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Bacteriological and Physicochemical Assessment of Well Water Quality in Wukari Metropolis, Taraba State, Nigeria

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ABSTRACT
Groundwater is an important source of domestic water in Wukari Metropolis, Taraba State, Nigeria, but inadequate well protection and human activities may compromise its quality. This study assessed the bacteriological and physicochemical characteristics of well water collected from three wards in Wukari Metropolis. Nine water samples were obtained from selected wells in Avyi, Hospital, and Puje wards and analysed using conventional microbiological and physicochemical methods. Bacterial isolates were identified presumptively from colony morphology, Gram staining, and biochemical tests. Four bacterial groups were reported: *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Klebsiella* spp. Total viable bacterial counts ranged from 1.0×10^6 to 1.6×10^6 CFU/mL. Of the 18 isolates recovered, *S. aureus* accounted for 38.9%, followed by *E. coli* (27.8%), *P. aeruginosa* (22.2%), and *Klebsiella* spp. (11.1%). The pH ranged from 6.8 to 8.3, electrical conductivity from 96.1 to 120.3 µS/cm, and total dissolved solids from 109.3 to 128.8 mg/L. Turbidity (25.8 to 29.4 NTU) exceeded the 5 NTU benchmark used in the study. The findings indicate substantial bacterial contamination and suggest that the sampled well water requires appropriate treatment before consumption. Improved well protection, sanitation, and routine water quality monitoring are recommended.

Keywords: Well Water, Groundwater Quality, Bacteriological Analysis, Physicochemical Properties, *Escherichia Coli*, Wukari, Nigeria

INTRODUCTION

Access to safe drinking water remains one of the major public health challenges in many developing countries. Groundwater, particularly from shallow wells, is widely used for domestic purposes, and in southern Malawi it is commonly drunk without treatment (Pritchard *et al.,* 2008). Groundwater often has better microbiological quality than surface water. Even so, contamination may occur through seepage from septic systems, refuse dumps, agricultural runoff, poorly constructed wells, and inadequate sanitation (Ashbolt, 2004; Chapman, 1996).

Contaminated drinking water is an important route for waterborne diseases such as cholera, typhoid fever, dysentery, gastroenteritis, and hepatitis. These diseases remain major causes of illness and death in many low and middle income countries (Ashbolt, 2004; World Health Organization, 2022). Pathogenic microorganisms present an immediate health risk, whereas chemical contaminants usually act through prolonged exposure.

Escherichia coli is the preferred indicator of faecal contamination in drinking water (WHO, 2022). Other bacteria, including *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Klebsiella* species, can enter groundwater from environmental or human sources. They may cause infection in people with weakened immunity (WHO, 2022).

Physicochemical characteristics such as pH, turbidity, electrical conductivity, total dissolved solids, dissolved oxygen, and temperature influence the suitability of water for drinking. They can also point to likely sources of contamination (Chapman, 1996). Turbidity affects the effectiveness of disinfection and the acceptance of water by consumers (Doria, 2010; WHO, 2022).

Several studies have examined groundwater and other drinking water sources in Nigeria and elsewhere in Africa. In Maiduguri, northeastern Nigeria, Isa *et al.,* (2013) analysed the physicochemical and bacteriological quality of drinking water from boreholes. Onyango et al. (2018) reported high microbial loads in ground and surface water sources in Isiolo County, Kenya, and Pritchard *et al.,* (2008) assessed the quality of shallow wells in southern Malawi. In Wukari, Aremu *et al.,* (2017) measured heavy metals and physicochemical parameters in hand-dug wells, boreholes, and rivers in Puje and Avyi during the wet and dry seasons. They found values within WHO limits.

This study addresses the need for bacteriological and physicochemical data from the same wells in Wukari Metropolis. *Tatah et al.* (2022) investigated heavy metals in water samples from Avyi, Puje, and Hospital wards. Their findings identified measurable concentrations of manganese, chromium, cadmium, lead, and iron, although the reported concentrations were generally below the permissible limits used for comparison. Aremu et al. (2017) also examined groundwater and river water in Avyi and Puje during wet and dry seasons. More recently, Chidi and Olawumi (2025) reported bacterial isolates, including *Escherichia coli* and *Klebsiella* species, in groundwater samples collected in Wukari. These studies demonstrate the importance of assessing both the chemical and microbiological quality of local water sources.

Potential environmental factors influencing groundwater quality include the proximity of wells to pit latrines, septic

tanks, refuse dumps, and wastewater disposal sites. Poorly constructed well walls, uncovered wells, inadequate drainage, and damaged well covers may also provide pathways through which contaminated surface water enters wells. Leakage from sanitation facilities and the movement of contaminated water through the soil may introduce faecal microorganisms and other pollutants into groundwater. However, the presence and extent of these conditions at individual sampling locations must be established through field observation rather than assumed from previous water-quality results.

Avyi, Hospital, and Puje wards are appropriate sampling locations because previous groundwater research has covered these wards, providing a basis for comparison with existing findings. In particular, Tatah *et al.* (2022) sampled water from all three wards, while Aremu *et al.* (2017) investigated groundwater and river water in Avyi and Puje. Sampling across the three wards would extend the geographical coverage of the assessment and allow comparisons among selected wells in different parts of Wukari.

Although previous studies have examined groundwater quality and selected contaminants in Wukari, the present study should establish its specific knowledge gap through a detailed review of the available literature. If no recent published study has systematically compared the bacteriological quality of hand-dug well water in Avyi, Hospital, and Puje using the same sampling design and analytical methods, the research may address this gap. Field documentation of sanitation conditions around the sampled wells would further help identify possible environmental factors associated with differences in bacteriological quality

Groundwater is an important source of domestic water in Wukari, Taraba State, where residents depend on hand-dug wells and boreholes for drinking and other household activities. Previous studies have documented variations in the physicochemical properties, heavy-metal concentrations, and microbiological quality of groundwater in the area (Oko *et al*., 2014; Aremu *et al*., 2017; Tatah *et al*., 2022; Chidi & Olawumi, 2025

This study aimed to assess the bacteriological and physicochemical quality of well water from selected wards in Wukari Metropolis, Taraba State, Nigeria, and evaluate its suitability for domestic consumption using relevant drinking water quality standards.

MATERIALS AND METHODS

Study Area

The study was conducted in Wukari Metropolis, the administrative headquarters of Wukari Local Government Area, Taraba State, Nigeria. Wukari lies in the southern part of the state at approximately 7.8716° N and 9.7779° E, at an elevation of about 180 to 200 m above sea level. The area has a tropical savanna climate with distinct wet and dry seasons. Annual rainfall ranges from approximately 1,000 to 1,500 mm, and mean annual temperatures lie between 20°C and 40°C. Relative humidity is generally higher in the rainy season than in the dry season. The climate is influenced by the interaction of the tropical maritime air mass from the Atlantic Ocean and the tropical continental air mass from the Sahara Desert (Dada, 2006).

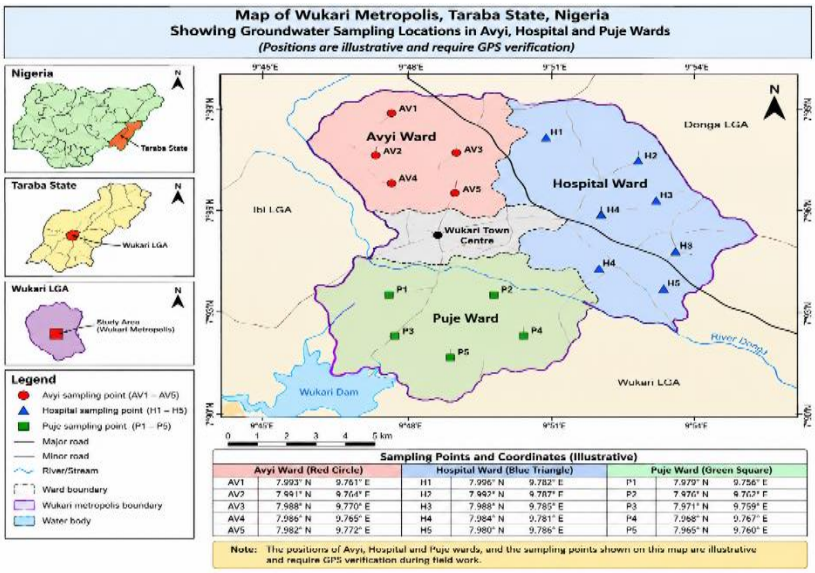


Figure 1: Map of the study area showing the selected well-water sampling locations in Wukari Metropolis.
Source of base map: Cartography Department of Taraba State Land and Survey, 2021

Sampling Design

Nine wells were sampled, three in each of Avyi, Hospital, and Puje wards. Sampling date was November 2025, during dry season and the criteria for selecting this ward were as the result of their less proximity with the dumping site,and other possible contamination sources such as pit latrine,septic tank, their coordinate are as follows Avyi 7.989° N,9.768° E,Hospital 7.989° N 9.768° E and Puje 7.989° N 9.768° E.

The design is limited to nine wells, so the findings describe the sampled wells and should not be generalised to all wells in Wukari Metropolis.

Sample Collection

Well water samples were collected aseptically from the nine wells. The method used to draw water from each well was documented, including whether a household bucket or a sterile sampling container attached to a suitable sterile rope

was used. Where household buckets were routinely used, this was recorded as part of the sampling conditions.
To minimise contamination during sample collection, sterile sample bottles were used, and the bottles were handled without touching their inner surfaces or the bottle openings. Samples were collected before or after routine household water abstraction, as specified in the field records, to ensure that the sampling conditions were documented consistently. Each sample was labelled with a unique identification code, the ward, the sampling date, and the collection time before transportation to the laboratory for bacteriological analysis.

Preparation of Culture Media
Nutrient agar and MacConkey agar (Oxoid, UK) were prepared according to the manufacturer's instructions. The media were sterilised by autoclaving at 121°C for 15 min under 15 psi pressure, cooled to approximately 45 to 50°C, and dispensed aseptically into sterile Petri dishes. Nutrient agar supports the growth of a wide range of bacteria and was used for total viable counts and subculture. MacConkey agar is selective for Gram-negative enteric bacteria and separates lactose fermenters from non-fermenters. It was used to isolate *E. coli*, *Klebsiella* spp., and *P. aeruginosa*. *Staphylococcus aureus* is generally inhibited on MacConkey agar, so its presumptive identification rested on growth on Nutrient agar, Gram reaction, and the catalase and coagulase tests,selective medium agar mannitol salt agar was also used

Isolation and Enumeration of Bacteria
Serial ten-fold dilutions of each water sample were prepared in sterile physiological saline. Serial tenfold dilutions of the water samples were prepared using sterile diluent, covering a dilution range of (10^{-1}) to (10^{-4}), as appropriate for the expected bacterial load. For each selected dilution, duplicate plates were inoculated using the appropriate culture medium and incubation conditions for the target bacterial group. Following incubation, colonies were counted on countable plates, and bacterial concentrations were calculated and expressed as colony-forming units per millilitre (CFU/mL), where applicable.One millilitre (1.0 mL) of the appropriate dilution was transferred into sterile Petri dishes, and molten Nutrient agar or MacConkey agar was poured over it by the pour plate technique. The plates were mixed gently, allowed to solidify, and incubated aerobically at 37°C for 24 to 48 h. Colonies were counted on plates within the countable range of 30 colonies per plate.Counts were expressed as colony-forming units per millilitre (CFU/mL) using the formula: number of colonies × dilution factor ÷ volume plated (1.0 mL). Representative colonies with distinct morphology were purified by repeated streaking on Nutrient agar until pure cultures were obtained.
Counts on Nutrient agar measure total viable heterotrophic bacteria and are not a measure of faecal contamination. Faecal indicator bacteria were not quantified per 100 mL by membrane filtration or the most probable number method. Isolates identified as *E. coli* are therefore reported as presumptive.

Morphological Characterization of Bacterial Isolates
Pure bacterial isolates were characterized based on their colonial morphology on Nutrient Agar and MacConkey Agar. Characteristics examined included colony size, colour, shape, margin, elevation, surface texture, pigmentation, and lactose fermentation pattern. Preliminary identification was carried out using standard microbiological identification procedures (Cheesbrough, 2006).

Gram Staining
Gram staining was performed according to the method described by Cheesbrough (2006). Thin bacterial smears were prepared on clean grease-free glass slides and air dried before heat fixation. The smears were stained with crystal violet for 1 min, rinsed with distilled water, treated with Gram's iodine for 1 min, decolourized with acetone for 10 to 15 s, and counterstained with safranin for 30s.
The stained preparations were examined microscopically under oil immersion using the ×100 objective lens to determine cell morphology and Gram reaction.

Biochemical Characterization of Bacterial Isolates
Purified bacterial isolates were presumptively identified using standard biochemical tests including catalase, coagulase, oxidase, indole, methyl red, Voges-Proskauer, and citrate utilization tests following standard microbiological procedures (Cheesbrough, 2006; Cappuccino & Welsh, 2017). Species level identification rests on this limited panel of tests and is therefore presumptive.

Catalase Test
A small portion of a pure bacterial colony was transferred onto a clean glass slide, and one drop of 3% hydrogen peroxide was added. Immediate bubble formation indicated a positive catalase reaction.

Coagulase Test
A loopful of the bacterial isolate was emulsified in sterile rabbit plasma and incubated at 37°C for up to 4 h. Clot formation was interpreted as a positive coagulase reaction.

Oxidase Test
The oxidase test was carried out using oxidase reagent (tetramethyl-p-phenylenediamine). A dark purple colour appearing within 30 s was considered a positive oxidase reaction.

Indole Test
The isolates were inoculated into peptone water and incubated at 37°C for 24 h. Following incubation, Kovac's reagent was added. Formation of a red ring at the surface indicated a positive indole reaction.

Methyl Red Test
Each isolate was inoculated into MR-VP broth and incubated at 37°C for 48 h. Five drops of methyl red indicator were added. Development of a stable red colour indicated a positive methyl red reaction.

Voges-Proskauer Test
Following incubation of MR-VP broth, α-naphthol and 40% potassium hydroxide were added. Development of a pink to red colour within 30 min indicated a positive Voges-Proskauer reaction.

Citrate Utilization Test
Pure isolates were inoculated onto Simmons citrate agar slants and incubated at 37°C for 24 to 48 h. Development of a blue colour indicated citrate utilization.

Determination of Physicochemical Parameters
Physicochemical analyses were performed according to the Standard Methods for the Examination of Water and Wastewater (APHA, 2012). Results were compared with the WHO (2022) and (SON, 2007). Several parameters, including dissolved oxygen, temperature, electrical conductivity, and

total dissolved solids, have no health-based guideline value. For these, aesthetic or operational benchmarks were used where available

Determination of pH
The pH of each water sample was measured using a calibrated digital pH meter (HI 2214, Hanna Instruments). The instrument was calibrated using standard buffer solutions of pH 4.00, 7.00, and 10.00 before measurement. Readings were taken in duplicate, and the average values were recorded.

Determination of Temperature
Water temperature was measured immediately after sample collection using a calibrated digital thermometer. Results were recorded in degrees Celsius (°C).

Determination of Electrical Conductivity
Electrical conductivity was measured using a digital conductivity meter (DDS-307A). The instrument was calibrated using a standard conductivity solution before analysis. Measurements were recorded in µS/cm

Determination of Turbidity
Turbidity was determined using a portable turbidity meter (TN-100), calibrated with standard formazin turbidity standards before analysis. Results were expressed in Nephelometric Turbidity Units (NTU).

Determination of Total Dissolved Solids
Total dissolved solids (TDS) were measured using a calibrated digital TDS meter (HI 9813-6). The probe was rinsed with distilled water before each measurement. Results were expressed in milligrams per litre (mg/L).

Determination of Dissolved Oxygen
Dissolved oxygen (DO) concentration was determined using a portable dissolved oxygen meter (Model 407510A). The probe was calibrated according to the manufacturer's instructions before use. Results were recorded in milligrams per litre (mg/L).

Statistical Analysis
Data were analysed using IBM SPSS Statistics version 24.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated separately for each physico-chemical parameter. Values of different parameters were not pooled, because they are measured in different units. One-way analysis of variance (ANOVA) was applied separately to each continuous parameter to compare the three wards. The F statistic, degrees of freedom, and exact p value are reported for each test. The frequency of bacterial isolates was expressed as percentages of the total number of isolates. Statistical significance was accepted at $p < 0.05$.

RESULTS AND DISCUSSION

Bacterial Identification
Four bacterial species were presumptively identified from the well water samples. Colony morphology, Gram staining, and biochemical reactions were consistent with *Escherichia coli*, *Klebsiella* spp., *Pseudomonas aeruginosa*, and *Staphylococcus aureus* (Tables 1 and 2). Species level identification rests on a limited panel of tests and requires confirmation.
Escherichia coli and *Klebsiella* spp. produced moist, lactose-fermenting colonies, whereas *P. aeruginosa* produced blue-green, non-lactose-fermenting colonies. *Staphylococcus aureus* produced small yellow colonies, appeared as Gram-positive cocci, and was catalase and coagulase positive.

Table 1: Colonial Morphology and Gram-Staining Characteristics of Bacterial Isolates from Well-Water Samples

Isolate	Colonial Morphology	Gram reaction
Escherichia coli	Moderate, moist, yellow, lactose-fermenting colonies	Gram-negative rod
Klebsiella sp.	Moderate, moist, pink, lactose-fermenting colonies	Gram-negative rod
Pseudomonas aeruginosa	Typically colourless or pale colonies due to non-lactose fermentation	Gram-negative rod
Staphylococcus aureus	Growth is generally inhibited or limited on MacConkey agar because it is selective for Gram-negative bacteria. Colony morphology is not reliably characterised on this medium	Gram-positive cocci, usually in clusters

Table 2: Biochemical Characteristics of Presumptive Bacterial Isolates Recovered from Well Water

Isolate	Catalase	Coagulase	Indole	Methyl red	Citrate	Oxidase	Gram Voges–reactionProskauer
Escherichia coli	Pos	Neg	Pos	Pos	Neg	Neg	Negative rod Neg
Klebsiella sp.	Pos	Neg	Neg	Neg	Pos	Neg	Negative rod Pos
Pseudomonas aeruginosa	Pos	Neg	Neg	Neg	Pos	Pos	Negative rod Neg
Staphylococcus aureus	Pos	Pos	Neg	Pos	Pos	Neg	Positive cocci Neg

Pos, positive. Neg, negative.

Total Viable Bacterial Count
The bacterial loads of the well water samples ranged from 1.0×10^6 to 1.6×10^6 CFU/mL (Table 3). The highest count was observed in Puje ward (Well I) and the lowest in Hospital ward (Well III). These values describe culturable heterotrophic bacteria and are not a direct measure of faecal contamination. [AUTHORS TO ADD replicate counts or an uncertainty estimate for each well.]

Table 3: Total Viable Bacterial Counts in Well-Water Samples Collected from Selected Wards of Wukari Metropolis

Sample Location	Total Viable Count (CFU/mL)
Avyi ward (Well I)	1.2×10^6
Avyi ward (Well II)	1.3×10^6
Avyi ward (Well III)	1.1×10^6
Hospital ward (Well I)	1.4×10^6
Hospital ward (Well II)	1.5×10^6

Sample Location	Total Viable Count (CFU/mL)
Hospital ward (Well III)	1.0×10^6
Puje ward (Well I)	1.6×10^6
Puje ward (Well II)	1.2×10^6
Puje ward (Well III)	1.1×10^6

Note: Each value represents one reported measurement per well. Replicate plate counts were not obtained

Frequency of Bacterial Isolates

A total of 18 bacterial isolates were recovered. *Staphylococcus aureus* accounted for the highest proportion (7 of 18, 38.9%), followed by *Escherichia coli* (27.8%), *Pseudomonas aeruginosa* (22.2%), and *Klebsiella* spp. (11.1%) (Table 4). These percentages are proportions of the isolates recovered. They do not give the prevalence of each organism among the nine wells.

Table 4: Frequency Distribution of Bacterial Isolates Recovered from the Sampled Wells

Isolate	Number of isolates	Total isolates	Percentage of isolates (%)
Escherichia coli	5	18	27.8
Klebsiella sp.	2	18	11.1
Pseudomonas aeruginosa	4	18	22.2
Staphylococcus aureus	7	18	38.9

Distribution of Isolates among Wards

Hospital ward recorded the highest number of isolates (8 of 18, 44.4%), whereas Avyi and Puje wards each accounted for 27.8% (Table 5). *Escherichia coli* was detected only in Hospital and Puje wards, while *S. aureus* and *P. aeruginosa* occurred in all three wards.

Table 5: Distribution of Bacterial Isolates across the Three Sampled Wards

Isolate	Avyi ward	Hospital ward	Puje ward	Total
Escherichia coli	0	3	2	5
Klebsiella sp.	1	1	0	2
Pseudomonas aeruginosa	2	1	1	4
Staphylococcus aureus	2	3	2	7
Total	5 (27.8%)	8 (44.4%)	5 (27.8%)	18

Physicochemical Characteristics

The physicochemical properties of the water samples are presented in Table 6. The pH values ranged from 6.8 to 8.3 and fell within the 6.5 to 8.5 range used for comparison. Electrical conductivity (96.1 to 120.3 µS/cm) and total dissolved solids (109.3 to 128.8 mg/L) were below the benchmarks adopted. Water temperature varied between 29.1°C and 30.8°C. Turbidity (25.8 to 29.4 NTU) exceeded the 5 NTU benchmark in all three wards. Dissolved oxygen ranged from 6.3 to 9.2 mg/L. No benchmark is applied to it, because no health-based guideline value exists for dissolved oxygen in drinking water.

Table 6: Physicochemical Characteristics of Well-Water Samples and Comparison with Drinking-Water Quality Benchmarks

Parameter	F-statistic	df	Exact p-value		Interpretation at 0.05
Colour	Colourless	Colourless	Colourless	Colourless	Colourless
pH	1.882	2,6	0.232084	6.5 to 8.5	Not-significant
Temperature (°C)	8.771	2,6	0.016556	NGV	Significant
Turbidity (NTU)	8.651	2,6	0.017073	5	Significant
Dissolved oxygen (mg/L)	2.773	2,6	0.140308	NGV	Not-significant
Electrical conductivity (µS/cm)	1.436	2,6	0.309267	1000	Not-significant
Total dissolved solids (mg/L)	3.132	2,6	0.117092	500	Not-significant

Discussion

The recovery of presumptive *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Klebsiella* spp. indicates that the sampled wells were microbiologically contaminated. *Escherichia coli* is the preferred indicator of faecal contamination (WHO, 2022), so its presence suggests that sewage or animal waste may have entered the wells. Because identification was presumptive and *E. coli* was not quantified per 100 mL, this interpretation needs confirmation.

The predominance of *S. aureus* may reflect frequent human contact with water containers or poor sanitary practices around the wells. This is a plausible explanation that the study did not test. Bacterial contamination of drinking water sources has also been reported in Maiduguri (Isa *et al*., 2013), Similarly, Chidi and Olawumi (2025) reported bacterial isolates including E. coli, Pseudomonas spp., Klebsiella spp. and S. aureus in groundwater samples from Wukari. The occurrence of these organisms in both studies supports concern about the microbiological quality of local groundwater. However, their study reported no coliform growth despite identifying some potentially important bacterial isolates. This highlights the need to distinguish the recovery of bacterial species from the direct measurement of faecal indicator bacteria. Differences in sampling locations, laboratory procedures, identification methods and reporting may also influence comparisons between studies.

The total viable counts of 1.0×10^6 to 1.6×10^6 CFU/mL are high. They measure culturable heterotrophic bacteria and do not prove faecal contamination. Surface runoff, poorly

constructed well linings, nearby septic tanks, and refuse disposal sites could contribute to such loads. These factors were not investigated here and remain hypotheses. Drinking untreated water that carries these organisms may increase the risk of diarrhoeal disease and opportunistic infection.

The reported pH values ranged from 6.8 to 8.3, falling within the 6.5–8.5 range adopted in this study. Electrical conductivity ranged from 96.1 to 120.3 µS/cm, while total dissolved solids ranged from 109.3 to 128.8 mg/L. These values were below the respective comparison benchmarks of 1,000 µS/cm for electrical conductivity and 500 mg/L for total dissolved solids. The results suggest that the sampled water had relatively low dissolved ionic content compared with these benchmarks. However, compliance with these parameters alone does not establish that the water is safe for consumption, particularly when bacteriological contamination has been detected.

The pH findings are broadly consistent with Aremu *et al*. (2017), who investigated hand-dug wells, boreholes and river water in Puje and Avyi during wet and dry seasons. Their study reported that the physicochemical parameters examined were within the WHO drinking-water limits used by the authors. The present study similarly found pH values within its adopted comparison range and relatively low electrical conductivity and total dissolved solids. However, this agreement should be restricted to the parameters and benchmarks actually compared. Aremu *et al*. (2017) examined several additional parameters, including nutrients, oxygen-demand measures and heavy metals, so their overall findings cannot be directly equated with the narrower set of measurements reported here.

Most physicochemical parameters were within the benchmarks adopted, which suggests low mineralisation of the groundwater. Aremu et al. (2017) likewise reported physicochemical values within WHO limits for wells in Puje and Avyi. Turbidity in the present study, however, exceeded 5 NTU in all three wards. Differences in sampling period, well type, and methods may explain this, and the comparison should be read with care. Turbid water can shield microorganisms from disinfectants (WHO, 2022) and is less acceptable to consumers (Doria, 2010). High turbidity may reflect suspended sediment, organic matter, or microbial cells.

This study has limitations. Only nine wells in three wards were sampled, so the results cannot be generalised to Wukari Metropolis. Samples were not collected across seasons. Faecal indicator bacteria were not quantified, and species level identification was presumptive. Well construction, depth, distance from latrines and septic tanks, and groundwater flow were not examined.

Conclusion

The study revealed substantial bacterial contamination in well-water samples collected from Avyi, Hospital, and Puje wards of Wukari Metropolis, Taraba State, Nigeria. Presumptive isolates of *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Klebsiella* spp. were recovered, while total viable bacterial counts ranged from 1.0 × 10^6 to 1.6 × 10^6 CFU/mL. Most reported physicochemical parameters were within the comparison ranges adopted in the study, although turbidity exceeded the 5 NTU benchmark at all three locations. These findings indicate that the sampled well water requires appropriate treatment and microbiological verification before consumption. Improved well protection, environmental sanitation, and routine monitoring are recommended. Further studies involving seasonal sampling, quantitative faecal-indicator testing, and more extensive groundwater-quality assessment are necessary to establish the wider public-health implications.

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