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(Research Article)

# Microbiological and physicochemical evaluation of drinking water sources in rural communities of Offa local government area, Nigeria

Idowu Sunday David [1,*], Awe Adewole Sunday [2] and Emiola Olawale K Steve [3]

[1] *Department of Biochemical and Chemical Sciences, Federal Polytechnic, Offa, Kwara State.*
[2] *Department of Biological Sciences, Federal Polytechnic, Offa, Kwara State.*
[3] *Department of Mathematics, Federal Polytechnic, Offa, Kwara State.*

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## Abstract

Access to microbiologically safe drinking water remains a major public health challenge in many rural communities across sub-Saharan Africa. This study evaluated the physicochemical characteristics and microbial quality of drinking water sources across twenty communities in Offa Local Government Area, Kwara State, Nigeria. Water samples were collected from boreholes, hand-dug wells, and surface streams during the dry season and analyzed for pH, turbidity, total coliforms, and *Escherichia coli* using a chromogenic microbial detection kit. The pH values ranged from 6.2 to 7.9, indicating that most water sources fell within the recommended World Health Organization (WHO) guideline range for drinking water (6.5–8.5). However, turbidity levels varied substantially among source types, with boreholes exhibiting low turbidity (0.8–1.1 NTU) while stream sources recorded significantly higher values (11.9–12.9 NTU), exceeding the WHO recommended limit of 5 NTU. Microbiological analysis revealed widespread contamination across the study area. Total coliform counts ranged from 1 to 200 CFU/100 mL, while *E. coli* concentrations varied between 0 and 110 CFU/100 mL. Sixteen out of the twenty sampled communities failed to meet WHO microbial safety standards due to the presence of *E. coli*. Surface water sources demonstrated the highest contamination levels, whereas boreholes exhibited comparatively lower microbial loads and higher compliance rates. A positive relationship was observed between turbidity and bacterial contamination, indicating that elevated particulate matter may facilitate microbial persistence in water systems. These findings highlight the substantial health risks associated with untreated water sources in the study area and underscore the need for routine water quality monitoring, improved sanitation infrastructure, and sustainable water treatment interventions to safeguard community health.

**Keywords:** Drinking water quality; Microbial contamination; Escherichia coli; Turbidity; Rural water systems; Nigeria

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## 1. Introduction

Access to clean and safe drinking water is a fundamental human right, yet millions of people worldwide lack this basic necessity. The global water crisis is a pressing issue, with approximately 2.2 billion people lacking access to safely managed drinking water services (World Health Organization [WHO], 2023). In Nigeria, the situation is particularly dire, as over 60 million people do not have access to clean water, and waterborne diseases such as cholera, typhoid, and diarrhea remain prevalent (UNICEF, 2022). Contaminated water sources, inadequate infrastructure, and rapid urbanization exacerbate the problem, disproportionately affecting rural and low-income communities (Akpan *et al.*, 2021).

Current water purification methods, such as chlorination, reverse osmosis, and ultraviolet (UV) treatment, have proven effective in many contexts. However, these methods often face significant limitations. For instance, chlorination can

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[*] Corresponding author: Idowu Sunday David

produce harmful by-products, while reverse osmosis and UV treatment are energy-intensive and costly, making them inaccessible to underserved populations (Okioga, 2020). Additionally, chemical-based purification methods can have adverse environmental impacts, such as the release of toxic residues into ecosystems (Adesina *et al*., 2019). These challenges highlight the need for innovative, affordable, and sustainable solutions to address water contamination.

Microbial-based water purification presents a novel and eco-friendly alternative to conventional methods. Certain microorganisms, such as Pseudomonas, Bacillus, and Actinobacteria, have demonstrated the ability to degrade organic pollutants, remove heavy metals, and eliminate pathogenic bacteria from water (Okeke *et al*., 2021). These microbial strains can be harnessed to develop a low-cost, locally produced water purification kit that is both effective and environmentally sustainable. By leveraging the natural capabilities of microorganisms, this approach offers a scalable solution that can be adapted to diverse contexts, particularly in resource-limited settings. This project aligns with both national and global sustainability goals, particularly United Nations Sustainable Development Goal 6 (SDG 6), which aims to ensure availability and sustainable management of water and sanitation for all by 2030 (United Nations, 2015). Furthermore, the initiative supports Nigeria's National Water Resources Policy, which emphasizes the importance of innovative technologies to improve water quality and accessibility (Federal Ministry of Water Resources, 2020). By developing a locally produced microbial water purification kit, this project seeks to address the urgent need for clean water while promoting environmental sustainability and community resilience.

## 2. Methodology

### 2.1. Study Area and Site Selection

The research was conducted across 20 distinct rural and peri-urban communities within the Offa Local Government Area of Kwara State, Nigeria. Offa is situated in the guinea savannah vegetation zone, characterized by a tropical climate with distinct wet and dry seasons. The selected communities—including Igbawere, Ikotun, Ajase-Ipo axis settlements, and Kani—were chosen based on their high reliance on untreated groundwater and surface water sources for domestic consumption. A total of 20 sampling sites were established, encompassing a mix of hand-dug wells (n=10), motor-pumped boreholes (n=6), and open streams or surface water collection points (n=4). These sites represent the primary water infrastructure available to the local population, where centralized municipal treatment is largely absent.

### 2.2. Water Sample Collection

Sampling was carried out during the peak of the dry season to capture baseline microbial loads when water tables are lower and contaminant concentrations often peak. Samples were collected aseptically using pre-sterilized 250 mL high-density polyethylene (HDPE) bottles. For boreholes and wells with pumps, the outlets were flamed and allowed to run for three minutes prior to collection. For open wells and streams, grab samples were taken at a depth of 20–30 cm using weighted sterile samplers. All samples were labeled, stored in insulated cool boxes at approximately 4°C, and transported to the laboratory for analysis within six hours of collection to maintain microbial integrity.

### 2.3. Physico-Chemical Analysis

Baseline physical parameters were measured in situ to provide environmental context for microbial survival. The pH of the water samples was determined using a portable digital pH meter (Hanna Instruments) calibrated with standard buffer solutions at pH 4.0 and 7.0. Turbidity, expressed in Nephelometric Turbidity Units (NTU), was measured using a pre-calibrated turbidimeter. These parameters serve as critical indicators; as high turbidity is often correlated with increased microbial shielding from natural or chemical disinfection.

### 2.4. Microbial Detection Using Water Testing Kit

Microbiological assessment was performed using a commercially available chromogenic microbial water testing kit designed for the rapid detection and semi-quantitative enumeration of indicator bacteria. The kit utilizes a defined substrate technology where specific enzymes produced by the target bacteria β-galactosidase for total coliforms and β-glucuronidase for *Escherichia coli* react with dehydrated nutrients and chromogenic/fluorogenic substrates.

A 100 mL volume of each sample was added to the test vessels and incubated at 35°C for 24 hours. Following incubation, presence was determined by a distinct color change (yellow for total coliforms) and fluorescence under long-wave UV light (366 nm) for *E. coli*. While these kits offer high sensitivity and field utility, it is acknowledged that they lack the precision of membrane filtration or multiple-tube fermentation for exact colony forming unit (CFU) counts, providing instead a reliable categorical risk assessment (Present/Absent or Most Probable Number estimates).

### 2.5. Quality Control and Data Analysis

Standard laboratory protocols were followed to ensure data reliability. Field blanks using sterile distilled water were processed alongside environmental samples to check for secondary contamination during transport. All tests were performed in duplicate. Data were compiled and analyzed using descriptive statistics to determine the percentage of samples exceeding the World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) limits, which mandate zero detectable *E. coli* per 100 mL.

## 3. Results

**Table 1** Physico-Chemical Characteristics of Water Samples from 20 Communities

| S/N | Community | Water Source | pH | Turbidity (NTU) |
|---|---|---|---|---|
| **1** | Igbawere | Hand-dug Well | 6.4 | 4.2 |
| **2** | Ikotun | Borehole | 7.1 | 0.8 |
| **3** | Igosun | Stream | 7.8 | 12.5 |
| **4** | Kani | Hand-dug Well | 6.2 | 5.1 |
| **5** | Ojoku Axis | Borehole | 6.9 | 1.1 |
| **6** | Ilemona | Hand-dug Well | 6.5 | 4.0 |
| **7** | Erin- ile | Hand-dug Well | 6.3 | 4.3 |
| **8** | Eleyoka | Hand-dug Well | 6.4 | 4.2 |
| **9** | Kere – aje | Stream | 7.9 | 12.3 |
| **10** | Igbodun | Stream | 7.7 | 12.5 |
| **11** | Inaji maliki | Stream | 7.9 | 12.1 |
| **12** | Iraa | Hand-dug Well | 6.9 | 4.1 |
| **13** | Ogbodoronko | Stream | 7.9 | 12.9 |
| **14** | Gaa- Fulani | Stream | 7.2 | 12.2 |
| **15** | Gaa – olomifunfun | Stream | 7.1 | 11.9 |
| **16** | Ipee 1 | Borehole | 7.1 | 1.1 |
| **17** | Ipee 2 | Hand-dug Well | 6.5 | 4.3 |
| **18** | Ipee 3 | Borehole | 6.9 | 1.0 |
| **19** | Igbawere | Stream | 7.8 | 12.5 |
| **20** | Aboto | Stream | 7.8 | 12.3 |

**Table 2** Microbial Quality and WHO Compliance

| S/N | Community | Total Coliforms (est. CFU/100 mL) | E. coli (est. CFU/100 mL) | WHO Compliance |
|---|---|---|---|---|
| **1** | Igbawere | 140 | 12 | No |
| **2** | Ikotun | 8 | 0 | Yes |
| **3** | Igosun | 197 | 45 | No |
| **4** | Kani | 86 | 4 | No |
| **5** | Ojoku Axis | 2 | 0 | Yes |

| | | | | |
|---|---|---|---|---|
| **6** | Ilemona | 120 | 23 | No |
| **7** | Erin- ile | 200 | 21 | No |
| **8** | Eleyoka | 140 | 110 | No |
| **9** | Kere – aje | 123 | 25 | No |
| **10** | Igbodun | 123 | 15 | No |
| **11** | Inaji maliki | 132 | 42 | No |
| **12** | Iraa | 180 | 20 | No |
| **13** | Ogbodoronko | 179 | 32 | No |
| **14** | Gaa- Fulani | 159 | 19 | No |
| **15** | Gaa – olomifunfun | 110 | 25 | No |
| **16** | Ipee 1 | 1 | 0 | Yes |
| **17** | Ipee 2 | 190 | 21 | No |
| **18** | Ipee 3 | 3 | 0 | Yes |
| **19** | Igbawere | 197 | 39 | No |
| **20** | Aboto | 187 | 50 | No |

The analytical results indicate a significant variation in water quality based on source type. Boreholes generally exhibited lower turbidity and higher compliance with safety standards, with 83% of borehole samples showing an absence of *E. coli*. Conversely, 100% of stream samples and 90% of hand-dug wells tested positive for both total coliforms and *E. coli*. Turbidity levels in surface water sources frequently exceeded the WHO recommended limit of 5 NTU, reaching as high as 12.5 NTU in community stream sites.

## 4. Discussion

The physicochemical and microbiological evaluation of water sources across the twenty sampled communities reveals substantial spatial variation in water quality and highlights significant public health concerns associated with untreated surface and groundwater supplies. The data demonstrate a clear relationship between water source type, physicochemical parameters, and microbial contamination, emphasizing the vulnerability of rural water systems to environmental and anthropogenic contamination.

The physicochemical analysis presented in Table 1 indicates that the pH of the sampled water sources ranged from 6.2 to 7.9, suggesting that most of the water samples fall within the acceptable limits recommended for drinking water (pH 6.5–8.5) by the World Health Organization guidelines. Slightly acidic conditions were observed in several hand-dug wells, including Kani (pH 6.2) and Erin-ile (pH 6.3), whereas stream sources such as Kere-aje (pH 7.9) and Ogbodoronko (pH 7.9) exhibited more alkaline conditions. Variations in pH among groundwater and surface water systems are commonly associated with mineral dissolution, soil composition, and microbial processes occurring within aquifers and catchment areas.

Turbidity levels displayed pronounced differences between water source categories. Borehole samples consistently exhibited low turbidity values (0.8–1.1 NTU), whereas hand-dug wells recorded moderate turbidity levels (4.0–5.1 NTU). In contrast, stream sources showed substantially elevated turbidity values ranging from 11.9 to 12.9 NTU, exceeding the recommended limit of 5 NTU for potable water. The highest turbidity was recorded in Ogbodoronko (12.9 NTU), followed by Igosun and Igbodun (12.5 NTU). Elevated turbidity in surface water systems often reflects suspended particulate matter, organic debris, and microbial aggregates, which may originate from runoff, erosion, or anthropogenic disturbances within the watershed.

High turbidity values are particularly concerning because suspended particles can protect microorganisms from environmental stress and disinfection processes, thereby facilitating microbial persistence in water systems. Similar findings have been reported in rural groundwater and surface water investigations, where increased turbidity was positively associated with microbial contamination and fecal indicator bacteria in drinking water supplies (Mutileni *et* *al*., 2023; Santos, Wendt *et al*., 2023). These results suggest that the elevated turbidity observed in stream sources within the study area may contribute to the higher microbial loads subsequently observed in these water systems.

Furthermore, the marked difference in turbidity between boreholes and surface waters underscores the role of natural filtration processes within aquifers. Borehole water typically undergoes filtration through soil and geological strata, which removes suspended particles and reduces microbial contamination. However, the effectiveness of this filtration depends on borehole construction integrity, proximity to contamination sources, and hydrogeological conditions.

The microbial analysis summarized in Table 2 reveals widespread bacteriological contamination across the majority of sampled water sources. According to the drinking water safety criteria of the World Health Organization, *Escherichia coli* must be absent in any 100 mL drinking water sample, as its presence indicates recent fecal contamination and potential exposure to enteric pathogens. In the present study, 16 of the 20 sampled communities failed to meet this standard, indicating that a large proportion of the water sources pose potential health risks.

Total coliform counts ranged from 1 to 200 CFU/100 mL, with the highest values observed in Erin-ile (200 CFU/100 mL), Igosun (197 CFU/100 mL), and Igbawere stream (197 CFU/100 mL). In contrast, borehole sources such as Ipee 1 (1 CFU/100 mL) and Ojoku Axis (2 CFU/100 mL) exhibited minimal contamination levels. Similarly, *E. coli* counts varied widely from 0 to 110 CFU/100 mL, with the highest concentration recorded in Eleyoka (110 CFU/100 mL). These findings indicate substantial fecal contamination within several water sources and suggest the possible infiltration of human or animal waste into the water supply.

The relationship between water source type and microbial contamination is evident in the data. Stream sources generally displayed the highest levels of bacterial contamination, whereas boreholes exhibited the lowest counts and achieved full compliance with WHO standards in several cases. For example, Ikotun, Ipee 1, and Ipee 3 boreholes showed zero E. coli counts, indicating microbiologically safer water compared with the other sources. This pattern aligns with previous studies demonstrating that surface water bodies are more susceptible to microbial contamination due to exposure to runoff, agricultural activities, and sanitation infrastructure deficiencies (Olalemi *et al*., 2021; Santos *et al*., 2023).

Hand-dug wells exhibited intermediate contamination levels, suggesting that they are vulnerable to microbial infiltration from surrounding environments. For instance, Ilemona (120 CFU/100 mL total coliforms) and Ipee 2 (190 CFU/100 mL) demonstrated significant bacterial loads despite being groundwater sources. Such contamination may occur when wells are poorly protected, shallow, or located near pit latrines and waste disposal areas. Recent investigations in rural African communities have similarly documented microbial contamination in groundwater systems due to inadequate sanitation infrastructure and insufficient protection of water abstraction points (Mutileni *et al*., 2023; Heliyon groundwater contamination study, 2024).

### 4.1. Relationship Between Physicochemical and Microbial Parameters

The combined analysis of Tables 1 and 2 reveals an important association between turbidity and microbial contamination. Communities supplied by highly turbid water sources, particularly streams, generally exhibited higher coliform and *E. coli* counts. For example, Igosun, which recorded a turbidity of 12.5 NTU, also exhibited one of the highest total coliform counts (197 CFU/100 mL) and 45 CFU/100 mL *E. coli*. Similarly, Ogbodoronko, with the highest turbidity (12.9 NTU), showed substantial bacterial contamination (179 CFU/100 mL total coliforms).

This correlation is consistent with the well-established role of turbidity as an indicator of microbial contamination risk. Suspended particles provide surfaces that facilitate bacterial attachment and biofilm formation, thereby increasing microbial persistence in aquatic environments. Consequently, elevated turbidity often reflects increased microbial activity and organic matter within water systems. Studies evaluating rural water supplies in sub-Saharan Africa have demonstrated that turbidity is strongly associated with fecal indicator bacteria in drinking water sources, particularly where untreated surface water is used for domestic consumption (Santos *et al*., 2023).

The widespread presence of fecal indicator bacteria observed in this study has important implications for public health. The detection of *E. coli* in 80 % of the sampled communities suggests a high likelihood of exposure to enteric pathogens, including bacteria, viruses, and protozoa that cause gastrointestinal infections. Contaminated drinking water remains a major contributor to waterborne diseases such as diarrhea, typhoid fever, and cholera, particularly in rural communities where water treatment and sanitation infrastructure are limited.

The relatively better microbiological quality of borehole water suggests that properly constructed and protected groundwater systems may represent safer drinking water options within the study area. However, even groundwater sources may become contaminated if located close to sanitation facilities or if the structural integrity of the borehole is compromised. Therefore, routine monitoring and protection of water infrastructure are essential to ensure the safety of community water supplies.

## 5. Conclusion

This assessment confirms that a significant portion of the drinking water used in the communities surrounding Offa does not meet international safety standards for human consumption. The high prevalence of *E. coli* in hand-dug wells and streams constitutes a clear public health risk. The study demonstrates that rapid microbial detection kits are effective tools for identifying "hotspots" of contamination where immediate intervention is required. To move toward achieving Sustainable Development Goal (SDG) 6, it is recommended that local health authorities implement regular microbial monitoring and prioritize the construction of deep, protected boreholes. Further research using molecular techniques is suggested to identify the specific strains of pathogens present in these sources.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest.

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