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Assessment of the Microbiological Quality of Borehole Water and Residents' Knowledge, Attitudes, and Practices in Ilese-Ijebu, Ogun State, Nigeria

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ABSTRACT

Access to microbiologically safe drinking water is essential for public health. In peri-urban and semi-rural communities such as Ilese-Ijebu, Ogun State, Nigeria, limited access to municipal water has increased reliance on groundwater boreholes, which may be compromised by poor sanitation and inadequate water-handling practices. This study evaluated the microbiological quality of borehole water and household-stored water and assessed residents' Knowledge, Attitudes, and Practices (KAP) regarding water safety and hygiene. Borehole water samples were analysed using Total Viable Count, multiple-tube fermentation for presumptive coliforms, faecal coliform enumeration, and biochemical characterization of bacterial isolates. Sanitary surveys of borehole surroundings and a structured KAP questionnaire administered to 100 water consumers (residents) were also conducted. Of the twenty-one (21) boreholes assessed, five (5) met microbiological requirements for potable water, while 16 showed varying degrees of contamination. The highest microbial contamination was recorded at one sampling location. Presumptive pathogenic organisms, including *Escherichia coli*, *Klebsiella spp.*, and *Enterobacter/Citrobacter spp.*, were isolated. Major sanitary risks included the proximity of boreholes to pit latrines, septic tanks, and open dump sites. Poor water-safety perceptions and inadequate treatment practices were also reported among residents. The findings indicate that a substantial proportion of borehole water sources were microbiologically unsafe for drinking, potentially increasing exposure to waterborne diseases. Contamination was associated with inadequate borehole siting, poor structural protection, and unsafe household water-storage practices. Strengthened sanitary regulation, community-based WASH education, routine microbiological monitoring, improved household storage hygiene, and appropriate point-of-use water treatment are recommended to reduce contamination and protect public health.

Introduction

Water is one of the most fundamental and indispensable natural resources required for human survival, health, and socio-economic development (Mishra *et al.*, 2021; du Plessis, 2023). Among the various sources of freshwater available for domestic and productive use, groundwater occupies a position of particular importance, providing a reliable supply for drinking, cooking, and other household needs, especially in communities where centrally treated, pipe-borne water supply is inadequate, unreliable, or completely absent (Mukherjee *et al.*, 2021; La Vigna, 2022; Ngayaga, 2025. Because it percolates through layers of soil and rock before reaching the water table, groundwater is widely presumed by consumers to be naturally purified and, by extension, safe for consumption. This perception, together with its relatively low cost of extraction, ease of access through boreholes and hand-dug wells, and year-

round availability, has made groundwater the fundamental source of water supply for a large proportion of households in developing countries, including Nigeria.

In many Nigerian towns and semi-urban communities, boreholes have become an essential and, in most cases, unavoidable substitute for public water systems that have either collapsed or never been extended to serve growing populations (Igimoh *et al.,* 2026). The clear, colourless and odourless qualities and hidden nature of borehole water reinforce the belief that it is inherently wholesome, leading households to rely on it for drinking, cooking, bathing, laundry, and other domestic and productive activities with little or no prior treatment. This widespread and largely unquestioned reliance on groundwater highlights just how indispensable the resource has become to everyday life and livelihoods in communities such as Ilese-Ijebu, Ogun State without any other drinking water sources.

However, the assumption that groundwater is automatically safe is increasingly being challenged by a growing body of scientific evidence. A number of studies conducted across African cities and towns have consistently demonstrated that borehole and well water sources are vulnerable to microbiological contamination, often at levels that pose direct threats to public health. In Sèmè-Podji, Benin, an assessment of well and borehole water found high proportions of samples contaminated with thermotolerant coliforms, *Escherichia coli* and *enterococci*, with virtually all samples testing positive for common germs, implicating poor maintenance and disregard for basic hygiene practices as underlying causes (Justin *et al.,* 2024). Similarly, an assessment of borehole water in Rumuokoro, Port Harcourt, revealed measurable coliform and faecal coliform loads alongside elevated heavy metal concentrations, producing a water quality index that classified the water as very poor, and non-carcinogenic health risks exceeding safe thresholds for children (Emeka *et al.,* 2026). In Awka, an evaluation of borehole water supplying a parish community found no bacterial growth but detected fungal contaminants, including *Aspergillus*, *Fusarium* and *Penicillium species*, indicating that microbiological risk extends beyond bacteria alone (Eze *et al*., 2024).

Further evidence from Yaoundé, Cameroon, showed that while sampled boreholes were compliant with recommended microbiological standards, water from developed wells in the same area, particularly those without regular disinfection, was heavily non-compliant, with contamination traced largely to the proximity of latrines to water sources (Sone *et al*., 2024). In Gusau metropolis, bacteriological analysis of borehole water detected total bacterial, coliform and faecal coliform counts that exceeded World Health Organization (WHO) allowable limits, with *Escherichia coli, Salmonella typhi* and *Shigella species* isolated from the samples (Okoye & Nyandjou, 2024). A related study of boreholes in Maroua, Far North Cameroon, similarly reported that a substantial majority of samples were contaminated with total coliforms and *Escherichia coli*, again attributing this to the closeness of boreholes to latrines and domestic waste, and recommending both public education and household water treatment as remedial measures (Djaouda *et al*., 2018). Taken together, these findings establish a consistent and recurring pattern: borehole water, despite its perceived purity, is frequently compromised by poor sanitation infrastructure, inadequate maintenance, and proximity to contamination sources, with implications for the burden of waterborne diseases in the communities that depend on it.

Importantly, the risk of contamination is not confined to the source alone. Water that meets acceptable microbiological standards at the point of abstraction can still become unsafe by the time it is consumed, as a result of the way it is transported, handled and stored within the household. Unclean storage containers, uncovered vessels, and repeated contact with hands, cups or ladles during fetching and dispensing all present opportunities for post-collection contamination, making household storage practices as critical to water safety as the quality of the source itself.

Beyond the technical dimension of water quality, the behavioural dimension of how residents perceive, understand, and manage their water is equally significant, and the evidence here points to a

troubling gap. A knowledge, attitude and practice study on groundwater vulnerability to petroleum tank leakages in Abeokuta Urban found that most respondents had poor awareness of groundwater contamination pathways and associated health risks, that attitudes were only moderately positive, and that protective practices, such as water treatment, were adopted by only a small minority of households; furthermore, while knowledge and attitude were weakly related, knowledge did not translate meaningfully into protective practice (Adegbite *et al.,* 2026). This disconnect between awareness and action is reinforced by an earlier study on residents' perception of groundwater microbiological quality across selected urban areas of Ogun State, including Ijebu Ode, which found that residents strongly preferred borehole water to other sources, yet held poor and generally low perceptions of the risk of its contamination, a gap that was associated with high incidences of water-borne disease in the study areas; notably, demographic characteristics such as age, gender and educational attainment did not significantly influence these perceptions, suggesting that the problem is not simply one of formal education but of targeted awareness and risk communication (Adegbite *et al*., 2022).

These studies collectively reveal a critical disconnect between the near-universal reliance of residents on borehole water and their limited knowledge, indifferent attitudes, and weak protective practices regarding its handling, treatment and storage. While the microbiological quality of groundwater sources has been investigated in several Nigerian and other African contexts, and residents' knowledge, attitudes and perceptions have been examined separately in others, relatively few studies have jointly assessed the actual microbiological quality of both source and stored household water alongside residents' knowledge, attitude and practice within the same community, particularly in a locality such as Ilese-Ijebu, Ogun State, that has not been directly captured in the existing literature. Given the consistent evidence of contamination risk associated with borehole water elsewhere, the demonstrated importance of household storage as an additional point of contamination, and the documented gap between water use and risk awareness among residents of Ogun State, there is a clear and need to investigate this relationship locally in Ilese-Ijebu, so as to generate evidence that can guide public health interventions and community water safety practices.

Aim and Objectives

This study aimed to assess the microbiological quality of borehole water and household storage facilities in Ilese-Ijebu, Ogun State, Nigeria, and to evaluate residents' knowledge, attitude, and practice regarding water handling and storage, in order to determine the public health implications for the community. The specific objectives are to:

1. Assess the microbiological quality of water fetched directly from the borehole sources and stored in household storage
2. To assess residents’ knowledge, attitudes, and practices regarding borehole water handling, storage, and hygiene and their implications for water safety and public health.

MATERIALS AND METHODS

Study area

This research was conducted in Ilese-Ijebu, a community located in the Ijebu North East Local Government Area of Ogun State, Southwestern Nigeria. The community is characterized by a tropical wet-and-dry climate with an active residential population. Ilese-Ijebu can be described as an emerging peri-urban community undergoing rapid population growth and spatial expansion, driven largely by the presence and expansion of the Ogun State Polytechnic of Health and Allied Sciences (OSPOHAS). The influx of students, staff, and other residents has stimulated the development of student accommodation, commercial activities, transportation services, and other supporting infrastructure. Consequently, the community is experiencing a gradual transition from a predominantly rural settlement into a more densely populated and economically active peri-urban environment, with increasing pressure on basic

services, including water supply, sanitation, drainage, and waste management. Twenty-one (21) functional borehole sources were purposively selected and referenced using Global Positioning System (GPS) coordinates (Table 1).

Table 1: GPS locations of the Borehole sources

Location	Latitudes	Longitude
Loc1	6.801716°N	3.953208°E
Loc2	6.798430°N	3.954418°E
Loc3	6.796691°N	3.953932°E
Loc4	6.797143°N	3.952139°E
Loc5	6.799539°N	3.953061°E
Loc6	6.799599°N	3.951401°E
Loc7	6.800518°N	3.953741°E
Loc8	6.801510°N	3.952803°E
Loc9	6.799538ºN	3.962820º E
Loc10	6.797663°N	3.962199°E
Loc11	6.795881°N	3.962076°E
Loc12	6.794267°N	3.961869°E
Loc13	6.795881°N	3.962076°E
Loc14	6.794267°N	3.961869°E
Loc15	6.793109°N	3.961439°E
Loc16	6.790030°N	3.960533°E
Loc17	6.791246°N	3.961577°E
Loc18	6.799022º N	3.962892ºE
Loc19	6.799001º N	3.962777ºE
Loc20	6.801092º N	3.957773ºE
Loc21	6.801243º N	3.957312ºE

The study area is summarized by the average geographic coordinates of the twenty-one sampling locations, which centered around latitude 6.797495°N and longitude 3.958186°E that fall namely around Aledo, Tollgate, Itale, Ajuwura, Central Mosque and the OSPOHAS.

Figure 1: showing some borehole locations

Sample Collection Procedure

At each of the 21 selected locations, water samples were collected directly from the borehole supply tap (after a 2-minute flushing protocol to eliminate stagnant water) and from corresponding household storage vessels using sterile 250 mL bottles. All collected samples were transported in an ice-pack at < 4°C to the Medical microbiology laboratory, OSPOHAS for immediate processing within 4 hours.

Laboratory Microbiological Analysis Procedure

i. Total Viable Count (TVC): Determined using the pour-plate method on sterile Nutrient Agar, with dilutions incubated at 37°C for 24-48 hours to enumerate heterotrophic bacteria (expressed in CFU/mL) (American Public Health Association [APHA], American Water Works Association [AWWA], & Water Environment Federation [WEF], 2017).

ii. Presumptive Coliform Count (MPN): Enumerated using the three-tube multiple-tube fermentation assay (most probable number technique) in lactose broth incubated at 37°C for 48 hours to detect lactose-fermenting coliforms (expressed in MPN/100 mL) (APHA *et al.*, 2017).

iii. Faecal Coliform Count (E. coli): Estimated using selective incubation at 44.5°C in Eosin Methylene Blue (EMB) agar. Colonies exhibiting a distinct green metallic sheen were presumptively identified as Escherichia coli. (APHA *et al.*, 2017)

iv. Biochemical Identification of Isolates: Pure bacterial colonies were sub-cultured and characterized using morphological staining (Gram and endospore staining) followed by standard IMViC biochemical tests: Methyl Red (MR), Voges-Proskauer (VP), Indole production, Catalase activity, Coagulase test, and Motility testing. This biochemical profiling allowed the presumptive taxonomic grouping of water-contaminating bacteria (Cappuccino & Welsh, 2020; MacFaddin, 2000).

Sanitary Survey Procedure.

An observational sanitary risk checklist was completed at each of the 21 borehole sites to record structural integrity and the presence of contamination sources (latrines, dump sites, wastewater pools around the sources).

Household Survey

A structured Knowledge, Attitudes, and Practices (KAP) questionnaire was administered to 100 residents (volunteers) randomly that were selected from households surrounding the boreholes. The survey captured demographics, responses on water treatment, hand hygiene, storage vessel types, container cleaning frequency, and perceptions of groundwater safety.

Data Analysis Procedure

Data obtained from microbiological analysis, sanitary inspection, household water-handling practices, and KAP assessment were coded, entered, cleaned, and analysed using descriptive statistics by SPSS vs 25. Frequencies, percentages, means, and standard deviations were used to summarise the results and presented in tables. The microbiological results were compared with relevant WHO drinking-water guidelines, while KAP and sanitary-risk findings were interpreted to identify key public-health concerns.

RESULTS AND DISCUSSION

Microbiological Contamination Profiling

Analysis of the 21-borehole water supply reveals a critical divide between pristine aquifers and contaminated water points. Only five locations (Loc1, Loc2, Loc3, Loc4, and Loc7) displayed absolute compliance with the World Health Organization (WHO) of zero viable or coliform counts. Conversely, the remaining 16 locations (76.2%) showed high levels of microbiological contamination, peaking at Location 14 (TVC: 82.2 ± 5.59 × 10^3 CFU/mL; MPN: 25.4 ± 5.06 MPN/100 mL; E. coli: 11.6 ± 2.14 CFU/100 mL). Tables 2, 3, and 4 compile these counts.

Table 2: Microbiological Quality of Water Samples across

Borehole Locations	Total Viable Count (TVC) (×10^3 CFU/mL)	Presumptive Coliform Count (MPN/100 mL)	Faecal Coliform (E. coli) (CFU/100 mL)
Loc1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Loc2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Loc3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Loc4	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Loc5	50.6 ± 6.92	7.0 ± 1.10	2.8 ± 0.97
Loc6	53.8 ± 6.03	5.4 ± 1.03	2.8 ± 1.16
Loc7	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Loc8	45.2 ± 7.22	6.8 ± 2.58	4.4 ± 1.33
Loc9	51.2 ± 10.53	6.4 ± 1.21	3.6 ± 1.08
Loc10	60.2 ± 4.21	10.4 ± 2.04	2.6 ± 1.21
Loc11	51.4 ± 4.47	8.4 ± 1.54	4.4 ± 0.87
Loc12	55.0 ± 3.61	8.6 ± 1.75	5.6 ± 1.40
Loc13	49.2 ± 4.80	10.0 ± 2.35	4.6 ± 2.04
Loc14	82.2 ± 5.59	25.4 ± 5.06	11.6 ± 2.14

Loc15	60.4 ± 4.41	8.4 ± 2.20	0.0 ± 0.0
Loc16	53.4 ± 4.28	10.6 ± 3.12	5.0 ± 1.92
Loc17	53.6 ± 6.65	8.0 ± 1.52	4.6 ± 1.33
Loc18	55.0 ± 6.48	13.4 ± 6.28	6.4 ± 1.21
Loc19	54.8 ± 5.82	8.8 ± 2.08	3.4 ± 1.21
Loc20	45.2 ± 6.82	10.8 ± 2.60	4.6 ± 1.29
Loc21	40.2 ± 6.82	7.8 ± 2.10	4.0 ± 1.09

Table 2 presents the microbiological quality of groundwater from 21 borehole locations based on Total Viable Count (TVC), presumptive coliform count, and faecal coliform (*E. coli*). Generally, microbial contamination was absent at four locations (Loc1–Loc4 and Loc7), where all three indicators recorded zero values. However, contamination was detected at most of the remaining locations, with Loc14 showing the highest microbial burden. TVC ranged from 40.2 × 10^3 CFU/mL at Loc21 to 82.2 × 10^3 CFU/mL at Loc14, while presumptive coliform counts ranged from 5.4 MPN/100 mL at Loc6 to 25.4 MPN/100 mL at Loc14. Faecal coliform (*E. coli*) ranged from 2.6 CFU/100 mL at Loc10 to 11.6 CFU/100 mL at Loc14. Notably, *E. coli* was detected at almost all contaminated locations, except Loc15, where faecal coliform was not detected despite relatively high TVC (60.4 × 10^3 CFU/mL) and coliform count (8.4 MPN/100 mL).

The results indicate significant spatial variation in microbiological quality across the boreholes. Loc14 had the highest values for all three indicators (TVC = 82.2 × 10^3 CFU/mL; coliform = 25.4 MPN/100 mL; *E. coli* = 11.6 CFU/100 mL), suggesting particularly poor microbiological quality and possible faecal contamination. Loc18 also recorded relatively elevated contamination, especially for coliforms (13.4 MPN/100 mL) and *E. coli* (6.4 CFU/100 mL). In contrast, Loc21 had the lowest TVC among the contaminated sites, although both coliforms and *E. coli* were still detected.

The analysis revealed substantial spatial variability in the quality of the sampled borehole water. While no microbial indicators were detected at Loc1–Loc4 and Loc7, measurable levels of TVC, presumptive coliforms and faecal coliforms were recorded at most other locations. TVC values ranged from 40.2 to 82.2 × 10^3 CFU/mL, presumptive coliform counts from 5.4 to 25.4 MPN/100 mL, and *E. coli* from 2.6 to 11.6 CFU/100 mL among contaminated locations. Loc14 recorded the highest concentrations across all three indicators, whereas Loc21 had the lowest TVC. The detection of *E. coli* at most contaminated locations indicates potential faecal contamination and raises concerns regarding the microbiological safety of the groundwater for domestic and drinking purposes. The marked differences among locations further suggest that contamination is spatially heterogeneous and may be associated with localized environmental and sanitary conditions.

Biochemical Profiling and Taxonomic Identification of the microorganisms isolated from samples.

Table 3: Bio-Chemical Characteristics of the samples

Locations	Characteristics	Morphology	Grams Reaction	Spore Staining	MR Test	VP Test	Indole Test	Catalase	Coagulase	Motility
Loc1	NO GROWTH/NO ISOLATE									
Loc2	NO GROWTH/NO ISOLATE									
Loc3	NO GROWTH/NO ISOLATE									
Loc4	NO GROWTH/NO ISOLATE									
Loc5	Raised elevation, round, smooth colonies, with grayish colour and entire margins.	ROD	-	-	+	-	+	+	-	+
Loc6	Small colonies, flat elevation with entire margins.	ROD	-	-	+	-	-	+	-	-
Loc7	NO GROWTH/NO ISOLATE									
Loc8	Round colonies, whitish and slightly raised elevation.	ROD	-	-	-	+	-	+	+	-
Loc9	Round, smooth colonies with entire margins and a whitish colour	ROD	-	-	+	-	-	+	-	-
Loc10	Smooth, circular, grayish, and raised colonies	ROD	-	-	+	-	+	+	-	+
Loc11	Round, smooth colonies entire margins whitish colour	ROD	-	-	+	-	-	+	-	-
Loc12	Raised creamy-colored colonies with entire margins.	ROD	-	-	+	-	-	+	+	-
Loc13	Small, whitish, raised, and entire white colonies.	ROD	-	-	+	+	-	+	-	-
Loc14	Raised elevation, smooth and entire circular.	ROD	-	-	+	-	-	+	+	-

Loc15	Round, smooth colonies, grayish and raised elevation with entire margins.	ROD	-	-	+	-	+	+	-	+
Loc16	Smooth, circular, grayish and raised colonies.	ROD	-	-	+	+	+	+	-	-
Loc17	Round, smooth colonies with entire margin and a whitish colour.-	ROD	-	-	+	-	-	+	-	-
Loc18	Raised, creamy-colored colonies with entire margins.	ROD	-	-	+	-	-	+	+	-
Loc19	Round, smooth colonies, grayish colour and flat elevation with entire margins.	ROD	-	-	+	-	+	+	-	+
Loc20	Small, whitish colour, smooth colonies and raised elevation with entire margins.	ROD	-	-	+	+	-	+	-	-
Loc21	Small, whitish colour, smooth colonies and raised elevation with entire margins.	ROD	-	-	+	+	-	+	-	-

Bacterial growth was observed in 16 of the 21 sampling locations (76.2%), while 23.8% of locations had no detectable bacterial growth or isolate. The recovered isolates were uniformly described as rod-shaped, Gram-negative and non-spore-forming, indicating a relatively consistent morphological profile across the positive sampling locations. The biochemical results showed considerable variation among the isolates. MR was positive in 15 of the 16 isolates (93.8%), making it the most common biochemical characteristic apart from catalase. Catalase was positive in all 16 isolates (100%), whereas VP and indole reactions were positive in 5 isolates each (31.3%). Coagulase was positive in only 4 isolates (25.0%), while 6 isolates (37.5%) demonstrated motility.

The colony morphology varied somewhat between locations, although most colonies were described as round/circular, smooth, whitish or greyish/creamy, with raised or flat elevation and entire margins. This variation in colonial appearance, despite the common Gram-negative rod morphology, suggests that the samples contained more than one bacterial phenotype or species as summarized in the table 4 below.

Table 4: Summary of the Bio-Chemical Characteristics of the samples

Characteristic/Test	Positive	Negative	Interpretation
Growth/isolation	16 (76.2%)	5 (23.8%)	Bacteria were isolated from most locations
Morphology	16 rods (100%)	0	All isolates were rod-shaped
Gram reaction	0 positive	16 negatives	All isolates were Gram-negative
Spore staining	0 positive	16 negatives	No spore-forming isolates detected
MR	15 (93.75%)	1 (6.25%)	Most isolates were MR-positive
VP	5 (31.25%)	11 (68.75%)	VP positivity occurred in fewer isolates
Indole	5 (31.25%)	11 (68.75%)	Indole production was detected in five isolates
Catalase	16 (100%)	0	All isolates were catalase-positive
Coagulase	4 (25.0%)	12 (75.0%)	Coagulase positivity was relatively uncommon
Motility	6 (37.50%)	10 (62.50%)	Six isolates were motile

As shown in the table 4 and figure 2, there is bacterial contamination of the sampled borehole-water sources, indicating variable microbiological quality across the selected locations. The prevalence of Gram-negative, non-spore-forming, rod-shaped isolates suggests the presence of bacterial groups commonly associated with environmental and potentially faecal contamination.

The observed variability in biochemical characteristics further indicates heterogeneity among the bacterial isolates, reflecting a diverse microbial population within the groundwater sources. Collectively, these findings suggest that the microbiological safety of borehole water in the study area may be compromised and highlight the need for routine microbiological monitoring, appropriate water treatment, and improved protection of borehole sources from potential contamination pathways.

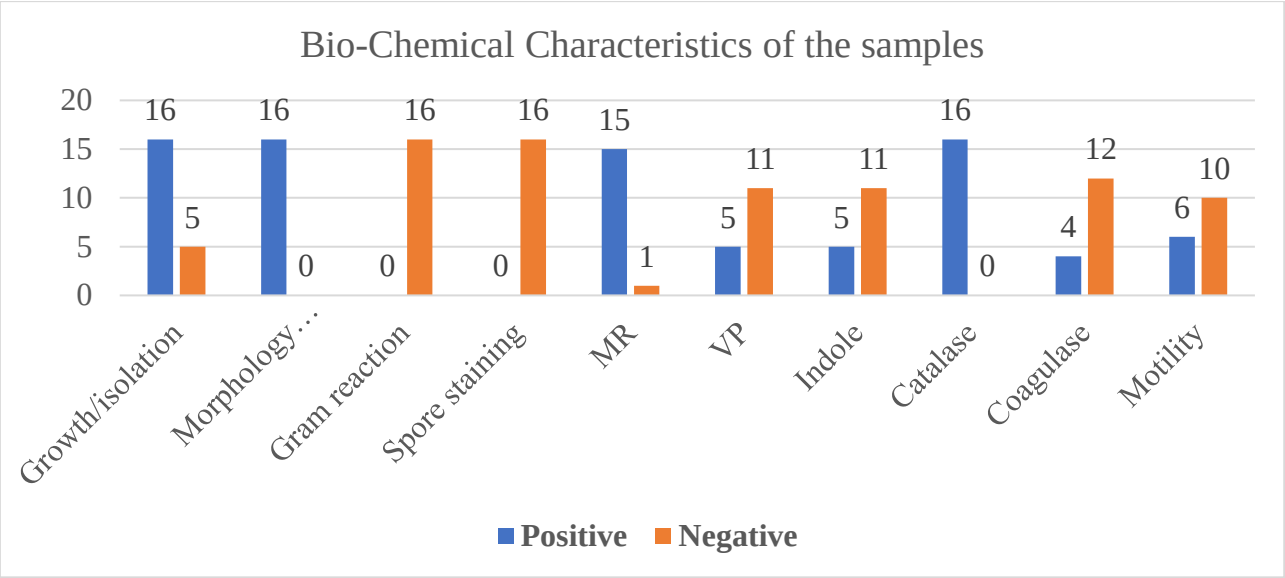

Figure 2: Showing the results of Biochemical Analysis

Results on Environmental Sanitation and Sanitary Assessment

Table 5: Environmental Sanitary Risk Indicators Surrounding the Boreholes

Sanitary Indicator	Occurrence (Yes/No)	Percentage (%)	Risk Public Health Implication
Toilet / Septic tank within 30m proximity	Yes (18) / No (3)	85.7%	Severe lateral sub-surface leaching of faecal coliforms into groundwater aquifers.
Open dump site near the borehole	Yes (16) / No (5)	76.2%	Surface water run-off contamination; leachate infiltration carrying microbial loads.
Absence of functional sanitary seal	Yes (12) / No (9)	57.1%	Surface run-off directly enters borehole casing, introducing airborne pathogens.
Wastewater flow / flooding near head	Yes (15) / No (6)	71.4%	Inundation of borehole casing during heavy rainfall causing biological contamination.

Table 5 showed that there is high prevalence of environmental and sanitary risk factors around the 21 assessed boreholes. The most frequently observed risk factor was the presence of a toilet or septic tank within 30 m of the borehole, occurring at 18 locations (85.7%). This represents a major potential source of groundwater contamination because faecal matter and septic effluent can migrate through the subsurface, particularly where the water table is shallow or the geological formation is permeable or with positive hydraulic gradient. The presence of open dump sites near the boreholes was also prevalent, occurring at 16 locations (76.2%). Such dumps can generate contaminated leachate and facilitate the movement of microbial and chemical pollutants into groundwater, particularly during rainfall and surface-water runoff.

Similarly, wastewater flow or flooding around the borehole head was observed at 15 locations (71.4%), indicating substantial vulnerability to contamination during rainfall events. Floodwater can carry faecal matter, household waste and other contaminants directly towards poorly protected boreholes and may enter through the borehole head or surrounding ground. Furthermore, absence of a functional

sanitary seal was recorded at 12 locations (57.1%). Although this was the least frequent of the four indicators, it remains an important structural vulnerability because it can permit contaminated surface water, debris and microorganisms to enter the borehole directly.

Meanwhile, at least three-quarters of the boreholes were affected by two major sanitary hazards close proximity to toilets/septic systems (85.7%) and open dumping (76.2%), while more than two-thirds were exposed to wastewater flow or flooding (71.4%). The simultaneous occurrence of several risk factors at individual boreholes suggests that contamination may result from multiple interacting pathways rather than a single source. These sanitary conditions provide a probable environmental explanation for the microbiological contamination observed in the groundwater, particularly the detection of presumptive coliforms and E. coli at some part of the study areas.

Results on Household Storage Activities

Table 6: Household Water Management and Post-Collection Storage Practices

Household Practice	**Risk-Associated Parameter**	**Frequency**	**Percentage (%)**	**Risk Public Health Implication**
Vessel Storage Method	Open Container	20	20.0%	Exposes drinking water to airborne pathogens, vector vectors, and dust.
Container Type	Jerry Can	90	90.0%	Narrow neck prevents visual inspection and scrubbing, allowing biofilm buildup.
Cleaning Frequency	Rarely / Never	16	16.0%	Sustains microbial colonies in stagnant residues on vessel walls.
	Sometimes	40	40.0%	Irregular sanitation schedules allow biofilm buildup and post-collection decay.
Hand Hygiene	Never Wash Hands before Fetching	80	80.0%	Direct mechanical transfer of human faecal bacteria from hands to fetching vessel.

Table 6 showed important household-level practices that may compromise the microbiological quality of drinking water after collection. The most prominent risk relates to hand hygiene, with 80 respondents (80.0%) reporting that they never wash their hands before fetching water. This practice might create an opportunity for direct transfer of faecal and other pathogenic microorganisms from contaminated hands to fetching containers and subsequently into stored drinking water.

The predominant container type was the jerry can, used by 90 respondents (90.0%). Although jerry cans are widely used for household water storage, their narrow openings may make thorough cleaning and visual inspection difficult. Consequently, accumulated residues and biofilms may provide suitable conditions for microbial persistence and multiplication, particularly where containers are not cleaned regularly.

However, with respect to cleaning frequency, 40 respondents (40.0%) reported cleaning their storage containers only sometimes, while 16 respondents (16.0%) rarely or never cleaned them. Thus, 56.0% of respondents did not maintain consistent container-cleaning practices, potentially allowing microbial biofilms and sediment to accumulate and contribute to deterioration of water quality during storage. Only the remaining 44.0% would presumably clean their containers more regularly, although the table does not specify their exact cleaning frequency.

For vessel storage, 20 respondents (20.0%) stored water in open containers. Such containers leave stored water exposed to dust, insects, airborne microorganisms and other environmental contaminants. Although this was less common than the use of closed containers, it remains an important post-collection contamination pathway.

The findings indicate that contamination of household drinking water may occur not only at the groundwater source but also during collection, handling and storage. The particularly high prevalence of inadequate hand hygiene (80.0%), irregular or absent container cleaning (56.0%), and widespread use of jerry cans (90.0%) suggests considerable potential for post-collection microbial contamination. These household practices could help explain why water that may initially have acceptable microbiological characteristics can become contaminated before consumption.

Results on Knowledge, Attitudes and Practices of the residents

Table 7: Knowledge, Attitudes, and Practices (KAP) on Borehole Water Consumption and Contamination

Variable	Risk-associated Belief/Action Indicator	Response	Frequency (%)	Public Health Implication
Knowledge	Belief that groundwater is immune to contamination	No (cannot contaminate)	62 (62%)	Complacency halts home water treatment or testing, relying on 'natural sterility' belief.
	Ignorance of latrine-borehole 30m distance rule	No / Don't Know	58 (58%)	Encourages spatial clustering of boreholes and soakaways in residential zones.
	Disbelief that borehole water requires treatment	No (doesn't need it)	71 (71%)	Ensures ingestion of raw, untreated water despite immediate sanitation risks.
Attitude	Perception of water treatment as unnecessary	Not Necessary	66 (66%)	Halts household investment in water boiling or chemical disinfection packages.
	Indifference to relocating latrines away from casing	Indifferent / Unwilling	54 (54%)	Locks in active sources of biological contamination on residential properties.
	Trust in water safety based entirely on appearance	Yes (Safe if clear)	74 (74%)	Ignores the invisible nature of bacteria, allowing high pathogenetic ingestion.
Practice	Active water treatment prior to ingestion	Never / Rarely	68 (68%)	Ensures direct transmission pathway of active coliform pathogens.
	Routine biological testing/monitoring of water	Never	99 (99%)	Biological contamination events go undetected until clinical outbreaks occur.
	Maintenance of concrete borehole sanitary apron	Poor / Neglected	60 (60%)	Allows surface wastewater run-off to bypass soil layers, flowing directly into aquifer.
	Open defecation or improper waste dumping near head	Yes / Sometimes	45 (45%)	Maintains active surface deposit of human faecal pathogens at borehole nozzle.

As shown in the table 7, The findings reveal substantial knowledge gaps, negative attitudes, and unsafe practices regarding borehole water safety. Knowledge-related misconceptions were particularly pronounced, where seventy-one (71%) of the respondents believed borehole water does not require treatment, while 58% were unaware of or did not know the recommended latrine–borehole separation distance. In addition, 62% held beliefs reflecting confidence in groundwater's resistance to contamination. Attitudinally, sixty-six (66%) considered water treatment unnecessary, 54% were indifferent or unwilling to relocate latrines away from boreholes, and 74% judged water safety primarily by its appearance (odour and colour). These perceptions may encourage complacency and reduce willingness to adopt preventive measures. However, practices were similarly concerning; because eighty-two (82%) respondents never routinely tested their water biologically, 99% never or rarely treated water before consumption, and 60% poorly maintained their borehole sanitary aprons. Furthermore, 45% reported open defecation or improper waste disposal near borehole heads.

Discussion of the results

The quantitative microbiological data and qualitative Knowledge, Attitudes, and Practices (KAP) survey results from Ilese-Ijebu provide critical, multi-dimensional insights into groundwater safety, demonstrating that water security is a fundamental pillar of public health that remains highly compromised in peri-urban areas due to structural and behavioral vulnerabilities (du Plessis, 2023; Mishra *et al.*, 2021). Although groundwater is traditionally perceived as naturally purified and safe due to soil filtration processes, the lack of municipal pipe-borne water has forced a near-universal reliance on groundwater boreholes, which consequently are highly vulnerable to contamination from surrounding sanitation infrastructure and poor post-collection hygiene practices (La Vigna, 2022; Mukherjee *et al*., 2021; Ngayaga, 2025; Igimoh *et al.*, 2026). This vulnerability is clearly illustrated by the microbiological analysis of the 21 sampled borehole water supplies, where only five locations, specifically Loc1, Loc2, Loc3, Loc4, and Loc7, displayed absolute compliance with the World Health Organization (WHO) Guidelines for Drinking-water Quality of 0.0 CFU/mL for Total Viable Count (TVC), 0.0 MPN/100 mL for presumptive coliforms, and 0.0 CFU/100 mL for Escherichia coli (World Health Organization, 2017). Conversely, the remaining 16 boreholes (76.2%) failed to meet these standard potable criteria, which represents a severe and immediate public health threat to the community. The magnitude of this contamination peaked at Location 14, which exhibited extreme biological pollution across all indicators, recording a TVC of $82.2 \pm 5.59 \times 10^3$ CFU/mL, a presumptive coliform count of 25.4 ± 5.06 MPN/100 mL, and a faecal coliform (E. coli) count of 11.6 ± 2.14 CFU/100 mL, whereas Location 21 recorded the lowest TVC among the contaminated sites at $40.2 \pm 6.82 \times 10^3$ CFU/mL, though it was still heavily contaminated with a presumptive coliform count of 7.8 ± 2.10 MPN/100 mL and an E. coli load of 4.0 ± 1.09 CFU/100 mL. Interestingly, Location 15 was the sole contaminated site where faecal coliforms were not isolated, despite displaying an elevated TVC of $60.4 \pm 4.41 \times 10^3$ CFU/mL and a presumptive coliform count of 8.4 ± 2.20 MPN/100 mL. In order to identify the specific pathogens driving this biological contamination, morphological and biochemical profiling was conducted, which confirmed the presence of three major presumptive taxonomic groups: presumptive *Escherichia coli* (isolated except from Loc1, 2, 3, 4, and 7), presumptive *Klebsiella spp.* (isolated from Loc6, 9, 11, and 17), and presumptive Enterobacter / *Citrobacter spp*. (isolated from Loc13, 20, and 21). The contaminated locations with E-coli serves as a definitive indicator of recent faecal contamination and highlights a high risk of waterborne gastroenteritis, typhoid, and bacillary dysentery. These microbiological findings align closely with several recent studies across Nigeria and Sub-Saharan Africa; for instance, Okoye and Nyandjou (2024) in the Gusau metropolis similarly reported bacteriological and coliform counts exceeding WHO allowable limits, isolating E. coli, *Salmonella typhi*, and *Shigella species*, while

Ndukauba et al. (2025) reported that both municipal and borehole water in Abia State failed WHO standards with heterotrophic counts exceeding 10^3 CFU/mL. Furthermore, Emeka et al. (2026) revealed measurable coliform and faecal coliform loads in the boreholes of Rumuokoro, Port Harcourt, classifying the water as very poor, which is consistent with findings by Justin *et al.* (2024) in Sèmè-Podji, Benin, who documented widespread borehole contamination with thermotolerant coliforms and E. coli, implicating poor maintenance and hygiene. In contrast, Eze et al. (2024) found no bacterial growth in parish boreholes in Awka, but detected fungal contaminants like *Aspergillus*, *Fusarium*, and *Penicillium species*, demonstrating that although bacterial pathogens represent the primary microbiological risk in Ilese-Ijebu, a comprehensive public health monitoring framework must remain cognizant of the wider microbial spectrum. This biological contamination is directly linked to substandard borehole siting and environmental sanitation hazards, as standard guidelines recommend a minimum 30-meter lateral separation distance between boreholes and on-site sanitation systems to permit natural subsurface filtration of pathogens. In Ilese-Ijebu, however, the observational sanitary survey revealed that 85.7% of the assessed boreholes violate this safety margin by being located within 30 meters of a toilet or septic tank. Additionally, 76.2% of the boreholes are situated in close proximity to open dump sites, 71.4% are exposed to surface wastewater flow or flooding near the borehole head, and 57.1% lack functional concrete sanitary seals, meaning that multiple interacting pathways allow surface run-off and subsurface leachate to enter the casings. This environmental vulnerability is strongly corroborated by Olowomofe and Olowomofe (2025) in Kaduna, who demonstrated that boreholes near municipal dump sites and latrines are highly susceptible to leachate migration, resulting in high total bacterial and faecal coliform loads, which is also consistent with Maroua, Far North Cameroon, where Djaouda et al. (2018) attributed widespread coliform and E. coli contamination to the physical closeness of boreholes to domestic waste and latrines. Conversely, Sone *et al*. (2024) reported that sampled boreholes in the Messassi district of Yaoundé, Cameroon, remained fully compliant with recommended microbiological standards, attributing this safety to proper structural protection and distance from contamination sources, which contrasts with the poor casing security and spatial clustering observed in Ilese-Ijebu. Beyond source contamination, this study also highlights household storage and handling practices as a major secondary contamination vector, as the household survey revealed that 90% of residents rely on narrow-necked plastic jerry cans and 20% store water in open containers. Because plastic jerry cans have narrow openings, they restrict internal scrubbing and facilitate the development of bacterial biofilms on container walls, a risk that is heavily compounded by the fact that 80% of residents reported never washing their hands before fetching water, 40% clean their containers only sometimes, and 16% rarely or never wash them. These results are strongly supported by Adeyemi et al. (2020) in Oyo town, who conducted a comparative analysis of stored borehole water in student hostels, isolating 13 bacterial genera including *Escherichia coli*, *Klebsiella pseudomonas*, *Aeromonas*, and *Staphylococcus* and finding that total viable counts reached 1.23×10^5 CFU/mL due to irregular storage sanitation and poor hand hygiene, confirming that post-collection handling routinely compromises initially clean groundwater. Ultimately, this physical and microbiological water safety crisis is heavily maintained by a profound public health knowledge-practice gap among Ilese-Ijebu residents. While groundwater is highly vulnerable to surface and subsurface contamination, the KAP survey showed that 62% of residents believe groundwater is naturally immune to pollution, 58% are ignorant of the 30-meter septic buffer rule, and 71% believe borehole water does not require any form of treatment before consumption. Furthermore, 66% considered water treatment unnecessary, 54% expressed indifference or unwillingness to relocate latrines away from boreholes, and 74% judged water safety purely based on sensory cues like visual clarity, colour, and lack of odour, ignoring the invisible nature of microbial pathogens. Consequently, unsafe practices are pervasive: 68% of residents never or rarely treat their

water before drinking, 99% have never conducted routine biological testing of their water, 60% maintain their borehole concrete sanitary aprons poorly, and 45% engage in open defecation or improper waste dumping near borehole heads. This pattern of behavioral complacency is consistent with observations by Nfor and Chigor (2025) in the Amansea livestock market settlements, where borehole water regularly failed coliform standards because very few households treated their water despite moderate hygiene awareness, and Ndukauba et al. (2025) in Abia State, who reported that a lack of point-of-use disinfection left households vulnerable to high coliform loads. This behavioral-practice disconnect is also supported by Adegbite et al. (2026) in Abeokuta Urban, who found that general knowledge of groundwater vulnerability does not translate meaningfully into protective practices like home treatment, as well as Adegbite et al. (2022) in urban centres of Ogun state namely Abeokuta, Ota, Sagamu and Ijebu Ode, where poor risk perceptions regarding groundwater quality were strongly associated with high local waterborne disease incidences regardless of formal education levels.

Therefore, this study demonstrates that the water quality issue in the study area, is a multi-dimensional challenge requiring both structural and behavioral solutions, including the enforcement of a strict 30-meter sanitary buffer zone between boreholes and septic systems, community-wide WASH sensitization campaigns to debunk the visual clarity myth, and the implementation of subsidized household point-of-use disinfection protocols such as boiling, chlorination, and filtration to bypass immediate infrastructural deficits.

CONCLUSION

The microbiological quality of borehole water in Ilese-Ijebu, Ogun State, was found to constitute a potential public health concern. Microbiological contamination was detected in several sampled boreholes, and pathogenic organisms, including presumptive *Escherichia coli*, *Klebsiella spp*., and *Enterobacter spp*., were isolated, suggesting faecal contamination. The contamination was considered to be associated with inadequate borehole siting, particularly where boreholes were located close to pit latrines and septic tanks. Poor domestic water-storage hygiene was also identified as a contributing factor. At the same time, inadequate knowledge, attitudes, and practices regarding borehole water safety were considered to have further increased the risk of contamination.

To address the identified water safety and public health challenges, sanitary buffer zones should be enforced to ensure adequate separation between boreholes and on-site sanitation facilities. Community-based WASH education should be strengthened to improve awareness of groundwater contamination and the limitations of visual assessment of water quality.

Residents should also be encouraged and trained to adopt appropriate point-of-use water treatment methods, including boiling, solar disinfection, and chlorination. Improved household water-storage hygiene should be promoted through regular cleaning of storage containers and proper hand hygiene during water handling. In addition, routine microbiological monitoring of borehole water should be established, while boreholes should be adequately protected with sanitary seals and concrete aprons to minimize the entry of contaminated surface runoff.

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