Original Research Article

Physico-chemical Parameters and Bacteriological Quality Assessment of some Domestic Water Sources in Pankshin LGA of Plateau State Nigeria

Abstract

Due to human activity and other natural influences, drinking water is seldom found in 100% pure forms in nature. Drinking polluted water is a major source of sickness in underdeveloped nations. The United States Environmental Protection Agency (USEPA) and standard methodologies for the investigation of water and wastewater were followed in the analysis of the collected water samples, which were conducted using automated instrumental methods. The obtained results indicated that the samples used had the following ranges of concentrations: SO_4^{2-} ranges from ND to 19.00 mg/L; NO_3^- ranges from 4.40 to 100.32 mg/L; PO_4^{2-} from 2.02-11,34 mg/L; pH 6.64 to 7.70; Cd from 0.0020 ± 0.001 to 0245 ± 0.01 mg/L; Ni, from 0.0074 ± 0.003 to 0.848 ± 0.021 mg/L; Cr, ND to 0.386 ± 0.082 mg/L; Pb ND to 0.428 ± 0.003 mg/L; total bacteria count TaBC, 4 x 10^2 to 3.3 x 10^4 CFU/mL.Most of the physicochemical parameters were above acceptable limits. 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, Physicochemical, Water quality, Disease, Treatment

1.0 INTRODUCTION

Water is a vital liquid to life and makes up a significant portion of the body [1]. According to[2], water makes up more than 65% of the human body. The availability of clean drinking water is essential to human physiology and to the continuous survival of man [3] [4]. A sizable portion of the global populace lacks access to clean drinking water. Over one billion people, or one in six of the world's population, do not have access to pure drinking water [2], particularly in developing nations like Nigeria. In Sub-Saharan Africa, there are currently over 300 million rural residents without access to clean water sources, and this number is rising [5]. The only realistic option for meeting rural water demands is through groundwater exploitation [6]. A large world population, especially in sub-Saharan Africa, depends on groundwater as their main source of domestic water [7] [8].

Approximately 1.8 billion people worldwide drink water tainted by faeces, which results in two million deaths from diarrheal illnesses each year [9]. The most frequent cause of chemically induced intoxication and infectious diseases may be water. Because of this, a single source frequently provides for a sizable population, making water quality the most crucial component in ensuring public health [10]. Certain aquatic illnesses can hinder a child's growth and cause cognitive impairment in young children under five years old [11]. Contaminated non-potable water harbouring pathogens is the medium via which waterborne infections are spread. Nearly 3.6% of all diseases with a worldwide burden are diarrheal illnesses, highlighting the need for water portability [12][13]. Even while newly discovered pollutants are common in aquatic environments, the majority of them originate from the release of wastewater effluents from municipal facilities. Because of the potential ecological effects (such as endocrine disruption) on the environment's biota, the presence of these pollutants is extremely concerning [14].

The demand for essential services, access to a suitable water supply, and sanitation has increased due to the urban population's fast development [15]. Due to overuse of resources, inefficient waste disposal techniques, and a rise in urban population, the fast expansion of metropolitan areas has further impacted water quality [16].

Total suspended solids (TSS), dissolved oxygen (DO), hardness, alkalinity, turbidity, pH, Cu, Fe, Mn, Zn, P, Cl, and other chemical and biological properties and components of surface and groundwater sources are all included in the concept of water quality [17]. Numerous substances found in drinking water are essential to human health. However, high quantities of these substances and consuming them in excess might lead to serious health issues [18][17][19]. This research is therefore aimed at assessing the Physico-chemical Parameters and Bacteriological Quality of some Domestic Water Sources in Shendam LGA 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

Exactly 25water samples were collected from different locations in Pankshin Local Government Area of Plateau State. The water samples were collected from different sources such as hand-dugwells, drilled boreholes, pipe and sachet water which serves as a source of drinking water for the inhabitants. The samples were collected in a sterile container suitable for sample transport to the laboratory for analysis.

2.3 Sample Analysis

2.3.1 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 States 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 an atomic absorption spectrophotometer.

2.3.2 Media preparation and Bacterial isolation

Plates of Nutrient agar (NA), Blood Agar (BA), Salmonella Shigella agar (SSA), and MacConkey (MCA) agars wereprepared according to the manufacturer's specification and number of dishes needed for bacterial identification. After a 10^{-4}serial dilution of water samples from various sources, dried NA plates were inoculated with 1.5ml of the samples from the 10^{-2} plate through the spread plate technique, to obtain the various heterotrophic bacteria counts and incubated at 37°C for 24hrs. Upon macroscopic identification of discrete bacterial colonies, isolates were picked and further sub-culture on BA, SSA, and MCA agars to obtain pure cultures of enteric and gram-positive organisms.

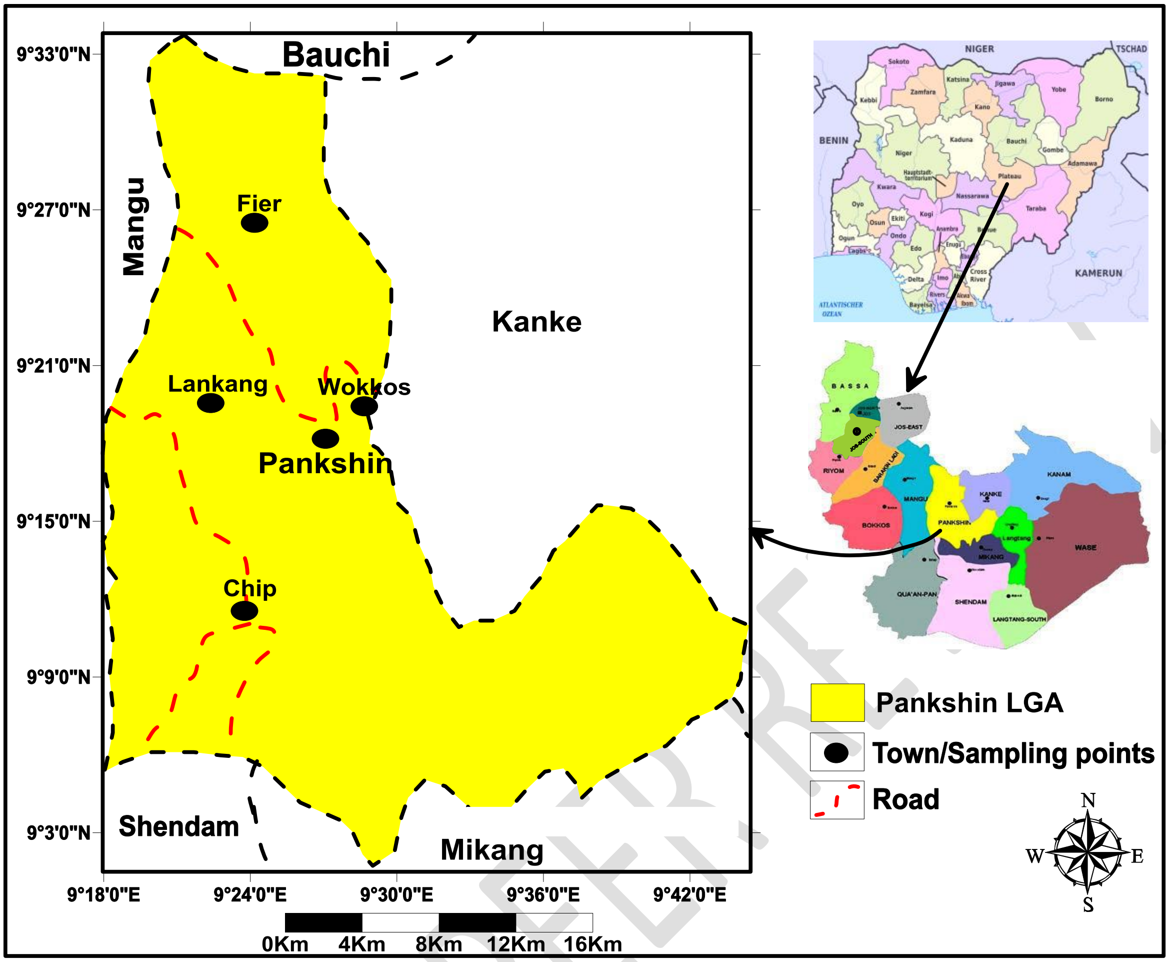

Figure 1: Map Pankshin Local Government Area of Plateau state.

3.0 Result and Discussion

Table 1: Result of the physicochemical analysis of water collected from Pankshin 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
FBW	4.00	4.89	38.72	0.00	0.28	1080.00	539.00	7.30	27.80
DWW	0.00	3.17	4.40	0.00	0.68	332.00	166.00	7.40	27.10
JfWW	3.00	2.02	26.40	3.00	1.23	366.00	183.00	7.11	26.70
McBW	0.00	7.21	4.40	0.00	0.25	915.00	457.00	7.39	27.30
GWW	8.00	5.96	100.32	0.00	1.06	903.00	451.00	7.18	27.10
FrBW	0.00	3.90	16.28	4.00	2.30	155.60	77.90	7.00	27.20
JfBW	3.00	8.35	31.68	6.00	2.10	331.00	165.00	7.70	26.40
KpBW	0.00	5.68	9.80	2.00	1.68	7.53.00	377.00	7.53	27.20
LkBW	19.00	4.52	93.72	0.00	0.35	1547.00	773.00	7.01	27.10
FcBW	0.00	6.55	8.36	0.00	0.26	205.00	99.60	7.62	26.90
TBW	0.00	2.19	10.12	0.00	0.94	55.80	27.90	7.36	27.10
LtWW	0.00	8.54	5.28	0.00	0.28	286.00	114.00	7.02	27.10
KBW	0.00	4.94	88.00	0.00	0.37	310.00	155.00	6.97	27.10
MWW	1.00	11.34	43.56	2.00	1.31	148.50	74.20	6.72	27.40
LBW	1.00	9.18	32.12	0.00	0.32	630.00	315.00	7.06	26.40
LcBW	0.00	10.98	38.28	0.00	0.42	301.00	150.00	6.77	27.30
GBW	0.00	10.30	28.16	5.00	2.25	198.60	99.60	7.03	27.10
LtBW	0.00	8.54	5.28	0.00	0.28	286.00	114.00	7.02	27.10
VBW	0.00	5.99	81.40	3.00	9.35	417.00	209.00	7.33	27.10
BWW	0.00	7.65	23.32	0.00	0.40	272.00	136.00	6.64	27.50
JBW	0.00	8.22	12.32	1.00	0.97	595.00	297.00	7.20	27.20
LKRW	5.00	6.16	43.56	0.00	0.45	83.50	41.80	7.39	27.00
VWW	0.00	9.64	57.20	0.00	0.54	467.00	233.00	6.66	27.70
TkWW	0.00	6.39	34.32	0.00	0.14	198.90	102.00	7.17	27.20
NSDWQ 2007	100	1.00	50		5.00	<1000	500.00	6.5-8.5	22-32

KEY - FBW = Fwenzak Bore Hole water:DWW=Dakatu Well Water : JfWW = Jari-Fier Well Water: McBW= Mugulum Chip Bore Hole Water: GWW = Gille Bore Hole water: FrBW= Fwor Bore Hole Water: JfBW= Jari-Fier Bore hole water: KpBW= Kapil Bore Hole water: LkBW= Langkang Bore Hole Water: FcBW= FCE Hostel Bore Hole Water: TBW = Tazuk Bore Hole water: LtWW= Le- Tazul Well: KBW= Kwalla Bore Hole water: MWW=-Mile 8 Well Water : LBW = Lepbwai Bore Hole water:LcBW= Lunchan Bore Hole Water: GBW = Gohotfwan Bore Hole: LtBW = LarpyaTakkas Bore Hole water: VBW= Vel Bore Hole Water: BWW = Bumnan Well Water : JBW= Jibam Bore Hole Water: LKRW= Langkang Spring (River) Water: VWW = Vel Well Water: TKWW= Tukung Well Water:

The physico-chemical parameters analyzed included Sulphate (SO_4^{2-}), Phosphate (PO_4^{2-}) Nitrates (NO_3^-), pH, TDS, turbidity and electrical conductivity.While the bacteriological parameter analysed was Total Aerobic Bacteria count,Tables 1 to 3present the values obtained from parameters analyzed for each sample alongside the maximum permitted levels for every parameter provided by Nigeria'sstandard for drinking water quality

The findings of the physicochemical study of the water showed that the pH of the 24 samples examined meets Nigerian recommendations for the quality of drinking water. The result of the findings falls within the 6.5 to 8.5, which is the pH range that is advised by the WHO, SON, NAFDAC, and NSDWQ. It is impossible to overstate pH's indirect impact on physiological processes, despite its lack of direct influence on human health [20][21]. With the exception of FBW, whose result was 538.00 mg/L, all of the samples that were evaluated had a total dissolved solids concentration (TDS) that was below the 500 mg/l limit that had been recommended by the NSDWQ, WHO, and NAFDAC. The inorganic salt and trace amounts of organic materials found in water or solutions are referred to as TDS. According to WHO [22], the main ingredients are typically carbonate, hydrogen carbonate, calcium, magnesium, sodium, and potassium cations, chloride, sulphate, and nitrate anion. Water's flavour may be impacted by TDS levels (WHO, 1996). According to reports, the flat, insipid taste of drinking water with exceptionally low TDS concentrations may make it undesirable [21]. All of the water samples utilized in this investigation had turbidity that complied with [23] and NWDSQ guidelines. Because high turbidity is frequently linked to larger concentrations of disease-causing microbes, such as bacteria and various parasites, water turbidity is particularly significant [24].

The electrical conductivity has the lowest value of 7.53 μScm^{-1} from KpBW and the highest value of 1080.00 μScm^{-1} in FBW. 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 NSDWQ (2007) standard. Though higher than normal value was recorded in FBW.As salinity and temperature increase, conductivity also increases, which can have a negative effect on the quality of water. This is because the higher the conductivity, the higher the amount of impurities (dissolved substances, chemicals, and minerals) in the water.Likewise, all the water samples analyzed in this study have an unobjectionable colour that agrees with the standard colour of 5 TCU by NWDSQ and WHO standards, even though an exception was seen in JfBWwhose colour was 6 TCU.

In all the samples analysed, the sulphate (SO_4^{2-}) result ranged from 0.00 mg/L to 19.00 mg/L, the findings of this study are lower than thoseof [25] in Jos South LGA of Plateau State Nigeria. However, it was found to be below the acceptable limits of 100 mg/L (NWDSQ). Nitrate (NO_3^-) range from 4.40 mg/L to 100.32 mg/L. A higherthan 50.00 mg/L acceptable limit was recorded in GWW, LkBW, KBW, VBW, and VWW respectively. All the other samples were below acceptable limits, higher than the acceptable limits of nitrates in drinking water may lead to health effects such as increased heart rate, nausea, headaches, and abdominal cramps. Phosphates (PO_4^{2-}) analysed in all the samples are above the 1.00 mg/L acceptable limits, which is also higher than the work of [25]. Phosphates are not toxic to people or animals unless they are present at very high levels. Digestive problems could occur from extremely high levels of phosphate. Phosphate itself does not have notable adverse health effects. However, phosphate levels greater than 1.0 may interfere with coagulation in water treatment plants.The increase in the level of nitrate and phosphate may be attributed to leaching into the water table that could have occurred from factors related to the soil type, geology, rate of Nitrogen utilization by crops in the study locationand the use of manure or phosphate fertilizer on farmlandaround the study area.

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

SAMPLE ID	Cd (mg/l)	Ni (mg/l)	Cr (mg/l)	Pb (mg/l)
FBW	0.0020 ± 0.001	0.00756±0.001	0.1041 ±0.009	0.0060 ± 0.013
DWW	0.0129 ± 0.009	0.0177 ± 0.009	ND	0.0027 ± 0.009
JfWW	0.0158 ± 0.003	0.3000 ± 0.003	ND	ND
McBW	0.0173 ± 0.002	0.7236 ± 0.053	ND	ND
GWW	0.0090 ± 0.005	0.0120±0.006	ND	0.0072 ± 0.010
FrBW	0.0135 ± 0.003	0.1470 ± 0.007	ND	0.0144 ± 0.005
JfBW	0.0169 ± 0.001	0.3573 ± 0.033	ND	ND
KpBW	0.0245 ± 0.001	0.2772 ± 0.049	ND	0.0048 ± 0.017
LkBW	0.0191 ± 0.008	0.2308 ± 0.008	ND	ND
FcBW	0.0170 ± 0.001	0.1975 ± 0.017	ND	0.0183 ± 0.013
TBW	0.0061 ± 0.002	0.0074± 0.003	0.0386 ± 0.002	0.0096 ± 0.015
LtWW	0.0206 ± 0.025	0.1642 ± 0.025	ND	ND
KBW	0.0091 ± 0.001	0.0169 ± 0.005	ND	0.0125 ± 0.014
MWW	0.0135 ± 0.003	0.0189 ± 0.008	ND	0.0067 ± 0.007
LBW	0.0139 ± 0.002	0.0556 ± 0.017	ND	0.4284 ± 0.003
LcBW	0.0122 ± 0.001	0.8483 ± 0.021	ND	ND
GBW	0.0093 ± 0.002	0.0061± 0.002	0.0145 ± 0.036	0.0073 ± 0.015
LtBW	0.0172 ± 0.003	0.6353 ± 0.035	ND	ND
VBW	0.0120 ± 0.004	0.0338 ± 0.008	ND	0.0024 ± 0.014
BWW	0.0095 ± 0.002	0.0073± 0.005	ND	0.0239 ± 0.012
JBW	0.0093 ± 0.001	0.0130 ± 0.008	ND	0.0052 ± 0.010
LKRW	0.0181 ± 0.004	0.5046 ± 0.062	ND	ND
VWW	0.0100 ± 0.004	0.0282 ± 0.002	ND	0.0078 ± 0.015
TkWW	0.0151 ± 0.017	0.1091 ± 0.017	ND	0.0075 ± 0.043
permissible limit WHO (2008)	0.003	0.07	0.05	0.01

n = 3

Key: ND = Not detected

The resultsof the analysis of heavy metal content in the water samples are presented in Table 2 above. Cd content in all the water samples used in this study ranged from 0.0020 ± 0.001 mg/l to 0.0245± 0.001mg/l. Thesevalues are lower than those reported by [26] along river Dilimi in Jos North Plateau state of Nigeria, but were found to be similar to[27]. Cd was found to be greater than the WHO standard of 0.003 mg/l. Cadmium does not easily leave our bodies and tends to build up in the kidney. As a result, both shorter, higher exposures and lifetime low level exposures to cadmium can cause kidney disease in older adults. Ni also range from 0.0061 ± 0.002 to 0.6353 ± 0.035 mg/l sample JfWW, McBW, FrBW, JfBW,KpBW, LkBW, FcBW, LtWW,LcBW, LtBW,LKWW and TkWW were all above the [29]recommended limit of 0.07 mg/l this are all water sampled from borehole and well, thus indicating that there is high concentration of Ni deep down the soil which is in line with the study of [28].Accumulation of nickel and nickel compounds in the body through chronic exposure may be responsible for a variety of adverse effects on the health of human beings, such as lung fibrosis, kidney and cardiovascular diseases and cancer of the respiratory tract. Cr was detected in only three sampling sites, with only one sampling point FBW having a value higher than the [29] permissible limit. Pb concentration ranges from ND to 0.4284 ± 0.003 mg/l. FrBW, FcBW, KBW, LBW, and BWW were all above the value recommended by the [29] limit of 0.01 mg/l. all except for BWW are water collected from the borehole.Lead can cause serious health problems if too much enters the body from drinking water or other sources. It can also cause damage to the brain and kidneys and can interfere with the production of red blood cells that carry oxygen to all parts of the body. The sources of heavy metals that could contaminate drinking water supplies include industrial and domestic wastes as well as the release of heavy metals into streams, lakes, rivers, and groundwater because of acid rain [30]. In general, a strong relationship between contaminated drinking water with heavy metals and the incidence of chronic diseases such as heart disease, stroke, cancer, renal failure, liver cirrhosis, hair loss, and chronicanaemia has been documented [31].

Table 3: 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
FBW	5	**5×10^{2}**	5	*Klebsiella aerogenes*
DWW	19	**1.9×10^{3}**	54	*Escherichia coli,* CoNS
JfWW	5	**5×10^{2}**	< 2	*Bacillus* species
McBW	15	**1.5×10^{3}**	20	*Bacillus species, Pseudomonas aeruginosa*
GWW	20	**2×10^{3}**	7	*E. coli*
FrBW	96	**9.6×10^{3}**	< 2	*Bacillus* species
JfBW	99	**9.9×10^{3}**	< 2	*Bacillus* species, CoNS
KpBW	148	**1.5×10^{4}**	< 2	*Bacillus* species
LkBW	332	**3.3×10^{4}**	280	*Klebsiella aerogenes*
FcBW	78	**7.8×10^{3}**	< 2	*Bacillus* species
TBW	4	**4×10^{2}**	< 2	*Bacillus* species
LtWW	310	**3.1×10^{4}**	< 2	*Bacillus* species, CoNS
KBW	228	**2.3×10^{4}**	54	*Klebsiella aerogenes*
MWW	19	**1.9×10^{3}**	20	*Enterobacter* species, *Bacillus* species
LBW	330	**3.3×10^{4}**	< 2	*Bacillus* species, CoNS
LcBW	19	**1.9×10^{3}**	25	*Klebsiella aerogenes, Bacillus* species
GBW	32	**3.2×10^{3}**	< 2	*Micrococcus* species
LtBW	342	**3.4×10^{4}**	11	*Klebsiella aerogenes, Bacillus* species
VBW	10	**1×10^{3}**	< 2	*Bacillus* species
BWW	13	**1.3×10^{3}**	54	*Pseudomonas aeruginosa*
JBW	80	**8×10^{3}**	< 2	*Micrococcus* species
LKRW	14	**1.4×10^{3}**	11	*Klebsiella aerogenes*
VWW	9	**9×10^{2}**	5	*Enterobacter* species
TkWW	44	**4.4×10^{3}**	< 2	*Bacillus* species, CoNS

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 3 above presents the result for the bacteriological content of the water samples. The results of the study show that most of the household water samples were contaminated with different species of bacteria. The FBW, LkBW, KBW, LcBW, LtBW, and LKWW were contaminated with *klebsiella aerogenes,*the highest count for *klebsiella aerogenes*was recorded in LtBW with a total count of 3.4×10^{4} CFU/mL, whereas the lowest was recorded in LKWW with a total count of 1.4×10^{3}. *E coli* was found in samples DWW and GWW, with the highest total bacteria count of 2×10^{3} CFU/mL recorded in GWW. The detection of coliforms indicated that the water samples were contaminated by faecal matter [32]. The majority of coliforms are non-pathogenic, however, some strains of coliforms such as *Escherichia coli* can cause diarrhoea [33]. Bacillus*species* total count ranges from 5×10^{2}CFU/mL to 3.3×10^{4} CFU/mL and was found in almost all the samples. CoNS count ranges from 3.3×10^{4} CFU/mL to 1.9×10^{3}CFU/mL respectively. Generally, bacteria can cause water-borne diseases such as gastrointestinal illness, diarrhoea, cholera and fever [34]. The total bacteria count in this study was found to be lower than those reported by [25] in Jos South LGA of Plateau State. Nigeria.

Conclusion

The examination of water quality parameters from different sources in Pankshin Local Government Area of Plateau State revealed that the water contained high levels of toxic metals such as Cadmium and Nickel, whereas chromium and Lead were below the respective permissible limits. Most of the physicochemical parameters were within acceptable limits except Phosphate which was above the acceptable limits. 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.

Reference

1. Mohammed M1., Mamudu, H. B., Amin, O. I., Florence, J M and Fatima A. (2020). Assessment of the Physicochemical and Microbiological Quality of Sachet Water Sold in Kumbotso LGA, Kano State, Nigeria. *Agricultural Research & Technology* 24 (1): 30 – 35.

2. Uduma, A. U and Uduma, B. (2014) Physicochemical Analysis of the Quality of Sachet Water Consumed in Kano Metropolis. *American Journal of Environment, Energy and Power Research* 2(1): 1-10.

3. Lamikanra A (1999) Essential Microbiology for Students and Practitioners of Pharmacy. Medicine and Microbiology, 2nd ed. **Amkra books**, Lagos pp. 406-410.

4. Sheshe, M.U and Magashi, A. M (2014) Assessment of Physicochemical Quality of Sachet Water Produced in Selected Local Government Areas of Kano Metropolis. Kano State - Nigeria *Bayero journal of pure and applied science* 7(2): 31-35.

6. MacDonald, A. M., Davies, J., Calow, R. C. And Chilton P. J. (2005). Developing groundwater: a guide for rural water supply. (Rugby: Practical Action Publishing)

7. Sha (2004) Characterization of precipitates in an aged 7xxx series Al alloy (36), :5-6, 564–568

8. Calow Roger, C., Alan M. McDonald, Alan L. Nicol and Nick Robins S. (2011): Groundwater Security and Drought in Africa. Linking Availability, Access and Demand.

9. WHO (World Health Organization) (2014) UN-Water Global Analysis and Assessment of Sanitation and Drinking Water (GLAAS) 2014-Report, Investing in Water and Sanitation: Increasing Access, Reducing Inequalities.

10. Madigan, T.M., Martinko, J.M., Bender, S.K., Buckley, D.H. and Stahl, D.A. (2010) Brock Biology of Microorganisms. 13th Edition, Benjamin Cummings, San Francisco, Chapter 35.

11. Dillingham, R. and Guerrant, R.L. (2004) Childhood Stunting: Measuring and Stemming the Staggering Costs of Inadequate Water and Sanitation. The Lancet, 363, 94-95. https://doi.org/10.1016/S0140-6736(03)15307-X

12. Murray, C.J., Vos, T., Lozano, R., Naghavi, M., Flaxman, A.D., Michaud, C., et al. (2012) Disability-Adjusted Life Years (DALYs) for 291 Diseases and Injuries in 21 Regions, 1990-2010: A Systematic Analysis for the Global Burden of Disease Study 2010. The Lancet, 380, 2197-2223. https://doi.org/10.1016/S0140-6736(12)61689-4

13. Clasen, T.F., Alexander, K.T., Sinclair, D., Boisson, S., Peletz, R., Chang, H.H., Major, F. and Cairncross, S. (2015) Interventions to Improve Water Quality for Preventing Diarrhea. Cochrane Database of Systematic Reviews, Issue 10, Art. No.: CD004794.

14. Bruce, P., Ruth, B. and Barbara, K. H. (2015) A Review on Emerging Contaminants in Wastewaters and the Environment: Current Knowledge, Understudied Areas, and Recommendations for Future Monitoring. *Water Research*, 72, 3-27. https://doi.org/10.1016/j.watres.2014.08.053

15. Satterthwaite, D., McGranahan, G. &Tacoli, C. (2010). Urbanization and its implications for food and farming. Philosophical Transactions of the Royal Society of London. Series B, *Biological Sciences* 365 (1554), 2809–2820. https://doi.org/ 10.1098/rstb.2010.0136

16. McGrane, S. J. (2016). Impacts of urbanisation on hydrological and water quality dynamics, and urban water management: a review. *Hydrological Sciences Journal* 61 (13), 2295–2311. https://doi.org/10.1080/02626667.2015.1128084

17. World Health Organization (2004) Guidelines for Drinking-Water Quality. World Health Organization.

18. Goldhaber, S.B. (2003) Trace Element Risk Assessment: Essentiality vs. Toxicity. Regulatory *Toxicology and Pharmacology*, 38, 232-242. https://doi.org/10.1016/S0273-2300(02)00020-X

19. Mastoi, G.M., Shah, S.G. and Khuhawar, M.Y. (2008) Assessment of Water Quality of Manchar Lake in Sindh (Pakistan). Environmental Monitoring and Assessment,

20. Adekunle I.M., Adetunji M.T., Gbadebo A. M and Banjoko O.B. (2007): Assessment of Groundwater Quality in a Typical Rural Settlement in Southwest Nigeria International *Journal Environmental Research Public Health*, 4(4), 307-318.

21. Nigerian Industrial Standard (NIS) (2007) Nigerian standard for drinking water quality (NSDWQ), standard organisation of Nigeria Abuja 554:13–14

22. World Health Organization (1996) Guidelines for Drinking-Water Quality. World Health Organization.

22. World Health Organization (WHO) (1996). Total dissolve solid in drinking water. Guideline for drinking water quality. 2:0-1.

23. World Health Organization (2007) Guidelines for Drinking-Water Quality. World Health Organization.

24. Shittu OB, Olaitan JO, Amusa TS (2008) Physico-Chemical and Bacteriological Analysis of Water Used for Drinking and Swimming Purpose. *African Journal of Biochemical Resources*. 11:285-290.

25. Chukwu A. C., Zipporah D.P., Gambo N. N., Lubis S and Denji K. B (2023). Assessment of the physicochemical and Bacteriological content of some drinking water sources in Jos South LGA in Northern Senatorial District of Plateau State Nigeria. *Asian Journal of Applied Chemistry research*. 14 (2): 36-45

26. Ezekiel O. and Dikam, K.I (2020). Assessment of Concentration Status of some Heavy Metals in Water along river Dilimi, Jos North, Plateau State-Nigeria. *Indonesian journal of urban and Environmental Technology*, 4 (10): 29-44

27. 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.

28. 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, south eastern Nigeria *Applied Water Science* .12: 224

29. World Health Organization (2008) Guidelines for Drinking-Water Quality. World Health Organization.

30 Mellor A (2001) Lead and Zinc in the Wallsend Burn, an Urban Catchment in Tyneside, UK. Science of the Total Environment 269(1- 3): 49-63.

31. Salem H.M., Eweida A.E and Faraq A (2000) Proceedings of the International Conference for Environmental Hazard MiTigaDamtion. Cairo, Egypt.

32. Adeleka,n 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. doi: 10.5897/ sre11.1045.

33. Grube,r 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. doi: 10.1371/journal.pone.0107429.