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Comparative Analysis of some Physicochemical and Biological parameters of Well and Borehole Water Samples obtained in Dustin-Ma Town, Katsina State, Nigeria.

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ABSTRACT
Water quality continues to pose a major challenge in many urban areas particularly in the developing countries, in which Dutsin-Ma town of Katsina State is not an exception. The aim of this study was to compare the physicochemical and biological characteristics of water obtained from three wells and three boreholes located in six different areas of Dutsin-Ma Local Government Area, Katsina State, Nigeria. The analysis was carried out using standard procedure recommended by the American Public Health Association (APHA). The physicochemical parameters analysed include the pH, electrical conductivity (EC), turbidity, total dissolved solids (TDS), Total suspended solids (TSS), total solids (TS), dissolved oxygen (DO), and temperature. Bacteriological examination of the water samples was assessed using the membrane filtration technique. Findings revealed that borehole water generally had better quality than well water, with most physicochemical parameters such as pH (6.90–7.40) and electrical conductivity (300–550 µS/cm) found to be within the permissible limits set by the WHO. In contrast, well water recorded higher turbidity levels (5.2–6.8 NTU) and significant microbial contamination, with *E. coli* counts reaching up to 18 CFU/100 mL, exceeding recommended standards. The Water Quality Index rated borehole water from "good" to "poor," whereas well water ranged from "poor" to "unsuitable" for consumption. Overall, borehole water was found to be relatively safer for domestic use, although treatment is still necessary for both water sources before consumption.

Keywords:
Physicochemical and Biological parameters,
Borehole, well,
Water pollution index

INTRODUCTION

Water is one of the most essential natural resources required for the survival of humans, animals, and plants (Khumalo, 2025). It plays significant roles in drinking, cooking, sanitation, agriculture, industrial production, and several domestic activities. Access to safe and clean water is therefore fundamental to public health, economic development, and environmental sustainability (Masum *et al.*, 2025). Despite its importance, the availability of potable water remains a major challenge in many developing countries, particularly in rapidly growing urban and semi-urban areas where population increase and inadequate infrastructure place pressure on existing water resources (Ghosh *et al.*, 2021).

Groundwater is one of the major sources of freshwater supply worldwide and serves as a dependable alternative to surface water in many communities (Das, 2025). It is commonly obtained through boreholes, tube wells, and hand-dug wells. Due to the natural filtration process that occurs as water passes through soil and rock layers, groundwater is often considered safer and less contaminated than surface water sources such as rivers, streams, and ponds (Ullah *et al.*, 2019). In developing countries, groundwater contributes significantly to domestic water supply and provides nearly half of the urban water demand (Foster, 2022). In Nigeria, especially in northern states such as Katsina, groundwater remains the primary source of water for domestic use because

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public pipe-borne water systems are either insufficient or unreliable.

However, the quality of groundwater has become a growing concern globally as a result of increasing anthropogenic activities (Lapworth *et al.,* 2022). Rapid urbanization, industrialization, agricultural practices, and indiscriminate disposal of wastes have contributed significantly to the deterioration of groundwater quality (Asif *et al.,* 2024). Contaminants from sewage, fertilizers, pesticides, refuse dumps, and industrial effluents can infiltrate into groundwater systems and affect their physicochemical and microbiological properties. Poor sanitation facilities, open defecation, and improper waste management further increase the risk of contamination, particularly in densely populated urban settlements (Dickson-Gomez *et al.,* 2023).

Boreholes and hand-dug wells differ considerably in terms of construction depth and vulnerability to contamination (Ogbole *et al.*, 2025). Boreholes generally access deeper aquifers that are naturally protected from surface pollutants by several layers of soil and rock (Aranguren-Díaz *et al.*, 2024). As a result, borehole water is usually of better quality and less susceptible to microbial contamination (Traore *et al.*, 2024). On the other hand, hand-dug wells are relatively shallow and are often poorly protected, making them highly vulnerable to contamination through surface runoff, seepage from septic tanks, refuse dumps, and other environmental pollutants (Falae *et al.*, 2024). In many communities, wells are located close to sources of contamination, thereby increasing the risk of groundwater pollution (Fang *et al.,* 2024).

In Dutsin-Ma Metropolis of Katsina State, the demand for potable water has increased due to population growth and urban expansion (Ndabula *et al.,* 2025). Government-supplied tap water is often inadequate and inconsistent, compelling residents to rely heavily on alternative sources such as boreholes and hand-dug wells for domestic water supply. Despite the widespread use of these groundwater sources, there is limited information regarding their quality and safety for human consumption (Xie *et al.*, 2023). Regular monitoring and evaluation of water quality are therefore necessary to ensure public health protection and sustainable water resource management (Makanda *et al.,* 2022).

This study was designed to assess and compare the physicochemical and biological quality of water obtained from wells, and boreholes in Dutsin-|Ma Metropolis. Specifically, the study aimed to determine important physicochemical parameters, including pH, electrical conductivity, turbidity, total dissolved solids, and temperature, as well as microbiological parameters such as *E. coli* and total coliform bacteria. The study also evaluated the compliance of the water samples with the standards established by the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ). Furthermore, the Water Quality Index (WQI) and Water Pollution Index (WPI) were calculated to provide a comprehensive assessment of the suitability of the water sources for domestic consumption and public health safety.

MATERIALS AND METHODS

Study Area

Dutsin-Ma town is located within Dutsin-Ma Local Government Area of Katsina State in northwestern Nigeria. The town lies approximately on latitude 12°27′ North and longitude 7°30′ East. It is situated about 61 kilometers southeast of Katsina, the state capital. Dutsin-Ma is located within the Sudan Savannah vegetation zone and experiences a tropical continental climate characterized by wet and dry seasons. The metropolis is bounded by Kurfi Local Government Area to the north, Safana and Dan Musa to the west, Charanchi and Kankia to the east, and Matazu to the south. The major occupation of the people in the area is farming especially irrigation agriculture and animal rearing (Samaila *et al.,* 2025**).**

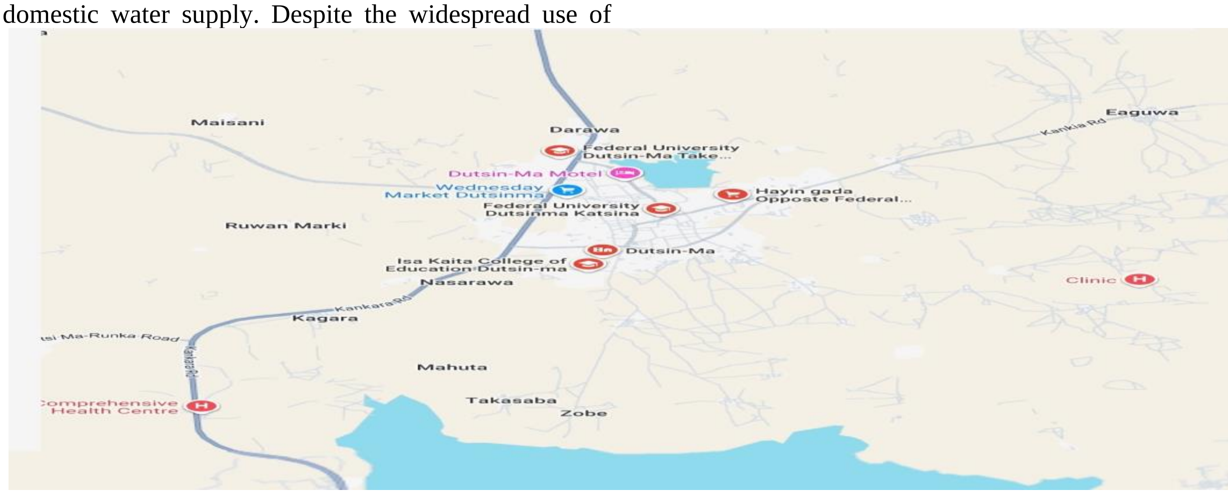

Fig. 1: Map of the study area showing sampling locations

Sample Collection

Water samples were randomly collected using cleaned and pre-labeled sterile high-density polyethylene (HDPE) bottles in strict compliance with the American Public Health Association (APHA, 2017) guidelines from six different locations in Dutsin-Ma Metropolis. The samples comprised three boreholes and three hand-dug wells. The borehole sampling sites included Unguwar Yarima (B1), Abuja Road (B2), and Hayin Gada (B3), while the well sampling sites were Hayin Gada (W1), Unguwar Kudu (W2), and Khadija Bread area (W3). Prior to sample collection, each borehole pump was allowed to run for approximately two to three minutes to flush out stagnant water and ensure that fresh groundwater samples were obtained. Physicochemical parameters such as pH, temperature, and electrical conductivity were measured on-site immediately after sample collection using standard portable instruments. The collected samples were then preserved in ice-filled coolers and transported to the laboratories of the Federal University Dutsin-Ma for further physicochemical and bacteriological analyses.

Physicochemical Analysis

The physicochemical properties of the water samples were determined using standard analytical procedures in compliance with APHA (2017) guidelines. The pH of each sample was measured using a calibrated Hanna pH meter (Model HI 8820N). Electrical conductivity (EC) was determined with a Hanna conductivity meter (Model HI 8820N), which was calibrated using a 0.01 M potassium chloride (KCl) solution before use. Turbidity was measured using a HACH turbidimeter (Model 44600-00), and the results were expressed in Nephelometric Turbidity Units (NTU).

Total dissolved solids (TDS) were determined by evaporating 100 mL of the filtered water sample at 105°C until a constant weight was obtained. To determine total suspended solids (TSS), 100 mL of the sample was filtered through a pre-weighed filter paper, which was subsequently dried at 103–105°C and reweighed. Total solids (TS) were calculated as the sum of total dissolved solids and total suspended solids. Dissolved oxygen (DO) was measured using a DO meter, while water temperature was recorded on-site using a calibrated thermometer. All analyses were conducted in accordance with standard laboratory procedures as reported by APHA (2017).

Bacteriological Analysis

Bacteriological examination of the water samples was carried out using the membrane filtration technique. Endo agar medium was prepared by dissolving 37.1 g of the medium in one liter of distilled water. The prepared medium was sterilized by autoclaving at 121°C for 15 minutes and then allowed to cool to a temperature of 45–50°C before use. A volume of 100 mL of each water sample was filtered through sterile membrane filters with a pore size of 0.45 µm. The membrane filters were carefully placed onto prepared Endo agar plates and incubated at 35–37°C for 24 hours. After incubation, coliform bacteria appeared as red colonies, while *Escherichia coli* (*E. coli*) colonies were identified by their characteristic blue coloration with a metallic sheen. The number of colonies was counted and expressed as colony-forming units per 100 mL (CFU/100 mL) (APHA, 2017).

Water Quality Index (WQI) and Water Pollution Index (WPI)

The Water Quality Index (WQI) was calculated using the weighted arithmetic index method to evaluate the overall suitability of the water samples for domestic consumption. The quality rating scale (Qi) for each parameter was determined using the following equations:

$$\mathrm{Qi} = (\mathrm{Vi} - \frac{\mathrm{Videal}}{\mathrm{Si} - \mathrm{Videal}}) \times 100 \tag{1}$$

Where Vi = observed value, Si = WHO standard value, Vi deal = ideal value

The ideal values are (0 for most parameters except where pH=7 and DO=14.6 mg/L).

$$\mathrm{WQI} = \Sigma(\mathrm{QiWi})/\Sigma\mathrm{Wi} \tag{2}$$

Where $\mathrm{Wi} = \frac{\mathrm{K}}{\mathrm{Si}}$, and K= Constant, the WQI classification values were (0-25 Excellent, 26-50 Good, 51-75 Poor, 76-100 Very Poor, >100 Unsuitable) (Nasir *et al.*, 2024).

The WPI was calculated as: $\mathrm{WPI} = \left(\frac{1}{\mathrm{n}}\right) \Sigma(\frac{\mathrm{Ci}}{\mathrm{Si}})$ (3)

Where Ci = measured concentration, Si = standard limit.

Data Analysis

All physicochemical measurements were performed in triplicate. The results were expressed as mean ± standard deviation (SD). Measured values were compared against WHO guideline values for drinking water quality. Statistical analysis was carried out using SPSS (version 2023) by mean comparison using analysis of variance (ANOVA) test. P-value of ≤ 0.05 was considered to be statistically significantly different.

RESULTS AND DISCUSSION

Physicochemical Parameters

The results of physicochemical analysis of all the water samples were show in Table 1.0. The results revealed that all the pH values ranged between 6.90 and 7.40, which falls within the permissible limits recommended by the World Health Organization (WHO) for drinking water (6.5–8.5). This indicates that the water sources were neutral to slightly alkaline and suitable for domestic consumption. Similar findings were reported by Adewoye *et al.* (2019, who observed comparable pH values in groundwater sources within northern Nigeria. The acceptable pH levels suggest that the water is unlikely to cause corrosion of pipes or adverse health effects associated with highly acidic or alkaline water.

Electrical conductivity (EC) values recorded in this study ranged from 300 to 550 µS/cm, which were considerably below the WHO recommended limit of 1500 µS/cm. These values indicate low salinity levels and moderate mineral content in the water samples. Borehole samples generally exhibited slightly lower conductivity values (420–500 µS/cm) compared to well water samples (300–550 µS/cm), suggesting relatively lower concentrations of dissolved ionic substances in the boreholes. This may be attributed to the anthropogenic activities and leaching of chemicals discharged by the human populace of the area, which may easily reach the well water bodies compared to the that of the borehole. The results of this study agrees with the findings of Ibrahim *et al.* (2020) and Abdulbasid *et al.* (2026) who reported similar conductivity patterns in groundwater sources within Katsina State. The relatively low EC values indicate that the groundwater sources are not significantly affected by excessive mineral dissolution or anthropogenic pollution.

Turbidity values obtained from the borehole samples ranged from 1.6 to 3.5 NTU, which were within the WHO permissible limit of 5 NTU for drinking water. In contrast, the well water samples recorded higher turbidity values, particularly at W1 (5.2 NTU), W2 (6.2 NTU), and W3 (6.8 NTU), exceeding the recommended standard. Elevated turbidity levels in the wells indicate the presence of suspended particles and possible microbial contamination. This may be attributed to poor sanitary conditions, surface runoff infiltration, and inadequate protection of the wells from environmental contaminants. Similar observations were reported by Olalekan *et al.*, 2018, in their assessment of groundwater quality in Sokoto State, where shallow wells were found to be more vulnerable to contamination than boreholes.

The concentrations of total dissolved solids (TDS), which ranged from 2.1 to 3.3 mg/L, and total solids (TS), ranging from 2.25 to 3.48 mg/L, were extremely low when compared with the WHO permissible limits of 1000 mg/L and 1500 mg/L, respectively. The findings of this study were relatively higher than that reported by Abdulbasid *et al.* (2026). These results indicate minimal mineralization and a high degree of water purity. Low TDS levels are generally desirable because excessive dissolved solids can affect water taste and may pose health risks when present in high concentrations. The low TS values further suggest that the water samples contained very little suspended or dissolved matter.

Table 1.0: Physicochemical Parameters of Water Samples (Mean ± SD)

Site code	Source	pH	EC (µS/cm)	Turbidity (NTU)	TDS (mg/L)	TSS (mg/L)	TS (mg/L)	DO (mg/L)	Temp (°C)
W1	Well	7.00±0.18	520±2.00	5.2±0.9	2.8±0.100	0.17±0.005	2.97±0.078	5.8±1.0	29.1±0.5
W2	Well	6.95±0.22	530±1.00	6.2±1.1	2.8±0.058	0.17±0.047	2.97±0.052	5.4±1.2	29.2±0.6
W3	Well	6.90±0.26	300±2.08	6.8±1.2	2.3±0.058	0.11±0.005	2.41±0.050	5.3±1.3	29.6±0.7
B1	Borehole	7.12±0.16	500±1.00	3.5±0.8	2.3±0.100	0.24±0.005	2.54±0.082	5.9±1.0	29.3±0.5
B2	Borehole	7.35±0.09	450±2.65	1.8±0.5	3.3±0.153	0.18±0.005	3.48±0.141	6.5±0.8	28.7±0.3
B3	Borehole	6.8010±0.15	470±1.53	3.0±0.8	2.5±0.115	0.10±0.005	2.60±0.082	6.3±1.0	29.0±0.5
p Value		0.435	0.775	0.009	0.857	0.633	0.813	0.035	0.264
WHO PL		6.5-8.5	≤1500	≤5	≤1000	—	≤1500	≤5	≤30

Key: W1, Hayin Gada, W2, Unguwar Kudu, W3, Khadija Bread area, B1, Unguwar Yarima , B2, Abuja Road, B3, Hayin Gada , WHO PL, World Health Organization permissible Limit

Dissolved oxygen (DO) concentrations ranged between 5.3 and 6.8 mg/L in all the water samples, meeting the WHO minimum recommended level of 5 mg/L. Borehole water samples showed slightly higher DO values (5.9–6.7 mg/L) compared to the well water samples (5.3–6.8 mg/L). The findings under this study is comparable to that reported by Abdulbasid *et al.* (2026). Higher dissolved oxygen levels in borehole water may indicate lower levels of organic pollution and better overall water quality. Adequate dissolved oxygen is essential for maintaining water freshness and limiting the growth of anaerobic microorganisms. The comparatively lower DO values observed in some well samples may be associated with organic contamination resulting from surface infiltration and poor environmental sanitation around the wells.

Water Quality Index (WQI) and Water Pollution Index (WPI)

The results of the Water Quality Index (WQI) and Water Pollution Index (WPI) are presented in Tables 1.2 and 1.3, respectively. The WQI results showed clear differences in water quality between borehole and tube well samples. Boreholes B2 and B3 recorded WQI values of 34.1 and 29.6, respectively, and were classified as having "good" water quality, indicating that the water was generally acceptable for domestic use. In contrast, borehole B1 had a WQI value of 52.4, which placed it in the "poor" water quality category, suggesting moderate contamination and the need for treatment before consumption.

Table 1.2: Water Quality Index (WQI) Results

Site code	Source	WQI	Water Quality	Status
B1	Borehole	52.4	Poor	Moderately polluted
B2	Borehole	34.1	Good	Acceptable
B3	Borehole	29.6	Good	Acceptable
W1	Tube well	66.8	Poor	Moderately polluted
W2	Tube well	78.6	Very Poor	Polluted
W3	Tube well	85.4	Very Poor	Polluted

Key: W1, Hayin Gada, W2, Unguwar Kudu, W3, Khadija Bread area, B1, Unguwar Yarima , B2, Abuja Road, B3, Hayin Gada, WQI, Water Quality Index

The well samples exhibited poorer water quality compared to the boreholes. W1 had a WQI value of 66.8 and was classified as "poor," while W2 and W3 recorded WQI values of 78.6 and 85.4, respectively, indicating "very poor" water quality. These elevated WQI values suggest that the wells are more susceptible to contamination due to their shallow depth and exposure to environmental pollutants. Poor sanitary practices, seepage from nearby waste disposal sites, and surface runoff may have contributed to the deterioration in water quality observed in the wells.

Table 1.3: Water Pollution Index (WPI) Results

Site code	Source	WPI	Status
B1	Borehole	2.13	Highly Polluted
B2	Borehole	1.12	Polluted
B3	Borehole	0.74	Slightly Polluted
W1	Well	0.67	Acceptable
W2	Well	0.81	Slightly Polluted
W3	Well	0.88	Slightly Polluted

Key: W1, Hayin Gada, W2, Unguwar Kudu, W3, Khadija Bread area, B1, Unguwar Yarima, B2, Abuja Road, B3, Hayin Gada , WPI, Water pollution Index

The Water Pollution Index (WPI) results also demonstrated varying levels of contamination among the sampled sites. Borehole B1 recorded the highest WPI value of 2.13 and was classified as "highly polluted," whereas B2 had a WPI value of 1.12, indicating that it was "polluted." Borehole B3 showed a lower WPI value of 0.74 and was therefore classified as "slightly polluted." Interestingly, the wells generally recorded lower WPI values compared to some boreholes, with W1 classified as "acceptable" (0.67) and W2 and W3 categorized as "slightly polluted" with values of 0.81 and 0.88, respectively.

The observed differences between WQI and WPI classifications, particularly for the wells, suggest that microbiological contamination contributed significantly to the deterioration of overall water quality. While WPI mainly reflects physicochemical pollution levels, it does not adequately account for microbial contamination.

Consequently, water sources with relatively acceptable WPI values may still pose serious health risks if bacteriological contamination is present. This explains why some well samples with moderate WPI values still recorded poor WQI classifications (Al Yousif and Chabuk, 2023).

Bacteriological Quality

Table 1.4: Microbiological Parameters (CFU/100 mL)

Site	Source	E. coli	Total Coliform
W1	Well	16	48
W2	Well	18	52
W3	Well	16	64
B1	Borehole	4	15
B2	Borehole	0	6
B3	Borehole	0	0
WHO PL		0	0

Key: W1, Hayin Gada, W2, Unguwar Kudu, W3, Khadija Bread area, B1, Unguwar Yarima , B2, Abuja Road, B3, Hayin Gada , WHO PL, World Health Organization permissible Limit

The results of bacteriological analysis were shown in Table 1.4. The results revealed significant differences between the borehole and well water samples. Boreholes B2 and B3 complied with WHO drinking water standards, recording zero *Escherichia coli* (*E. coli*) and total coliform counts, indicating the absence of fecal contamination and better microbiological safety. However, borehole B1 recorded 4 CFU/100 mL of *E. coli* and 15 CFU/100 mL of total coliform bacteria, suggesting possible contamination, likely resulting from poor borehole maintenance or infiltration from nearby pollution sources. These findings were consistent with that reported by Abdulbasid *et al.* (2026) and Usman and Aliyu (2025) who reported the faecal coliform contamination of well and borehole water samples in Katsina state.

Furthermore, all well water samples showed considerable microbial contamination. *E. coli* counts ranged from 16 to 18 CFU/100 mL, while total coliform counts ranged from 48 to 64 CFU/100 mL, far exceeding the WHO recommended standard of 0 CFU/100 mL for potable water. The presence of *E. coli* in the well water is a strong indication of fecal contamination and poses serious public health risks, including the transmission of waterborne diseases such as cholera, typhoid fever, dysentery, and diarrhea as reported by Agbabiaka *et al.* (2019).

The high microbial contamination observed in the tube wells may be attributed to their shallow depth, poor structural protection, and proximity to potential contamination sources such as pit latrines, septic tanks, and refuse disposal sites. These findings are consistent with the report of Oyedele *et al.* (2015), who associated microbial contamination in tube wells with inadequate sanitary conditions and the close location of wells to waste disposal facilities. The results therefore emphasize the need for proper water treatment, improved sanitation practices, and regular monitoring of groundwater sources in Dutsin-ma Metropolis to safeguard public health.

CONCLUSION

In conclusion, the study revealed that the borehole water samples in all the study areas often has better physicochemical and microbiological quality than well water, according to this comparison study of the two types of water in Dutsin-ma town. Every parameter, including pH, EC, TDS, DO, and temperature, was within WHO acceptable bounds. However, well water was dangerous for direct ingestion due to high turbidity and substantial microbiological contamination (total coliform and *E. coli*). Boreholes were rated as "good" to "poor" by the Water Quality Index, whereas tube wells were rated as "poor" to "unsuitable," indicating that boreholes are a safer source. To guarantee sustainable access to drinkable water in Dutsin-ma town, regular monitoring, appropriate waste management, water treatment (filter and disinfection), and public awareness programs are crucial.

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