Original Research Article

ASSESSMENT OF THE PHYSICOCHEMICAL AND BACTERIOLOGICAL CONTENT OF SOME DRINKING WATER SOURCES IN JOS SOUTH LGA IN NORTHERN SENATORIAL DISTRICT OF PLATEAU STATE NIGERIA

ABSTRACT

Drinking water is hardly found 100% pure in nature due to human activities and other natural factors. Many diseases in developing countries are caused by drinking contaminated water. Water samples collected were analyzed by automated instrumental methods prescribed by standard methods for the analysis of water and wastewater and the United State Environmental Protection Agency (USEPA). The results showed SO_4^{2-} range from ND to 60.00mg/L; pH 5.27 to 6.79; NO_3^- 1.19-11,64 mg/L; PO_4^{2-} 10.12 to 352.00mg/L; Cd range from 0.011± 0.00 to 0.032 ± 0.00mg/L; Ni, from ND to 0.04 mg/L; Cr, ND to 0.686 ± 0.07mg/L; Pb ND to 0.34 ± 0.01mg/L, total bacteria count TaBC, 1.5 x 10^4 to 8.5 x 10^4 CFU/mL in the samples used. The calculated average daily intake (ADI) for Cd, Ni, Cr and Pb were within acceptable limits while the hazard quotients (HQ) for all the metals were >1, signifying that the population would experience non-cancer risks due to exposure to these metals in drinking water. The bacteriological study of the water samples also revealed that the water samples were all polluted with bacteria and coliforms. From the foregoing, these drinking water sources, therefore require treatment before consumption to minimize or avoid the incidences of water-related diseases.

Keywords: Bacteriology, Disease, Hazard, Heavy metals, and Water

1.0 INTRODUCTION

"Drinking water quality is a worldwide concern and has a great impact on human health" [1]. "The safety of drinking water is shown in terms of its physical, chemical (mineral), and bacteriological parameters" [2] [1]. "In developing countries such as Nigeria, most of the rural settlements are poor with a lack of access to safe water supplies and hence rely mainly on rivers, streams, and wells as water sources for their daily needs" [1,3] . "Water provides essential elements, but when polluted with excess minerals and chemical solvents it becomes an undesirable substance that is injurious to human health" [4][5][7]. "Contamination of drinking water may arise from the introduction of chemical compounds into the water supply systems through leaks, cross-contamination or direct contamination by human activities around water bodies" [3] and [7].

Studies have shown that "over one billion people in the world lack access to safe drinking water and 2.5 billion people do not have access to adequate sanitation services" [8] "In many developing countries including Nigeria, clean pipe-borne water availability is limited and inadequate for the teeming population. Thus, an increasing number of people in semi-urban areas in the country depend on dug wells and water vendors for water supply" [9].

[10], stated that "hand-dug wells are in most cases cited in poor sanitary locations (close to refuse dumps, pit latrines, or suck-away systems). Some of the wells are even left open and are therefore prone to contamination of various types and degrees". [10], further stated that "the addition of any undesirable substance (s) to ground or well water either through human activities or natural processes is considered contamination. Two chief sources of water pollution are point source and non-point source".

"Water is a potential vehicle for the transmission of organisms of specific disease, accounting for over 80% of all human illnesses in developing countries" [11]. "Among the major waterborne diseases are cholera, typhoid, bacillary dysentery, infections hepatitis and giardiasis, while the major washed disease (i.e., diseases due to lack of water) are scabies, skin diseases, sepsis ulcers, leprosy, trachoma, dysentery and ascaria" [12]. This research was therefore aimed at the assessment of the physicochemical and bacteriological content of some drinking water sources in selected villages of Jos South LGA in Northern Senatorial Districts of Plateau State Nigeria.

2.0 MATERIALS AND METHODS

2.1 materials/equipment

The materials used for this analysis were a spectrophotometer HACH/DR 900, Wagtech Photometer 7100, wagtech pH/conductivity/TDS meter and atomic absorption spectrometer (AAS).

2.2 Sample collection and analysis

Water samples were collected from different locations in Jos South Local Government Area of Plateau state. The water samples were collected from different sources such as hand dug well, drilled boreholes, pipe borne and sachet water which serves as a source of drinking water to the inhabitants. The samples were collected in a sterile container suitable for sample transport to the laboratory for analysis.

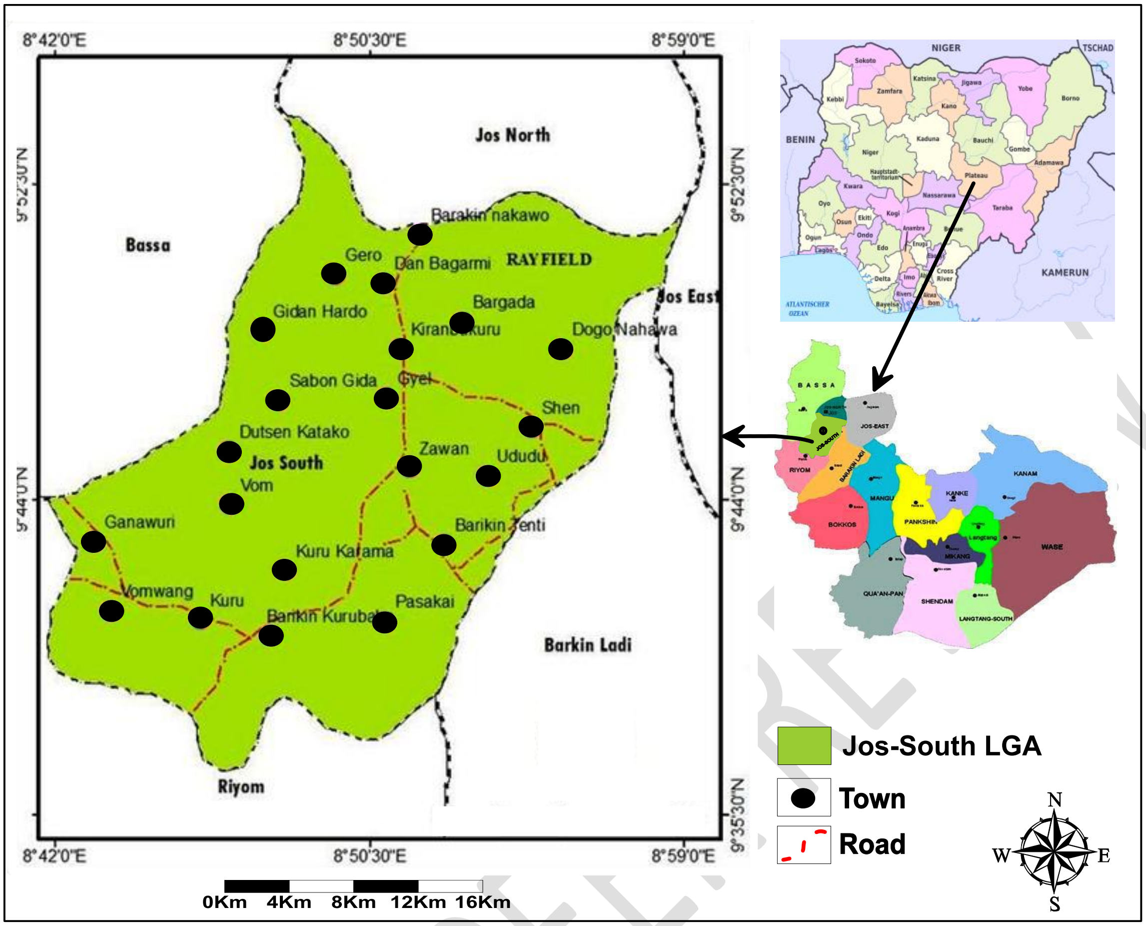

Figure 1:Map of Jos South Local Government Area

2.3 Sample Analysis

Physicochemical Analysis: Water samples collected were analyzed by automated instrumental methods prescribed by standard methods for the analysis of water and wastewater and the United State Environmental Protection Agency (Standard Method, 1999). The concentrations of major ions; such as Sulphates (SO_4^{2-}), Nitrates (NO_3^-) and Phosphate (PO_4^{2-}) were determined spectroscopically using HACH/DR 900. The water surface temperature was determined by lowering the probe to about 1cm below the water surface for about five (5) minutes until it stabilized and the temperature was recorded immediately. Conductivity, Total Dissolved Solids, Turbidity and pH were measured by Wagtech Photometer 7100 and wagtech pH/conductivity/TDS meter respectively, while the heavy metal content was analyzed using atomic absorption spectrophotometer.

2.4. Health Risk Assessment of the Water

Using equations 1 and 2 below, the health risk of drinking water from different sources daily was determined from the average daily intake (ADI) and hazard quotient (HQ) of heavy metals in the water (EPA, 2011).

ADI= <u>Cx x Ir x Ef x Ed</u> … Equation --- I

Bwt x At

Where: ADI=average daily ingestion of heavy metals per kilogram of body weight; Cx=concentration of heavy metals in water; Ir = ingestion rate per unit time; Ef = exposure frequency; Exposure duration; Bwt=body weight; At = the average time (Ed x Ef). According to [13], the standard values and units of the mentioned variables are as follows: EF=365 days/years; Ir=2L/day; Ed=55 years; Bwt=65 kg; At=20075 days.

$HQ = \frac{ADI}{RFD}$ … Equation ---2

Where: HQ=hazard quotient; RFD=heavy metal oral reference dose. According to [14], the RFD (mg/L/day) of Pb=0.0035; Cd=0.0005; Ni=0.020; Cr=0.0003.

In general, the value of HQ or HI 1 indicates significant non-carcinogenic effects, which increased with the increasing value of HQ or THQ [15]; [16].

3.0 RESULTS AND DISCUSSION

3.1 Result

Table 1 Result of the physicochemical analysis of water collected from Jos South Local Government Area of Plateau State

Sample Code	SO_4^{2-} Mg/l	PO_4^{2-} Mg/l	NO_3^- Mg/l	Colour Pt.co	Turbidity NTU	Conductivity µS/cm	TDS Mg/l	pH	Temp ^0C
KWW	60.00	3.45	352.00	0.00	0.00	1670.00	836.00	6.50	28.70
KPW	12.00	5.67	13.64	350.00	50.00	90.50	45.10	6.77	28.90
H_SPW	6.00	4.65	16.28	0.00	13.00	93.40	46.60	6.64	29.20
DWW	5.00	4.77	111.67	15.00	26.00	160.10	80.10	6.51	28.70
KJBW	2.00	11.64	39.16	0.00	15.00	119.80	59.80	6.28	29.20
KVWW	3.00	3.99	133.32	0.00	5.00	700.00	350.00	6.11	28.90
RKPW	5.00	3.02	16.72	0.00	10.00	86.10	43.00	6.29	28.80
N_gPW	10.00	5.48	28.60	210.00	31.00	81.30	40.50	6.42	28.20
NgWN	2.00	3.35	24.64	0.00	2.00	171.10	85.30	6.19	28.20
GBW	0.00	4.34	39.16	0.00	0.00	273.00	135.00	6.44	28.20
SW	0.00	1.19	10.12	0.00	0.00	747.00	37.30	6.79	28.00
GTBW	1.00	2.20	11.00	0.00	1.00	412.00	20.40	6.47	28.00
SGWW	3.00	3.13	308.00	0.00	13.00	829.00	4.14	6.15	28.30
KVBW	2.00	9.17	18.92	65.00	4.00	164.40	82.20	6.40	28.40
GTWW	2.00	2.21	42.24	0.00	26.00	124.00	62.10	6.50	28.30
DBWW	0.00	4.55	10.12	0.00	2.00	29.50	14.70	6.03	28.40
HBW	3.00	4.74	112,64	25.00	0.00	114.50	572.00	5.89	28.50
RKWW	3.00	3.68	83.16	5.00	1.00	266.00	133.00	6.28	28.30
DKBW	0.00	2.30	18.48	0.00	0.00	67.10	33.60	6.60	28.50
KJWW	2.00	3.74	56.76	5.00	7.00	299.00	149.00	6.35	28.00
GWW	6.00	2.46	98.12	0.00	0.00	7.86.00	393.00	6.15	28.10
GPW	7.00	3.32	15.84	155.00	16.00	87.30	43.70	6.29	28.70
HPW	10.00	5.66	18.04	225.00	36.00	104.60	52.30	6.45	27.70
HsWW	0.00	24.07	121.00	0.00	0.00	1287.00	644.00	5.27	28.30
HWW	5.00	2.84	154.00	0.00	0.00	1299.00	652.00	6.0	28.00
NIS-555-2015	100	1.00	50						

KEY: KWW= Kufang well water; KPW= Kufang pipe-borne water; H_SPW=Hwolshe pipe-borne water; DWW=Danchol well water; KJBW= Kuru Jenta borehole water; KVWW K-Vom well water; RKPW= Rahwol Kanang pipe borne water; NgPW= Nyango Gyel pipe borne water;NgWN= Nyango Gyel well water; GBW=Giring borehole water; SW= Sachet water; GTBW=Gura Top borehole water;

SGWN=Sankan Gyel well water;KVWW= K-Vom well water; GTWW=Gura Top well water; DbWW= dahwol Bob well water; HBW=Hwak borehole water; RKWW=Rahwol Kanang well water; DKBW= Danchol Kushe borehole water; KJWW= Kuru Jenta well water; GWW= Giring well water; GPW = Giring pipe borne water; HPW=Hwolshe pipe borne water; HsWW= Hwolshe well water; HWW= Hwak well water

3.2 Discussion

The physicochemical parameters determined in this study were temperature, pH, conductivity, turbidity, total dissolved solids, phosphate, nitrate, sulphate and colour (Table 1). The temperature of the water samples ranged from 29.20^0C to 27.70°C, all the temperatures were within a similar range. The highest and least pH values of 6.77 and 5.27 were recorded in KPW and H_SWW respectively. All the water samples were slightly acidic except HsWW where the acidity was slightly higher than others. The water samples with pH < 6.5 which is below the recommended range of 6.5-8.5 by NIS-554-2015 were the well water samples collected from different locations. However, there was no significant difference (p>0.05) in the values of pH obtained from the water samples.

The total dissolved solids recorded in this study were within acceptable limits with very few deviations recorded in KWW, HBW, HSWW and HWW whose values were higher than 500 maximum permissible limits by NIS-554-2015. Similarly, the turbidity values were within the range of 0 to 50 NTU. Turbidity has no direct health impact but can harbour microorganisms protecting them from disinfection and can entrap heavy metals and biocides which can bring problems in the water treatment process and can also be a potential risk for pathogens in treated water.

The electrical conductivity has the least value of 7.86 μScm^{-1} from GWW and the highest value of 1670.00 μScm^{-1} from KWW. Most of the values recorded in the other samples were not significantly different (p>0.05) as they were within the recommended limit of ≤1000.00 of the NIS-554-2015 standard. Though higher than normal values were recorded in HWW, HsWW and KWW respectively.

The nitrate concentration of the water sample ranges from 10.12mg/L to 352 mg/L, most of the values recorded in well water were greater than the 50 mg/L maximum permissible limit by the NIS-554-2015 standard. High concentration of nitrate in water is responsible for Cyanosis and asphyxia in infants under three months. The values of the monitored nitrates revealed the following order of magnitude:

well>borehole> pipe-borne water >sachet waters. The higher level of nitrate in HWW and the HBW may be a result of the leaching of nitrate into the water table which depends on factors bordering on geology, soil type, crop utilization rate of nitrogen, microbial conversion rate of nitrate and fertilizer application pattern. Thus, it can be deduced that relatively high nitrate values may be due to leaching from sewages, pit latrines and refuse dumps located close to wells.

High concentration of sulphate above the recommended limit in drinking water is known to cause diarrheal stools, dehydration and gastrointestinal irritation [10]. All the SO_4^{2-} in the water samples recorded lower values than the maximum permissible limit of 100 mg/L, thus posing no threat to the water analyzed. Phosphate concentrations in all the water analyzed ranged from 1.19 mg/L to 24.07 mg/L all the values were higher than the (WHO, 2011) standard limits of 1.00mg/L [17]. This observation is also in agreement with the findings of other workers in similar studies [18]

Table 2 Result of the heavy metal analysis of water collected from Jos South Local Government Area of Plateau State

SAMPLE ID	Cd (μg/g)	Ni (μg/g)	Cr (μg/g)	Pb (μg/g)
DWW	0.003±0.002	ND	0.050±0.035	0.002±0.064
DKBW	0.007±0.001	0.002±0.006	0.188±0.038	ND
DbWW	0.009±0.001	0.001±0.002	0.051±0.001	0.030±0.052
GBW	0.014±0.014	0.009±0.000	0.035±0.133	ND
GPW	0.018±0.000	0.005±0.001	0.003±0.098	ND
GTBW	0.020±0.001	ND	0.047±0.172	ND
GWW	0.025±0.001	0.006±0.004	0.081±0.187	ND
GTWW	0.027±0.004	0.010±0.005	0.265±0.077	ND
HBW	0.029±0.000	0.007±0.007	0.137±0.058	ND
HSWW	0.025±0.014	0.009±0.001	0.187±0.083	ND
HsPW	0.007±0.002	0.003±0.007	ND	ND
HPW	0.011±0.000	0.003±0.001	0.052±0.035	ND
HWW	0.013±0.000	ND	ND	ND
KPW	0.015±0.001	0.002±0.002	0.156±0.147	ND
KvBW	0.020±0.001	ND	0.318±0.190	0.034±0.065
KWW	0.024±0.001	0.001±0.003	0.526±0.096	ND
KJWW	0.024±0.000	0.001±0.00	0.523±0.026	ND
KJBW	0.031±0.000	0.002±0.007	0.407±0.110	ND
KVWW	0.032±0.000	0.004±0.002	0.666±0.111	0.005±0.060
NgWW	0.004±0.001	0.002±0.004	0.686±0.073	0.086±0.062
NgPW	0.007±0.000	0.002±0.002	0.027±0.015	0.131±0.105
SGWW	0.013±0.000	0.004±0.001	0.158±0.032	0.175±0.034
RKPW	0.013±0.002	0.003±0.007	0.126±0.034	0.271±0.094
RKWW	0.017±0.003	0.003±0.001	0.005±0.043	0.327±0.054
SW	0.021±0.000	0.004±0.002	0.380±0.033	0.34±0.012
Maximum permissible limit WHO (2008)	0.003	0.07	0.05	0.01

n=3

The heavy metal concentrations analyzed in the various water samples were Cd, Cr, Ni, and Pb. The concentration of Cd ranged from 0.003 ± 0.002 to 0.032 ± 0.00 with an average of 0.028 (Table 2). These values are lower than the findings of [19] in the same study area. Most of the results obtained from the study are above the acceptable limit of WHO (2011). Cadmium is very toxic and is a non-essential element with very harmful effects on living organisms [20]

The result of Ni recorded in the water samples was found to range from ND to 0.01 ± 0.002 with a mean value of 0.0015, which is similar to the work [21], but lower than the average reported by [22] in river kampani. According to [23], Ni^{+} deficiency results in decreased plasma cholesterol, increased liver cholesterol, ultrastructural changes in the liver cells, rough hair, impaired reproduction, and poor growth of offspring. Cr ranges from ND to 0.686 ± 0.073 chromium was not detected in HsPW and HWW, however, the values obtained from this study were higher than those reported in river Kampani by [22] but similar to the findings of [19]. Pb concentrations vary from ND to 0.34 ± 0.012 mg/L. Pb was not detected in most of the sample water. The concentration of Pb in the samples followed the order WS > RKWW > RKPW > SGWW > NgPW > NgWW > KvBW > DbWW respectively. This study reaffirmed the work of [23], who assessed Trace Metals' Contamination of Stream Water and Irrigated Crops at Naraguta, Jos, in November 2008 and reported the mean concentration value of 1.57ppm at the centre section of the river, which is higher than the obtained values in this research where the samples were collected in January, this is indicative of the fact that Pb concentration level increases as the rains deplete as reported by [24]. The outcome of this research is also in line with the work of [23], who assessed Trace Metals' Contamination of Stream Water and Irrigated Crops at Naraguta-Jos. They reported the concentration status of Pb to be 0.138 ppm at the lower section of the river in November 2008, which is similar to the result obtained in some of the sample values during this study as presented in Table 2. Likewise, this seems to be at par with the work of [25], who assessed Pb levels in vegetables from an artisanal mining site of river Delimi and reported the Pb mean value of 2.50 ppm which is higher than the values obtained during this study (Table 2)

Table 3 Average daily intake and non-cancer hazard quotients for drinking water collected from Jos South Local Government Area of Plateau State

	ADI				HQ			
Sample Code	**Cd**	**Ni**	**Cr**	**Pb**	**Cd**	**Ni**	**Cr**	**Pb**
DWW	0.00009	-	0.00154	0.000062	0.18	-	3.08	0.124
DKBW	0.00022	0.000062	0.005785	-	0.44	0.124	11.57	-
DBSWW	0.00028	0.000031	0.001569	0.00092	0.56	0.062	3.14	1.84
GBW	0.00043	0.00028	0.001077	-	0.86	0.56	2.15	-
GPW	0.00055	0.00015	0.000092	-	1.10	0.3	0.18	-
GTBW	0.00062	-	0.001446	-	1.24	-	2.89	-
GWW	0.00077	0.00018	0.00249	-	1.54	0.36	5.98	-
GTWW	0.00083	0.00031	0.00082	-	1.66	0.62	1.64	-
HBW	0.00089	0.00022	0.00042	-	1.78	0.44	0.84	-
HSWW	0.00077	0.00028	0.005753	-	1.54	0.56	1.15	-
HSPW	0.00022	0.000092	-	-	0.44	0.18	-	-
HPW	0.00034	0.000092	0.0015999	-	0.86	0.18	3.20	-
HWW	0.00040	-	-	-	0.8	-	-	-
KPW	0.00046	0.000062	0.0047999	-	0.92	0.12	9.60	-
KVBW	0.00062	0.000031	0.0097845	0.001046	1.24	0.06	19.57	2.10
KWW	0.00074	0.000062	0.016092	-	1.48	0.12	32.18	-
KJWW	0.00074	0.00012	0.0125229	-	1.48	0.24	25.05	-
KJBW	0.00095	0.000062	0.0204922	-	1.90	0.12	40.98	-
KVWW	0.00098	0.00012	0.0211075	0.000154	1.96	0.24	42.21	0.31
NGWW	0.00012	0.000092	0.00083	0.0026461	0.24	0.18	1.66	5.29
NGPW	0.00022	0.000092	0.004862	0.0040307	0.44	0.18	9.72	8.06
SGWW	0.00040	0.00012	0.0038769	0.005385	0.80	0.24	7.75	10.77
RKPW	0.00040	0.00012	0.000153	0.0083383	0.80	0.80	0.31	16.68
RKWW	0.00052	0.000092	0.01169222	0.01144607	1.04	0.18	23.38	22.89
SW	0.00065	0.00012	0.01169222	0.01046146	1.30	0.24	23.38	20.922
RDI Ullah *et al*. (2017)	0.06	0.50	0.20	0.21				

The health risk of drinking water from different sources daily was determined using equations 1 and 2 above to assess the average daily intake (ADI) and hazard quotient (HQ) of heavy metals in the water [26]. The calculation was made based on the life expectancy of a fifty-five years old adult Nigerian. The results presented in Table 2 revealed that the average daily intake of all the water sources fell below the recommended daily intake limits of all the heavy metals analyzed. The Hazard quotients HQ for Cd, in DWW, DKBWW, DBSWW, GBW, HSPW, HPW, HWW, KVBW, NgWW, SGWW, RKPW and RKWW were < 1 for Borehole and well water respectively, signifying that the population would not experience non-cancer risks due to exposure to these metals in drinking water. Hazard indices >1 were obtained in all the other sampling locations, indicating an unacceptable risk for non-carcinogenic adverse health effects on the populace. Nickel in all the water samples had HQ values <1, whereas Cr in almost all the water samples has HQ >1 except GPW, HBW and RKPW with values of HQ<1. Pb was not detected in most of the samples but the few that were detected had HQ>1.

Table 4: Bacteriological analysis of some drinking water samples in Jos South Local Government Area of Plateau State

SAMPLE CODE	Raw count for TaBC	TaBC (CFU/mL)	MPN/100 mL of water	Bacterial isolate
GBW	13*	**6.5×10^4**	**20**	*Escherichia coli, Bacillus* species *(spp)*
DWW	49	**2.5×10^5**	**220**	*E. coli, Streptococcus faecalis*
GTBW	8*	**4×10^4**	**22**	*Bacillus* spp*, E. coli*
KVWW	6*	**3×10^4**	**4**	*E. coli, Streptococcus faecalis*
SW	3*	**1.5×10^4**	**11**	*Bacillus spp., Pseudomonas aeruginosa,* CoNS *Staphylococci*
HSPW	96	**4.8×10^5**	**520**	*E. coli*
HBW	11*	**5.5×10^4**	**47**	*Klebsiella aerogenes,* CoNS
GTWW	47	**2.4×10^5**	**36**	*E. coli*
KJBW	302**	**1.5×10^6**	**17**	*Citrobacter freundii, Bacillus* spp
SGWW	65	**3.3×10^5**	**81**	*Citrobacter freundii, Streptococcus faecalis*
KWW	30	**1.5×10^5**	**2**	*Bacillus* spp., *Pseudomonas aeruginosa*
GPW	96	**4.8×10^5**	**9**	*Klebsiella aerogenes, Bacillus* spp
RKPW	104	**5.2×10^5**	**11**	*E. coli*
GWW	33	**1.7×10^5**	**17**	*E. coli*
H_SWW	352**	**1.8×10^6**	**11**	*E. coli, Streptococcus faecalis, Bacillus* spp.
N_gWW	64	**3.2×10^5**	**1600**	*E. coli*
DbWW	36	**1.8×10^5**	**9**	*E. coli, Bacillus* spp
KJWW	15*	**7.5×10^4**	**220**	*Klebsiella aerogenes*
HPW	16*	**8×10^4**	**2**	*Klebsiella aerogenes*
NgPW	39	**1.9×10^5**	**< 2**	CoNS*, Bacillus* spp
HWW	58	**2.9×10^5**	**220**	*Bacillus* spp, *E. coli*
RKWW	311**	**1.6×10^6**	**14**	*Staphylococcus aureus, Bacillus* spp*., C. freundii*
D/KBW	324**	**1.6×10^6**	**12**	*Staphylococcus aureus, Bacillus* spp*, E. coli*
KPW	17*	**8.5×10^4**	**2**	*Bacillus* spp*., Klebsiella aerogenes*
KVBW	31	**1.6×10^5**	**>1800**	*Bacillus* spp*., E. coli, K. aerogenes*
Limit of TaBC		**100**		

Key: * = Too Few To Count (TFTC), ** = Too Numerous To Count (TNTC), TaBC = Total Aerobic Bacterial Count, MPN = Most Probable Number, CFU = Colony Forming Unit, CoNS = Coagulase-negative Staphylococci.

Table 4 shows the bacterial and coliform counts in the borehole, stream pipe borne and well water samples collected from Jos South Local Government Area of Plateau State. Accordingly, the water samples of the locations had abnormal bacterial counts (Table 4). HsWW had the highest bacterial count (1.8×10^6 CFU/mL), while SW had the lowest bacterial count (1.5×10^4 CFU/mL). In all the water samples of the different locations, total bacterial count and coliform counts were above the permissible limits of 100 CFU/mL and 0 CFU/mL respectively [27]. Therefore, it was concluded that all the sources of water in the studied areas may not be suitable for drinking unless treated. The bacteriological analysis of this study showed similar results to those of [28] [29][30], in drinking water sources from different parts of Jos. Their findings suggested that all the drinking water within the Jos metropolis was required to be treated before consumption. Several bacterial species produce nutrients, digest food, and boost the immune function [31]. On the other hand, some waterborne bacteria may cause diseases such as cholera, diarrhoea, typhoid fever, and dysentery [32]. The presence of coliforms in the water samples of the different locations indicated that the water would have been contaminated by environmental pollutants, particularly faecal matter [33]. Most coliforms are harmless, while certain strains of *Escherichia coli* 0157:H7, which are the most common faecal coliforms often found in animal faeces may cause diseases, especially diarrhoea [34]. In previous studies, [35] and [33] have also detected *E. coli* and enteric bacteria in several wells, boreholes, and lagoons in Lagos. However, total bacteria were detected at significantly higher counts in the present study compared to the other findings in this regard. Apart from sanitary conditions and anthropogenic activities that may vary across the Local Government, seasonal variations might be an important factor involved in this issue being that the current research was carried out in the dry season.

Conclusion

The examination of water quality parameters from different sources in Jos South Local Government revealed that the water contained high levels of toxic metals such as Chromium and Lead, whereas Cadmium and Nickel were below the respective permissible limits. Most of the physicochemical parameters were within acceptable limits. The calculated average daily intake for Cd, Ni, Cr, and Pb where within acceptable limits while the hazard quotients (HQ) for all the metals were>1, signifying that the population would experience non-cancer risks due to exposure to these metals in drinking water. The bacteriological study of the water samples also reveals that the water samples were all polluted with bacteria and coliforms. It is therefore concluded that the water samples require treatment before consumption to avoid water-related diseases.

Acknowledgement

The authors are grateful to the Tertiary Education Trust Fund (**TETFund)** for the sponsorship of this research.

Reference

1: Bisi-Johnson, A., Adediran, O., Akinola, A., Popoola, O., Okoh, I. (2017). Comparative physicochemical and microbiological qualities of source and stored household waters in some selected communities in Southwestern Nigeria. *Sustainability*; 9(454):1-11.

2: Alexandra P. (2008). Evaluation of groundwater quality of Mubi town in Adamawa State, Nigeria. *African Journal of Biotechnology*; **7**:1712-1715.

3: Committee on Environmental Health, Committee on Infectious Diseases (2009). Drinking water from private wells and risks to children. *Paediatrics*, 123(6):1599- 1605

4: Odeyemi T, Adebayo A and Adeosun O. (2013). Bacteriological and physiochemical studies of three major dams in Ekiti State, Nigeria. *Journal of Environmental and Earth Science.* 3(7):210-218.

5: Makinde A and Akande F. (2012). Effects of lead and simulated acid rain on chlorophyll contents of selected tropical mosses. *Ife Journal of Science.* 14(2):309-313.

7: Odeyemi, T., Faweya, B., Agunbiade, O and Ayeni S. (2011). Bacteriological, mineral and radioactive contents of leachate samples from dump sites of Ekiti State Government Destitiue Center in Ado Ekiti. *Archives of Applied Science Research.* **3**(4):92- 108

8: Tar, A., Eneji, I., Ande, S., Oketunde, F., Ande, S and Shaaton, R., (2009). Assessment of arsenic in drinking water in Makurdi metropolis of Benue State, Nigeria. *Journal of Chemical Society of Nigeria* **34**:56-62

9: Idowu, A., Oluremi, B and Odubawo, K., (2011). Bacteriological analysis of well water samples in Sagamu. *African Journal Clinical and Experimental Microbiology*, 12.

10: Jidauna, G.G., Dabi, D.D., Saidu, B.J., Ndabula, C and Abaje, I.B (2014). Chemical Water Quality Assessment in Selected Location in Jos, Plateau State, Nigeria. *Research Journal of Environmental and Earth Sciences* **6**(5): 284-291

11: WHO, (2002). Global water and sanitation assessment report. Author, Geneva.

12: WHO (World Health Organization), 2004. Guidelines for drinking water quality. 3rd Edn., Who, Geneva, Vol. 1 Recommendation.

13: Yahaya, T. O., Oladele, E.O., Fatodu, I.A., Abdulazeez, A and Yeldu, Y.I (2020). The concentration and health risk assessment of heavy metals and microorganisms in the groundwater of Lagos, Southwest Nigeria *Journal of Advance Environmental Health Research*: **8**(3):225-33

14: United States Environmental Protection Agency (1993). Reference Dose (RfD): Description and Use in Health Risk Assessments Background Document 1A. March 15, 1993. Available at https://www.epa.gov/iris/reference-dose-rfd-description and-use-health-risk-

15: Siyue, L. & Quanfa Z. (2010), Risk assessment and seasonal variations of dissolved trace elements and heavy metals in the Upper Han River, China, *Journal of Hazard Material*, 181, 1051-1058.

16: US EPA, (2001), Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. OSWER 9355.4-24

17: World Health Organization, Standards for Heavy Metals Concentration in Drinking Water,2011.

18: Oyeleke, S. B., Oyewole, O. A., Shaba, A. M., Mohammed, S. S. D., Adelere, I. A., Dung, C. S. *et al.* (2017). Bacteriological and physicochemical analysis of water from mining ponds in Bassa and Jos south Local Government Areas of Plateau State. *International Journal of Applied Biological Research* Vol. 8(1): 17 - 29

19: Denkok, Y., Adesina, O., Gurumtet, I & Kopdora, S.W (2021). An evaluative study on metal concentration in different ground and industrial water sources in Jos south local Government Area of Plateau State Nigeria. *Asian Journal of Biochemistry Genetics and Molecular Biology*. 7(1) 25-33

20: Ogunfowokan, A.O., Ajibola, R.O & Akani M.S (2010). Physicochemical quality and trace metal levels of municipal water from three reservoirs in Osun state Nigeria. *Asian Journal of water environmental pollution* 7(4) 49-62.

21: Ozoko, D.C., Onyekwelu, I.L and Aghamelu, O.P (2022). Multivariate and health risks analysis of heavy metals in natural water sources around Enugu dumpsite, southeastern Nigeria Applied Water Science .12: 224

22: Lawal, R.A Lohdip, Y.N & Egila, J.N (2014). Water Quality Assessment of Kampani River, Plateau State, Nigeria. *Asian Review of Environmental and Earth Sciences* 1. (2) 30-34.

23: Plant J.A and Raiswell, R (1983). Principles of environmental geochemistry. In: Thornton I (ed) Applied Environmental Geochemistry. Academic Press, London,

24: Ahmed, S. I. A., Sabo, D. D. Maleka. (2011). Trace Metals contamination of Stream Water and Irrigated crops at Naraguta Jos, Nigeria. *ATBU Journal of Environmental Technology.* **4**(1): 49-55

25: Aliyu A. A., Abdulhakeen, S. A.. Balel, Y. Y., Babanyara, A,. Salis, A., Ibrahim, D. B. *et al*. (2019). Heavy Metals in Water and Plants along Rivers Delimi and Jenta Jos, Plateau, State, Nigeria. *America Journal of Engineering Research.* **8**(3): 32-38.

26: Orish, E. O., Dagur, E.A., Mbagwu, H. O. C and Udowelle, N.A (2019). Lead Levels in Vegetables From Artisanal Mining Sites of Dilimi River, Bukuru and Barkin Ladi, North Central, Nigeria. Cancer and non-cancer Risk Assessment. *Asian Pac Journal of Cancer Preview* 2017. 18(3): 621-627

27: United States Environmental Protection Agency (EPA, 2011). Exposure Factors Handbook 2011 Edition (Final Report). Washington, DC

28: World Health Organization (2008). Guidelines for Drinking Water Quality: Incorporating 1st and 2nd Addenda, Vol.1, Recommendations. Geneva, Switzerland:

31: Zhang Y.J., Li S., Gan R.Y., Zhou T., Xu D.P., and Li, H.B (2015). Impacts of gut bacteria on human health and diseases. *International Journal Molecular Science*; **16**(4): 7493– 519.

32: Philip, J. L., Richard, F., Nereus, J.R.A., Olusoji, A., Robert, A., Niladri, B., *et al*. (2017). The Lancet Commission on pollution and health. *Lancet Communications*; 391: 462-512.

33: Adelekan, B.A and Ogunde, O.A (2012). Quality of water from dug wells and the lagoon in Lagos Nigeria and associated health risks. *Science Research Essays*; **7**(11): 1195-211.

34: Gruber, J.S., Ercumen, A and Colford, J.M (2014). Coliform bacteria as indicators of diarrheal risk in household drinking water: Systematic review and meta-analysis. *PloS one*; **9**(9): e107429

35: Egwari, L and Aboaba, O.O. (2002). Environmental impact on the bacteriological quality of domestic water supplies in Lagos, Nigeria. *Rev Saúde Pública*; **36**(4): 513-20