below and within the standard limit recommended by WHO (2011) except the turbidity values of samples W_3, W_5, B_5, and electrical conductivity of sample W5 which exceeded the threshold value. Also, only four samples (W_1, W_5, W_6 and W_7) were within the range of 100 - 300 mg/L set by WHO (2011) for total hardness. The results also confirmed that the pH values of water sample W_4, W_5, B_4, and B_5 were below the recommended standard of WHO (2011). The results of the heavy metal analysis also revealed that the metals, in most of the samples, were present at concentrations that had no adverse health effects on the consumers. But the concentration of iron in samples W_2 and W_7 were beyond the threshold value (0.30 mg/L) set by WHO (20110).

While concluding that most of the groundwater samples in the study area analyzed in this study are suitable for consumption and other domestic purposes as at the time the study was conducted for the parameters analyzed, it is recommended that indiscriminate discharge of wastes containing metal scraps be checked in locations of samples W_2 and W_7 as high iron content in drinking water could pose a health risk to the consumers.

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