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Research Article

Comparative Evaluation of the Bacteriological and Physicochemical Quality of Water from Borehole, Tapwater and Rivers in Eziama/Mgbaja Ossah, Abia State

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ABSTRACT

Diseases caused by contamination of water consumption and poor hygiene are among the leading causes of diarrhoea especially in children and immune-compromised individuals. Samples of borehole, river and public tap water were collected from Eziama/Mgbaja Ossah Ibeku, Abia State, Nigeria and analysed for their bacteriological and physic-chemical properties using standard methods. Each sample was inoculated onto Nutrient and MacConkey agar plates using the spread plate technique. The physicochemical parameters of the water sources were within required WHO standard for water except that chloride had higher values. The bacteriological analyses revealed that the highest total coliform counts of $6.1x10^3$cfu/mL was observed in borehole water sample; while the least counts of $3.2x10^3$cfu/mL was in public tap water. The total viable counts for all the water samples were generally high exceeding the < 100 CFU/mL limit for drinking water. Bacteria count values obtained from this study did not meet the international standard as they were higher than World Health Organization Standard of zero per 100mL. The isolated organisms were identified to be *Pseudomonas aeruginosa, Staphylococcus aureus, Escherichia coli, Micrococcus* species, *Enterococcus* species and *Salmonella* species. The heavy metals values obtained were within the accepted limit of water standard in all the various water samples investigated. The t-test analysis revealed significant difference between the quality of the water sources in the study area. From the findings, it is recommended that water supply within the study area should be properly treated and handled before human consumption and other domestic purposes.

Keywords: Borehole; Diarrhoea; Pathogen; Quality; Safety

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INTRODUCTION

A large proportion of the world population estimated at 2.2 billion people need water for vital daily functions. However, availability and access to safe drinking water remains a critical global burden as various households lack quality water in especially in low-income countries (WHO, 2023). Several communities rely on diverse water sources in the form of groundwater (e.g., boreholes, hand-dug wells), surface water (like rivers, lakes) as well as atmospheric water (rainwater). The quality of water from these various sources is influenced by multifaceted interactions between hydrogeology, anthropogenic activities, and climate variability (Foster *et al.,* 2020).

While boreholes typically exhibit higher mineral content (e.g., Ca^{2+}, Mg^{2+}, Fe) due to mineral leaching (Sunkari *et al.,* 2020), surface water shows greater turbidity, organic matter, and seasonal pH fluctuations. However, both are vulnerable to microbiological contamination, primarily from faecal matter containing enteric pathogens like *Vibrio cholerae*, *Salmonella* spp., *Shigella* spp., enteroviruses, and protozoan parasites (WHO, 2017). In terms of

microbiological safety, boreholes have been reported to be particularly vulnerable to *E. coli* and nitrates from septic systems (Lapworth *et al.,* 2017); whereas surface water have higher risk of pathogenic protozoa (e.g., *Cryptosporidium*), bacteria and viruses (Pandey *et al.,* 2014). Rivers are highly susceptible to contamination from agricultural runoff, sewage discharge, wildlife, and urban storm water leading to dynamic fluctuations in faecal indicator bacteria (FIB) concentrations (Sorensen *et al.,* 2021). Boreholes**,** while generally protected by geological strata, can be compromised by inadequate construction, cracked casings, or seepage from nearby pit latrines or livestock operations, allowing subsurface infiltration of contaminants (Bain *et al.,* 2014).

Many infectious diseases in developing countries are associated with consumption of contaminated water sources (Ogunlana *et al*., 2010; Ekhosuehi *et al.,* 2018). The most important and immediate risks to human health from using contaminated water drinking water is diarrhoea disease especially among children in poor countries (WHO, 2002). Data from epidemiological and prevalence studies indicated that endemic transmission of disease associated with diarrhoea and other gastro-intestinal disease estimated at 22 million deaths were attributable to unsafe water and sanitation, including lack of hygiene (Ekhosuehi *et al.,* 2018; Ateba *et al.,* 2020; WHO, 2023).

Bacteriological assessment serves as a frontline public health tool to evaluate water safety by quantifying faecal indicator bacteria (FIB), notably *Escherichia coli* and intestinal enterococci. These indicators correlate with faecal pollution and the potential presence of pathogens, as they are excreted abundantly by warm-blooded animals (Olufeyikemi and Abimbola, 2020; Uzairue *et al.,* 2023). Regular monitoring of these water sources is essential to prevent waterborne disease outbreaks. There are also reports of rainwater being particularly vulnerable to atmospheric pollutants (e.g. Pb, SO_4^{2-}) and poor storage hygiene (Ateba *et al.,* 2020). Given the source-specific contamination profiles and their critical public health implications, this study aims to quantify seasonal variations in key contaminants (bacterial pathogens, physicochemical and metal contamination) in different water sources (borehole, surface, river water) within the Eziama/Mgbaja community, Umuahia North LGA, Abia State.

MATERIALS AND METHODS

Collection of Water Samples

A total of 20 water samples were obtained from boreholes (n=8), river (n=8) and public tap water (n=4) sources at Eziama/Mgbaja Community in Umuahia North LGA Abia State. A 250 mL capacity sterile bottles were used for collecting water samples. Water samples were obtained by allowing water to flow aseptically from the dispensing tap into the sterile bottles. The bottles were then corked and transported to the laboratories for microbial analysis.

Isolation and identification of heterotrophic bacteria

Sample of each water source was serially diluted in ten folds. Total heterotrophic plate counts were determined using spread plate technique. One milliliter (1 mL) of each water sample was transferred into 9 mL of normal saline and further dilutions were made. Aliquots (0.1 mL) of the dilutions 10^{-2} and 10^{-3} of the serially diluted samples were then inoculated onto Nutrient agar plates and MacConkey agar plates for total heterotrophic bacterial and coliform counts respectively and spread evenly across the surface of the agar plates using an alcohol flame sterilized glass rod. Inoculated plates were incubated at 37°C for 24 h.

Analysis of water samples for coliform and faecal coliforms

The most probable number (MPN) technique for coliform and total coliform was used for the water analysis. The procedure, which involved the use of three dilutions (10, 1, and 0.1 mL) of each sample, was adapted from APHA (1992). Results were expressed as the most probable number per 100 mL (MPN/100mL). Then, 10mL, 1mL and 0.1mL each of the water samples were transferred respectively into prepared MacConkey broth at 10mL (double strength), 5mL (double strength) and 5mL (single strength) for the enumeration of faecal coliform. The bottles were incubated at 37^{o}C and left there for 48h, and thereafter observed for a colour change Positive results that contained coliforms changed from pink to yellow. The positive results from MacConkey broth were sub-cultured into Eosin Methylene Blue agar (EMB) to produce discrete colonies of total coliform and to isolate faecal coliform respectively. Inoculated plates were incubated at 37^{o}C for 24h. Colonial characteristics and morphological analysis were carried out on those agar plates (Efuntoye and Apanpa, 2002).

Physicochemical analysis

Water samples were analyzed for pH, turbidity, total dissolved solids, electrical conductivity, BOD, alkalinity, and presence of calcium, chlorides, and magnesium.

RESULTS

The bacteriological quality of the evaluated water samples in the present study is shown in Table 1 to 3. In the borehole water samples, the range of the numbers of total viable heterotrophic bacterial counts was

between 8.4 x 10^5 cfu/mL to 1.12 x 10^5cfu/mL. The total counts for tap water samples ranged between 6.8 x 10^5 cfu/mL to 8.4 x 10^5cfu/ml, while for rivers, the total counts were 5.4 x 10^5cfu/mL to 6.2 x 10^5 cfu/mL. The results show very high microbial counts for the various drinking water samples when compared with the WHO standard of 1.0 × 10^2 cfu/mL. The results show that six different bacterial genera were isolated with *Staphylococcus aureus* as the dominant bacteria with a frequency occurrence of 90.0% (Figure 1). The other five genera of bacteria isolated and percentages of their occurrence were: *Pseudomonas aeruginosa* (40.0%), *Escherichia coli* 40.0%), *Enterococcus* sp (40.0%), *Micrococcus* spp (40.0%) and *Salmonella* spp (20.0%).

The physicochemical parameters analyzed in this study are namely, pH, Temperature, Turbidity, electrical conductivity, biochemical oxygen demand (BOD), total hardness, total dissolved solids (TDS), Calcium, Magnesium and chloride. The results of the analysis are shown in Tables 4, 5 and 6. The results show that the pH of all the water samples, irrespective of source, was within a narrow range which was between 5.2 and 6.2. All the pH values fall within the acid range and showed overlapping tendencies. The tap water samples showed higher chloride content (511.0 to 545.0mg/L) levels than the borehole and river water samples (borehole: 412.5 to 535.0mg/L and river: 507.8 to 519.9mg/L), respectively. The total dissolved solids for river water samples ranged from 131.2 to 14.17mg/l which was significantly higher ($p \leq 0.05$) than the values for borehole and tap water samples, respectively. The findings from this study revealed that the BOD values of river waters for the study area ranged from 4.80mg/l to 4.83mg/l lower than that of borehole water samples. The lowest BOD of 4.32mg/l was recorded from one of the tap water samples. BOD values of samples from borehole differed significantly from those of tap water and rivers

The electric conductivity (EC) ranged between 79.8–103.1ohm/cm (borehole), 30.0-37.6ohm/cm and 30–34.3ohm/cm (tap water). The highest EC value was recorded from one of the borehole water samples (B) with 103.1ohm/cm and the lowest value of 30.0ohm/cm was from one of the rivers and tap water samples.

The mean temperature values obtained in this study ranged from 27.0–28.5^{o}C. There was no significant difference in temperature. The mean turbidity value ranged from 5.13 – 8.51NTU, the lowest was from tap water meanwhile the highest was from borehole water. Turbidity was highly significant across the sample types and well above acceptable limits of >5 NTU. Also, the TDS value of borehole water ranged from 61.8-101.2mg/L, river ranged from 131.2-141.7mg/L and tap from 20.0-80.0mg/L which are within the standard recorded by WHO. Chlorine (Cl^-) values of all the water samples were outside the standards recommended by WHO (1996). Also, Ca^{2+} ranged from 74.7 -80.4mg/L for borehole water sample, 79.9- 85.7mg/L for river samples and 70.0- 85.7 for tap water. The highest and lowest recorded value was from tap water sample.

Table 1. Total Heterotrophic and Coliform Load of the Samples from Borehole water

Sample codes	Total bacterial load (cfu/mL)	Total coliform count (cfu/mL)	MPN/100mL	*E. coli* Count (cfu/mL)	*Salmonella* count (cfu/mL)
B1	1.09 x 10^5	6.1 x 10^3	6	NG	2.5 x 10^3
B2	1.12 x 10^5	5.2 x 10^3	2	NG	NG
B3	8.4 x 10^5	3.8 x 10^3	1	1.7 x 10^3	2.1 x 10^3
B4	9.2 x 10^5	4.6 x 10^3	0	NG	4.6 x 10^3
B5	1.74 x 10^6	8.5 x 10^3	11	NG	NG
B6	1.92 x 10^6	7.2 x 10^3	7	2.4 x 10^3	NG
B7	1.26 x 10^6	5.1 x 10^3	2	NG	NG
B8	1.14 x 10^6	4.6 x 10^3	0	NG	1.8 x 10^3

B1 – B8: Water samples from eight different boreholes. NG: No Growth

Table 2. Total Heterotrophic and Coliform Load of the Samples from Tap water

Sample codes	Total bacterial load (cfu/mL)	Total coliform count (cfu/mL)	MPN/100mL	*E. coli* Count (cfu/mL)	*Salmonella* count (cfu/mL)
T1	6.8 x 10^5	3.2 x 10^3	0	NG	NG
T2	8.4 x 10^5	3.8 x 10^3	0	NG	NG
T3	7.7 x 10^5	4.6 x 10^3	1	2.1 x 10^3	NG
T4	8.3 x 10^5	3.2 x 10^3	0	NG	NG
T5	8.1 x 10^5	3.7 x 10^3	0	NG	NG
T6	8.8 x 10^5	4.4 x 10^3	0	2.7 x 10^3	NG
T7	7.7 x 10^5	5.1 x 10^3	1	NG	1.8 x 10^3
T8	9.1 x 10^5	4.8 x 10^3	0	NG	NG

T1 – T8: Water samples from eight different tap water sources. NG: No Growth

Table 3. Total Heterotrophic and Coliform Load of water samples from the river

Sample codes	Total bacterial load (cfu/mL)	Total coliform count (cfu/mL)	MPN/100mL	*E. coli* Count (cfu/mL)	*Salmonella* count (cfu/mL)
R1	5.4×10^5	3.8×10^3	0	NG	1.8×10^3
R2	6.2×10^5	4.6×10^3	0	2.4×10^5	NG
R3	6.4×10^5	4.8×10^3	1	1.7×10^3	2.1×10^3
R4	7.4×10^5	4.9×10^3	1	2.1×10^3	1.6×10^3

R1 – R4: Water samples from four different river water sources. NG: No Growth

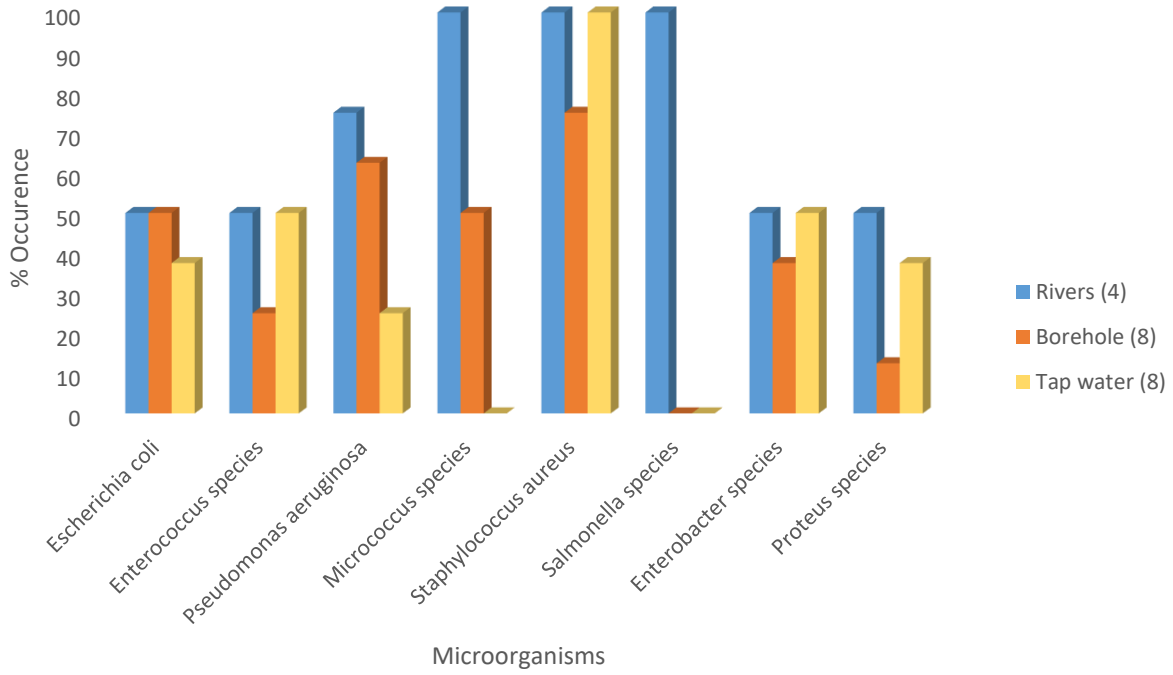

Figure 1. Frequency of Bacterial Isolates across the Samples

Table 4. Physico-Chemical and Heavy Metal Composition of Tap Water Samples

Parameters	Sample Codes								WHO
	T1	T2	T3	T4	T5	T6	T7	T8	Standard
Zinc (mg/L)	1.385^{a}±0.01	1.35^{a}±0.04	1.155^{c}±0.02	1.285^{b}±0.03	1.14^{c}±0.01	1.08^{c}±0.04	1.02^{c}±0.02	1.32^{a}±0.03	3.00
Lead (mg/L)	ND	0.02^{a}±0.01	ND	ND	ND	ND	ND	ND	0.01
Iron (mg/L)	0.595^{a}±0.02	0.525^{a}±0.02	0.18^{d}±0.00	0.26^{c}±0.03	0.41^{b}±0.02	0.51^{a}±0.02	0.13^{d}±0.00	0.22^{c}±0.03	3.00
Copper (mg/L)	0.19^{c}±0.01	0.38^{b}±0.02	0.64^{a}±0.02	0.18^{c}±0.00	0.17^{c}±0.01	0.35^{b}±0.02	0.61^{a}±0.02	0.17^{c}±0.00	2.00
pH	5.6^{b}±0.00	5.5^{b}±0.14	6.2^{a}±0.00	5.75^{b}±0.07	5.9^{b}±0.00	5.7^{b}±0.14	6.6^{a}±0.00	5.8^{b}±0.07	6.5-8.5
Temp. (°C)	28.5^{b} ±0.70	28.0^{b} ±0.00	28.0^{b}±0.00	27.0^{bc}±0.00	29.5^{b}±0.70	29.0^{ab}±0.00	31.0^{a}±0.00	30.0^{a}±0.00	
Turbidity	5.87^{b}±0.21	6.17^{a}±0.12	5.13^{c}±0.09	5.19^{c}±0.12	6.00^{a}±0.21	6.11^{a}±0.12	5.04^{d}±0.09	5.01^{d}±0.12	5.00
EC	37.0^{a}±0.42	30.0^{e}±0.42	35.4^{b}±0.28	37.6^{a}±1.27	36.0^{b}±0.42	28.6^{f}±0.42	32.1^{d}±0.28	34.6^{c}±1.27	900
TDS	80.0^{a}±1.97	20.0^{e}±2.26	39.6^{cd}±2.04	41.7^{c}±0.49	76.4^{b}±1.97	18.8^{e}±2.26	39.08^{d}±2.04	40.7^{c}±0.49	100
BOD	4.63^{b}±0.04	4.91^{a}±0.01	4.71^{b}±0.04	4.32^{d}±0.03	4.42^{c}±0.04	4.08^{f}±0.01	4.08^{f}±0.04	4.21^{e}±0.03	
Alkalinity	130.5^{c}±4.94	133.5^{b}±3.53	123.0^{d}±7.07	112.5^{f}±7.77	131.6^{c}±4.94	136.5^{a}±3.53	124.7^{d}±7.07	116.2^{e}±7.77	200
Cl	524.9^{c}±5.37	531.0^{b}±4.24	545.0^{a}±4.24	511.0^{d}±2.82	497.1^{g}±5.37	511.0^{d}±4.24	507.2^{e}±4.24	501.3^{f}±2.82	250
Ca	85.7^{a}±0.71	70.0^{d}±0.28	72.2^{c}±0.84	74.5^{b}±0.35	85.7^{e}±0.71	70.0^{d}±0.28	72.2^{c}±0.84	74.45^{b}±0.35	75
Mg	168.0^{c}±4.24	180.5^{a}±2.12	113.0^{g}±1.41	121.0^{e}±4.24	165.5^{d}±1.24	174.8^{b}±2.12	112.0^{g}±1.41	117.3^{f}±2.12	150

T1-T8: Water samples from 8 different Tap water sources. ND: Not Detected. Values are the mean ± standard deviation of two replication of each parameter
Values with different superscript across a row are significantly different from each other

Table 5. Physico-Chemical and Heavy Metal Composition of Borehole Water Samples

Parameters	Sample codes								WHO Standard
	B1	B2	B3	B4	B5	B6	B7	B8	
Zinc (mg/L)	1.29^{c}±0.03	1.065^{d}±0.03	1.13^{c}±0.01	1.5^{a}±0.09	1.37^{b}±0.12	1.28^{b}±0.03	1.13^{c}±0.01	1.5^{a}±0.09	3.00
Lead (mg/L)	0.075^{c}±0.01	0.18^{a}±0.01	0.036^{d}±0.01	0.12^{b}±0.00	0.13^{b}±0.01	0.22^{a}±0.01	0.03^{b}±0.01	0.12^{b}±0.00	0.01
Iron (mg/L)	0.345^{c}±0.03	0.305^{d}±0.01	0.495^{a}±0.02	0.3^{d}±0.04	0.44^{b}±0.03	0.49^{a}±0.01	0.49^{a}±0.02	0.24^{e}±0.04	3.00
Copper (mg/L)	0.18^{c}±0.00	0.19^{c}±0.01	0.12^{d}±0.02	0.18^{c}±0.00	0.23^{a}±0.00	0.21^{b}±0.01	0.11^{d}±0.02	0.12^{d}±0.00	2.00
pH	5.2^{e}±0.14	6.2^{b}±0.14	5.95^{c}±0.07	4.6^{f}±0.00	5.6^{d}±0.14	6.8^{a}±0.14	6.3^{b}±0.07	5.4^{e}±0.00	6.5-8.5
Temp. (°C)	28.0^{b} ±1.14	28.0^{b}±0.00	28.5^{b}±0.70	28.5^{b}±0.70	31.0^{a}±1.14	29.0^{b}±0.00	29.5^{b}±0.70	29.5^{b}±0.70	
Turbidity	6.18^{f}±0.07	6.52^{e}±0.03	8.51^{d}±0.15	5.8^{g}±0.41	10.82^{b}±0.07	12.21^{a}±0.03	9.22^{c}±0.15	6.1^{f}±0.41	5.00
EC	97.7^{c}±0.56	103.1^{b}±0.98	86.95^{d}±0.35	79.8^{e}±1.27	104.2^{b}±0.56	117.8^{a}±0.98	78.05^{e}±0.35	72.8^{f}±1.27	900
TDS	62.7^{g}±0.74	61.8^{g}±0.78	82.8^{d}±2.05	101.2^{a}±1.13	87.14^{c}±0.74	77.5^{f}±0.78	80.5^{e}±2.05	93.1^{b}±1.13	100
BOD	5.57^{c}±0.66	6.26^{b}±0.09	5.11^{d}±0.04	5.12^{d}±0.04	7.07^{a}±0.66	6.97^{a}±0.09	6.23^{b}±0.04	5.08^{b}±0.04	
Alkalinity	110.0^{f}±4.24	125.5^{c}±3.53	123.5^{cd}±6.36	136^{a}±5.65	114.8^{e}±4.24	128.2^{b}±3.53	124.8^{c}±6.36	137.7^{a}±5.65	200
Cl	412.5^{f}±6.36	418.5^{e}±4.94	424.0^{c}±4.24	535.5^{a}±4.94	421.9^{d}±6.36	426.3^{c}±4.94	412.0^{f}±4.24	505.4^{b}±4.94	250
Ca	78.1^{c}±0.14	74.7^{e}±0.56	76.1^{d}±0.07	80.4^{b}±0.49	82.4^{a}±0.14	77.1^{c}±0.56	76.05^{cd}±0.07	80.35^{b}±0.49	75
Mg	151.5^{b}±4.94	136.5^{e}±0.71	133.5^{f}±6.36	161.5^{a}±4.94	146.2^{d}±0.14	132.5^{f}±0.01	129.4^{g}±0.36	148.6^{c}±1.41	150

B1-B8: Water samples from 8 different boreholes. Values are the mean ± standard deviation of two replication of each parameter. Values with different superscript across a row are significantly different ($p<0.05$) from each other.

Table 6. Physico-Chemical and Heavy Metal Composition of River Water Samples

Parameters	Sample Codes				WHO
	R1	R2	R3	R4	Standard
Zinc (mg/L)	1.045^{c}±0.04	1.425^{a}±0.09	1.01^{c}±0.04	1.26^{b}±0.09	3.00
Lead (mg/L)	ND	ND	ND	ND	0.01
Iron (mg/L)	0.38^{b}±0.02	0.64^{a}±0.02	0.31^{bc}±0.02	0.46^{b}±0.02	3.00
Copper (mg/L)	0.21^{a}±0.02	0.12^{b}±0.00	0.17^{a}±0.02	0.11^{b}±0.00	2.00
pH	5.35^{b}±0.07	5.1^{b}±0.00	5.7^{a}±0.07	5.7^{a}±0.00	6.5-8.5
Temp. (°C)	28.0^{b} ±1.14	27.5^{a} ±0.70	30.0^{a}±1.14	28.5^{b}±0.70	
Turbidity	5.48^{b}±0.31	5.46^{b}±0.21	5.68^{a}±0.31	5.49^{b}±0.21	5.00
EC	30.6^{b}±0.77	34.3^{a}±0.64	31.4^{b}±0.77	33.8^{a}±0.64	900
TDS	141.7^{a}±3.53	131.2^{c}±0.56	138.3^{b}±3.53	131.4^{c}±0.56	100
BOD	4.80^{a}±0.10	4.83^{a}±0.02	4.76^{a}±0.10	4.66^{b}±0.02	
Alkalinity	132.5^{b}±0.70	126.0^{c}±1.41	135.1^{a}±0.70	126.8^{c}±1.41	200
Cl	507.8^{b}±5.09	519.9^{a}±8.98	489.2^{d}±5.09	505.3^{c}±8.98	250
Ca	83.4^{a}±1.06	79.9^{b}±0.77	83.35^{a}±1.06	79.85^{b}±0.77	75
Mg	164.5^{c}±4.94	177.5^{a}±2.12	144.8^{d}±1.41	171.2^{b}±2.12	150

R1-R4: Water samples from 4 different rivers. ND: Not Detected. Values are the mean ± standard deviation of two replication of each parameter. Values with different superscript across a row are significantly different from each other.

DISCUSSION

Heterotrophic bacterial count measures a range of bacteria that are naturally present in a sample. From the obtained results for heterotrophic bacterial count, the load exceeded the limit set by the WHO for drinking water samples (WHO, 2023). A similar trend was observed for the total coliform bacteria count. The coliform counts observed in this study were comparable to those recorded by Guetouache and Guessas (2015) as well as Mennane *et al.* (2008). However, the microbial load of borehole and well waters samples obtained in this study were lower than those reported by Ehiowemwenguan *et al.* (2014) and Adebawore *et al.* (2016), but relatively similar to reports from Bello *et al.* (2013) and Adogo *et al.* (2015).

In this study, pathogens of public health significance such as *Salmonella* spp and *Escherichia coli* were isolated from river sources. This is consistent with the work of Ehiowemwenguan *et al*. (2014) where pathogens such as *Salmonella*, *Shigella*, *Escherichia coli* and *Vibrio cholerae* were isolated. The group of microorganisms as seen in this study is comparable with those of Awoke *et al.* (2024). Similar group of bacteria has also been reported by Lawal and Lohdip, (2015) in Mimyak River in Kanke LGA of Plateau State, as well as those of Sadiya *et al.* (2018). The presence of *Escherichia coli* meant for drinking is generally unaccepted. The detection of *Escherichia coli*, *Salmonella* species and *Pseudomonas* species in water that is intended for human consumption is a cause for concern. These isolates may pose severe health complications to humans especially if they harbour virulence genes.

The presence of such bacteria as *Pseudomonas aeruginosa* and *E. coli* is of significant value in determining the extent of water pollution. Okonko *et al.* (2008), Lateef *et al*. (2012) and Olorunjowon *et al.* (2012) also isolated organisms for domestic water supplies isolated such as *Pseudomonas aeruginosa*, *Escherichia coli*, *Klebsiella* sp, *Enterobacter* sp and *Proteus* sp from borehole water. Ekhosuehi *et al.* (2018) had earlier reported that water may have a wide range of organisms which include indigenous species, saprophytic species as well as human pathogen contaminant, such as *Salmonella, Proteus, Escherichia coli* and other species of *Enterococcus*. The presence of coliform bacteria found in the water samples across the sampling points could imply faecal contamination of the samples.

Physiochemical parameters

The pH levels of the river, tapwater and borehole water samples in this study (4.60 to 6.80) was in consonance with those reported in the work of Awoke *et al.* (2024). The pH range observed in this study also corroborates with earlier results of Ruma (2011). This indicates that the water samples were more acidic. The pH values obtained in this study showed the water samples to be slightly acidic and below the lower permissible limit recommended by WHO (1996). A related study by Udom *et al.* (2002) also recorded similar low pH as seen in this study. They attributed the low pH to the abundance of organic matter in the overlying soils. Decomposition of organic matter leads to a decrease in pH (acidity).

The findings of Gadhia *et al*. (2012) as well as Borthakur and Singh (2020) recorded mean turbidity values of 152 ± 48.28 NTU and 29.35 ± 2.01 NTU which were higher than the range of values obtained in our study. In addition, the findings of this study is in contrast with those reported by Geetha *et al.* (2014), Fatombi *et al.* (2012) that came from other water bodies. From the results, the increase in value of turbidity from water sample in the river is similar to those reported by Taiwo *et al.* (2014) and Olorode *et al.* (2015). Water turbidity is very important because high turbidity is often associated with higher level of disease-causing microorganism such as bacteria and other parasites (Shittu *et al.,* 2008).

Chloride is one of the major anions in water, and it is generally associated with sodium. High level of chloride ions results in an objectionably salty taste (Fatombi *et al.,* 2012). According to WHO, the presence of chlorides in drinking water must be 250mg/L as a limit. All evaluated samples in this study showed acceptable values. The results of this investigation however, varied with those reported by several authors (Fatombi *et al.*, 2012; Taiwo *et al.,* 2014; Olorode *et al.,* 2015). The alkalinity values recorded in this study was significantly higher the range of 11.33 ± 3.00 – 17.33 ± 1.15 and 10.3 ± 1.7 recorded by Idemudia *et al.* (2024) and Idowu *et al.* (2020). This variation in values recorded may be due to the volume of water and the concentration of bicarbonates and other salts dissolved in the water. Meanwhile, the electric conductivity values were found to be higher in the river and tap water samples in contrast to the borehole samples. The values recorded for EC in this study compared favourably with the 32.27 ± 4.84 µS/cm and 1102.75 ± 414.53 µS/cm documented by Gadhia *et al*. (2012) as well as Akinbile and Omoruyi (2018) respectively.

The BOD values recorded in this study ranged was found to be higher than the 1.37 ± 0.21 mg/l – 1.73 ± 0.15 mg/l reported by Idemudia *et al.* (2024). However, the findings of Okoye *et al.* (2016) which reported a BOD value of 23.50 ± 0.71, as well as that of Borthakur and Singh (2020), which reported values ranging from 2.00 – 28.00 mg/l is comparable with the findings of this present study. A low BOD is an indicator of good quality water, while a high BOD indicates polluted water. The BOD findings from the study were higher compared to those presented by Durmishi *et al*., (2008).

The results of the physicochemical assessment of the collected water samples conformed to earlier studies in Ilorin (Adewoye *et al*., 2011), and Ota (Chinedu *et al*., 2011). It is noteworthy, however, that some assessment of water samples in studies of Onifade and Ilori, (2008); Kalpana *et al*., (2011) and Oladipo *et al*., (2009) had physicochemical values of concern and evidence of feacal coliforms. These contradictory reports highlight the need for implementation of several legislations within local settings in Nigeria.

The mean concentrations of heavy metals (Zinc, Lead, Iron, and Copper) were low compared to WHO standards. This finding is consistent with studies by Itah and Akpan (2005) as well as Mwegoha and Kihampa (2010). Lead was not detected in majority of samples in this study. This finding is in agreement with the study done by Elsherief *et al.* (2014) and Enabulele *et al.* (2022) who also reported that lead was not detected in their study, especially during the dry season. A major factor affecting water quality is anthropogenic activities arising from rapid industrialization and urbanization (Ukpong and Okon, 2013). For instance, trace metals gain access into rivers possibly through anthropogenic and natural sources. These trace metals can be accumulated in three basic reservoirs: water, marine biota and sediments. The presence of heavy metals in water exerts a great impact on both the water and the aquatic organisms. As heavy metal persists in the environment, it results to bioaccumulation and a higher degree of toxicity to all forms of life.

CONCLUSION

The bacteriological values for total coliform counts did not meet the international standard as they were higher than World Health Organization standard of zero per 100ml. The bacteriological quality of the samples was unsatisfactory due to the presence of coliform bacteria found in the water samples across the sampling points which is of great concern and implies faecal contamination of the samples. The detection of *Escherichia coli*, *Salmonella* species and *Pseudomonas* species in water that is intended for human consumption is a cause for concern. These isolates may pose severe health complications to humans especially if they harbour virulence gene determinants. The presence of such bacteria as *Pseudomonas aeruginosa* and *E. coli* is of significant value in determining the extent of water pollution.

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