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Bacteriological Quality of Borehole Water, its Health and Environmental Implications in Nnewi North L. G. A, Anambra Metropolis

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A B S T R A C T

This research evaluated the bacteriological safety of borehole water in Nnewi North Local Government Area (LGA) of Anambra State, Nigeria, to determine its suitability for human consumption and its potential environmental impact. Ten borehole water samples were collected from five communities within the LGA: Ndimgbu, Ukpor, Amiliba, Okofia, and Utuh. These samples were analyzed for total bacterial count (TBC), total coliforms, and fecal coliforms. Using standard morphological and biochemical tests, we isolated and identified various bacterial species. The results showed that all ten water samples were heavily contaminated, exceeding safe levels for TBC, total coliforms, and fecal coliforms. The water was therefore deemed unfit for drinking. Six bacterial species were identified: *Streptococcus pyogenes*, *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella sp.*, *Proteus sp.*, and *Bacillus subtilis*. *Staphylococcus aureus* and *Streptococcus sp.* were the most frequently isolated organisms. A one-sample t-test confirmed the statistical significance of the contamination, revealing a substantial difference ($p < 0.05$) between the bacterial counts in the borehole water and the World Health Organization's (WHO) recommended safety standards. This confirmed the water's unsafe quality. Based on these findings, the study concludes that the high level of contamination in Nnewi North LGA's borehole water poses a serious health risk to residents. We recommend a multi-faceted approach to address this issue, including the installation of water treatment facilities, promotion of improved hygiene and sanitation, and regular water quality monitoring. Public awareness campaigns are also essential to educate the community on the risks of waterborne diseases. It is crucial for local government and health authorities to prioritize sustainable solutions to ensure safe drinking water and protect public health in the region. This study underscores the urgent need for action to improve water management and sanitation in Nnewi North LGA and similar communities in Nigeria.

Keyword: *Bacteriological quality, Environment, Health risks, Monitoring, Portable water*

Introduction

Water is critical for all life and ecological stability. Although a person can survive without food for an extended period, they cannot go without water for more than three days (Awari et al., 2023; Ukpong et al., 2013; Akin-Osanaiye et al., 2018). Globally, over a billion people lack access to safe drinking water, and even more lack adequate sanitation (Tar et al., 2009). In many developing nations like Nigeria, the public water supply is unreliable or nonexistent. Due to this, people often rely on groundwater from shallow wells and boreholes as a primary water source (LAWMA, 2000). While natural groundwater is typically high-quality, poor management and inadequate protection can lead to contamination (Awari et al., 2023; Sadiya et al., 2018; Agu et al., 2014). Clean, safe, and sufficient freshwater is vital for the health of all living

organisms, ecosystems, and economies (Akoteyon, 2013; Amadi-Ikpa & Awari, 2023). Water is essential for daily domestic, agricultural, and industrial activities. These demands, particularly on groundwater resources, put pressure on available reserves and can compromise water quality (Lapworth et al., 2016; Awari et al., 2023). Ensuring water is potable for drinking is therefore crucial for public health (Olaniyan & Tsuzom, 2014). While surface water sources like rivers and lakes are generally more susceptible to contamination, groundwater sources (wells and boreholes) are often considered more reliable for household and agricultural use (Okeola et al., 2010; Agu et al., 2023). However, even groundwater can be compromised, leading to significant public health concerns. As noted by Abana et al. (2024), access to clean water is a fundamental human right, and its absence can lead to waterborne illnesses like cholera and typhoid fever. This is a major issue in Nigeria, where many people depend on unregulated and vulnerable water sources (WHO, 2018; Agu et al., 2023; Ezeokoli et al., 2023). The **bacteriological quality** of water, which indicates the presence of bacteria such as coliforms, is a key metric for determining its safety.

In Nnewi North Local Government Area (LGA), like many similar communities in Nigeria, boreholes are a primary water source. While boreholes are often viewed as a safer alternative to surface water, they are not immune to contamination from factors such as faulty construction, proximity to septic tanks, or agricultural runoff (Ibe et al., 2014; Agu et al., 2014). This contamination is a serious public health concern, as ingesting tainted water can cause gastrointestinal diseases, particularly in vulnerable populations. Despite the widespread use of boreholes in this region, there has been limited research into their bacteriological quality. The goal of this study is to address this gap by analyzing the **microbial contamination** levels in Nnewi North LGA boreholes. By measuring indicators like total coliform and fecal coliform, we aim to assess the safety of these water sources and provide essential data for local authorities and policymakers.

Methodology

Study Design

This study employed a comparative research design to systematically analyze and compare the bacteriological quality of borehole water in Nnewi North LGA. The design allows for a direct comparison of water quality from different boreholes to identify significant differences in contamination levels. The research will focus on isolating and quantifying bacterial indicators to provide insights into the safety and suitability of these water sources for human consumption.

Study Area and Population

The study was conducted in Nnewi North LGA, located in Anambra State, Nigeria. The area features a blend of urban and rural settlements and a diverse range of water sources. The target population consisted of water samples from boreholes used by households and the public. Samples were collected from various geographic and socioeconomic settings to provide a comprehensive overview of water quality.

Sampling

A **random sampling technique** was used to select at least 10 borehole water samples from across the LGA to ensure the data is representative and statistically significant. This method helps to eliminate bias and accounts for potential variations due to environmental or infrastructural factors.

Laboratory Analysis

- **Sterilization:** All laboratory materials, including glassware and culture media, were sterilized by autoclaving at 121°C for 15 minutes or in a dry oven at 150°C for one hour. The workbench was cleaned with isopropyl alcohol.

- **Sample Dilution:** A **spread plate method** was used for total bacterial counts. A tenfold serial dilution of the water samples was prepared in sterile saline solution up to a 10−5 dilution. A specific volume of the diluted sample

was then spread onto various agar plates for incubation. The colonies were counted and the total count per ml was calculated.

- **Coliforms:** The **Multiple-Tube Fermentation (MTF) Technique**, also known as the Most Probable Number (MPN) method, was used to determine fecal coliforms. This test involves three stages: **presumptive**, **confirmatory**, and **completed** tests.
- **Biochemical Tests:** Isolated colonies were identified using a series of biochemical tests, including:
    - **Oxidase test:** Detects the presence of cytochrome c oxidase.
    - **Catalase test:** Tests for the enzyme catalase.
    - **Indole test:** Determines if the bacteria can break down tryptophan.
    - **Coagulase test:** Checks for the enzyme coagulase, which causes plasma to clot.
    - **Motility test:** Assesses bacterial movement in a semi-solid medium.
    - **Triple Sugar Iron (TSI) test:** Identifies bacteria based on their ability to ferment sugars and produce hydrogen sulfide.
    - **Gram Staining:** This fundamental test differentiates bacteria into **Gram-positive** (purple) or **Gram-negative** (red/pink) based on their cell wall.

Data Analysis

The bacteriological data will be analyzed using statistical methods:

- **Descriptive Statistics:** Measures like mean and standard deviation will be used to summarize the data.
- **Inferential Statistics:** T-tests or ANOVA will be used to compare contamination levels between different water sources and determine if the differences are statistically significant.
- **Correlation Analysis:** This will be used to explore the relationship between contamination levels and environmental variables like the depth of the borehole or proximity to sewage.

RESULTS

Table 1: Bacterial Load in Borehole Water in Nnewi North LGA, Anambra State.

Sample ID	TBC (cfu/ml)	Total Coliform (cfu/ml)	Feacal coliform (MPN/ml)
ND1	2.0×10^{5}	1.0×10^{2}	1.0×10^{2}
ND2	2.0×10^{5}	1.0×10^{2}	1.0×10^{2}
UK1	6.0×10^{4}	0	0
UK2	2.0×10^{5}	0	0
AM2	4.0×10^{4}	2.0×10^{4}	0

Sample ID	TBC (cfu/ml)	Total Coliform (cfu/ml)	Feacal coliform (MPN/ml)
OK1	102	1.0×10^{2}	1.0×10^{2}
OK2	8.0×10^{4}	1.0×10^{2}	1.0×10^{2}
UT1	2.0×10^{5}	0	0
UT2	1.2×10^{5}	0	0

ND1: Ndimgbu community 1, ND2: Ndimgbu community 2, UK1: Ukpor community 1, UK2: Ukpor community 2, AM1: Amiliba community 1, AM2: Amiliba community 2, OK1: Okofia community 1, OK2: Okofia community 2, UT1: Utuh community 1, UT2: Utuh community 2.

The table above shows the bacterial load present in borehole water in Nnewi LGA, Anambra State.

Table 2: Identification of Bacteria Isolates by Characterization, Morphology and Biochemical Test from Borehole Water in Nnewi LGA, Anambra State.

S/N	GST	Mor	Ure	MTR	Ind	VoP	Cit	Cat	Oxi	Coa	Glu	Mal	Probable Bateria
1	+	Cocci	-	+	-	-	-	-	+	-	+	+	*Streptococcus pyogenes*
2	+	Cocci	-	+	-	-	-	+	-	+	+	+	*Staphylococcus* sp
3	+	Rod	-	-	-	+	-	+	+	-	+	+	*Bacillus subtilis*
4	-	Rod	+	+	+	-	-	+	-	-	+	+	*Proteus* sp
5	-	Rod	-	+	+	-	-	+	-	-	+	-	*Escherichia coli*
6	-	Rod	+	-	-	+	+	+	-	-	-	+	*Klebsiella* sp

S/N for Isolates, Mor: Morphology, Gst: Gram staining, Ur: Urea, MR:Methyl red, Ind: Indole, VP: Voges Proskauer, Cit: Citrate, Oxi: Oxidase, Coa: Coagulase, G: Glucose, M: Maltose, Co: Cocci, R: Rod.

The table above shows that six (6) organisms were isolated from the borehole water in Nnewi LGA, Anambra state and they include, *Streptococcus pyogenes*, *Staphylococcus* sp, *Bacillus subtilis*, *Proteus* sp, *Escherichia coli* and *Klebsiella* sp.

Table 3: The Bacteriological Quality of Borehole Water in Nnewi North LGA, Anambra State.

Sample ID	Bacteriological quality
ND1	Unsafe according to WHO Standard
ND2	Unsafe according to WHO Standard
UK1	Unsafe according to WHO Standard
UK2	Unsafe according to WHO Standard

Sample ID	Bacteriological quality
AM1	Unsafe according to WHO Standard
AM2	Unsafe according to WHO Standard
OK1	Unsafe according to WHO Standard
UT2	Unsafe according to WHO Standard
UT1	Unsafe according to WHO Standard
OK2	Unsafe according to WHO Standard

ND1: Ndimgbu community 1, ND2: Ndimgbu community 2, UK1: Ukpor community 1, UK2: Ukpor community 2, LJAM1: Amiliba community 1, AM2: Amiliba community 2, OK1: Okofia community 1, LJOK2: Okofia community 2, UT1: Utuh community 1, UT2: Utuh community 2.

The table above shows that all 10(100%) of the borehole water in Nnewi North LGA, Anambra state is unsafe for drinking. Water was declared unsafe according to WHO standard (WHO, 2023).

Recommended Standards for Safe Drinking Water (Bacteriological Quality) by WHO:

Total Coliforms

WHO Standard: 0 CFU/100 mL (Colony Forming Units per 100 mL of water) for potable water.

Presence of coliform bacteria indicates possible contamination from the environment or fecal matter.

Fecal Coliforms (E. coli)

WHO Standard: 0 CFU/100 mL

E. coli serves as an indicator of recent fecal contamination, which may pose a serious health risk.

Enterococcus spp.

WHO Standard: 0 CFU/100 mL

Indicates fecal contamination, often used as an additional bacteriological marker in water quality assessment.

Total Heterotrophic Bacteria Count (THBC)

WHO Guideline: Not specifically stated, but generally ≤ 500 CFU/mL is considered acceptable for drinking water.

Elevated levels may indicate poor water treatment or microbial regrowth.

Vibrio cholerae (Cholera bacterium)

WHO Standard: 0 CFU/100 mL

Critical for areas prone to cholera outbreaks.

Salmonella spp.

WHO Standard: 0 CFU/100 mL

Presence indicates significant health risks.

Shigella spp.

WHO Standard: 0 CFU/100 mL

Indicates contamination from human or animal fecal sources.

Local Nigerian Standards

In Nigeria, NAFDAC and the Standard Organization of Nigeria (SON) align closely with WHO standards:

Total Coliforms and E. coli: 0 CFU/100 mL.

The water must be free from any pathogens, toxins, or microbial contaminants that could endanger public health.

Table 4: Identification of Bacteria Present in Borehole Water Sources in Nnewi North LGA, Anambra State.

Sample ID	Isolate
ND1	*Staphylococcus aureus*
	Streptococcus sp
	Klebsiella sp
ND2	*Staphylococcus aureus*
	Streptococcus sp
	Enterobacter
UK1	*Staphylococcus aureus*
UK2	*Staphylococcus aureus*
	Streptococcus sp
	Bacillus subtilis
AM1	*Bacillus subtilis*
	Staphylococcus aureus
	Proteus sp
AM2	*Staphylococcus aureus*
	Streptococcus sp

Sample ID	Isolate
	Enterobacter
OK1	*Streptococcus* sp
	E. coli
UT2	*Staphylococcus aureus*
	Streptococcus sp
	Bacillus subtilis
UT1	*Staphylococcus aureus*
	Streptococcus sp
OK2	*Staphylococcus aureus*
	Streptococcus sp
	E. coli

ND1: Ndimgbu community 1, ND2: Ndimgbu community 2, UK1: Ukpor community 1, UK2: Ukpor community 2, AM1: Amiliba community 1, AM2: Amiliba community 2, OK1: Okofia community 1, OK2: Okofia community 2, UT1: Utuh community 1, UT2: Utuh community 2.

The table above shows the microorganisms isolated from the borehole water in Nnewi LGA, Anambra.

Table 5: Prevalence of Bacteria in Borehole Water Sources in Nnewi North LGA, Anambra state.

Isolates	Number of samples	Frequency	Percentage
Staphylococcus aureus	10	9	90.0
Streptococcus sp	10	8	80.0
Klebsiella sp	10	1	10.0
Enterobacter	10	2	20.0
Bacillus subtilis	10	3	30.0
Proteus sp	10	1	10.0
E. coli	10	2	20.0

The table above shows that 9(90%) of the samples were contaminated by *Staphylococcus aureus*, 8(80%) were contaminated with *Streptococcus* sp, 3(30%) were contaminated by *Bacillus subtilis*, 2(20%) each were contaminated with *Enterobacter* and *E. coli* while 1(10%) each was contaminated with *Klebsiella* sp and *Proteus* sp.

Table 6 HYPOTHESIS TESTING

Parameter tested/100ml	Recommended standard	Samples	t-value	*p*-value
TBC (CFU/ml)	0	7.4×10^4	3.079	0.013

Significant mean difference at p<0.05, TBC: Total bacteria count.

Hypothesis 1

H_0: There is no significant difference between the bacterial count of borehole water compared to that of WHO.

H_1: There is a significant difference between the bacterial count of borehole water compared to that of WHO.

Test: One sample t-test

Alpha level: 0.05

t-value: 3.079

p-value: 0.013

Decision: Since p<0.05, the alternate hypothesis was therefore **accepted** and the null hypothesis was **rejected**. Hence, there was a significant difference between the bacterial count of borehole water compared to that of WHO. Therefore, the water quality is generally considered unsafe.

Discussion

This study on the bacteriological quality of borehole water in Nnewi North Local Government Area (LGA), Anambra State, provides a critical assessment of water safety in the region. The findings indicate that the water quality in this area is significantly below the standards set by the World Health Organization (WHO) and is generally unfit for human consumption.

As shown in our results, all collected borehole water samples exhibited varying degrees of bacterial contamination. Indicators of contamination, such as the total bacterial count (TBC), total coliforms, and fecal coliforms, were found at concerningly high levels in many samples. For instance, water from the Ndimgbu community had a TBC of 2.0×105 cfu/ml. This suggests unsanitary conditions, likely due to factors like poor waste disposal, inadequate sanitation practices, or pollution from nearby agricultural or industrial activities.

The study successfully isolated six distinct bacterial species from the samples. Of particular concern were the pathogenic bacteria identified, including *Staphylococcus aureus*, *Streptococcus sp.*, and *Escherichia coli*. The presence of *E. coli* is a strong indicator of fecal contamination, while *Staphylococcus aureus* is known to cause a variety of infections. The frequent occurrence of these pathogens confirms that the borehole water is a public health risk.

Further analysis of bacterial prevalence revealed that *Staphylococcus aureus* was the most common isolate, found in 90% of the samples. This aligns with other studies that have reported the presence of *Staphylococcus aureus* in contaminated water sources, especially in areas with substandard sanitation. Similarly, *Streptococcus sp.* was isolated from 80% of samples, and *Bacillus subtilis* from 30%, highlighting the widespread nature of the contamination. The regular detection of *E. coli* and other harmful bacteria constitutes a severe health hazard.

Statistical analysis confirmed that the bacterial contamination levels in the borehole water samples were significantly higher than the WHO's recommended safety limits for drinking water. A t-test with a p-value of 0.013 indicated a substantial difference between the observed bacterial counts and the acceptable standard of 0 cfu/100ml. This finding unequivocally supports the conclusion that the borehole water in the study area is unsafe for consumption and poses a serious health threat.

Conclusion

In summary, this study provides conclusive evidence that borehole water in Nnewi North LGA, Anambra State, is contaminated with alarming levels of bacteria and is unsafe to drink. The frequent isolation of pathogenic bacteria such as *Escherichia coli*, *Staphylococcus aureus*, and *Streptococcus sp*. points to significant public health risks. Our findings demonstrate that the water quality in this region fails to meet global standards for potable water.

Addressing this problem requires a comprehensive, collaborative approach. This should involve improving sanitation, implementing effective water treatment systems, and educating the community on safe water practices. It is imperative that both government bodies and local communities work together to improve water quality, which will, in turn, help reduce the incidence of waterborne diseases and protect public health. This research serves as a call to action for policymakers and health practitioners to prioritize water management and sanitation improvements in the region.

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