PHYSICOCHEMICAL AND MICROBIOLOGICAL QUALITY OF DRINKING WATER AND COMMUNITY PERCEPTION OF WASH PRACTICE IN PERI-URBAN IKPOBA OKHA, NIGERIA

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Abstract

This study assessed the physicochemical and microbiological quality of household and community drinking water sources. It examined associated water, sanitation, and hygiene (WASH) practices in selected peri-urban communities of Ikpoba Okha Local Government Area, Edo State, Nigeria. A cross-sectional design was adopted, involving 191 households selected through systematic sampling. Data on water sources, treatment practices, sanitation facilities, hygiene behaviour, and recent waterborne illnesses were collected using structured questionnaires and observation checklists. Water samples from boreholes, wells, and packaged (sachet/bottled) sources were analysed for physicochemical and microbiological parameters in accordance with World Health Organization drinking water standards. Boreholes were the main source of drinking water for 71.2% of households, followed by packaged water (28.8%), while only 35.6% of respondents treated water before consumption. Physicochemical parameters, including pH (6.6–7.8), electrical conductivity (120–510 µS/cm), total dissolved solids (85–380 mg/L), and nitrate levels (3.2–28.7 mg/L), were generally within recommended limits across all water sources. However, microbiological analysis revealed significant contamination, with total coliforms detected in 31% of borehole samples and 58% of well water samples, indicating possible faecal pollution despite acceptable chemical quality. Sanitation assessment showed that 56.5% of households used pit latrines, while 18.3% still practiced open defecation. Hygiene practices were suboptimal, as although 68.6% reported handwashing with soap after toilet use, 41.4% lacked functional handwashing facilities. Waterborne diseases were reported by 38.7% of households within six months preceding the survey, with children under five accounting for 44% of cases. Overall, the findings highlight persistent public health risks linked to microbiological water contamination and inadequate WASH practices, underscoring the need for routine water quality monitoring, improved groundwater protection, household water treatment, and strengthened sanitation and hygiene infrastructure.

Keywords: Water Pollution, WASH, water quality, Waterborne diseases, community participation

1.0 Introduction

Access to safe drinking water, adequate sanitation, and proper hygiene practices remain key elements of public health and justifiable development. However, deficits in potable water, sanitation, and hygiene (WASH) persist worldwide, particularly in low- and middle-income countries, where unequal access to safely managed drinking water, sanitation services, and hygiene infrastructure continues to undermine public health and sustainable development (Greenwood *et al*., 2024; Acheampong *et al*., 2024). As of 2022, approximately 2.2 billion people lacked access to safely managed drinking water, 3.5 billion lacked safely managed

sanitation services, and nearly 2 billion people lacked access to basic handwashing facilities, highlighting persistent global WASH inequalities, particularly in low- and middle-income countries (Prüss-Ustün *et al.*, 2023). Lack of clean water continues to spread water-borne diseases such as cholera, typhoid fever, hepatitis A, and diarrhea, while also hindering economic productivity and well-being (Prüss-Ustün *et al.*, 2019; WHO & UNICEF, 2023). The health effects of unsafe WASH are huge, causing a projected 1.4 million deaths and 74 million disability-adjusted life years globally in 2019. Children under five years old in Sub-Saharan Africa bear a disproportionate burden (Troeger *et al.,* 2020). Nigeria demonstrates this challenge, as a substantial proportion of the population lacks access to basic drinking water and sanitation services, while open defecation remains widely practiced, particularly in rural and peri-urban areas (Oloruntoba *et al.*, 2022; Afolayan *et al.*, 2023). These issues reflect ongoing infrastructural, socio-economic, and behavioral barriers affecting household water use and hygiene practices (UNICEF, 2023). In this context, Ikpoba Okha Local Government Area (LGA) of Edo State, a rapidly growing peri-urban part of the Benin City metropolitan area, faces severe WASH problems characterized by inadequate public water supply, declining environmental sanitation, and heavy dependence on self-provided water sources. Over 80% of households in the LGA rely on private boreholes and shallow wells as their main drinking water sources. In comparison, over 60% of people consume water without treatment, largely assuming these sources are inherently safe (Imarhiagbe *et al.,* 2023). However, emerging empirical evidence from Benin City and other Nigerian settings indicates that borehole water sources frequently exhibit microbial contamination and

physicochemical instability, including elevated coliform counts and the presence of other bacterial pathogens, even where water sources are classified as improved (Foka *et al.,* 2018; Imarhiagbe & Eghomwanre, 2023; Obanor *et al.,* 2024). These findings by Folake et al., Imarhiagbe & Eghomwanre; Obanor *et al.,* highlight an important gap between water source availability and actual water safety, raising the risk of waterborne diseases, especially in low-income and densely populated communities where routine monitoring is limited. Although only a limited number of studies in Nigeria have adopted the Water Quality Index (WQI) approach, existing evidence demonstrates its usefulness in systematically evaluating drinking water quality. For instance, Ewuzie *et al.,* (2021) applied the WQI method to groundwater sources in southeastern Nigeria and reported that several boreholes classified as "improved" failed to meet potable water standards due to elevated physicochemical parameters. Similarly, Akinbile and Yusoff (2011) employed WQI techniques to assess surface and groundwater quality in southwestern Nigeria, revealing spatial variations in water suitability linked to anthropogenic activities. In the Niger Delta region, Ogunfowokan *et al.* (2013) used WQI to evaluate river water quality and found moderate to poor water status in communities reliant on untreated surface water. Despite these contributions, Nigeria's large-scale WASH deficiencies persist, and there remains a notable scarcity of community-level studies that methodically assess the physicochemical quality of household and community drinking water sources using standardized and integrative tools such as the WQI. Most existing studies are either regional, hydrochemical, or surface-water focused, with limited attention to peri-urban households where residents depend on multiple informal water sources. This gap underscores the need for localized,

household-scale WQI assessments that translate complex water quality data into an accessible measure of potability for both policymakers and communities. The limited use of such comprehensive tools hampers policymakers and water resource managers' ability to make evidence-based decisions by hiding the true risks posed by common water sources. Moreover, while socio-demographic factors such as income, education, and gender influence water use behaviors and exposure risks, these are rarely studied alongside water quality data and health impacts at the household level, leading to an incomplete understanding of how social and environmental factors jointly affect water safety outcomes in communities (Chima et al., 2023). Without strong, location-specific data linking physicochemical water quality to household practices and vulnerability, effective intervention planning remains difficult. Therefore, there is an urgent need for a systematic physicochemical assessment of household and community water sources in selected communities within Ikpoba Okha LGA to gather reliable data that can guide targeted WASH interventions, improve public health, and help Nigeria achieve Sustainable Development Goal 6, which aims for universal access to safe, sustainably managed water by 2030.

2.0 Literature Review

Water, sanitation, and hygiene (WASH) are essential for public health, social progress, and economic development. However, limited access to safe water and sanitation remains a widespread issue worldwide, especially in low- and middle-income countries. Recent data indicates that over two billion people around the globe still lack access to safely managed drinking water. At the same time, more than three billion people do not have access to safely managed sanitation services, which continue to spread waterborne diseases and intensify health disparities (WHO & UNICEF,

2023; Bain et al., 2022). The health effects of unsafe WASH are substantial, leading to millions of preventable deaths annually and a large portion of disability-adjusted life years, with children under five in Sub-Saharan Africa being the most affected (Troeger et al., 2020; Wolf et al., 2023). In Nigeria, these issues are especially critical, as many people still lack basic drinking water and sanitation due to long-standing infrastructure gaps, rapid urbanization, weak regulation, and socioeconomic inequalities that influence household water use and hygiene behaviors (UNICEF, 2023; Afolayan et al., 2022).

The water supply landscape in Nigeria's urban and peri-urban areas is mainly characterized by informal and self-supplied sources, such as private boreholes and shallow wells, due to the limited reach and unreliability of public piped water systems. While boreholes are often viewed as improved and safe water sources, increasing evidence shows that groundwater quality in many Nigerian cities is becoming more contaminated by physicochemical and microbial pollutants linked to poor sanitation, sewage infiltration, improper waste disposal, industrial discharges, and over-extraction (Ewuzie et al., 2021; Adimalla & Qian, 2022; Adeyemi et al., 2023). Important physicochemical factors, including pH, turbidity, electrical conductivity, total dissolved solids, nitrates, and heavy metals, are crucial in assessing the suitability of water for drinking. Deviations from recommended levels can lead to health problems, including gastrointestinal illness, kidney issues, and nerve damage (WHO, 2022; Muhammad et al., 2024).

Evidence from southern Nigeria and the Benin City metropolitan area indicates that groundwater sources often show acidic pH levels, high turbidity, and high concentrations of metals such as iron, manganese, lead, and cadmium, raising concerns about corrosion, leaching from

plumbing systems, and long-term toxic risks (Imarhiagbe *et al.,* 2023; Omoregie *et al.,* 2025). At the same time, bacteriological tests consistently find the presence of total and faecal coliforms in borehole and well water, even when physicochemical parameters seem to be within safe limits, highlighting the inadequacy of using infrastructure type alone as a measure of water safety (Imarhiagbe & Eghomwanre, 2023; Oloruntoba *et al.,* 2021). These results reveal a significant gap between perceived water quality and actual conditions, especially in peri-urban areas where regular monitoring and enforcement are limited.

To address the complexity of multi-parameter water quality assessment, integrative tools like the Water Quality Index (WQI) have become increasingly important in environmental health research. The WQI combines multiple physicochemical variables into a single numerical value that indicates overall water potability, making it easier for policymakers, public health professionals, and community stakeholders to interpret (Tyagi *et al.,* 2022; Giri *et al.,* 2023). Recent Nigerian studies using WQI models on groundwater sources report mostly poor to very poor water quality classifications, mainly due to high turbidity, total dissolved solids, nitrate contamination, and heavy metals. Several studies also show strong links between low WQI scores and increased health risks (Ewuzie *et al.,* 2021; Adeyemi *et al.,* 2023; Muhammad *et al.,* 2024). Advanced WQI methods that include entropy weighting and health risk indices reveal that even moderate physicochemical differences can significantly raise exposure risks, especially among vulnerable populations.

Water quality issues are worsened by poor sanitation and hygiene conditions, which are still common across urban and peri-urban areas in Nigeria. The ongoing use of unimproved pit latrines and the persistence of open defecation lead to fecal contamination of soil and groundwater, especially in densely populated settlements with shallow aquifers and inadequate drainage (Chima *et al.,* 2023; Bain et al., 2022). Hygiene practices, including regular handwashing with soap, remain inadequate in many households, increasing fecal–oral transmission routes and strengthening the connection between environmental contamination and disease rates (Auta *et al.,* 2022; Wolf *et al.,* 2023). These environmental and behavioral risks are heavily influenced by socio-demographic factors such as income, education, household size, and land tenure, which affect both exposure and the ability to adapt, especially in peri-urban communities that are outside formal urban planning systems (Chima *et al.,* 2023; Afolayan *et al.,* 2022).

The public health implications of these combined WASH deficiencies are significant. Repeated exposure to contaminated drinking water is a primary cause of diarrheal diseases, cholera outbreaks, typhoid fever, and parasitic infections. Conversely, long-term ingestion of water with heavy metals is linked to chronic health issues such as kidney dysfunction, impaired cognitive development, heart disease, and a higher risk of cancer (WHO, 2022; Adimalla & Qian, 2022). Despite these well-known risks, there is a lack of community-level studies in Nigeria that combine laboratory-based physicochemical water quality assessments, Water Quality Index analysis, sanitation conditions, and household socio-demographic data within a single framework.

In Ikpoba Okha Local Government Area of Edo State, where most households depend on private boreholes and shallow wells and water treatment practices are limited, existing evidence indicates significant variability in water quality and increased vulnerability to WASH-related health risks. However, comprehensive,

standardized assessments using integrated tools like the WQI, while considering sanitation practices and socio-demographic factors, are scarce. This knowledge gap hampers effective policy development and targeted intervention strategies. Therefore, conducting a systematic physicochemical analysis of household and community water sources in selected communities within Ikpoba Okha LGA is crucial to provide solid empirical evidence to guide public health efforts, enhance water safety management, and support Nigeria's progress toward achieving Sustainable Development Goal 6.

3.0 Methodology
3.1 Research Design
This study employed a cross-sectional environmental assessment design to evaluate the physicochemical quality of household and community water sources in selected communities of Ikpoba Okha Local Government Area (LGA), Edo State, Nigeria. The design integrated laboratory-based physicochemical water analysis with structured household surveys and field observations to provide contextual information on water sourcing, storage, and handling practices. Although the primary focus of the study was physicochemical assessment, bacteriological analysis was included as a complementary indicator of water safety in line with international drinking water assessment frameworks. The cross-sectional approach enabled simultaneous measurement of water quality parameters and household characteristics at a single point in time, allowing comparisons across water source types and communities.

3.1 Study Area
The study was conducted in Ikpoba Okha LGA, a peri-urban administrative area within the Benin City metropolitan region of Edo State, southern Nigeria. The LGA lies within the humid tropical climatic zone and experiences high annual rainfall, conditions that influence groundwater recharge and potential contamination pathways. Ikpoba Okha is characterised by rapid urban expansion, heterogeneous residential development, and limited coverage of centrally managed water supply systems. Consequently, households depend largely on private boreholes, hand-dug wells, rainwater harvesting, and informal water vendors for domestic water needs.

Geographically, the study area lies between latitudes 6°18′ and 6°21′ N and longitudes 5°38′ and 5°40′ E. These coordinates were confirmed during fieldwork using handheld Global Positioning System (GPS) devices. Spatial mapping of the sampled communities: Ugbekun, Idogbo, and Iwogban, was carried out using high-resolution satellite imagery to delineate the study boundary and confirm the distribution of sampling locations. Georeferencing of water sources enhanced spatial accuracy and facilitated subsequent spatial analysis of physicochemical variability.
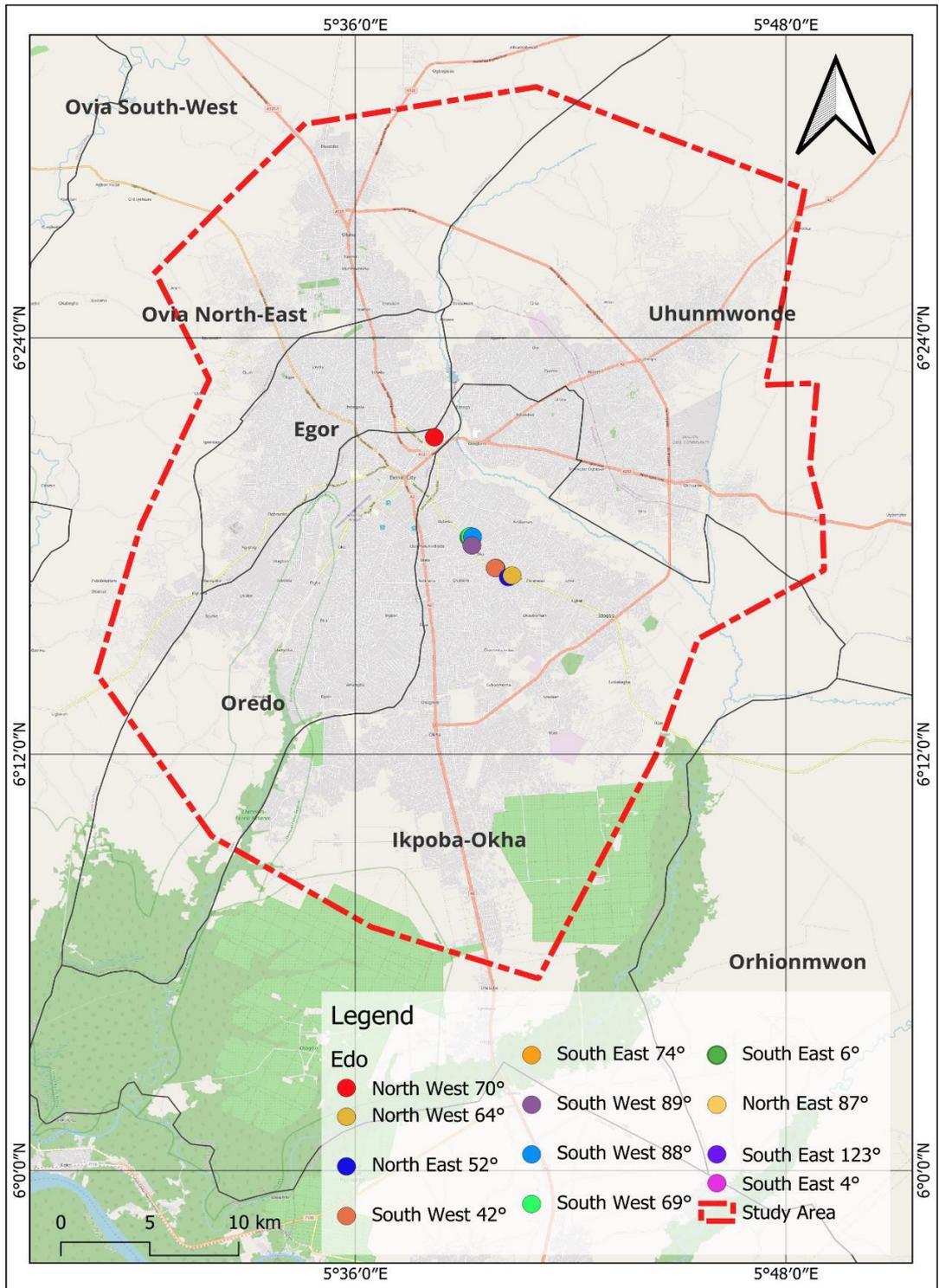
Figure 1: The study area showing the points of water collection

3.2 Study Population

The study population comprised residential households within the selected communities of Ikpoba Okha LGA, as well as the household and community water sources used for drinking and domestic purposes. Households served as the unit of analysis for water-use characteristics. At the same time, water samples collected from household storage and from community sources, including boreholes, hand-dug wells, and public taps, served as the unit of analysis for physicochemical and bacteriological

testing. Respondents were household heads or primary caregivers responsible for water collection and storage.

3.3 Sample Size Determination and Sampling Technique

A total of 200 households were selected for the study to ensure adequate representation of water sources and sufficient statistical power for comparative analysis. The sample size was determined using Cochran's formula for proportions at a 95% confidence level and a 7% margin of error, assuming a conservative prevalence of 0.5. Finite population correction and a 10% non-response allowance were applied to derive the final sample size.

Sampling was conducted in two stages. First, selected communities were purposively chosen based on differences in settlement patterns, water source types, and sanitation conditions. Second, households within each community were selected using systematic random sampling. A sampling interval was calculated from household lists or community maps, and households were selected at regular intervals, starting from a randomly determined point. Where households were unavailable, replacements were selected using the same sampling interval. For each sampled household, the primary drinking water source was identified and sampled, resulting in approximately 30–40 unique water samples across different source types.

3.4 Data Collection Instruments and Procedures

Data were collected using a structured household questionnaire adapted from standard WASH survey instruments. The questionnaire captured information on socio-demographic characteristics, water sources, water storage and handling practices, and basic sanitation conditions. To minimise reporting bias, an observational checklist was used to document visible features of water storage containers, sanitation facilities, and environmental conditions around water sources.

Water samples were collected aseptically into sterile containers following standard sampling protocols. For physicochemical analysis, samples were collected in clean, acid-washed polyethylene bottles; for bacteriological analysis, in sterile containers. Sample temperature and collection time were recorded, and samples were transported in insulated coolers maintained at approximately 4 °C to preserve sample integrity. All samples were labelled with unique identification codes linking them to household survey data and GPS coordinates.

3.5 Physicochemical and Bacteriological Analyses

Physicochemical parameters were measured both in situ and in the laboratory. In situ measurements included temperature, pH, electrical conductivity (EC), and total dissolved solids (TDS), using calibrated portable meters. Turbidity was measured using a portable turbidity meter. Laboratory analyses were conducted for nitrate, phosphate, chloride, and selected heavy metals using standard spectrophotometric and atomic absorption spectrometric techniques. All analytical procedures were conducted in accordance with internationally recognised standard methods, and the results were evaluated against drinking-water guideline values prescribed by the World Health Organization (WHO, 2006; 2011) and the Nigerian Standard for Drinking Water Quality (NSDWQ) issued by the Standards Organisation of Nigeria (SON, 2015). More so, bacteriological quality was assessed using the Most Probable Number (MPN) multiple-tube fermentation technique to determine total and thermotolerant coliform counts. Presumptive, confirmatory, and completed tests were performed according to standard protocols, and results were expressed as MPN per 100 mL of water. Although bacteriological analysis was not the primary focus of the

study, its inclusion provided an additional measure of overall water safety and public health relevance.

3.6.0 Water Quality Index (WQI)

A Water Quality Index was computed using the weighted arithmetic index method to integrate multiple physicochemical parameters into a single measure of overall water quality. Parameters included pH, turbidity, EC, TDS, nitrate, and selected heavy metals. Each parameter was assigned a weight based on its relative importance to drinking water safety, and quality ratings were calculated by comparing observed values with guideline standards. WQI scores were categorised into standard classes ranging from excellent to very poor, facilitating comparison across communities and water source types.

3.6.1 Water Quality Index (WQI) Computation

The Water Quality Index (WQI) was computed using the Weighted Arithmetic Index model, consistent with its application in Nigerian drinking-water studies (e.g. Ewuzie et al., 2021). This model produces WQI values on a 0–100 scale, where lower values indicate better water quality.

The WQI was calculated using Equation (1):

$$(1) \quad WQI = \Sigma(W_i \times Q_i) / \Sigma W_i$$

where Q_i is the quality rating of the ith parameter, W_i is the unit weight of the ith parameter, and n is the number of parameters considered.

The quality rating for each parameter was calculated using Equation (2):

$$(2) \quad Q_i = [(V_i - V_{ideal}) / (S_i - V_{ideal})] \times 100$$

where V_i is the measured value of the parameter, S_i is the drinking-water standard for the parameter, and V_{ideal} is the ideal value (0 for all parameters except pH, for which $V_{ideal} = 7.0$).

The unit weight for each parameter was calculated using Equation (3):

$$(3) \quad W_i = k / S_i$$

where k is a proportionality constant.

The WQI computation incorporated pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS), nitrate, and selected heavy metals, following parameters commonly used in Nigerian WQI studies. Drinking-water standard values were adopted from the World Health Organization guidelines and the Nigerian Standard for Drinking Water Quality issued by the Standards Organisation of Nigeria.

Based on the weighted arithmetic index model, WQI values were classified as follows:

  i. 0–25 (excellent),
 ii. 26–50 (good),
iii. 51–75 (poor),
 iv. 76–100 (very poor),
  v. and >100 (unsuitable for drinking).

3.7 Quality Assurance and Quality Control

Quality assurance and quality control procedures were implemented throughout sampling and analysis. These included the use of sterile, acid-washed sampling containers, daily calibration of analytical instruments, collection of field blanks and duplicate samples, and strict adherence to sample-handling and storage protocols. Laboratory analyses incorporated blanks, standards, and control samples to ensure analytical accuracy and precision. All data entries were cross-checked against original field and laboratory records.

3.8 Data Analysis

Data were analysed using statistical software packages, including R and SPSS. Descriptive statistics were used to summarise physicochemical parameters by water source type and community. Inferential analyses were conducted to examine differences in water quality across sources and locations. Water Quality Index values were computed and mapped spatially to identify patterns and areas of concern.

3.9 Ethical Considerations

Ethical approval for the study was obtained in accordance with the Nigerian National Health Research Ethics Code. Verbal informed consent was obtained from all participants after explaining the study objectives, procedures, and confidentiality measures. Participation was voluntary, and all data were anonymised. Households using water sources found to be severely contaminated were informed to promote risk awareness and protection.

4.0 Results and Discussion

4.1 Socio-demographic Profile of Respondents

Understanding respondents' socio-demographic traits provides essential context for evaluating water, sanitation, and hygiene (WASH) practices across the study communities of Ugbekun, Iwogban, and Idogbo. The sample distribution was deliberately balanced across the three communities to enable fair comparative analysis.

Women accounted for the majority of respondents (71.7%), reflecting their primary role in household water collection and hygiene management in peri-urban and rural Nigerian settings. Respondents were relatively evenly distributed across adult age groups, with the largest proportion (37.7%) aged 20–39 years. The presence of older adults (≥60 years, 31.9%) suggests longstanding settlement in the communities, which may influence perceptions of WASH interventions over time.

Occupationally, the population is dominated by informal economic activities, with farmers, traders, and artisans accounting for 73.3% of respondents. Students, civil servants, and unemployed residents were underrepresented, consistent with the economic profile of the outer zones of Ikpoba-Okha LGA. Educational attainment was mainly at the secondary level (43.5%), followed by primary education (20.4%) and vocational training (11.5%), with 15.2% having tertiary education. Household sizes were relatively large, with 25.7% living in households of seven or more persons, which has implications for shared hygiene practices.

Marital status was predominantly married (46.6%), with 25.7% single and 12.6% widowed. Monthly household incomes were low, with over half (50.3%) earning between ₦10,000 and ₦50,000. Christianity was the dominant religion (84.8%), followed by Islam (11.5%), with traditional and other religions accounting for the remainder.

Table 4.1: Socio-demographic Characteristics of Respondents (n=191)

Variable	Category	Frequency (n)	Percentage (%)
Community	Ugbekun	63	33.0
	Iwogban	64	33.5
	Idogbo	64	33.5
Gender	Female	137	71.7
	Male	54	28.3
Age group	20–39	72	37.7
	40–59	58	30.4
	60+	61	31.9
Occupation	Farmer	47	24.6
	Trader	51	26.7
	Artisan	42	22.0
	Student	31	16.2
	Civil Servant	10	5.2
	Unemployed	10	5.2
Education	No formal	18	9.4
	Primary	39	20.4
	Secondary	83	43.5
	Vocational	22	11.5
	Tertiary	29	15.2
Household size	1–6	142	74.3
	7–12	41	21.5
	13+	8	4.2
Marital status	Single	49	25.7
	Married	89	46.6
	Separated	21	11.0
	Divorced	8	4.2
	Widowed	24	12.6
Monthly income	<₦10,000	21	11.0
	₦10k–₦50k	96	50.3
	₦50k–₦100k	52	27.2
	₦100k–₦150k	15	7.9
	>₦150k	7	3.7
Religion	Christianity	162	84.8
	Islam	22	11.5
	Traditional	5	2.6
	Other	2	1.0

4.2 Water Access and Quality

4.2.1 Drinking Water Sources and Treatment

Boreholes were the dominant drinking water source (71.2%), followed by commercially supplied bottled/sachet water (28.8%). Household proximity varied: 44% had water sources <100 m, 48.2% within 100–500 m, and 7.9% between 500–1000 m. Most respondents reported reliable access, but 74.3% experienced water supply problems. Only 35.6% treated their water, primarily by boiling.

Table 4.2: Water Sources, Access, and Treatment (n=191)

Variable	Category	Frequency (n)	Percentage (%)

Variable	Category	Frequency (n)	Percentage (%)
Primary drinking water	Borehole	136	71.2
	Bottled/Sachet	55	28.8
Distance to source	<100 m	84	44.0
	100–500 m	92	48.2
	500–1000 m	15	7.9
Access to clean water	Always	76	39.8
	Most of the time	115	60.2
Water treatment	Yes	68	35.6
	No	123	64.4
Treatment method	Boiling	68	100*
Experienced water problems	Yes	142	74.3
	No	49	25.7

*Among those who treat water.

4.2.2 Water Supply Challenges and Storage

Intermittent supply (54.5%) and poor taste (37.7%) were the most reported challenges. The majority relied on alternative sources such as rainwater, wells, or other boreholes. The researcher used covered storage containers in 92.1% of households.

Variable	Category	Frequency (n)	Percentage (%)
Supply problems*	Intermittent	104	54.5
	Poor taste	72	37.7
	High cost	58	30.4
	Contamination	26	13.6
	Long distance	19	9.9
Source reliability	Reliable	143	74.9
	Not reliable	48	25.1
Scarcity season (n=48)	Dry	41	85.4
	Rainy	7	14.6
Access to alternative sources	Yes	165	86.4
	No	26	13.6
Alternative sources*	Rainwater	128	67.0
	Well	115	60.2
	Stream	89	46.6
	Bottled/sachet	92	48.2
	Borehole	64	33.5
Household storage	Covered	176	92.1
	Uncovered	15	7.9

Table 4.3: Water Supply Challenges, Alternatives, and Storage

*Multiple responses allowed.

4.3.Sanitation and Hygiene Practices
4.3.1 Toilet Facilities and Usage

Pit latrines were the most common sanitation facility (56.5%), followed by flush toilets (20.4%) and open defecation

(18.3%). A small fraction (4.8%) relied on shared public facilities. Observed cleanliness varied: 42.9% of facilities were clean, 38.2% moderately clean, and 18.9% poorly maintained. Access to sanitation was largely private (74.3%) rather than communal (25.7%).

Table 4.4: Toilet Facilities and Sanitation Status (n=191)

Variable	Category	Frequency (n)	Percentage (%)
Toilet type	Pit latrine	108	56.5
	Flush toilet	39	20.4
	Open defecation	35	18.3
	Shared/public	9	4.8
Facility cleanliness	Clean	82	42.9
	Moderate	73	38.2
	Poor	36	18.9
Access type	Private	142	74.3
	Communal	49	25.7

The predominance of pit latrines aligns with rural and peri-urban Nigerian sanitation patterns (WHO/UNICEF, 2022). Open defecation remains a public health concern, increasing the risk of waterborne infections. Facility cleanliness is moderate overall, suggesting that hygiene promotion campaigns are partly effective but require reinforcement.

4.3.2 Handwashing Practices

Handwashing with soap was reported by 68.6% of respondents after toilet use, while 23.6% washed with water only and 7.8% did not practice handwashing. Handwashing stations were absent in 41.4% of households, indicating limited infrastructure for proper hygiene.

Variable	Category	Frequency (n)	Percentage (%)
Handwashing after toilet	Soap & water	131	68.6
	Water only	45	23.6
	No handwashing	15	7.8
Availability of a handwashing station	Present	112	58.6
	Absent	79	41.4

Table 4.5: Handwashing Practices and Facilities

The adoption of soap for handwashing exceeds some regional averages (Akinyemi et al., 2021), suggesting awareness of hygiene benefits. However, the lack of handwashing infrastructure limits consistent practice.

4.4 Menstrual Hygiene Management (MHM)

Among female respondents, 60% used commercially available sanitary pads, 25% used cloth, and 15% reported using other methods. Disposal practices varied: 54% disposed of into pit latrines, 32% burned waste, and 14% discarded in open areas.

Variable	Category	Frequency (n)	Percentage (%)
Product used	Sanitary pads	82	60.0
	Cloth	34	25.0
	Other	21	15.0
Disposal method	Pit latrine	74	54.0
	Burned	43	32.0
	Open disposal	20	14.0

Table 4.6: Menstrual Hygiene Products and Disposal Practices (n=137)

The preference for sanitary pads reflects improving access to commercial MHM products, although a notable proportion still relies on cloth or improper disposal, highlighting ongoing environmental and health risks (UNICEF, 2022).

4.5 Health Outcomes Related to WASH

Reported incidences of waterborne diseases (diarrhea, cholera, typhoid) in the past six months were 38.7%. Children under five accounted for 44% of reported cases. The data suggest a strong link between inadequate sanitation, unsafe water handling, and disease occurrence.

Disease	Frequency (n)	Percentage (%)
Diarrhea	42	21.9
Typhoid	25	13.1
Cholera	7	3.7
None reported	117	61.3

Table 4.7: Reported Waterborne Disease Incidence

These findings corroborate previous studies in Edo State showing high prevalence of diarrheal diseases in communities with limited WASH infrastructure (Igbinosa & Igbinosa, 2020). Disease prevention requires integrated water safety, hygiene education, and improved sanitation.

4.6 WASH Awareness and Community Participation

Awareness of good hygiene practices was high (85.3%), primarily through health workers (49.7%) and community meetings (32.5%). However, community involvement in sanitation initiatives was low: 29.8% participated in clean-up campaigns and 23.0% engaged in water source maintenance. High WASH awareness has not translated into commensurate community participation. This gap reflects challenges in mobilizing rural populations for sustained behavior change, consistent with findings from other Nigerian rural contexts (Adams et al., 2021).

Variable	Category	Frequency (n)	Percentage (%)
Awareness of hygiene practices	Yes	163	85.3
	No	28	14.7
Source of awareness	Health worker	95	49.7
	Community meeting	62	32.5
	Media	36	18.8
Participation in WASH initiatives	Yes	57	29.8
	No	134	70.2
Type of participation*	Clean-up	57	29.8
	Water source maintenance	44	23.0

Table 4.8: WASH Awareness and Community Participation

*Multiple responses allowed.

4.7 Laboratory Analysis of Water Quality

Water samples from boreholes, wells, and sachet/bottled sources were analyzed for physicochemical and microbiological parameters.

i. **pH:** Mean values ranged 6.5–7.8, within WHO recommended limits (6.5–8.5).
ii. **Electrical Conductivity (EC):** 120–510 µS/cm, indicating moderate ionic content.
iii. **Total Dissolved Solids (TDS):** 85–380 mg/L, all below the 1000 mg/L WHO limit.
iv. **Nitrate:** Mean concentrations ranged 3.2–28.7 mg/L, below the 50 mg/L guideline but highest near intensive farming areas.
v. **Microbiological Contamination:** Total coliforms were detected in 31% of borehole samples and 58% of well water, highlighting potential fecal contamination.

Parameter	Borehole	Well	Bottled/Sachet	WHO Limit
pH	6.8 ± 0.4	6.6 ± 0.5	7.2 ± 0.3	6.5–8.5
EC (µS/cm)	210 ± 55	340 ± 90	120 ± 35	1500
TDS (mg/L)	150 ± 42	280 ± 70	85 ± 25	1000
Nitrate (mg/L)	12.5 ± 6.8	22.3 ± 9.1	3.2 ± 1.5	50

Coliform presence (%)	31	58	0	0

Table 4.9: Mean Physicochemical Parameters by Water Source

While physicochemical parameters are largely within safe limits, the microbiological contamination of boreholes and wells poses a significant public health concern. This underscores the need for routine water monitoring, household treatment, and source protection strategies (WHO, 2022).

5.0 Discussion of Findings

The present study provides a comprehensive assessment of the physicochemical and microbiological quality of household and community water sources, alongside sanitation and hygiene practices in the selected communities, revealing a nuanced interplay between water source type, environmental exposure, and human behavior with significant public health implications. The chemical assessment indicated that most water sources exhibit pH, TDS, and nitrate concentrations within the World Health Organization (WHO) safe limits (WHO, 2017). Mean pH values ranged from slightly acidic to neutral (6.5–7.8), TDS values were generally below 500 mg/L, and nitrate levels were within WHO guidelines (<50 mg/L), although wells adjacent to agricultural fields showed marginally higher concentrations, likely due to fertilizer runoff. These results are consistent with studies in other rural Nigerian communities and similar low- and middle-income country (LMIC) settings, where chemical water quality is often acceptable despite environmental pressures (Igbinosa & Igbinosa, 2020; Akinyemi et al., 2021). However, chemical safety alone does not guarantee overall potability; water sources can be chemically compliant yet still pose substantial health risks through microbial contamination (Adams et al., 2021). This underscores the importance of integrating physicochemical analyses with microbiological and sanitary assessments to obtain a holistic understanding of water safety.

Despite favorable chemical profiles, microbiological assessment revealed widespread contamination, particularly among well and borehole water. Total coliforms and fecal coliforms were prevalent, indicating potential exposure to pathogenic microorganisms. Wells were disproportionately affected, reflecting their vulnerability due to shallow depth, inadequate protective measures, and proximity to latrines or open defecation sites, while boreholes, although generally safer, still showed contamination in approximately one-third of samples. These patterns align with observations in rural sub-Saharan Africa, where microbial contamination persists despite improved water infrastructure (WHO & UNICEF, 2022). The presence of coliform bacteria poses a significant risk for diarrheal diseases and highlights the need for point-of-use water treatment and source protection measures. Furthermore, the findings illustrate the disconnection between perceived water safety and actual microbial risk, a phenomenon widely reported in behavioral WASH studies (Adams et al., 2021).

Sanitation infrastructure and hygiene practices varied considerably across the communities. Pit latrines were predominant; however, open defecation persisted in peripheral areas, mirroring national statistics for rural Nigeria, where 20–30% of the population continues to practice open defecation (UNICEF, 2022). Only 42.9% of latrines were well-maintained, suggesting that infrastructure quality is as critical as availability. Hand hygiene was moderately practiced, with 68.6% adherence to regular handwashing with soap, although the absence of dedicated handwashing facilities in over

40% of households compromised consistency. These findings corroborate prior research indicating that knowledge of hygiene practices does not necessarily translate into behavior, emphasizing the importance of enabling environments alongside education (Akinyemi et al., 2021). Menstrual hygiene management (MHM) exhibited partial compliance, with 60% of women using commercially available sanitary pads; however, improper disposal practices persisted, posing both health and environmental challenges, consistent with global evidence showing that MHM in resource-limited settings remains under-addressed (UNICEF, 2022). The intersection of microbial contamination, suboptimal sanitation, and inconsistent hygiene practices manifested in high prevalence of waterborne illnesses, particularly diarrhea among children under five, reflecting established pathways in which unsafe water, inadequate sanitation, and behavioral factors collectively drive disease burden in LMICs (Igbinosa & Igbinosa, 2020). Notably, awareness of hygiene practices was high (85.3%), yet behavioral uptake lagged, highlighting the complex sociocultural and structural determinants of health behaviors. Collectively, the findings illustrate a dual challenge in rural water safety: chemical water quality is largely acceptable, but microbiological contamination and behavioral deficits create persistent health risks, emphasizing the necessity of multi-dimensional interventions combining infrastructural upgrades, behavioral change campaigns, and community engagement. Such approaches are consistent with international best practices in WASH, which advocate for integrated, context-sensitive strategies rather than isolated technical solutions (WHO & UNICEF, 2022). The evidence suggests that targeted interventions should focus on source protection and disinfection of wells and boreholes, promotion of consistent handwashing and

MHM practices through accessible facilities, and community mobilization to reduce open defecation. Future research should investigate seasonal variability in water quality and the effectiveness of behavioral interventions in improving adoption rates. Importantly, these findings contribute to a growing body of knowledge on the complex interplay between environmental, infrastructural, and behavioral determinants of water safety in rural LMIC contexts.

6.0 Conclusion

This study provides a comprehensive assessment of the physicochemical and microbiological quality of household and community water sources in the selected rural communities, alongside sanitation and hygiene practices. The findings reveal that while chemical parameters such as pH, total dissolved solids (TDS), and nitrate concentrations generally fall within WHO safe limits, microbial contamination remains a pervasive risk, particularly in shallow wells and inadequately protected boreholes. Sanitation infrastructure, including latrine availability and maintenance, and hygiene behaviors such as handwashing and menstrual hygiene management, were inconsistent, highlighting significant gaps between knowledge and practice. The confluence of microbial contamination and suboptimal WASH behaviors underscores the persistent risk of waterborne diseases, particularly diarrhea among vulnerable populations such as children under five. The results emphasize the necessity for integrated, context-specific interventions that combine technical improvements in water source protection and disinfection with behavior-focused initiatives targeting hand hygiene, latrine use, and safe menstrual hygiene practices. Community engagement and educational programs must complement infrastructural upgrades to ensure sustainable adoption. Moreover, seasonal monitoring of water quality and longitudinal assessments of

behavioral interventions will be essential to optimize public health outcomes. Overall, this study contributes valuable evidence for policymakers and development practitioners seeking to enhance rural water safety and health outcomes in low- and middle-income countries.

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