Original Article

ASSESSMENT OF PHYSICO-CHEMICAL PARAMETERS AND BACTERIAL ANALYSIS OF WELL AND BOREHOLE WATER IN ZARIA, NIGERIA

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ABSTRACT

Water is an essential natural resource that sustains life, but increasing industrialization, population growth, and poor sanitation practices have resulted in the contamination of many water sources. This study assessed the physico-chemical parameters and bacterial quality of well and borehole water in Samaru, Zaria, Kaduna State. Water samples were collected from four locations Danraka, Samaru New Extension, Hayin Dogo and Hayin Dan Yaro and analyzed using standard analytical and microbiological techniques. Physico-chemical parameters such as pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), alkalinity, hardness, chloride, phosphate, sulphate, and nitrate were determined. Results showed that pH values (6.93–8.11) were within the World Health Organization (WHO) permissible limits, while EC and TDS varied across sites, suggesting mineral leaching and anthropogenic influence. Parameters such as chloride, nitrate, sulphate, and hardness also fell within acceptable limits. However, bacteriological analysis revealed the presence of Gram-negative, short rod-shaped coliforms including Escherichia coli, Salmonella *sp.*, Shigella *sp.*, Vibrio *sp.*, Serratia *sp., and* Providencia *sp. Total coliform counts exceeded the WHO standard of zero coliforms per 100 ml in all samples, with some exceeding 1800 MPN/100 ml, indicating fecal contamination. The study concludes that although most physico-chemical parameters were within acceptable limits, the high bacterial load renders the water unsafe for direct consumption. It is recommended that all well and borehole water in the area be properly treated before use, and public health sensitization on water hygiene should be intensified.*

KEYWORDS: Physico-chemical Parameters, Well, Borehole, Bacteria, Samaru

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INTRODUCTION

Water is a very important resource used to enhance living. Water quality can be defined in relative terms. However, due to anthropogenic activities and industrialization as well as ever increasing human population, the quality of water is being compromised. This is also exacerbated by poverty, especially in rural communities in different parts of Nigeria. About 27 % of rural dwellers in Northwest of Nigeria, depend absolutely on springs, streams, ponds, rivers, dams and rainwater as their main sources of water for their domestic uses due to lack of clean water (Adeniyi *et al.,* 2016).

Apart from being very essential for life; water is also one of the most important means of transmitting disease in humans and a major cause of infant mortality in many developing countries (Bloem *et al.,* 2017). According to the World Health Organization (WHO), about 80 % of diseases are water borne and bout 3.1% deaths occur due to the unhygienic and poor quality of water (Pawari and Gawande, 2015).

Water supplies are contaminated by pathogens such as bacteria, fungi, viruses, protozoans and other biological organisms due to a variety of causes, including animal waste, open defecation, pollution from on-site sanitation facilities such as pit latrines and septic systems, and urban runoff (Chigor *et al.,* 2019, Okullo *et al.,* 2017).

In Africa, groundwater is a significant source of drinking water and acts as an important buffer to surface water levels (World Health Organization, 2017). Concerns have been raised about attempts to achieve Sustainable Development Goal 6, which intends to guarantee access to safe health, inexpensive drinking water, and appropriate sanitation services by 2030 (Nwinyi *et al.,* 2020). Sanitation and availability of safe drinking water vary around the globe, nonetheless the worrying problem of water shortages and a lack of basic sanitation services is mostly seen in developing nations (WHO, 2021). Insufficient clean water supplies in Nigeria may be due to inadequate management of treatment facilities, anthropogenic activities, and poor policy implementation (WHO, 2019).

Physico chemical parameters refers to the physical and chemical characteristics of a substance, often used to access water quality e.g. temperature, turbidity, pH etc. (Asif *et al.,* 2021).

Contamination and pollution of water bodies due to increased urbanization and indiscriminate waste disposal are increasing at alarming rate. Well and Borehole water serves as the major source of drinking water in the Nigerian population, as such, it is imperative to examine the parameters of well and borehole water (Chapman, 2019). Contamination alters the quality of portable water in terms of physiochemical and bacteriological quality indices (Spellman, 2017).

Access to safe and clean drinking water is a fundamental human right and a critical component of public health. However, in Samaru, Sabon Gari Local Government, Kaduna State, the quality of well and borehole water remains a significant concern. Several studies have been carried out on physicochemical quality of water, but relatively fewer studies have compared bacteriological analysis of well and borehole water (WHO, 2020). Hence, this study was conducted to bridge this gap.

MATERIALS AND METHODS

Study Area and Sample Collection

The study was conducted within Samaru, Zaria. The study area lay on latitude of 11°99'E and longitude of 7°41'N. The sampling locations were Danraka, Samaru New Extension and Hayin Dogo respectively. Samples were collected from different domestic water sources (Borehole

and Well) within the study area. The water samples were collected at regular intervals in sterilized plastic bottles of 1000 ml capacity for physicochemical analysis, while 100 ml sampling bottles were used for bacterial analysis. The samples were labelled, stored in an ice box at low temperature, and were immediately transported to the laboratory.

Experimental Design

Water samples were collected from three locations—Danraka, Samaru New Extension, and Hayin Dogo in sterilized containers and analyzed in the laboratory. Physico-chemical parameters such as pH, temperature, electrical conductivity, alkalinity, hardness, and dissolved oxygen were determined using standard analytical procedures. Bacteriological analysis was carried out using the Multiple Tube Fermentation Technique to estimate the Most Probable Number (MPN) of coliforms.

Bacteria Analysis

The bacterial analysis of water was determined using the multiple tube fermentation technique as described by Ajogi *et al.* (2005). This technique involved the following:

Presumptive Test

Lactose broth was prepared by dissolving 6.5 g nutrient broth powder, 2.5 g lactose powder, and 0.05 g bromothymol blue in 500 ml distilled water. 10 ml of the broth was dispensed into three sets of 5 tubes with inverted Durham vials. These tubes were sterilized at 121°C for 15 minutes in an autoclave, allowed to cool, and inoculated with 10 ml, 1 ml, and 0.1 ml of the water sample respectively. The inoculated tubes were incubated at 37°C for 48 hours and examined for gas production and cloudiness. The Most Probable Number (MPN) index was determined using a standard table based on positive tubes observed. The positive tube containing the least inoculum volume was then used for the confirmatory test (Ajogi *et al.*, 2005).

Confirmatory Test

Brilliant green bile broth was prepared by dissolving 40 g of brilliant green bile broth powder in 1 litre of distilled water. 10 ml of the broth was dispensed into a test tube with an inverted Durham vial, stoppered with cotton wool, and sterilized at 121°C for 15 minutes. A loopful of positive lactose broth culture with the least inoculum was then transferred into this tube and incubated at 37°C for 24 hours. Cloudiness and gas production were noted as evidence of a positive confirmatory test. Brilliant green bile broth screened out Gram-positive organisms that could give false positives and inhibited anaerobic spore formers, achieving approximately 92% coliform detection (Ajogi *et al.*, 2005).

Determination of Sediment (Total Suspended Solids)

The sediment in the water samples was determined as total suspended solids (TSS) using the gravimetric method. A clean, glass fiber filter paper was dried in an oven at a temperature of 103–105 °C for about one hour, cooled in a desiccator, and weighed to obtain its initial weight. A known volume of the thoroughly mixed water sample was then filtered through the pre-weighed filter paper using a vacuum filtration apparatus. After filtration, the filter paper containing the retained sediment was dried in an oven at 103–105 °C for at least one hour or until a constant weight was achieved. The filter paper was then cooled in a desiccator and reweighed to obtain the final weight. The difference between the final and initial weights of the filter paper was used to calculate the total suspended solids in milligrams per litre (mg/L) of the

sample volume filtered, according to standard methods.

Calculation:

TSS (mg/L) = $\frac{W2-W1}{Sample\ (L)}$

Where:

W1 = initial weight of filter paper (mg)

W2 = weight of filter paper + sediment after drying (mg)

Volume = volume of water sample filtered (mL)

DATA ANALYSIS

Descriptive statistics, expressed as Mean ± Standard Deviation (SD), were used to summarize the physico-chemical parameters of the collected water samples. For the bacteriological analysis, data obtained from the Multiple Tube Fermentation Technique comprising both presumptive and confirmatory tests were used to estimate the Most Probable Number (MPN) of coliform organisms per 100 ml of water. The estimation was carried out using a standard MPN probability table**,** based

Differences between mean values were tested using one-way Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT**)** to determine significant variations ($p < 0.05$) among groups.

RESULTS

Physico-chemical Parameters of Well and Borehole Water Samples in Samaru

The results show variations in water quality across the sampling sites. The pH values ranged from 6.93 ± 0.38 in Hayin Dogo Well (HDW) to 8.11 ± 0.86 in New Extension Well (NEW) (Table 1). The temperature values were relatively stable, ranging from 25.43 ± 1.06°C in Danraka Borehole (DRB) to 27.33 ± 0.46°C in Hayin Dogo Well (HDW). Electrical conductivity (EC) showed variation across the sampling locations, with values ranging from 1585.33 ± 330.83 µS/cm in New Extension Borehole (NEB) to 1962.00 ± 25.24 µS/cm in New Extension Well (NEW). The Total Dissolved Solids (TDS) values were mostly consistent, ranging between 942.67 ± 23.54 mg/L and 973.60 ± 23.37 mg/L**,** except in Hayin Dogo Well (HDW), which recorded a notably higher value of 3704.73 ± 4741.78 mg/L**.** The Dissolved Oxygen (DO) concentration ranged from 1.13 ± 0.51 mg/L in Danraka Well (DRW) to 4.03 ± 2.15 mg/L in New Extension Well (NEW), Biochemical Oxygen Demand (BOD) values were low in all locations, ranging from 0.67 ± 0.12 mg/L in HDW to 1.13 ± 0.74 mg/L in Hayin Dan Yaro Borehole (HDYB). Alkalinity values ranged from 26.33 ± 3.06 mg/L in HDYB to 51.00 ± 4.58 mg/L in DRW. The chloride concentration varied from 64.67 ± 5.03 mg/L in NEB to 131.33 ± 15.56 mg/L in HDYB. The phosphate content was generally low, ranging between 0.03 ± 0.00 mg/L in HDYW and 0.15 ± 0.14 mg/L in HDB.

Sulphate concentrations were also low, ranging from 0.12 ± 0.15 mg/L in DRW to 0.29 ± 0.02 mg/L in HDW, while nitrate values were between 0.24 ± 0.02 mg/L in HDYW and 0.33 ± 0.08 mg/L in DRB. The hardness values ranged from 163.00 ± 9.54 mg/L in HDYW to 225.00 **±** 11.53 mg/L in NEW.

Statistical analysis revealed that pH ($p = 0.023$)**,** EC ($p = 0.033$)**,** TDS ($p = 0.009$)**,** DO ($p = 0.001$)**,** alkalinity ($p = 0.002$)**,** nitrate ($p = 0.007$)**,** and hardness ($p = 0.003$) showed significant differences among the sampling locations, while other parameters were not significantly different.

Table 1: *Physico-Chemical Parameters of Well and Borehole Water Samples in Samaru, Sabon Gari Local Government, Kaduna State*

Parameter	HDB (M±SD)	HDW (M±SD)	DRB (M±SD)	DRW(M±SD)	NEB (M±SD)	NEW(M±SD)	HDYB (M±SD)	HDYW (M±SD)	p-value
Ph	7.77±0.49^{a}	6.93 ± 0.38^{a}	7.24 ± 0.17^{a}	7.35 ± 0.93^{a}	7.78 ± 0.34^{a}	8.11 ± 0.86^{a}	7.33 ± 0.40^{a}	7.58 ± 0.21^{a}	0.023
Temperature	26.27±1.67^{b}	27.33 ± 0.46^{b}	25.43 ± 1.06^{b}	26.77 ± 1.02^{b}	25.83 ± 1.46^{b}	27.23 ± 0.67^{b}	27.27 ± 0.60^{b}	26.60 ± 0.46^{b}	0.104
EC.	1655±334.31^{a}	1915 ± 56.72^{a}	1705 ± 243.05^{a}	1686.00 ± 355.58^{a}	1585.33 ± 330.83^{a}	1962.00 ± 25.24^{a}	1582.67 ± 313.31^{a}	1866.67 ± 85.50^{a}	0.033
TDS	958.33±17.81^{c}	3704.73 ± 4741.78^{c}	942.67 ± 23.54^{c}	957.67 ± 35.92^{c}	956.33 ± 26.35^{c}	973.60 ± 23.37^{c}	954.77 ± 22.27^{c}	952.00 ± 23.58^{c}	0.009
DO	1.43±0.28^{c}	2.45 ± 0.59^{c}	1.56 ± 0.18^{c}	1.13 ± 0.51^{c}	1.90 ± 0.62^{c}	4.03 ± 2.15^{c}	4.03 ± 1.25^{c}	2.85 ± 0.84^{c}	0.001
BOD	0.75±0.48^{b}	0.67 ± 0.12^{b}	1.00 ± 0.50^{b}	0.77 ± 0.32^{b}	0.70 ± 0.30^{b}	0.80 ± 0.26^{b}	1.13 ± 0.74^{b}	1.03 ± 0.67^{b}	0.121
Alkalinity	28.00±4.58^{c}	39.67 ± 14.01^{c}	35.00 ± 9.54^{c}	51.00 ± 4.58^{c}	29.67 ± 8.14^{c}	37.33 ± 13.05^{c}	26.33 ± 3.06^{c}	41.67 ± 15.18^{c}	0.002
Chloride	73.67±8.50^{b}	79.33 ± 16.07^{b}	97.00 ± 18.00^{b}	69.00 ± 6.24^{b}	64.67 ± 5.03^{b}	84.67 ± 8.08^{b}	131.33 ± 15.56^{b}	105.33 ± 27.50^{b}	0.123
Phosphate	0.15±0.14^{b}	0.04 ± 0.03^{b}	0.06 ± 0.03^{b}	0.07 ± 0.02^{b}	0.04 ± 0.01^{b}	0.05 ± 0.00^{b}	0.05 ± 0.01^{b}	0.03 ± 0.00^{b}	0.427
Sulphate	0.19±0.08^{b}	0.29 ± 0.02^{b}	0.25 ± 0.04^{b}	0.12 ± 0.15^{b}	0.25 ± 0.06^{b}	0.24 ± 0.02^{b}	0.18 ± 0.02^{b}	0.25 ± 0.01^{b}	0.409
Nitrate	0.27±0.08^{a}	0.27 ± 0.06^{a}	0.33 ± 0.08^{a}	0.30 ± 0.08^{a}	0.25 ± 0.03^{a}	0.32 ± 0.02^{a}	0.26 ± 0.02^{a}	0.24 ± 0.02^{a}	0.007
Hardness	176.33±73.57^{c}	172.33 ± 8.62^{c}	200.33 ± 83.21^{c}	187.67 ± 77.09^{c}	181.67 ± 16.26^{c}	225.00 ± 11.53^{c}	211.00 ± 56.90^{c}	163.00 ± 9.54^{c}	0.003

Note: Means in the same row followed by different superscript letters indicate level of significance: *a* = significant ($p < 0.05$), *b* = not significant ($p > 0.05$), and *c* = highly significant ($p < 0.01$), based on one-way ANOVA followed by Duncan's multiple range test.

Note: HDB = Hayin Dogo Borehole, HDW = Hayin Dogo Well DRB = Danraka Borehole DRW = Danraka Well NEB = New Extension Borehole NEW = New Extension Well HDYB = Hayin Dan Yaro Borehole HDYW = Hayin Dan Yaro Well

Confirmatory Test

The results of the confirmatory test for bacterial isolates from well and borehole water samples in Samaru, Sabon Gari Local Government are presented in Table 2. The results showed that, all isolates from the different sampling sites, showed a negative Gram reaction. The cell morphology across all samples was identified as short rods, while the cell arrangement was scattered.

Coliform isolates from Biochemical Test

The biochemical characterization of coliform isolates from borehole and well water samples in Samaru, is shown in Table 3. The results revealed diverse reactions to the biochemical tests (indole, Methyl red, Voges-Proskauer and Citrate) .Salmonella species were observed in Danraka (DRB) and Hayin Dan Yaro (HDYB) boreholes, while Escherichia coli species was seen in New Extension Borehole (NEB) and Hayin Dan Yaro (HDYB) boreholes. The results also indicated that Serratia , Shigella, Vibrio and Providencia species were found in Hayin Dogo borehole, Hayin Dogo Well, Danraka Well and New Extension Well respectively.

Presumptive Test: Total Coliform Count

The presumptive test for total coliform count in well and borehole water samples from the study area is presented in Table 4. The results showed variations in the most probable number (MPN) of coliforms per 100 ml across the different sampling locations. The Hayin Dogo Borehole (HDB) and Hayin Dogo Well (HDW) recorded high coliform counts with MPN values exceeding 1800/100 ml, indicating heavy fecal contamination. Similarly, the New Extension Borehole (NEB) and New Extension Well (NEW) also had coliform counts greater than 1800/100 ml, suggesting severe pollution and possible health hazards. The Danraka Borehole (DRB) had a moderately high coliform count of 920/100 ml, while the Danraka Well (DRW) recorded the lowest count of 50/100 ml, though still above the World Health Organization (WHO) permissible limit of zero coliforms per 100 ml for potable water. The Hayin Dan Yaro Borehole (HDYB) and Hayin Dan Yaro Well (HDYW) recorded coliform counts of 220/100 ml and 350/100 ml respectively, reflecting intermediate levels of contamination compared to other sites. The results further revealed that the highest occurring coliforms were Salmonella and E. coli with 25 percent occurrence (Figure 1.).

Table 2: Confirmatory Test

Sample code	Gram reaction	Cell morphology	Cell arrangement
HDB	-	Short rod	Scattered
HDW	-	Short rod	Scattered
DRB	-	Short rod	Scattered
DRW	-	Short rod	Scattered
NEB	-	Short rod	Scattered
NEW	-	Short rod	Scattered
HDYB	-	Short rod	Scattered
HDYW	-	Short rod	Scattered

Note: HDB = *Hayin Dogo Borehole, HDW = Hayin Dogo Well DRB = Danraka Borehole DRW = Danraka Well NEB = New Extension Borehole NEW = New Extension Well HDYB = Hayin Dan Yaro Borehole HDYW = Hayin Dan Yaro Well*

Table 3: Coliform isolates from Biochemical Test

Sample code	Indole	MR	VP	Citrate	Organism identification
HDB	-	+	-	-	*Serratia* sp
HDW	-	-	-	+	*Shigella* sp.
DRB	-	+	-	+	*Salmonella* sp.
DRW	+	+	+	+	*Vibro* sp
NEB	+	-	+	-	*E.coli*
NEW	+	+	-	-	*Providence sp*
HDYB	-	+	-	+	*Salmonella sp*
HDYB	+	+	-	-	*E.coli*

***Note: HDB** = Hayin Dogo Borehole, HDW = Hayin Dogo Well DRB = Danraka Borehole DRW = Danraka Well NEB = New Extension Borehole NEW = New Extension Well HDYB = Hayin Dan Yaro Borehole HDYW = Hayin Dan Yaro Well*

Table 4: Presumption Test: Total coliform Count

Sample code	10ml	1ml	0.1ml	MPN/100ml
HDB	5	5	5	>1800
HDW	5	5	5	>1800
DRB	5	5	3	920
DRW	4	2	5	50
NEB	5	5	5	>1800
NEW	5	5	5	>1800
HDYB	5	4	2	220
HDYW	5	5	4	350

***Note: HDB** = Hayin Dogo Borehole, HDW = Hayin Dogo Well DRB = Danraka Borehole DRW = Danraka Well NEB = New Extension Borehole NEW = New Extension Well HDYB = Hayin Dan Yaro Borehole HDYW = Hayin Dan Yaro Well*

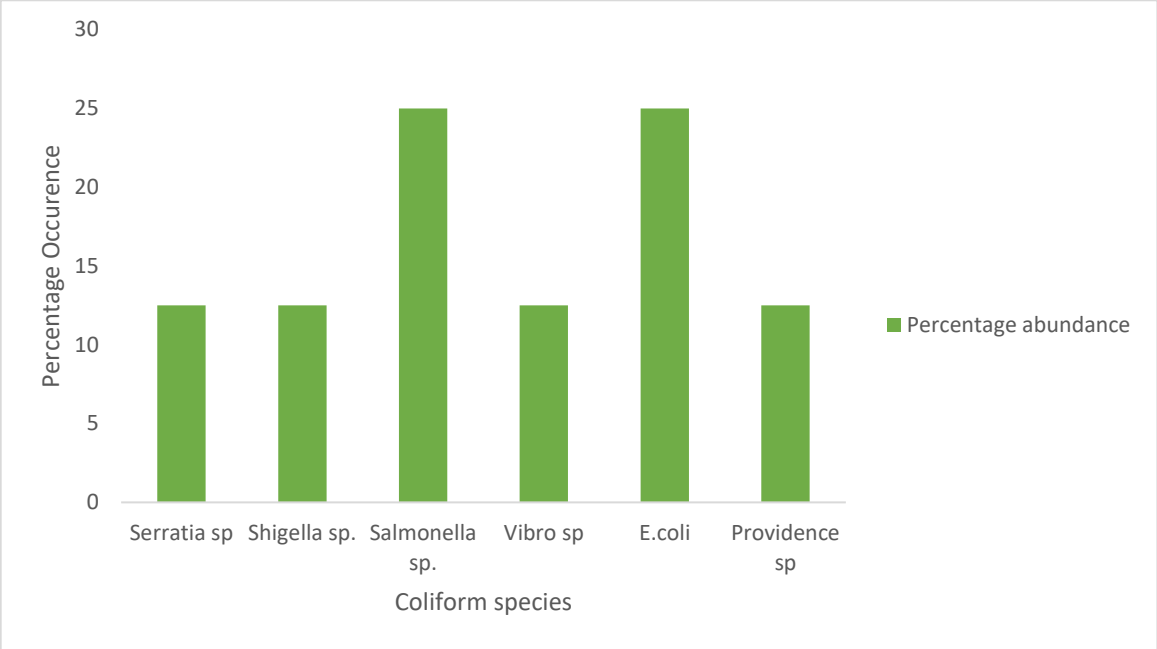


Figure 1: Percentage occurrence of coliform species isolated from water samples in Samaru,

DISCUSSION

This study assessed the Physico-Chemical Parameters and Bacterial Quality of Well and Borehole water samples in Samaru, The results revealed variations in water quality across the sampling sites. The physico-chemical parameters indicated that most of the sampled waters had pH values ranging from 6.93 ± 0.38 to 8.11 ± 0.86, which falls within the World Health Organization (WHO, 2017) recommended range of 6.5–8.5 for potable water. Similar findings were reported by Ojekunle *et al.* (2015), who observed comparable pH values in borehole waters in Ogun State, Nigeria.

However, the observed fluctuations in electrical conductivity (EC) and total dissolved solids (TDS) suggest possible mineral leaching and anthropogenic inputs. For instance, Hayin Dogo Well (HDW) and New Extension Well (NEW) recorded higher EC values of 1915 ± 56.72 µS/cm and 1962.00 ± 25.24 µS/cm, respectively. Likewise, TDS values ranged from 942.67 ± 23.54 mg/L in Danraka Borehole (DRB) to 973.60 ± 23.37 mg/L in New Extension Well (NEW), with Hayin Dogo Well (HDW) showing a markedly higher value of 3704.73 ± 4741.78 mg/L. These findings are consistent with the observations of Ocheri *et al*. (2014), who linked elevated EC and TDS levels to groundwater contamination from household and agricultural activities.

Dissolved oxygen (DO) values varied considerably across the study area, ranging from 1.13 ± 0.51 mg/L in Danraka Well (DRW) to 4.03 ± 2.15 mg/L in New Extension Well (NEW). The variations reflect differences in organic load and microbial activity, as similarly reported by Oladipo *et al*. (2009) in their study of groundwater in Kwara State. The biochemical oxygen demand (BOD) values were generally low, ranging between 0.67 ± 0.12 mg/L in HDW and 1.13 ± 0.74 mg/L in Hayin Dan Yaro Borehole (HDYB), indicating limited organic pollution. However, the detection of coliform bacteria suggests that even low BOD levels may not necessarily guarantee microbial safety.

Alkalinity values ranged from 26.33 ± 3.06 mg/L to 51.00 ± 4.58 mg/L, while chloride concentrations varied between 64.67 ± 5.03 mg/L and 131.33 ± 15.56

mg/L. Similarly, nitrate and sulphate levels were low, ranging from 0.24 ± 0.02 mg/L to 0.33 ± 0.08 mg/L and 0.12 ± 0.15 mg/L to 0.29 ± 0.02 mg/L, respectively. These parameters generally remained within WHO permissible limits, similar to findings by Musa *et al*. (2017) in Kaduna State. The hardness of the samples ranged from 163.00 ± 9.54 mg/L in Hayin Dan Yaro Well (HDYW) to 225.00 ± 11.53 mg/L in New Extension Well (NEW), indicating that the groundwater in the area is moderately hard to hard, which may influence its suitability for domestic use over time.

The microbiological assessment revealed the presence of Gram-negative short rod-shaped bacteria across all samples, confirming contamination. Biochemical characterization identified *E. coli* (25%)**,** *Salmonella* sp. (25%)**,** *Serratia* sp. (12.5%)**,** *Shigella* sp. (12.5%)**,** *Vibrio* sp. (12.5%)**,** and *Providencia* sp. (12.5%)**.** The predominance of *E. coli* and *Salmonella sp.* indicates fecal contamination, corroborating previous reports by Edokpayi *et al.* (2018), who highlighted similar bacterial profiles in groundwater sources in developing communities. The detection of pathogenic bacteria such as *Shigella* and *Vibrio* species further underscores the potential health risks, as these organisms are associated with dysentery, typhoid fever, and cholera, respectively.

The presumptive coliform count (MPN) exceeded the WHO standard of zero coliforms/100 ml in all samples, with some sites (HDB, HDW, NEB, NEW) recording counts greater than 1800 MPN/100 ml. This finding is consistent with earlier studies by Dada (2019) in Lagos and Sule *et al.* (2011) in Zaria, who reported high coliform counts in well waters due to poor sanitation and seepage from pit latrines. The consistently higher contamination levels in wells compared to boreholes highlight the greater vulnerability of shallow aquifers to surface pollution, as observed in the work of Oyem *et al.* (2015). The physico-chemical analysis showed that most parameters: pH, chloride, nitrate, sulphate, and hardness, were within WHO permissible limits. However, variations in electrical conductivity, TDS, and DO suggested possible anthropogenic and geogenic influences on groundwater quality. The bacterial analysis revealed the presence of coliforms, with high total coliform counts across all samples. Pathogenic bacteria including *E. coli*, *Salmonella sp.*, *Shigella sp.*, *Vibrio sp.*, *Serratia sp.*, and *Providencia sp.* were isolated, indicating fecal contamination and rendering the water unsafe for drinking without prior treatment.

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