



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

Muhammad Taoheed Bisiriyu^{1*}, Mustapha Adekomi Ganiyu², Lawal Idris Audu³, AbdulHakam Safiu Abdullahi⁴ and Iyanda Murtala Animashaun⁵

^{1*}Department of Chemistry, Federal University of Technology, Minna, Nigeria, m.bisiriyu@futminna.edu.ng

²Department of Chemistry, Federal University of Technology, Minna, Nigeria. mustaphaadekomi@gmail.com

³Department of Chemistry, Federal University of Technology, Minna, Nigeria. lawalidris1357@gmail.com

⁴Department of Chemistry, Federal University of Technology, Minna, Nigeria. ubaydallah144@gmail.com

⁵Department 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 $\mu\text{S}/\text{cm}$, 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 citizenry 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 challenge 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 anthropogenic 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 km² 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).

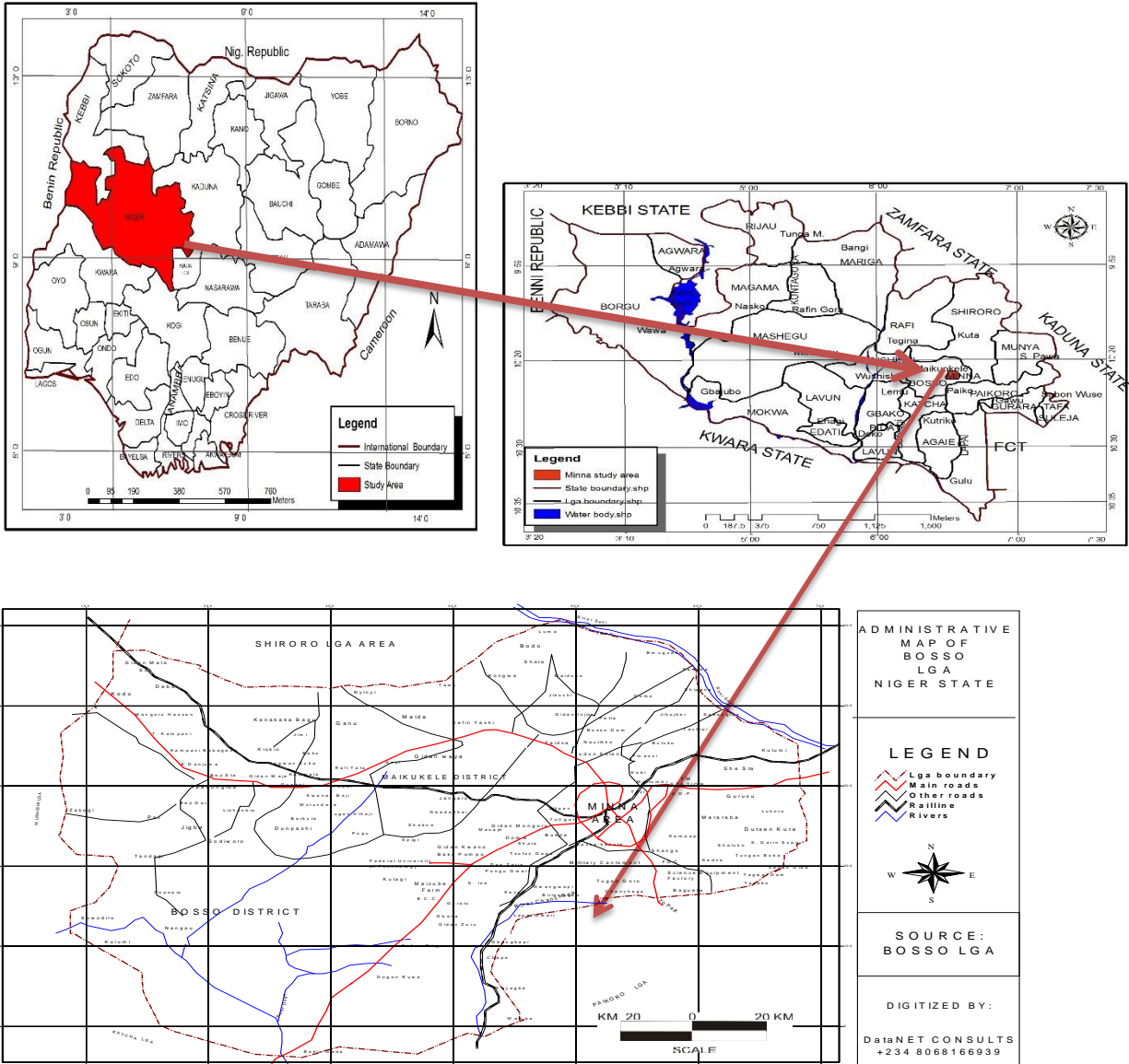


Fig. 1. Map of Nigeria showing the sampling site

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 cm³) was measured into conical flask (250.00 cm³) and potassium dichromate (1.00 cm³, 5%) was added as an indicator. The resulting mixture was then titrated against silver nitrate (AgNO₃) 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 samples 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 AgNO₃ used for titrating sample (cm³), B = Volume of AgNO₃ used for titrating blank (cm³), N = Normality of AgNO₃ solution (0.014 N), and V = Volume of water sample (cm³).

2.3.2.2 Total hardness

Water sample (50.00 cm³) was measured into Erlenmeyer flask (250.00 cm³) using a measuring cylinder. NH₄Cl buffer solution (pH 10.00, 2.00 cm³) 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 least two consistent values (Regional Water Quality Laboratory Minna, 2011). The total hardness in each water samples 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 (cm³), B = Volume of EDTA used for titrating blank (cm³), M = Molar concentration of EDTA solution (mol/dm³), and V = Volume of sample used for analysis (cm³)

2.3.2.3 Alkalinity due to methyl orange

Water sample (50.00 cm³) was measured into conical flask (250.00 cm³) and methyl orange (2 drops) were added. The mixture was then titrated with H₂SO₄ (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 samples was calculated as follows:

$$\text{Methyl orange alkalinity (mg/L, as CaCO}_3\text{)} = \frac{(A-B) \times N \times 50 \times 1000}{V(\text{cm}^3)}$$

Where: A = Volume acid used for titrating sample, B = Volume acid used for titrating blank, N = Normality of acid used (N) and V = Volume of sample used for analysis (cm³)

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 \pm 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 \pm 0.0014	0.16 \pm 0.007	0.002 \pm 0.000	0.020 \pm 0.0028
2	W ₂	0.380 \pm 0.0028	0.23 \pm 0.000	0.004 \pm 0.0000	0.012 \pm 0.0007
3	W ₃	0.200 \pm 0.0099	0.18 \pm 0.000	0.001 \pm 0.0000	0.010 \pm 0.0014
4	W ₄	0.100 \pm 0.0014	0.02 \pm 0.000	0.003 \pm 0.0007	0.041 \pm 0.0035
5	W ₅	0.230 \pm 0.0021	0.14 \pm 0.0007	BDL	0.030 \pm 0.0000
6	W ₆	0.180 \pm 0.0000	0.28 \pm 0.001	0.009 \pm 0.0007	0.010 \pm 0.0007
7	W ₇	0.430 \pm 0.0014	0.24 \pm 0.003	BDL	0.021 \pm 0.0014
8	B ₁	0.120 \pm 0.0000	0.15 \pm 0.010	0.001 \pm 0.000	0.050 \pm 0.0028
9	B ₂	0.181 \pm 0.0007	0.17 \pm 0.000	BDL	0.031 \pm 0.0000
10	B ₃	0.170 \pm 0.0028	0.11 \pm 0.010	BDL	0.022 \pm 0.0000
11	B ₄	0.101 \pm 0.0007	BDL	BDL	0.032 \pm 0.0007
12	B ₅	0.130 \pm 0.0000	0.10	BDL	0.040 \pm 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 \pm 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 W₄ (5.87 \pm 0.025), W₅ (5.72 \pm 0.005), B₄ (6.38 \pm 0.00) and B₅ (6.19 \pm 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 W₃ (7.33 \pm 0.13 NTU) and W₅ (6.78 \pm 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 W₃ and W₅ 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 μ S/cm as presented in Table 1. All the water samples, except W₅ (1095 \pm 0.50 μ S/cm), had a mean value above the maximum limit of 1000 μ S/cm set by WHO (2011). These values are similar to 176.00 – 1193.00 μ S/cm reported for hand-dug well water in Lapai, Niger State (Amadi *et al.*, 2017), but higher than 280.00 μ S/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).

4.2 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 W₁ (100.60 ± 0.019 mg/L), W₅ (170.20 ± 0.020 mg/L), W₆ (140.60 ± 0.008) and W₇ (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).

4.3 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 W₅, W₇, B₂, B₃, B₄, B₅ while manganese was detected in one sample B₄. 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).

5. 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 W₃, W₅, B₅, and electrical conductivity of sample W₅ which exceeded the threshold value. Also, only four samples (W₁, W₅, W₆ and W₇) 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 W₄, W₅, B₄, and B₅ 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 W₂ and W₇ were beyond the threshold value (0.30 mg/L) set by WHO (2011).

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 W₂ and W₇ as high iron content in drinking water could pose a health risk to the consumers.

6. Acknowledgement

The authors sincerely appreciate Mr. Abidemi Adedayo Koleola of Soil Science laboratory for his technical assistance during the laboratory analyses.

References

- Adefemi S.O. & Awokunmi E.E. (2010). Determination of Physico-Chemical Parameters and Heavy Metals in Water Samples from Itaogbolu Area of Ondo-State, Nigeria. *African Journal of Environmental Science and Technology*, 4(3), 145-148.
- Adegbehin, A.B., Yusuf, Anumonye, E.N., & Shehu, A.U. (2016). Problems of Domestic Water supply in Dutsen Kura Gwari, Chanchaga Local Government Area of Niger State. *Nigeria Journal of Geography, Environment and Earth Science International*, 7(4), 1-9.
- Adekola, O., Bashir, A., & Kasimu, A. (2015). Physico-Chemical Characteristics of Borehole Water Quality in Gassol Taraba State, Nigeria. *African Journal of Environmental Science and Technology*, 9(2), 143-154. doi: 10.5897/AJEST2014.1794
- Adeleye, B.A., Medayese, S.A., & Okelola, O.L. (2014). Problems of Water Supply and Sanitation in Kpakungu Area of Minna Nigeria. *Journal of Culture, Politics and Innovation*, 9(2), 1-29.
- Adeyemi, O., Oloyede, O.B. & Oladiji, A.T. (2007). Physico-Chemical and Microbial Characteristics of Leachate Contaminated Groundwater. *Asian Journal of Biochemistry*, 2, 343-348.



- Adgidzi, E.A., Usman, A., & Ogan, I.M. (2016). Quality of Public Water Supply and Selected Boreholes in Lafia Metropolis, Nigeria. *Proceeding of the 12th Chemclass Conference* 92.
- Afuye, G.G., Oloruntade, A.J., and Mogaji, K.O. (2015). Groundwater Quality Assessment in Akoko South East Area of Ondo State. *International Journal of Science and Technology*, 5(9), 122-131.
- Akoto, O., & Adiyiah, J. (2007). Chemical Analysis of Drinking Water from some Communities in the Brong Ahafo Region. *Internatinal Journal of Environmental Science and Technology*, 4, 211-214.
- Alexander, P. (2008). Evaluation of Groundwater Quality of Mubi Town in Adamawa State, Nigeria. *Africa Journal of Biotechnology*, 7 (1):1712 – 1715.
- Amadi, A.N., Obaje, N.G., Goki, N.G., Abubakar K.U., Shaibu, I. & Nwakife, C.N. (2016). Studies on Water Quality in Suleja, Niger State for Domestic and Irrigational Purposes. *Journal of Natural and Applied Sciences*, 5(1), 16-29.
- Amadi, A.N., Olasehinde, P.I., Obaje, N. G. , Nnuevho, C.I., Yunusa, M.B., Keke, U.N., Ameh, A. I. (2017). Investigating the Quality of Groundwater from Hand-Dug Wells in Lapai, Niger State using Physicochemical and Bacteriological Parameters. *Minna Journal of Geosciences (MJG)*, 1, (1), 77-92.
- APHA (1998). Standard for the Examination of Water and Wastewater, 18th Edition. American Public Health Association (APHA). American Water Works Association (AWWA) and Water Pollution Control Federation (WPCF) Washington, D.C, 10-195.
- Barati, A.H., Maleki, A., & Alasvand, M. (2010). Multitrac Element Level in Drinking Water and the Prevalence of Multichronic Arsenical Poisoning in Residents in the West Area of Iran. *Science of the Total Environment*, 408(7), 1223-1233.
- Bataiya, A.G., Muhammad, H., Ahmad, S.I., and Muazu, J. (2017). Analysis of Water Quality using Physicochemical Parameters of Boreholes Water taken from Areas Around Dala Hills, Northwestern Nigeria. *American Journal of Water Science and Engineering*, 3(6), 80-83. doi: 10.11648/j.ajwse.20170306.13
- Chawaza Foundation Worldwide (2020). Facts and Figures of Bosso Local Government Area, Niger State, Nigeria, 12pp.
- Chinedu, S.N., Nwinyi, O. C., Oluwadamisi, A. Y., & Eze, V.N. (2011). Assessment of Water Quality in Canaanland, Ota, Southwest Nigeria. *Agriculture and Biology Journal of North America*, 2(4), 577-583. doi:10.5251/abjna.2011.2.4.577.583.
- Ehigiator, O.A. & Jimoh, O.I. (2015). Evaluation of Raw Water Quality of Bosso Lake in North- Central, Nigeria. *Journal of Civil Engineering & Construction Technology*, 6, (5), 80-85.
- Emigilati, A.H., Mohammed, I.I., Kuta, G.I, Usman, B.Y., & Hassan, A.B. (2014). An Assessment of Alternative Water Source for Domestic use in Minna Metropolis, Niger State. *Nigeria. Journal of Environment and Earth Science*, 4(18), 10-15.
- Gimba, P.B. (2011). Assessment of Quality of Drinking Water in Bosso Town, Niger State. M.Sc Dissartation, ABU, Zaria. 2000pp.
- Gwemmar, N.C., Kolawole, S.A., & Okunoye, L.K. (2013). Physical and Chemical Assessment of some Selected Borehole Water in Gwagwalada, Abuja. *International Journal of Scientific & Technology Research*, 2(11), 324-328.
- Ince, M., Bashir, D., Oni, O.O.O., Awe, E O., Ogbechie, V., Korve, K., Adeyinka, M. A., Olufolabo, A.A., Ofordu, F., & Kehinde, M. (2010). Rapid Assessment of Drinking-Water Quality in the Federal Republic of Nigeria: Country Report of the Pilot Project Implementation in 2004-2005. *World Health Organization and UNICEF*. ISBN 978 92 4 150060 9.
- Kangpe, N.S., Egga, E.S., & Mafuyai, G.M. (2014). Physicochemical and Microbial Assessment of some Well Water from Mista-Ali Town, Bassa L.G.A, Plateau State. *Asian Review of Environmental and Earth Science*, 1(21), 39-42.
- Kassie, B. (2018). Solutions for Nigeria's Water Quality Challenges. Available on <http://borgenproject.org/nigerias-water-quality-solution/> Accessed on November 27, 2019.
- Likambo, W. (2014). Assessment of Worehole water Quality and Consumption in Yei County South Sudan. M.Sc. Dissertation Makerere University, Kampala, Uganda.



- Meena, B.S., & Bhargava, N. (2012). Seasonal Variations of Physico-Chemical Characteristics in Open-Well Water Quality in Bakani Tehsil of Jhalawar District, Rajasthan, India. *Ultra Chemistry*, 8 (3), 386-390.
- Mlipano, C.N., Richard, M., & Lawrence, C. (2018). Effect of Depth and Distance of the Borehole from the Septic tank on the Physico-chemical Quality of Water. *Journal of Food Studies*, 7(1), 41-55. doi:10.5296/jfs.v7i1.12187.
- Ndamitso, M.M., Idrisi, S., Likita, M.B., Tijani, Y.O, Ajai A.I., & Bala, A. A. (2013). Physico-Chemical and *Escherichia coli* Assessment of Selected Sachet Water pProduced in some areas of Minna, Niger State, Nigeria. *International Journal of Water Resources and Enviromental Engineering*, 5(3), 134-140.
- Nemade, P.D. Kadam, A.M. Shankar, H.S. (2009). Removal of Iron, Arsenic and Coliform Bacteria from Water by Novel Constructed Soil Filter System. *Ecological Engineering*, 35 (8), 1152-1157.
- Odukoya, A.M. & Abimbola, A.F. (2010). Contamination Assessment of Surface and Ground Water within and Around Two Dumpsites. *International Journal of Environmental Science and Technology*, 2(2), 367-376.
- Ojutiku, R.O., Ibrahim, A., & Raymond, A. (2014). Assessment of Water Quality Parameters and Trace Metals Contents of Drinking Water Sources in Minna Metropolis, Niger State. *International Journal of Current Microbiology & Applied Sciences*, (ISSN: 2319 – 7706), 3 (50), 1029 -1037.
- Okoro, H.K., Adeyinka, A., Jondiko, O.E. & Ximba, B.J. (2012). Physicochemical Analysis of Selected Groundwater Sample of Ilorin Town in Kwara State, Nigeria. *Scientific Research amd Essay*, 7 (23), 2063-2069.
- Olasehinde, P. I., Amadi, A.N., Dan-Hassan M.A., & Jimoh, M. O. (2015). Statistical Assessment of Qroundwater quality in Ogbomosho, Southwest Nigeria. *American Journal of Mining and Metallurgy*, 3(1), 21 – 28, doi:10.12691/ajmm-3-1-4.
- Olatunji, J.A., Odeiran, O.A., Obaro, R.I., & Olasehinde, P. I. (2015). Assessment of Groundwater Quality of Ilorin Metropolis using Water Quality Index Approach. *Nigerian Journal of Technological Development*, 12(1), 18-21. doi:http://dx.doi.org/10.4314/njtd.v12i1.4
- Olubanjo, O.O., Alade, A.E., & Olubanjo A. M. (2019). Physicochemical Assessment of Borehole and Well Water used in Akungba-Akoko, Ondo State, Nigeria. *ABUAD Journal of Engineering Research and Development*, 2(1), 143-153.
- Payment, P. Waite, M. Dufour, A. (2003). *Introducing Parameters for the Assessment of Drinking Water Quality: In Assessing Microbial Safety of Drinking Water Improving Approaches and Method*, WHO and OECD, IWA Publishing: London, UK pp. 47-77.
- Ranjana, A., (2009). Study of Physico-Chemical Parameters of Groundwater Quality in Dudu Town in Rajasthan. *Rasanya Journal of Chemistry*, 2 (4), 969-971.
- Reda, A.H. (2016). Physicochemical Analysis of Drinking Water Quality of Arbamin Town. *Journal of Environmental & Analytical Toxicology*, 6, 356. Doi:10.4172/2161-0525.1000356.
- Regional Water Quality Laboratory Minna (2011). Determination of Total Hardness in Water. Laboratory Work Instruction, 1, (31), 5 pp.
- Taiwo, A.M., Adeogun, A.O, Olatunde, K.A., & Adegbite, K.I. (2011). Analysis of Groundwater Quality of Hand-Dug Wells in Peri-Urban Area of Obantoko, Abeokuta, Nigeria for Selected Physicochemical Parameters. *The Pacific Journal of Science and Technology*, 12(1): 527-534.
- UNESCO —United Nations Educational, Scientific and Cultural Organization (2012).World’s Groundwater Resources are Suffering from Poor Governance. UNESCO Natural Sciences Sector News. Paris, UNESCO.
- Venkateswara, B.R. (2011). Physicochemical Analysis of Selected Groundwater Samples of Vijayawda Rural and Urban in Krishna District, India. *International Journal of Environmental Sciences*, 2, 710.
- WHO (2011). *Guidelines for Drinking Water Quality*, 4th ed., Geneva, Switzerland, 554pp. [Available on : <http://www.who.int>]
- Yisa, J., Gana, P.J., Jimoh, T.O., & Yisa, D. (2012). Underground Water Quality Assessment in Doko Community, Niger State Nigeria. *Journal of Emerging Trends in Engineering and Applied Sciences*, 3(2), 363-366.