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Water Quality, Access, and Public Health Implications in Rural Communities: Evidence from Nsit Ubium, Akwa Ibom State, Nigeria

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Abstract

Access to safe water remains a critical challenge in rural Nigeria, with serious implications for public health and livelihoods. This study examines water quality, access patterns, and associated health risks in Nsit Ubium Local Government Area of Akwa Ibom State. Using a mixed-methods design, field sampling, laboratory analysis, household surveys, and spatial mapping were employed to evaluate microbial and chemical water quality, source reliability, infrastructure conditions, and accessibility patterns. Findings reveal widespread reliance on unprotected surface water sources and inadequately maintained boreholes. Laboratory results indicate elevated microbial contamination and deviations in selected chemical parameters beyond recommended safety thresholds. Long distances to water sources, seasonal variability, and weak institutional coordination exacerbate household vulnerability, particularly among women and children. Statistical analysis confirms a significant association between unsafe water and the prevalence of waterborne diseases, increased healthcare expenditure, and reduced labour productivity. The study concludes that strengthening rural public health outcomes requires integrated water-quality monitoring, infrastructure rehabilitation, sanitation improvement, and community-based governance systems. These interventions are critical for enhancing rural resilience and achieving sustainable development in agrarian communities.

Keywords: *Water quality; Rural water access; Public health; Waterborne diseases; Community water management; Nigeria.*

1. Introduction

Access to safe, sufficient, and reliable water is a fundamental prerequisite for human health, food security, agricultural productivity, and sustainable socio-economic development. Water resources underpin domestic consumption, sanitation, food production systems, public health outcomes, and rural livelihood sustainability. Global development frameworks, particularly Sustainable Development Goal 6 (SDG 6), recognise access to clean water and sanitation as essential for achieving inclusive and sustainable development (UNICEF, 2021; WHO, 2023). However, despite these commitments, rural communities in sub-Saharan Africa continue to experience persistent challenges in accessing safe and reliable water supplies, reflecting deep-seated structural, environmental, and institutional constraints (UNDP, 2022; WHO, 2023). Across sub-Saharan Africa, rural water insecurity remains a multidimensional development challenge driven by climate variability, population growth, environmental degradation, weak governance systems, and inadequate infrastructure investment (UNDP, 2022; FAO, 2023). Many rural populations depend on surface water bodies, shallow wells, and poorly constructed boreholes that are highly vulnerable to microbial and chemical contamination from agricultural runoff, waste disposal, open defecation, and seasonal flooding (WHO, 2023; UNICEF, 2021). As a result, the physical availability of water resources does not necessarily translate into access to safe potable water, exposing rural populations to significant public health risks.

Nigeria, these challenges are particularly pronounced in agrarian and riverine regions where households rely heavily on untreated and poorly monitored surface and groundwater sources (UNICEF, 2021; UNDP, 2022). Limited water treatment infrastructure, inadequate monitoring systems,

and poor maintenance of water facilities exacerbate the vulnerability of rural populations. Water insecurity in these contexts transcends technical deficiencies and constitutes a broader development problem with profound implications for public health, education, economic productivity, and social wellbeing (FAO, 2023). Contaminated water remains a major driver of waterborne diseases, including diarrhoea, cholera, typhoid fever, and dysentery, which disproportionately affect children, women, and economically productive populations (WHO, 2023). These health burdens reduce labour productivity, increase household healthcare expenditures, and impose sustained pressure on fragile rural health systems. Beyond health outcomes, unreliable access to water constrains agricultural production and food security. Seasonal scarcity, long distances to water sources, and time-intensive water collection practices reduce farming efficiency, limit livelihood diversification, and weaken household income security (FAO, 2023; UNDP, 2022). Women and children, who are often primarily responsible for water collection, bear a disproportionate burden, with implications for school attendance, educational attainment, and gender equality (UNICEF, 2021). Consequently, water insecurity reinforces cycles of poverty and socio-economic vulnerability in rural communities.

Nsit Ubium Local Government Area (LGA) in Akwa Ibom State exemplifies these dynamics of rural water insecurity. Although the area is naturally endowed with rivers, streams, wetlands, and groundwater resources, many communities rely on unprotected and poorly managed water sources that are vulnerable to contamination and seasonal variability. Infrastructure limitations, inadequate maintenance of boreholes and water schemes, weak institutional capacity, and ineffective governance frameworks further restrict access to safe and reliable water supplies. This paradox of water abundance coexisting with unsafe water access highlights the structural nature of rural water insecurity in resource-endowed environments. Against this background, this study investigates the quality of available water sources, patterns of water access and distribution, and the public health implications of water insecurity in Nsit Ubium LGA. By integrating water quality assessment with access dynamics and health-related outcomes, the study provides empirical evidence on the interconnections between water insecurity, disease burden, and rural livelihood vulnerability. The findings aim to inform evidence-based policy formulation, community-level interventions, and sustainable rural water management strategies to improve public health outcomes and strengthen livelihood resilience in rural Nigeria.

1.2 Statement of the Problem

Despite Nigeria's extensive surface and groundwater resources, access to safe, reliable, and potable water remains severely limited for a substantial proportion of the rural population. National and regional assessments consistently indicate that many rural households depend on unprotected wells, rivers, streams, and untreated groundwater sources that are highly susceptible to microbial and chemical contamination (UNICEF, 2021; WHO, 2023). The absence of effective water treatment systems, weak water quality monitoring mechanisms, and poor maintenance culture of existing infrastructure have entrenched widespread reliance on unsafe water sources in rural communities. This situation has profound public health implications. Waterborne diseases such as diarrhoea, typhoid fever, cholera, and dysentery remain prevalent in rural Nigeria, contributing to high morbidity, reduced labour productivity, and increased healthcare costs at household and community levels (WHO, 2023; UNDP, 2022; Abraham et al, 2025). Vulnerable populations, particularly children, women, and the elderly, are disproportionately affected, thereby deepening health inequalities and social vulnerability. These disease burdens further undermine rural development by weakening human capital and reducing economic productivity. In addition to health consequences, water insecurity imposes significant socio-economic constraints. Seasonal water scarcity, long distances to water sources, and unreliable water supply systems increase physical, economic, and time burdens on households, particularly women and children (UNICEF, 2021; FAO, 2023; Abraham et al, 2025). These constraints reduce agricultural efficiency, limit livelihood opportunities, weaken food security, and reinforce cycles of poverty and dependency in rural settings.

Furthermore, weak governance structures, limited institutional coordination, inadequate funding for rural water infrastructure, and poor community participation in water management undermine the sustainability of existing water systems (UNDP, 2022; FAO, 2023). Despite ongoing policy commitments to SDG 6, progress toward equitable and sustainable rural water access remains slow, fragmented, and uneven. In Nsit Ubium LGA, these challenges are particularly evident. Although the area possesses significant natural water resources, safe water access remains constrained by poor infrastructure, inadequate maintenance, weak governance, and limited institutional capacity. There is also a lack of localized, integrated empirical evidence that systematically links water quality conditions, access patterns, and public health outcomes in the area. Existing studies often treat water supply, health, and livelihoods as separate domains, limiting the effectiveness of policy interventions and

development planning. Therefore, the central problem addressed by this study is the persistent disconnect between water resource availability and safe, equitable access to potable water in Nsit Ubium LGA, and the resulting negative implications for public health, agricultural productivity, and socio-economic resilience. By adopting an integrated analytical framework that links water quality, access dynamics, and health outcomes, this study seeks to generate context-specific evidence necessary for designing sustainable, inclusive, and community-responsive water governance and public health interventions in rural Nigeria. The study seeks to:

1. Assess the quality of major water sources) in Nsit Ubium LGA, with particular focus on physico-chemical and microbial parameters.
2. Examine patterns of water access and availability, including source reliability, infrastructure conditions, distance to water sources, and seasonal variability.
3. Analyse the public health and livelihood implications of water insecurity, with emphasis on waterborne diseases, healthcare expenditure, labour productivity, and agricultural livelihoods.

2. Review of Related Literature

2.1 Concept of Water Quality and Rural Water Security

Water quality refers to the physical, chemical, and biological characteristics of water that determine its suitability for domestic, agricultural, industrial, and ecological uses. Safe drinking water should be free from pathogenic microorganisms, harmful chemicals, and excessive concentrations of dissolved substances that may pose risks to human health (WHO, 2022). Water security, on the other hand, extends beyond water availability to include the accessibility, reliability, affordability, and safety of water resources. According to UN-Water (2023), water security exists when populations have sustainable access to adequate quantities of acceptable quality water for livelihoods, health, and socio-economic development.

Globally, access to safe water remains uneven despite significant improvements in water infrastructure over the past decades. WHO and UNICEF (2021) estimate that over two billion people worldwide lack safely managed drinking water services, with rural populations accounting for the majority of those affected. In sub-Saharan Africa, water insecurity is particularly acute due to inadequate infrastructure, rapid population growth, environmental degradation, and weak institutional governance. Consequently, many rural households depend on rivers, streams, ponds, shallow wells, and poorly maintained boreholes that are vulnerable to contamination and seasonal fluctuations.

In Nigeria, rural water supply challenges persist despite numerous government interventions. Studies have shown that water infrastructure development has not kept pace with population growth, leading to continued dependence on unimproved water sources (Adebayo & Hassan, 2022). The situation is especially severe in riverine and agrarian communities where access to treated water remains limited. As a result, the quality of available water sources often fails to meet recommended health standards, exposing communities to numerous environmental and public health risks.

2.2 Sources and Determinants of Water Contamination in Rural Communities

Water contamination occurs when physical, chemical, or biological substances degrade water quality beyond acceptable limits. Rural water sources are particularly susceptible to contamination because of limited protective infrastructure and inadequate environmental management practices. Bain et al. (2014) observed that microbial contamination remains the most widespread form of drinking water pollution in low- and middle-income countries, primarily due to faecal contamination arising from open defecation, poorly constructed sanitation facilities, and livestock activities.

Agricultural activities constitute another major source of water pollution. Fertilizers, pesticides, herbicides, and animal wastes are frequently transported into nearby rivers, streams, and groundwater systems through surface runoff, especially during periods of intense rainfall (FAO, 2023). Such contamination introduces excessive nutrients, pathogens, and toxic substances into drinking water supplies. Industrial discharges, improper waste disposal practices, and urban expansion further contribute to declining water quality in many developing regions.

Groundwater contamination has also emerged as a growing concern. Although boreholes are generally regarded as safer than surface water sources, poorly constructed or inadequately maintained boreholes may become contaminated through seepage from septic tanks, refuse dumps, and agricultural fields (WHO, 2022). Studies conducted in southern Nigeria have reported elevated concentrations of iron, manganese, nitrates, and microbial contaminants in groundwater systems, indicating increasing vulnerability of rural water supplies (Abraham et al., 2025). These findings suggest that groundwater cannot automatically be assumed safe without routine monitoring and treatment.

2.3 Water Access, Availability and Rural Livelihoods

Access to water encompasses physical availability, affordability, reliability, and ease of collection. The mere presence of water resources within a geographical area does

not necessarily guarantee access to safe water. Rural households often face significant challenges related to distance, waiting time, seasonal scarcity, and infrastructure breakdowns. According to WHO and UNICEF (2021), households that spend more than 30 minutes collecting water are considered water insecure due to the substantial opportunity costs associated with water collection.

Distance to water sources is particularly important in rural settings. Long travel distances reduce the quantity of water collected and increase physical burdens on household members. Women and children bear the greatest burden because they are traditionally responsible for water collection in many African societies. OECD (2020) reported that excessive time spent collecting water reduces school attendance among children and limits economic participation among women, thereby reinforcing gender inequality and poverty.

Reliable water access is equally important for sustaining rural livelihoods. Water serves as a critical input for crop production, livestock rearing, food processing, and small-scale enterprises. Scoones (1998) identified water as one of the essential natural assets underpinning sustainable rural livelihoods. Where water access is unreliable, agricultural productivity declines, food insecurity increases, and household resilience to economic shocks weakens. Consequently, improving water access contributes not only to public health but also to broader socio-economic development objectives.

2.4 Waterborne Diseases and Public Health Implications

Unsafe drinking water remains one of the leading environmental determinants of disease worldwide. Contaminated water serves as a transmission pathway for numerous pathogens responsible for diarrhoea, cholera, typhoid fever, dysentery, hepatitis A, and other infectious diseases. According to Prüss-Ustün et al. (2019), inadequate water, sanitation, and hygiene conditions account for a significant proportion of the global burden of disease, particularly in low-income countries.

The World Health Organization (2023) emphasizes that diarrhoeal diseases remain among the leading causes of mortality among children under five years of age. Exposure to contaminated water weakens nutritional status, increases vulnerability to infections, and contributes to long-term developmental challenges. Repeated episodes of waterborne illness also reduce educational attainment and labour productivity.

Beyond direct health effects, unsafe water generates substantial economic costs. Households frequently incur healthcare expenses associated with disease treatment, transportation to health facilities, and purchase of medicines. Illness-related absenteeism reduces labour availability for farming and other income-generating activities. World Bank (2021) estimates that water-related diseases impose significant economic losses on developing countries through reduced productivity and increased healthcare expenditures. Thus, investments in safe water supply systems produce both health and economic benefits.

2.5 Gender Dimensions of Rural Water Access

The relationship between water access and gender has received increasing scholarly attention. Across much of sub-Saharan Africa, women and girls are primarily responsible for collecting water for domestic use. This responsibility often requires travelling long distances and carrying heavy loads, creating physical and time burdens that disproportionately affect females (UNICEF, 2021).

Studies have shown that inadequate water access contributes to gender inequality by limiting educational opportunities, reducing participation in income-generating activities, and increasing exposure to health risks. Girls may miss school due to water collection responsibilities, while women often experience reduced productivity because of time spent searching for water. According to OECD (2020), improving rural water access contributes significantly to women's empowerment by reducing unpaid labour burdens and enhancing opportunities for education and economic participation.

The gendered nature of water collection underscores the need for inclusive water governance approaches that recognize women's roles in water management and decision-making processes. Community-based water programmes that actively involve women have been found to exhibit higher levels of sustainability and effectiveness than programmes that exclude female participation (Harvey & Reed, 2007).

2.6 Water Governance and Community-Based Water Management

Effective water governance is fundamental to ensuring sustainable access to safe drinking water. Water governance encompasses the institutions, policies, regulations, and decision-making processes that influence water resource management. In many developing countries, weak governance structures, inadequate funding, poor maintenance culture, and limited community participation undermine the sustainability of water supply systems (UNDP, 2022).

Community-based water management has emerged as an important strategy for addressing these challenges. Harvey and Reed (2007) argue that involving local communities in planning, operation, and maintenance enhances ownership, accountability, and sustainability of rural water

infrastructure. Community participation improves responsiveness to local needs and reduces dependence on external agencies for routine maintenance.

Integrated Water Resources Management (IWRM) further emphasizes coordinated management of water resources across sectors and governance levels. Biswas (2004) notes that successful water management requires balancing environmental sustainability, economic efficiency, and social equity. However, implementation challenges remain significant in many African countries due to institutional fragmentation and limited technical capacity. Strengthening governance systems through improved institutional coordination, community engagement, and sustainable financing mechanisms remains critical for achieving long-term water security.

Several empirical studies have documented the relationship between water quality, access, and public health outcomes in developing countries. Bain et al. (2014), in a global meta-analysis covering 319 studies, found that nearly 38% of improved water sources in low-income countries contained faecal contamination, highlighting significant gaps between infrastructure provision and water safety. Prüss-Ustün et al. (2019) similarly reported that inadequate water, sanitation, and hygiene conditions contribute substantially to disease burdens and preventable mortality worldwide.

In Nigeria, Abraham et al. (2025) analysed groundwater quality in Uyo Capital City and reported elevated concentrations of iron and microbial contaminants in several commercial and private boreholes. Their findings revealed that groundwater sources commonly assumed to be safe may still pose significant public health risks without regular monitoring and treatment. Adebayo and Hassan (2022) examined rural water supply sustainability in Nigeria and identified weak governance, poor infrastructure maintenance, and inadequate community participation as major constraints to effective water service delivery.

Studies conducted across sub-Saharan Africa consistently demonstrate that households relying on unimproved water sources experience higher rates of diarrhoeal diseases, greater healthcare expenditures, and lower productivity compared to households with access to safe water supplies (WHO, 2023; UNDP, 2022). However, relatively few studies have simultaneously examined water quality conditions, access patterns, and public health outcomes within a single integrated analytical framework at the local community level. This gap is particularly evident in Akwa Ibom State, where localized evidence linking water quality, accessibility, and health impacts remains limited.

Consequently, the present study contributes to the literature by providing an integrated assessment of water quality, water access dynamics, and public health implications in Nsit Ubium Local Government Area. By combining laboratory analysis, household surveys, and spatial assessment techniques, the study generates context-specific evidence capable of informing sustainable water governance and rural development planning.

3. Materials and Methods

3.1 Materials

Nsit Ubium LGA is located in southern Nigeria within Akwa Ibom State. The area lies between latitudes 4°39'N and 4°50'N and longitudes 7°50'E and 8°06'E. It shares boundaries with Nsit Atai (north), Uyo (south), Uruan (east), and Ikono (west). The region experiences a tropical climate with distinct wet (April–October) and dry (November–March) seasons. Annual rainfall ranges between 2,000 and 3,000 mm. The predominantly low-lying terrain supports agriculture, which constitutes the main livelihood activity. Surface water resources include the Urua River and numerous streams, while groundwater is accessed through boreholes and hand-dug wells. Despite resource availability, water quality concerns persist due to agricultural runoff, poor sanitation, and inadequate infrastructure.

3.2 Methods

A mixed-methods approach was employed to assess water quality, access, and public health implications in Nsit Ubium LGA, Akwa Ibom State, Nigeria. Water samples were collected from rivers, boreholes, wells, and streams across selected communities and analysed in the laboratory for microbial (total coliforms and *E. coli*) and physico-chemical parameters (pH, turbidity, iron, nitrate) using standard procedures. Structured household questionnaires captured water access patterns, reliability, distance to sources, and health experiences, while GIS mapping was used to determine the spatial distribution of water sources. Data were analysed using descriptive statistics, correlation analysis, and thematic coding, with hypothesis testing conducted at a 0.05 significance level to examine relationships between water quality, prevalence of waterborne diseases, and rural productivity.

4. Results

4.1 Water Source Distribution

Five out of six communities relied predominantly on unprotected surface water sources (rivers). Only Ikot Edibon depended mainly on commercial boreholes.

Table 1. Primary Water Sources by Community (n = 383)

Community	Primary Source	Frequency	Percentage (%)
Ikot Obio Ndon	River	70	18.3
Ikot Mfon	River	65	17.0
Itit Eto	River	60	15.7
Ikot Ekpene Udo	River	70	18.3
Edem Idim Okpot	River	72	18.8
Ikot Edibon	Borehole	46	12.0
Total		**383**	**100**

Source: Field Data, 2026

Reliance on rivers exposes households to seasonal variability and contamination, while borehole dependence is limited to privately operated sources in Ikot Edibon.

4.2 Water Quality Assessment

Laboratory findings revealed:

i. High microbial loads in river-dependent communities
ii. Slightly acidic pH in some boreholes (Ikot Edibon)
iii. Elevated chloride and iron levels in selected communities

Table 2: Selected Physicochemical and Heavy Metal Parameters

Community	pH	TDS (mg/L)	Hardness (mg/L)	Chloride (mg/L)	Iron (mg/L)	Microbial Load (E. coli cfu/100 ml)	Assessment
Ikot Obio Ndon	6.62	183	60	217	0.71	7	High microbial and chloride
Ikot Edibon	6.48	73.4	80	217	1.05	7	Slightly acidic pH; heavy metals
Ikot Mfon	7.30	60.1	57.8	100	0.93	4	Microbial elevated
Itit Eto	6.66	183	171	181	0.93	6	Microbial & iron concerns
Ikot Ekpene Udo	6.82	104	60	217	0.93	5	Chloride and microbial elevated
Edem Idim Okpot	6.95	130	90	42.3	0.543	1	Microbial low; metals moderate

WHO Standards: pH 6.5–8.5; TDS ≤1000 mg/L; Hardness ≤500 mg/L; Chloride ≤250 mg/L; Iron ≤0.3 mg/L; E. coli absent. The physicochemical, heavy metal, and microbial parameters measured across the study communities were systematically compared with World Health Organization (WHO) drinking-water quality standards to determine compliance and public health safety.

pH:
WHO standard: 6.5–8.5
Observed values: 6.48–7.30

All communities fall within or very close to the acceptable range. However, Ikot Edibon (pH 6.48) is slightly below the WHO minimum, indicating mild acidity, which increases the risk of pipe corrosion and metal leaching, thereby indirectly affecting water safety.

Total Dissolved Solids (TDS):

WHO standard: ≤ 1000 mg/L
Observed values: 60.1–183 mg/L

All communities are well within safe limits, indicating low salinity and minimal mineral loading. TDS does not pose a health or aesthetic concern in the study area.

Hardness:
WHO guideline: ≤ 500 mg/L
Observed values: 57.8–171 mg/L
All values are far below the WHO threshold, confirming that hardness does not represent a water quality problem in any of the communities.

Chloride:
WHO guideline: ≤ 250 mg/L

Observed values: 42.3–217 mg/L

Although all communities remain technically within WHO limits, several communities (Ikot Obio Ndon, Ikot Edibon, Ikot Ekpene Udo) record high chloride levels close to the threshold, indicating possible contamination from surface runoff, domestic waste, and environmental pollution, and signaling vulnerability to future exceedance.

Iron (Fe):

WHO guideline: ≤ 0.3 mg/L

Observed values: 0.543–1.05 mg/L

All communities exceed the WHO safe limit for iron, in some cases by more than three times the recommended value (e.g., Ikot Edibon: 1.05 mg/L). This represents a clear chemical contamination risk, affecting water safety, taste, colour, and long-term health exposure.

Microbial Load (*E. coli*):

WHO standard: 0 cfu/100 ml (absence required)

Observed values: 1–7 cfu/100 ml

All communities fail to meet WHO microbial safety standards. The presence of *E. coli* confirms fecal contamination and indicates that the water is unsafe for direct human consumption without treatment. River-dependent communities show the highest contamination levels, reflecting direct exposure to sanitation failures and environmental pollution.

4.3 Accessibility and Infrastructure

i. Average walking distances exceeded 1 km in most communities
ii. Seasonal drying of shallow wells observed during dry months
iii. Poor maintenance and lack of treatment systems were common

Table 3. Distance Travelled to Fetch Water

Distance	Frequency	Percentage (%)
< 1 km	64	16.7
1–2 km	169	44.1
2–5 km	114	29.8
> 5 km	36	9.4
Total	**383**	**100**

Table 4. Frequency of Water Shortages

Category	Frequency	Percentage (%)
Rarely	18	4.7
Sometimes	79	20.6

Category	Frequency	Percentage (%)
Often	144	37.6
Always	142	37.1
Total	**383**	**100**

Water insecurity is chronic, with over 74% of households experiencing shortages often or always.

4.4 Health Outcomes

Table 5: Chi-Square Test of Association Between Water Source Type and Diarrhoeal Incidence

Variable	Category	χ^2	df	p-value	Decision
Water Source Type × Diarrhoeal Incidence	River vs Borehole	18.72	1	< 0.01	Significant

At $\alpha = 0.05$, since $p < 0.01$, the null hypothesis of no association is rejected.

There is a statistically significant relationship between water source type and diarrhoeal incidence among households. Households relying on untreated surface water (rivers) experience significantly higher diarrhoeal prevalence than those using improved water sources (boreholes). This confirms that unsafe water sources are significantly associated with increased disease occurrence.

4.5 Health and Livelihood Implications

6.1 Agricultural Impact

Table 6. Effect of Water Scarcity on Agriculture

Response	Frequency	Percentage (%)
Severe Effect	341	89
No Effect	42	11

Water scarcity severely reduces agricultural productivity, especially in river-dependent communities.

Table 7. Economic Consequences of Water-Related Illness

Indicator	Value
Average medical cost per episode	₦8,450
Average workdays lost	4.6 days
Households reporting reduced productivity	58%

Unsafe water contributes to high medical expenditure and reduced household productivity.

Table 8. Water Collection Responsibility

Responsible Group	Percentage (%)
Women	61
Children	27
Men	12

Women and children bear the majority (88%) of water collection tasks, reflecting disproportionate gender labour burden.

4.6 Discussion

The findings of this study provide strong empirical evidence that water insecurity in Nsit Ubium Local Government Area is fundamentally a public health challenge embedded within broader governance and infrastructure constraints. Although the region is hydrologically endowed, the prevalence of microbial contamination, infrastructure deterioration, and weak monitoring systems underscores the widely acknowledged principle that water crises in developing regions are predominantly management crises rather than absolute shortages (Biswas, 2004; UN-Water, 2023). The laboratory results showing high total coliform counts, E. coli presence, elevated turbidity, and iron concentrations above recommended thresholds confirm substantial contamination risks. According to WHO (2022), safe drinking water should contain zero detectable E. coli per 100 ml. The presence of microbial contamination in surface sources in Nsit Ubium suggests direct exposure pathways to diarrhoeal diseases, dysentery, and other enteric infections.

The significant association between contaminated water use and reported diarrhoeal cases aligns with global

epidemiological evidence demonstrating that unsafe water remains a leading cause of preventable mortality in low-income regions (Prüss-Ustün et al., 2019). UNICEF and WHO (2021) estimate that nearly half of rural populations in sub-Saharan Africa rely on unimproved water sources, increasing disease vulnerability. Furthermore, slightly acidic pH levels in borehole samples may accelerate pipe corrosion, potentially increasing metal leaching into drinking water systems (WHO, 2022). While boreholes generally performed better than surface sources, inadequate maintenance reduces their long-term safety reliability.

These findings support the Water–Health–Development Nexus framework by empirically demonstrating how water contamination directly undermines community health outcomes and human capital development. The finding that average walking distances exceed 1 km in several communities reinforces the economic and social implications of water access inequality. Time spent fetching water represents a significant opportunity cost, particularly for women and children who traditionally bear primary responsibility for water collection in rural Nigeria (UN-Water, 2023). Long collection times reduce educational participation and income-generating activities, reinforcing intergenerational poverty cycles. Studies across West Africa have demonstrated that improved proximity to water significantly enhances school attendance rates and women's economic participation (OECD, 2020).

From a livelihoods perspective, water constitutes a foundational asset within the Sustainable Livelihoods Framework (Scoones, 1998). Limited access constrains productive use in agriculture, food processing, and small-scale enterprises, thereby reducing income diversification and resilience capacity. The widespread reliance on unprotected surface water and poorly maintained boreholes reflects systemic infrastructure deficits. Inadequate funding and weak maintenance culture are recurring barriers to rural water sustainability across Nigeria (Adebayo & Hassan, 2022). The absence of routine water-quality monitoring further exacerbates risk exposure. According to Bain et al. (2014), lack of monitoring often results in "false security," where nominally improved sources remain microbiologically unsafe. Institutional fragmentation, where local governments lack technical capacity and financial resources, limits effective enforcement of water safety standards. Integrated Water Resources Management (IWRM) emphasizes coordination across governance levels; however, implementation gaps remain pronounced in many African contexts (UNDP, 2022). This study reinforces the argument that rural water systems require hybrid governance models combining technical oversight from state institutions with community-level management structures (Harvey & Reed, 2007). Elevated turbidity during the rainy season indicates surface runoff contamination, while dry-season well depletion reduces water reliability. Climate variability intensifies these seasonal dynamics. The IPCC (2023) highlights increasing rainfall variability in West Africa, which may exacerbate both flooding-related contamination and dry-season shortages. Climate-resilient water systems, such as improved borehole construction standards, rainwater harvesting infrastructure, and protected catchment zones, are therefore critical for long-term sustainability (Grey & Sadoff, 2007). Failure to integrate climate adaptation into rural water planning risks deepening vulnerability, particularly in agrarian communities dependent on predictable water availability.

Beyond health implications, the study demonstrates that unsafe water contributes to increased medical expenses, lost workdays, and reduced agricultural productivity. Illness-related labour loss directly constrains farm output in subsistence economies. The strong linkage between water safety and labour productivity supports economic growth models emphasizing infrastructure investment as a driver of rural transformation (World Bank, 2021). Water security thus functions as both a health intervention and an economic stimulus. Grey and Sadoff (2007) describe water as a "development multiplier," and the present findings reinforce this proposition. In Nsit Ubium, improved water safety would likely generate cascading benefits across health, education, agriculture, and income generation sectors.

The evidence strongly supports the need for integrated, multi-sectoral water governance approaches. Water quality monitoring, sanitation improvement, infrastructure rehabilitation, and community participation must operate as interconnected components rather than isolated interventions. The Water–Health–Development Nexus framework demonstrates that improvements in water safety generate cross-sectoral dividends. Achieving Sustainable Development Goal 6 (Clean Water and Sanitation) therefore directly contributes to SDG 3 (Good Health and Well-being) and SDG 1 (No Poverty) (UN, 2023).

5. Conclusion and Policy Recommendations

This study examined water quality, access patterns, and associated public health implications in Nsit Ubium Local Government Area of Akwa Ibom State, Nigeria. The findings reveal that despite the availability of surface and groundwater resources, access to safe and reliable drinking water remains a significant challenge for rural households. The majority of communities rely on unprotected river sources that are highly susceptible to microbial contamination, while the limited number of boreholes available are often poorly maintained and inadequately

monitored. Laboratory analyses confirmed the presence of *E. coli* contamination in all sampled communities, indicating widespread faecal pollution and rendering many water sources unsafe for direct human consumption. Elevated iron concentrations and high chloride levels in some locations further underscore the deteriorating quality of available water resources.

The study also established that water insecurity extends beyond water quality concerns to encompass accessibility and reliability challenges. Long distances travelled to obtain water, frequent water shortages, and seasonal fluctuations in water availability place considerable burdens on households, particularly women and children who bear the primary responsibility for water collection. Statistical evidence confirmed a significant relationship between the use of unsafe water sources and the incidence of diarrhoeal diseases, highlighting the direct link between water insecurity and poor public health outcomes.

Beyond health implications, unsafe and unreliable water supply systems contribute to increased healthcare expenditures, loss of productive workdays, reduced agricultural productivity, and weakened household resilience. The findings therefore validate the Water–Health–Development Nexus framework by demonstrating that water insecurity simultaneously affects health, livelihoods, gender equity, and socio-economic development. Consequently, improving rural water security in Nsit Ubium requires an integrated approach that combines infrastructure development, water quality management, public health interventions, institutional strengthening, and community participation. Achieving sustainable access to safe water will not only improve health outcomes but also enhance agricultural productivity, reduce poverty, and contribute significantly to the attainment of Sustainable Development Goals 1, 3, and 6. The following policy recommendations are outlined;

1. **Improve Rural Water Infrastructure:** Government should rehabilitate existing boreholes and provide additional safe water facilities in underserved communities.
2. **Strengthen Water Quality Monitoring:** Regular testing of community water sources should be conducted to ensure compliance with drinking water standards and prevent health risks.
3. **Promote Sanitation and Hygiene:** Integrated WASH programmes should be implemented to reduce contamination from poor sanitation and unsafe hygiene practices.
4. **Encourage Community Participation:** Community water management committees should be established to support maintenance, monitoring, and sustainability of water facilities.
5. **Enhance Household Water Treatment:** Public awareness campaigns should promote water treatment methods such as boiling, filtration, and chlorination before consumption.
6. **Adopt Climate-Resilient Water Strategies:** Investments in rainwater harvesting, protected boreholes, and water storage systems are needed to address seasonal shortages and climate variability.
7. **Increase Funding and Institutional Collaboration:** Greater investment and coordination among government agencies, development partners, and local communities are essential for sustainable rural water management. Upgrade for your team.

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