HOUSEHOLD WATER QUALITY ASSESSMENT AND HYGIENE PRACTICES IN UPPER MISSION COMMUNITY, OREDO LOCAL GOVERNMENT AREA, BENIN CITY

BY

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AN UNDERGRADUATE PROJECT SUBMITTED TO THE DEPARTMENT OF ENVIRONMENTAL MANAGEMENT AND TOXICOLOGY, FACULTY OF LIFE SCIENCES, UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, NIGERIA; IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR AWARD OF BACHELOR OF SCIENCE (B.Sc) DEGREE IN ENVIRONMENTAL MANAGEMENT AND TOXICOLOGY.

NOVEMBER, 2025

CERTIFICATION

This is to certify that this research titled “**Household Water Quality Assessment And Hygiene Practices In Upper Mission, Benin City**” was carried out by **“Faith Eshiofune Ganiyu”** and presented to the Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, Benin City; in partial fulfilment of the requirements for the award of Bachelor of Science (B.Sc) in Environmental Management and Toxicology. It was conducted under suitable conditions, was carefully supervised and subsequently approved as having met the requirements for the award of Bachelor of Science degree in Environmental Management and Toxicology.

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Head of Department

DECLARATION

I "**Faith Eshiofune Ganiyu**" declare that "**Household Water Quality Assessment and Hygiene Practices in Upper Mission, Benin City**" is my own work and that all sources that I have used or quoted have been acknowledged by means of complete references and that this work has not been submitted before for any other degree at any other University.

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FAITH ESHIOFUNE GANIYU Date

DEDICATION

This project is dedicated to Almighty God, whose grace, wisdom, and strength made this work possible. I also dedicate it to my beloved parents and family for their constant love, encouragement, and unwavering support throughout my academic journey. Finally, this work is dedicated to my friends, colleagues, and mentors who inspired and motivated me to give my best and persevere to the end.

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Finally, I want to thank myself for not giving up, even when it was tough. Ganiyu Faith Eshiofune, you did great. Thank you.

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ABSTRACT

Public health and illness prevention depend on having access to clean drinking water and practicing good hygiene. To determine their effects on community health, the Upper Mission community in Benin City's water quality and cleanliness practices were examined. One hundred households chosen by multistage sampling were included in the community-based cross-sectional design. To investigate water sources, storage procedures, treatment techniques, and hygiene practices, structured questionnaires were given out. Additionally, physicochemical and microbiological analyses were performed on 30 drinking water samples obtained from river sources, sachet water, and boreholes. 89% of households have access to water within 100 meters of their homes, with sachet water (52%) and borehole water (41%) serving as the main sources of drinking water. There is a significant gap between accessibility and safety practices, as 80% of individuals did not purify the water before drinking it.

With pH values ranging from 4.6 to 8.0, total dissolved solids between 24 and 136 milligrams per liter, and electrical conductivity between 44 and 219 microsiemens per centimeter, the physicochemical parameters mostly satisfied WHO requirements. River water had the highest contamination (mean: 202.4×10^{0} colony-forming units per milliliter), followed by borehole water (79.7×10^{0} colony-forming units per milliliter) and sachet water (43.2×10^{0} colony-forming units per milliliter), according to microbiological analysis, which found heterotrophic bacterial counts ranging from 26×10^{0} to 235×10^{0} colony-forming units per milliliter). River water (mean: 42.6×10^{0} colony-forming units per milliliter) and some borehole samples (mean: 24.9×10^{0} colony-forming units per milliliter) had total coliforms, but sachet water did not. Only one sample of river water had Escherichia coli.

Although the infrastructure is good, there are notable shortcomings in environmental hygiene, handwashing with soap (34%), and water treatment, with 38% of residences located close to waste disposal sites. There is an immediate need for improved waste management systems, borehole maintenance, targeted health education initiatives, and increased water quality monitoring.

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND STUDY

Access to clean and safe water, along with good hygiene practices, is essential for human health and wellbeing. It plays a direct role in preventing waterborne diseases and improving overall health. This concept is recognized as a basic human right that helps protect human health and support environmental sustainability (Biswas *et al*., 2024). The Human Right to Safe Drinking Water and Sanitation (HRTWS) was established in 2010 through a United Nations resolution. This resolution highlighted the need for drinking water and sanitation services to be safe, affordable, acceptable, available, and accessible to everyone (Hutton and Chase, 2017). In 2022, the United Nations reported that 2.2 billion people lacked access to safely managed drinking water. Among them, 703 million did not have basic water services. Additionally, 3.5 billion people did not have safely managed sanitation. This included 1.5 billion individuals without basic sanitation services and 2 billion people who lacked a basic handwashing facility. Out of these, 653 million had no handwashing facility at all. According to the 2021 WASHNORM report, about 48 million Nigerians still practiced open defecation, and only 8% of the population followed safe handwashing practices. Furthermore, 23% of the population did not have access to basic water supply services, while only 10% had access to a combination of basic water, sanitation, and hygiene services (UNICEF, 2021). The World Health Organisation states that proper hygiene and safe water are crucial in preventing various neglected tropical diseases (NTDs), such as trachoma, soil-transmitted helminth infections, and schistosomiasis. During the Millennium Development Goal (MDG) era from 1990 to 2015, diarrheal deaths linked to poor water quality and hygiene dropped significantly, mainly due to improvements in access to water and sanitation services.

In areas like Edo State, Nigeria, studies show reliance on unprotected water sources and poor hygiene practices, which increase the risk of waterborne diseases. These conditions are major health risks, particularly for children and vulnerable groups. Many households in this region depend on wells, boreholes, and rainwater for daily water needs. Despite the widespread use of boreholes, many households do not treat the water before using it, which increases the chances of exposure to contaminants (Imarhiagbe and Eghomwanre, 2023; Omoregie *et al*., 2025). Access to sanitation facilities varies among households. Some have pit latrines or flush toilets, yet many still do not have proper handwashing facilities. The ongoing practice of open defecation continues to be a serious problem, worsening the spread of infectious diseases in communities.

Water quality assessment can be defined as the process of evaluating the physical, chemical, and biological characteristics of water, considering its natural state, the impact of human activities, and its potential future uses (Adelagun *et al*., 2021). The assessment of water quality, typically conducted by evaluating its physicochemical and biological properties or parameters against established standards, helps determine whether the water is safe for consumption or environmentally sustainable. Hygiene refers to a variety of daily practices aimed at maintaining cleanliness and promoting health. These include washing hands, bathing, brushing teeth, and wearing clean clothes. Although these actions may seem ordinary, they play a crucial role in preventing the spread of diseases. Regular handwashing with soap and clean water is one of the simplest and most effective methods for preventing the transmission of infectious diseases (Heukelbach, 2023). While water quality and hygiene are often seen as separate issues, they are closely connected at home. Even if drinking water comes from a safe source, its quality can be greatly affected by poor handling. This includes using dirty or uncovered storage containers, gathering water with unwashed hands or utensils, and not cleaning vessels regularly. Global water safety guidelines remind us that water should be collected in clean, covered containers and drawn in a way that prevents hand contact. Not following these practices often leads to microbial contamination before consumption (Trevett and Carter, 2008). Additionally, having enough safe water is crucial for hand hygiene at key times, like after using the toilet or before cooking. This greatly reduces disease transmission when combined with good hygiene practices (UNWater, 2025). Ultimately, only when safe water access and hygienic handling are guaranteed can water keep its protective value. Otherwise, even clean source water can spread illness.

The aim of this project is to assess the quality of water used by households and evaluate their hygiene practices. Evaluating water quality and hygiene behaviours is essential for safeguarding public health, preventing waterborne diseases, and enhancing general wellbeing. Water quality monitoring helps detect harmful contaminants, while examining hygiene practices, such as regular handwashing; plays a key role in minimizing the spread of infectious illnesses. These assessments are vital for ensuring access to safe drinking water and adequate sanitation, both of which are fundamental to human development and critical for poverty reduction (Hutton and Chase, 2017).

1.2 PROBLEM STATEMENT

Despite numerous public health initiatives, many households in Upper Mission still depend on potentially unsafe water sources and demonstrate poor hygiene practices. This persistent challenge significantly increases the risk of disease outbreaks and impedes efforts to achieve Sustainable Development Goal 6, which focuses on ensuring access to clean water and sanitation for all. Therefore, a thorough assessment of household water quality and hygiene behaviours is urgently needed to inform targeted interventions, shape effective policies, and promote sustainable health outcomes (Ihezie and Obaniyi, 2023).

1.3 JUSTIFICATION OF RESEARCH

Assessing water quality and hygiene practices is essential because of their direct impact on public health, socioeconomic development, and environmental sustainability (Ejiohuo *et al.*, 2025). It helps identify health risks, guide resource allocation, and support strategies that improve living conditions and promote sustainable development.

- Public Health Significance: Contaminated water and inadequate hygiene practices are major contributors to the spread of waterborne diseases, including diarrhea, cholera, and typhoid fever. These conditions pose serious health risks, particularly to children and vulnerable populations. Conducting assessments of water quality and hygiene behaviours is essential for identifying sources of contamination and informing the design of effective interventions aimed at reducing the incidence and spread of these preventable diseases (UNICEF, 2021).
- Socio-Economic Impact: Poor water quality and hygiene practices have farreaching socio-economic consequences. They contribute to a higher incidence of illness, resulting in school absenteeism among children and reduced productivity among working adults. This hinders educational attainment and economic growth. Conversely, access to safe water, improved sanitation, and proper hygiene practices can significantly reduce the burden of disease, enhance school attendance, and boost economic participation, ultimately contributing to community development and poverty reduction (Okesanya *et al.*, 2024)
- Alignment with Sustainable Development Goals (SDGs): Assessing water quality and hygiene practices in households directly supports Sustainable Development Goal 6, which seeks to ensure the availability and sustainable management of water and sanitation for all by the year 2030. By assessing household water quality and hygiene

practices, the study helps identify critical gaps and challenges that hinder progress toward this goal. The insights gained will inform targeted interventions and policy actions aimed at expanding access to safe water and sanitation services, thereby contributing to the overall achievement of SDG 6 (Hutton and Chase, 2017).

- Community Empowerment and Behaviour Change: Involving communities in the assessment of their water sources and hygiene practices promotes greater awareness and fosters positive behaviour change (Bose *et al.*, 2024). When local residents actively participate in evaluating their daily practices, they develop a deeper understanding of the health risks associated with unsafe water and poor hygiene. This engagement not only encourages the adoption of healthier behaviour s but also empowers communities to take ownership of solutions, leading to more sustainable and impactful outcomes

1.4 AIM AND OBJECTIVES

The aim of this study was to evaluate the water quality and hygiene practices of households at Upper Mission, New Benin axis, Benin City.

The specific objectives of this study were to:

i. evaluate household water quality practices and hygiene behaviors using a structured questionnaire survey;
ii. determine physicochemical properties of drinking water in the households;
iii. evaluate the total heterotrophic bacterial count of drinking water in the households;
iv. determine the distribution of heterotrophic bacterial based on water source;
v. evaluate the total coliforms and *Escherichia coli* bacterial counts of drinking water in the households;

vi. determine the distribution of total coliforms and *Escherichia coli* based on water source.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 CONCEPTUAL REVIEW

2.1.1 WATER QUALITY

Water quality is evaluated based on physical factors like turbidity, chemical factors such as heavy metals and pH, and microbiological factors like coliform counts. These are compared to standards set by organisations such as WHO (Alabi *et al.*, 2024). Although water is essential for survival, many households and countries in Africa still lack access to safe drinking water. Natural water sources often become contaminated, either directly or indirectly, due to human and animal activities. This contamination requires thorough treatment before the water is considered safe to drink (Akhtar *et al.*, 2021). In Nigeria, untreated boreholes and wells lead to contamination both at the source and during use (Imarhiagbe and Eghomwanre, 2023). Research shows that groundwater sources frequently exceed acceptable limits for various contaminants, including bacteriological issues and heavy metals like lead and cadmium (Yahaya *et al.*, 2020). According to the WHO (2017), microbiological contamination, especially from *E. coli*, represents the greatest and most immediate health risk in drinking water.

2.1.2 HYGIENE PRACTICES

Hygiene includes personal habits like handwashing and keeping the environment clean. Poor hygiene is a major factor in the spread of diarrheal diseases (Aminu and Udeze, 2023). Hand hygiene is still not widely practiced in Nigeria, even though many people know about its health benefits. The 2021 WASHNORM report shows that although nearly all Nigerians understand that handwashing helps prevent disease, only about 4% do it at important times, like after using the toilet or before preparing food (FMWR *et al.*, 2022). UNICEF estimates that only 17% of households have basic handwashing facilities, which means having soap and water available in a specific spot (Victor *et al.*, 2025). Research in healthcare settings highlights the gap between what people know and what they actually do: at the University of Nigeria Teaching Hospital, nurses showed moderate knowledge of handwashing, but only about 25% used the correct technique. This points to serious behavioural and infrastructure issues, even among health professionals (Nwosu *et al.*, 2024). These trends illustrate a "handwashing paradox" that exists in both urban and rural areas.

The health effects of poor hygiene are serious. Handwashing with soap can cut diarrhea-related child deaths by up to 50% (Wolf *et al.*, 2022) and reduce respiratory infections by about 25% (Ross *et al.*, 2023). However, Nigeria still faces high rates of preventable diseases due to inadequate hygiene facilities and behaviours. A national analysis of over 22,000 children (2025) found that about two-thirds lived in homes without access to hygiene facilities. This is a clear risk factor for waterborne illnesses and malnutrition in children under 18 (Victor *et al.*, 2025). Limited access to handwashing stations, such as Veronica buckets or permanent sinks, along with gaps between knowledge and practice, makes it hard for people to adopt effective hygiene in their daily lives.

2.1.3 SANITATION

Sanitation is about properly managing human waste. When managed safely, it helps limit the spread of disease. In Nigeria, sanitation remains mostly inadequate. Nearly 48 million people still practice open defecation, particularly in rural areas (31%) compared to urban areas (8%) as of 2021 (Mohammed and Oguntola, 2022). Despite national initiatives and the Community-Led Total Sanitation (CLTS) approach, lasting behaviour change has been hard to achieve. In Ebonyi State, for instance, high awareness of CLTS (over 70%) coexisted with an 85% rate of open defecation, even among educated and employed residents. This situation shows that strong cultural norms, lack of enforcement, and limited access to latrine facilities hinder progress in sanitation (Agha *et al.*, 2024). CLTS tends to work best in poorer communities where change is most needed, but it struggles to maintain progress without institutional support and oversight.

Improved sanitation facilities are not evenly spread out, and traditional pit latrines are still common. A study in Kaduna State found that 65.7% of households used traditional pit latrines, while 22.8% practiced open defecation. Only 5.9% had access to improved pit toilets, with financial constraints being the main barrier to upgrading sanitation facilities (Sridhar *et al.*, 2020). Additionally, poor access to sanitation is linked to health risks beyond gastrointestinal diseases. An analysis of the 2021 Malaria Indicator Survey found that lacking proper sanitation significantly increased malaria infection rates among children under five. This highlights the connected effects of sanitation infrastructure on vector-borne diseases and overall child health (Asifat *et al.*, 2025).

2.1.4 WASH

The integrated Water, Sanitation, and Hygiene (WASH) approach is crucial for public health and is connected to Sustainable Development Goal 6 (Okesanya *et al.*, 2024). In Nigeria, recent UNICEF-led surveys show that only about 10% of the population had access to combined basic water, sanitation, and hygiene services as of 2021. Approximately 48 million people still practice open defecation, and around 80 million lack access to improved sanitation facilities (World Bank, 2021). Evaluations of WASH programs, including assessments in Anambra State, report improved awareness and increased access to safe water and handwashing practices. However, they also reveal significant challenges such as inadequate funding and poor sustainability of hygiene facilities. Initiatives like the World

Bank’s SURWASH, launched in 2021, aim to provide clean water services to 6 million Nigerians and improve sanitation for 1.4 million. This shows institutional commitment to closing the WASH gap (World Bank, 2021).

Research shows the strong impact of WASH conditions on child health and nutrition. A study in Beere/OjaOba, Ibadan, found that poor WASH practices, including unsafe water sourcing and inadequate hand hygiene, were linked to high rates of stunting (44%), wasting (37.5%), and underweight (34%) among children aged 6 to 59 months. Nearly 48.5% experienced diarrhea during the study period, which connected directly to environmental and behavioural risk factors (Aleru *et al*., 2023). Another assessment in Sokoto State (2022) found that over 79% of households depended on unprotected wells, while only 69% stored water in safe, covered containers. This highlights prevalent risks in dry communities where resource scarcity makes WASH provision difficult (Mustapha *et al*., 2022). These findings emphasize that without simultaneous improvements in infrastructure, behaviour, and access, fragmented WASH efforts may not achieve sustainable health benefits.

2.2 EMPIRICAL REVIEW

2.2.1 NIGERIAN HOUSEHOLD STUDIES

Alabi *et al*. (2024) studied the quality of household water in five municipal LGAs in Ibadan. They collected 447 samples during both the dry and wet seasons. The results showed that non-potable water was very common, at 86.8% in the dry season and 74.1% in the wet season. *Escherichia coli* was found in 25.7% of the samples, along with Salmonella and pathogenic *E. coli* strains (Alabi *et al*., 2024). The study also noted significant seasonal differences in aerobic bacteria counts, coliform levels, and pH values, highlighting how the risk of contamination changes with rainfall and environmental exposure.

In Oyo State (2025), stored drinking water was contaminated with coliforms. This contamination was connected to poor WASH facilities (Israel *et al*., 2023). The study indicated that contamination was linked to shared or inadequate toilets, a lack of handwashing facilities, and the use of open containers for storage. The findings show a strong link between poor WASH infrastructure and declines in microbial water quality at the household level.

In a 2023 survey of 120 households in urban slums across four LGAs in Lagos, Aminu and Udeze found that 71.8% of respondents had experienced diarrhoea. Typhoid fever affected 67.5%, dysentery 45.3%, and cholera 32.5%. Their logit regression analysis identified key factors influencing disease incidence, including education level, household size, occupation, water treatment habits, type and sharing of toilets, and environmental sanitation practices (Aminu and Udeze, 2023). The study highlights how water contamination, sanitation problems, and hygiene practices together impact waterborne disease outcomes in crowded informal settlements.

A 2015 study in Ibadan North, involving 450 households, found that 56.4% treated their water using methods like boiling, alum, or chlorine. Additionally, 67.3% had pour-flush toilets, but less than half washed their hands after using the toilet (Orimoloye *et al*., 2015). These results show a partial adoption of safe practices. While many homes have treatment methods and sanitation facilities, consistent hygiene behaviour is still lacking. This early research illustrates the ongoing challenge of connecting knowledge, infrastructure, and actual practices in household WASH dynamics.

2.2.2 URBAN COMPARATIVE ANALYSES

A 2025 review across Lagos, Kano, Ibadan, and Enugu confirmed widespread contamination from heavy metals and coliforms, along with a high prevalence of waterborne diseases. This study highlighted gaps in infrastructure (Babalola *et al*., 2025). In their thorough review of WASH conditions in these areas, Babalola *et al*. (2025) looked at multiple studies conducted between 2022 and 2023. They found consistently high levels of heavy metals, such as lead, chromium, and cadmium, along with high counts of total coliform bacteria in both surface and groundwater sources across all four cities. Many of these values surpassed WHO and FEPA safety limits, showing serious contamination of drinking sources even in urban centers.

Furthermore, the review pointed out problems in sanitation infrastructure, including poor waste management and limited access to better latrine facilities. These issues contribute to widespread exposure to waterborne pathogens and higher rates of disease in densely populated areas. The health outcomes in these urban centers were alarming: frequent outbreaks of diarrhea, typhoid fever, and cholera were closely linked to both infrastructure problems and behaviours related to the use of shared or unimproved sanitation facilities and improper waste disposal methods.

2.2.3 WASH IN BROADER CONTEXT

Hlongwa *et al*. (2024) reviewed WASH literature from Sub-Saharan Africa and identified key barriers. These include institutional issues, such as weak governance, economic challenges like lack of funding, political problems including corruption and accountability gaps, and geographic obstacles like remote rural conditions. They note that rural and low-income communities are hit hardest by these overlapping constraints, which hinder progress toward SDG 6, access to safe water and sanitation. The review emphasizes how weak institutional frameworks, such as unclear policy directives or poor coordination among agencies, hurt sustainability and local ownership of WASH projects. Consequently, even well-designed initiatives often struggle to take hold without support from political will, financial planning, and community involvement.

Idigbe *et al.* (2024) looked into the feasibility and acceptability of point-of-use chlorination through qualitative research. They conducted six focus-group discussions and interviews with pregnant women, caregivers, health workers, and shopkeepers in Nigeria from late 2022 to early 2023. Participants were generally open to using chlorine treatment if it was accessible, affordable, and had a minimal impact on taste and smell. However, concerns about the availability of chlorine products and cultural beliefs sometimes limited its adoption. The study found that integrating chlorination messages through existing maternal and child health services, with support from local leaders and health promoters, boosted community trust and acceptance. Despite this willingness, inconsistent dosage practices and limited product availability pose challenges in turning willingness into regular, safe use.

2.3 THEORETICAL FRAMEWORK

In examining how households handle hygiene and water safety, the Health Belief Model (HBM) provides a useful perspective. It highlights how people's perceived susceptibility, like the belief that their family might get sick from untreated water, and perceived severity, such as worry about serious diseases like cholera or typhoid, affect their decisions about water treatment and sanitation (Ezeaka and Bartholomew, 2025). Also important are perceived benefits, like knowing that boiling water or using a covered container can prevent illness, and perceived barriers, such as the cost of fuel or soap and limited access to facilities. These barriers often outweigh motivation, even when people are aware of the risks. The model also points out the impact of cues to action, including community health campaigns or visible signs like outbreaks of waterborne illnesses, which can inspire changes in behaviour. Self-efficacy, or confidence in one's ability to frequently boil water or maintain a latrine, plays a role too (Ezeaka and Bartholomew, 2025). In a study conducted in a Lagos slum with mothers of children under five, even positive views on susceptibility and benefits did not always lead to safe water, sanitation, and hygiene (WASH) practices. This is due to gaps in infrastructure and economic limitations, showing that psychological factors alone do not guarantee action without the right conditions and triggers to support behaviour change (Orivri and OgwezzyNdisika, 2023).

2.4 GAPS IN THE LITERATURE

Despite a growing interest in research on household water and hygiene, significant gaps remain in Nigeria. Most studies focus on urban slums, schools, or peri-urban areas, often failing to combine laboratory water quality tests with thorough household surveys. This limits understanding of how microbial and chemical contamination interacts with household practices. For example, many WASH assessments done in Edo State, including those in Ekosodin and Benin City, mainly use questionnaires and observational data rather than paired water analysis alongside behavioural surveys. Additionally, recent, location-specific studies in Edo State are limited. These limitations emphasize how important integrated studies are. The current study bridges this knowledge gap by integrating laboratory water testing and household hygiene surveys in Upper Mission, offering a more thorough and location-specific understanding of household water safety.

CHAPTER THREE

3.0 MATERIALS AND METHODOLOGY

3.1 STUDY DESIGN

To assess the infrastructures, practices, and services related to water and hygiene at the household level, a community-based cross-sectional study was conducted. This design allowed for the collection of data at a single point in time from a representative sample of households, providing a snapshot of current water quality conditions and hygiene behaviours. This enabled the identification of prevailing challenges and risk factors associated with poor water quality and poor hygiene.

3.2 Study area

The research was carried out in Benin City, the capital of Edo State, located in the southern region of Nigeria.

3.3 Sample location

This study was conducted in households at Upper Mission, New Benin axis, Benin City. Upper Mission is part of Oredo Local Government Area in Edo State. The area is predominantly inhabited by artisans and small-scale business owners.

It is located at approximately 6.32° N, 5.60° E, within the Egor/Ikpoba-Okha metropolitan area. Benin City itself spans latitudes 6°16′–6°33′ N and longitudes 5°31′–5°45′ E. It is bordered by Ovia North-East LGA to the west, Oredo LGA to the south, and Ikpoba-Okha LGA to the east (Ayeki, Asikhia and Ojeh, 2018). Upper Mission is situated on the New Benin–Aduwawa corridor, north of the city center. Its main road is Upper Mission Road, also known as Aduwawa Road. This road connects southward to New Lagos Road and the city core, and northward to the Aduwawa Junction on the Benin–Auchi Expressway. Data specific to Upper Mission is limited. However, it shares characteristics of a dense urban fringe. Oredo

LGA covers about 249 km² and had around 536,827 residents in 2006. The entire Benin City area, including Egor, Oredo, and Ikpoba-Okha, now has over 1 million residents. Upper Mission likely has several thousand residents (Cirella, Iyalomhe and Adekola, 2019).

The climate in Benin City is tropical wet and dry (Aw in Köppen), featuring two seasons: a heavy rainy season from March to October, and a dry season from November to February. The city's annual rainfall is high, ranging from 2,000 to 2,300 mm per year, with monthly averages around 180 mm during the wet months. Temperatures vary from the mid20s °C (with minimums around 24 °C in the rainy season) to over 30 °C during the day. Humidity is high, around 80% in the rainy season and about 70% in the dry season. Upper Mission experiences these patterns, marked by intense summer downpours and warm nights throughout the year (Cirella, Iyalomhe and Adekola, 2019).

Topographically, Benin City is located in the southern coastal plain. The area has generally low elevations, with an average of about 78 m above sea level. The land gently slopes southwest (Ayeki, Asikhia and Ojeh, 2018). Upper Mission is on slightly higher ground, about 80 to 100 m north of the city core, sloping down toward the Ikpoba River basin to the south. The soils in the Benin area are typically lateritic (red-yellow ferralsols), ranging from sandy in the southeast to clayey in the northwest. Soil permeability varies; some parts of the city have clayey soil that drains poorly. Originally, vegetation was a rainforest that gradually changed to savannah. North of Benin, the land is mainly savannah where wild palm oil grows. The lowlands were once rainforest and mangroves (Cirella, Iyalomhe and Adekola, 2019). Today, in Upper Mission, most natural vegetation has been cleared for development, leaving only scattered palms or patches of secondary grassland.

Upper Mission is mainly residential, though it does have some commercial and institutional areas. The layout is semi urban: the older sections near New Benin have dense housing on small lots, while the newer parts north of Upper Mission Road have larger compounds. Most houses are one or two-story bungalows or duplexes.

Commercial and institutional uses are concentrated along main roads. The Upper Mission Road corridor features shops, small businesses, and food stalls. A key commercial landmark is Aduwawa Market at Upper Mission Extension, a large open-air market known for livestock and agricultural trade. Other businesses include gas stations, auto shops, and building supply vendors. Religious and educational facilities, such as churches (including Upper Mission SDA Church) and nearby secondary schools (in New Benin/Uteh), serve the community. The area's layout is mostly linear along the roads, with most homes facing or accessible to the streets. There is no formal town center. Instead, the district centers around major junctions, such as the Aduwawa junction, and markets. The settlement pattern reflects piecemeal development. Although some roads were planned, many side streets are narrow and lacked drainage initially. Urbanization has sped up in the past 20 to 30 years, pushing the city's border northward, meaning that previously semirural areas are now built up. Consequently, Upper Mission is a mix of older compounds and new developments, with fewer vacant lots remaining.

3.4 Sample Size and Sampling Technique

Sample-size calculation: The sample size was determined using Yamane's formula:

$n = N / (1 + N(e)^2)$ Where:

n = sample size

N = total number of households

e = margin of error (typically 0.05 for 95% confidence level) (Ying and Idrakisyah, 2024).

Sampling method: A multistage sampling method was used to choose the needed number of households to reach the final sample size (Sesay *et al.*, 2022). The area was divided into clusters. Within each cluster, a systematic sampling strategy ensured fair coverage across the clusters.

3.5 Questionnaire Survey

A structured questionnaire was utilized to evaluate household water quality management and hygiene practices. It was designed to obtain both quantitative and qualitative information on water sources, storage techniques, treatment methods, and sanitation behaviors. Prior to data collection, the questionnaire was pretested to ensure clarity and reliability. Respondents were chosen through a random sampling method to ensure a fair representation of households. Questionnaires were administered through face-to-face interviews to minimize errors in interpretation. Data collected were coded, entered, and analyzed using both descriptive and inferential statistical techniques. In total, 100 households were surveyed.

3.6 Sample Collection

Thirty (30) drinking water samples were collected using sterile plastic containers. Each sample was properly labelled and immediately transported to the laboratory for analysis.

3.7 Material/Apparatus

Field Sampling Equipment: Sterile sampling bottles (50mL), Cooler box with ice pack, Labels, waterproof marker, and sample logbook

Laboratory Equipment: Autoclave, Incubators, Analytical balance, Magnetic stirrer, Colony counter, Micropippette, Bunsen burner, Refrigerator (4 °C) for media and sample storage and Volumetric glassware (flasks, cylinders, pipettes).

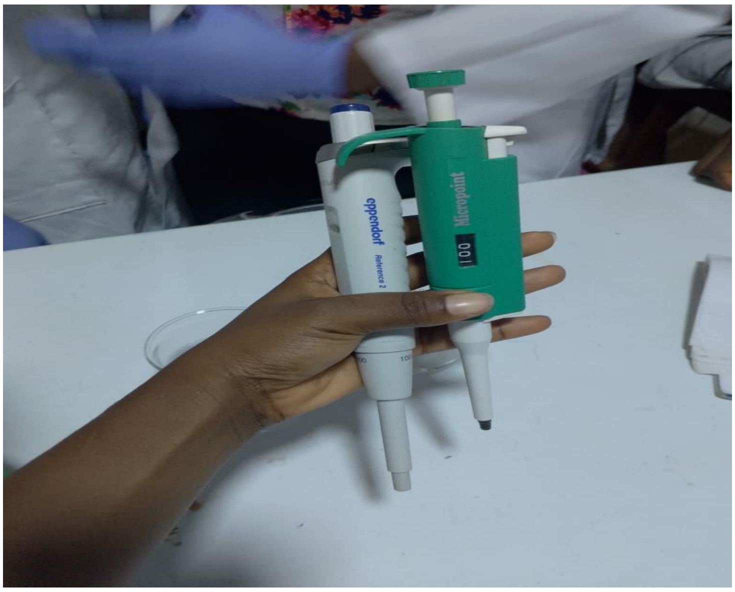

Plate 3.1. Micropippette

Plate 3.2. Sample bottles and petri dishes containing agar media

3.8 Preparation of Culture Media

Nutrient Agar (NA) (Lab M, Lancashire, United Kingdom) was prepared by dissolving 28 g of agar powder in 1000 mL of distilled water, followed by sterilization in an autoclave at 121°C for 15 minutes. Chromogenic Coliform Agar (CCA) (Lab M, Lancashire, United Kingdom) was prepared by dissolving 26.5 g of agar powder in 1000 mL of distilled water and heating with constant stirring using a magnetic stirrer until completely dissolved. The CCA medium was neither autoclaved nor overheated.

3.9 Determination of physicochemical parameters

Physicochemical properties such as pH, temperature, electrical conductivity, salinity, and total dissolved solids were measured using a digital water quality tester (MWCTDS2355, China) in accordance with the manufacturer's guidelines. The instrument was calibrated with standard buffer solutions before use. After calibration, the electrode was rinsed with distilled water, immersed in the sample, and allowed to stabilize for 2–5 minutes to obtain consistent readings.

3.10 Enumeration of Total Heterotrophic Bacteria

The water samples were inoculated directly onto agar plates without prior dilution. Total heterotrophic bacterial counts were determined using the spread plate technique, in which 200µL of each sample was dispensed onto sterile Nutrient Agar plates (Lab M, Lancashire, United Kingdom). The plates were incubated at 37°C for 18–24 hours. Bacterial colonies were enumerated, and the results were expressed as mean colony-forming units per millilitre (CFU/mL).

Table 3.1. Coordinates of Samples taken from each Household

S/N	Sample Codes	Sample Sources	Latitude	Longitude
1	UPM04	Borehole	6°21′20″ N	5°38′2″ E
2	UPM05	Borehole	6°21′22″ N	5°38′2″ E
3	UPM06	Borehole	6°21′22″ N	5°38′3″ E
4	UPM08	Sachet water	6°21′25″ N	5°38′4″ E
5	UPM10	Borehole	6°21′26″ N	5°38′13″ E
6	UPM11	Borehole	6°21′27″ N	5°38′14
7	UPM12	Borehole	6°21′27″ N	5°38′14″ E
8	UPM13	Borehole	6°21′28″ N	5°38′22″ E
9	UPM14	Borehole	6°21′26″ N	5°38′23″ E
10	UPM16	Borehole	6°21′22″ N	5°38′19″ E
11	UPM20	Sachet water	6°21′33″ N	5°38′18″ E
12	UPM23	Borehole	6°21′41″ N	5°38′22″ E
13	UPM24	Borehole	6°21′49″ N	5°38′31″ E
14	UPM25	Borehole	6°21′50″ N	5°38′32″ E
15	UPM26	Sachet water	6°21′50″ N	5°38′33″ E
16	UPM27	River	6°21′49″ N	5°38′35″ E
17	UPM28	River	6°21′49″ N	5°38′45″ E
18	UPM29	River	6°21′50″ N	5°38′44″ E
19	UPM30	River	6°21′50″ N	5°38′41″ E
20	UPM31	River	6°21′51″ N	5°38′39″ E
21	UPM34	Borehole	6°21′54″ N	5°38′32″ E
22	UPM35	Borehole	6°21′51″ N	5°38′31″ E
23	UPM37	Borehole	6°21′53″ N	5°38′34″ E
24	UPM38	Borehole	6°21′53″ N	5°38′34″ E
25	UPM39	Borehole	6°21′53″ N	5°38′36″ E

26	UPM40	Borehole	6°21′53″ N	5°38′36″ E
27	UPM41	Borehole	6°21′53″ N	5°38′36″ E
28	UPM42	Sachet water	6°21′55″ N	5°38′36″ E
29	UPM43	Sachet water	6°21′60″ N	5°38′32″ E
30	UPM46	Borehole	6°21′60″ N	5°38′32″ E

3.11 Cultural Characterization and Enumeration of Total Coliforms and *Escherichia coli*

Total coliform and *Escherichia coli* counts were determined using the spread plate method. A 200µL aliquot of each sample was spread evenly on sterile Chromogenic Coliform Agar plates (Lab M, Lancashire, United Kingdom) using a sterile glass spreader. The plates were incubated at 44°C for 18–24 hours. After incubation, colonies were enumerated, and the mean counts were expressed as colonyforming units per millilitre (CFU/mL). Distinct blue or violet colonies were identified as presumptive *E. coli* (fecal coliforms), whereas pink or red colonies represented other coliforms (non-fecal coliforms). Presumptive isolates were purified by sub-culturing on Nutrient Agar plates and subsequently maintained on Nutrient Agar slants for further analysis.

3.12 Biochemical Characterization of Coliform Bacteria

Presumptive coliform isolates were subjected to biochemical screening, including Gram reaction using the potassium hydroxide (3% KOH) test, catalase test, and oxidase test. For **KOH test,** a sterile wire loop was used to mix bacterial cells with 2–3 drops of 3% KOH on a clean glass slide. A viscous or slimy reaction indicated a positive result. The **catalase test** was determined by having a few drops of freshly prepared 3% hydrogen peroxide placed on a bacterial smear. The production of gas bubbles indicated catalase activity (positive reaction). The oxidase test was determined using a piece of filter paper that was moistened with 2–3 drops of freshly prepared oxidase reagent. Presumptive colonies were smeared onto the paper. The appearance of a purple-blue coloration within 10 seconds indicated a positive oxidase reaction, while the absence of colour change indicated a negative result.

Presumptive coliform isolates were characterized as KOH-positive, catalase-positive, and oxidase-negative.

3.13 Data Analysis

Data obtained from the study were processed and analyzed using Microsoft Excel and the Statistical Package for the Social Sciences (SPSS) version 22.0 (SPSS Inc., Chicago, IL, USA). Data that followed a normal distribution were presented as mean ± standard deviation (SD).

CHAPTER FOUR

4.0 RESULTS

Table 4.1 presents the demographic characteristics and environmental conditions of the surveyed households (n = 100). The results reveal that females constituted the majority (65%) of respondents, while males accounted for 35%**.** The age distribution shows that most respondents were within the 18–37 years age bracket (78%) while those aged 38 years and above represented 22%. Regarding marital status**,** 61% of respondents were married, 37% single, and 2% widowed. In terms of religion**,** Christianity (88%) and Islam (12%) were the only affiliations reported, indicating a largely Christian-dominated community. Educational status varied, with 44% completing secondary education and 28% attaining tertiary education, while **7%** had no formal education. A smaller proportion completed vocational (8%)**,** Quranic (2%)**,** or primary (11%) education.

Occupational data show that traders/business owners formed the largest group (42%)**,** followed by students (21%), while civil servants, artisans/skilled workers, and private sector employees each accounted for 8%. Most households consisted of 4–6 members (60%), followed by smaller families of 1–3 members (35%), and only 5% had 7–9 members**.** Monthly income distribution shows that 44% of households earned ₦150,000 and above**,** 34% earned between ₦100,000–₦149,999**,** while only 22% earned below ₦100,000. Environmental observations revealed that 38% of respondents had a waste dump site near their homes, while 62% did not. Among those with nearby waste sites, the majority **(**60.5%**)** lived within 50 meters of the dumpsite. Additionally, only 7% reported open sewage or stagnant water near their residence. Finally, 52% of respondents have their surroundings as moderately clean**,** 43% as clean, and 5% as dirty**.**

Table 4.1. Demographics and Environmental Observations of Households

Parameters		Frequency (n=100)	Percentage (%)
Sex	Male	35	35.0
	Female	65	65.0
Age in years	1827	38	38.0
	2837	40	40.0
	3847	11	11.0
	4857	7	7.0
	58 and above	4	4.0
Marital status	Single	37	37.0
	Married	61	61.0
	Divorced	0	0.0
	Widowed	2	2.0
Religion	Christianity	88	88.0
	Islam	12	12.0
	Traditional	0	0.0
Educational Level Attained	No Formal Education	7	7.0
	Vocational	8	8.0
	Quranic	2	2.0
	Primary School	11	11.0
	Secondary School	44	44.0
	Tertiary Education	28	28.0
Occupation	Student	21	21.0
	Private sector Employee	8	8.0
	Trader/Business Owner	42	42.0
	Civil Servant	8	8.0
	Artisan/Skilled Worker	8	8.0
	Farmer	0	0.0
	Unemployed	0	0.0
	Retired	0	0.0
Household Size	13	35	35.0
	46	60	60.0
	79	5	5.0
	10 and above	0	0.0
Monthly Household Income (₦)	<20,000	0	0.0
	20,00049,999	4	4.0
	50,00099,999	18	18.0
	100,000149,999	34	34.0
	≥150,000	44	44.0
Is there a waste dump site near the household?	Yes	38	38.0
	No	62	62.0
If yes, distance of wastedump to residence	<50m	23	60.5
	50100m	14	36.9
	>100m	1	2.6
Is there any open sewage or stagnant water nearby?	Yes	7	7.0
	No	93	93.0
Environmental condition	Clean	43	43.0
	Moderately clean	52	52.0
	Dirty	5	5.0

Table 4.2 presents the findings on the types, accessibility, handling of drinking water sources among the households. The results show that the main sources of drinking water were sachet water (52%) and borehole water (41%), while a small fraction relied on river/stream (6%) and bottled water (1%). For secondary sources, borehole water (44%), sachet water (44%), while rainwater and bottled water were 6%. In terms of accessibility, 89% of respondents reported that their main water source was located within 100 meters of their homes, while 11% accessed water from 100–500 meters away. Regarding water treatment practices, only 20% of households treated their water before drinking, while 80% consumed it without any treatment. Among those who practiced treatment, boiling (45%) and filtration (30%) were the most common methods, followed by chlorination (15%) and combined filtration with alum (10%).

A substantial 88% of respondents stored water for drinking with covered containers (80.7%). Others used jerry cans (8%), overhead tanks (8%), and plastic cans (2.2%), while uncovered containers is 1.1%. Water retrieval practices revealed that 79.6% used a cup with handles, 19.3% used a bowl, and only 1.1% used a cup without handles. The frequency of cleaning storage containers was mostly daily (65.9%), followed by weekly (20.4%), monthly (8%), and rarely (5.7%). In terms of water source reliability, 86% indicated that their main source was available year-round, while 14% experienced seasonal interruptions. Nearly half (45%) of the respondents reported having problems with their water supply, mainly intermittent supply (60%), high cost (24.4%), poor taste (13.3%), and minimal contamination issues (2.2%). Most respondents (82%) believed that people do not get sick from the water they drink. Only 10% reported water-related illnesses within the previous six months, primarily typhoid fever (80%), followed by diarrhea (20%). Finally, when asked about unpleasant physical characteristics, 91% of respondents reported none, while 8% mentioned taste issues and 1% reported colour changes.

Table 4.2. Water Source and Quality Assessment of Households

Parameters		**Frequency (n=100)**	**Percentage (%)**
Main source of drinking water?	Borehole	41	41.0
	Sachet Water	52	52.0
	River/Stream	6	6.0
	Bottled Water	1	1.0
Secondary source of drinking water?	Borehole	44	44.0
	Bottled Water	6	6.0
	Sachet Water	44	44.0
	Rain Water	6	6.0
Distance of main source of drinking water from home?	<100m	89	89.0
	100500m	11	11.0
	>500m	0	0.0
Do you treat your water before drinking?	Yes	20	20.0
	No	80	80.0
If yes, what treatment method do you use?	Boiling	9	45.0
	Filtration	6	30.0
	Chlorination	3	15.0
	Filtration and Alum	2	10.0
Do you store water for drinking purpose?	Yes	88	88.0
	No	12	12.0
If yes, how do you store your drinking water?	Covered container	71	80.7
	Jerry can	7	8.0
	Uncovered container	1	1.1
	Overhead tank	7	8.0
	Plastic can	2	2.2
How do you collect water from the storage container?	Cup with handles	70	79.6
	Cup without handles	1	1.1
	Bowl	17	19.3
How frequently do you clean your water storage containers?	Daily	58	65.9
	Weekly	18	20.4
	Monthly	7	8.0
	Rarely	5	5.7
Is your source available year-round?	Yes	86	86.0
	No	14	14.0
Have you faced any problem with your water supply recently?	Yes	45	45.0
	No	55	55.0
If yes, what kind of problems?	Contamination	1	2.2
	High cost	11	24.4
	Intermittent supply	27	60.0
	Poor taste	6	13.3
	Bad odour	0	0.0
Can people get sick with the water they drink?	Yes	18	18.0
	No	82	82.0
Have your household experienced water-related illness in the past 6 months?	Yes	10	10.0
	No	90	90.0
If yes, which illness(es)?	Diarrhea	2	20.0
	Typhoid	8	80.0
	Cholera	0	0.0
	Others	0	0.0
Any unpleasant physical characteristics associated with your water? If yes, name them	No	91	91.0
	Colour	1	1.0
	Taste	8	8.0

The results in Table 4.3 provide insight into the sanitation and hygiene behaviours of the surveyed households. A large proportion (82%) of respondents reported using flush toilets, indicating that most households have access to improved sanitation facilities. Only 12% used pit latrines, while open defecation was completely absent. In terms of infrastructure, most toilets (76%) had tiled floors, enhancing hygiene and ease of cleaning, while 24% had concrete floors. Approximately half of the respondents (51%) indicated that their toilet facilities were shared with other households. In addition, only 42% reported having a regular handwashing facility near the toilet.

Regarding toilet cleaning routines, 61% cleaned their facilities weekly, while 38% did so daily but 1% cleaned monthly. In terms of personal hygiene, 80% of respondents reported always washing their hands after using the toilet, and 73% stated that they washed their hands whenever they became dirty. Yet, only 34% always used soap, while 42% used soap sometimes and 24% only when available. Before food preparation, 57% of respondents reported always washing their hands, while 43% did so only sometimes. Encouragingly, all respondents (100%) reported bathing daily, demonstrating strong personal hygiene behaviour. With respect to environmental sanitation, 84% disposed of household waste through formal waste management services, whereas 11% dumped waste in open spaces and 5% used burning as a disposal method. Regular environmental cleaning was also practiced by most respondents, with 83% cleaning daily and 17% weekly. Awareness of safe water, sanitation, and hygiene (WASH) principles was high, with 51% being very aware and 39% somewhat aware. However, only 37% of respondents were aware of recent water quality testing programs in their area. Despite this, a strong 73% expressed willingness to consent to having their water tested, indicating openness to public health interventions.

Table 4.3. Sanitation and Hygiene Practices of Households

Parameters		**Frequency (n=100)**	**Percentage (%)**
What type of toilet facility is available to your household?	Flush toilet	82	82.0
	Pit latrine	12	12.0
	Open defecation	0	0.0
	Others	0	0.0
Type of floor in the toilet?	Concrete	24	24.0
	Wooden	0	0.0
	Tiles	76	76.0
Is the toilet shared with other households?	**Yes**	51	51.0
	No	49	49.0
Do you have access to regular handwashing facility near the toilet?	**Yes**	42	42.0
	No	58	58.0
How often is the toilet facility cleaned?	Daily	38	38.0
	Weekly	61	61.0
	Monthly	1	1.0
How often do you wash your hands after using the toilet?	Always	80	80.0
	Sometimes	20	20.0
How often do you wash your hands per day?	13 times	6	6.0
	46 times	9	9.0
	Whenever hands are dirty	73	73.0
	Not sure	12	12.0
How often do you wash your hands before preparing food?	Always	57	57.0
	Sometimes	43	43.0
How often do you use soap when you wash your hands?	Always	34	34.0
	Sometimes	42	42.0
	When available	24	24.0
Do you bath daily?	Yes	100	100.0
	No	0	0.0
How do you dispose your household waste?	Waste management services	84	84.0
	Burning	5	5.0
	Buried	0	0.0
	Dump in Open Space	11	11.0
How often do you clean your surroundings?	Daily	83	83.0
	Weekly	17	17.0
	Occasionally	0	0.0
Are you aware of the importance of safe water, sanitation, and hygiene (WASH)?	Very aware	51	51.0
	Somewhat aware	39	39.0
	Not aware	10	10.0
Have there been any water quality testing programs in your area recently?	Yes	37	37.0
	No	63	63.0
	Not sure	0	0.0
Would you consent to having your water source tested for quality parameters?	Yes	73	73.0
	No	27	27.0

The physicochemical characteristics of household drinking water samples presented in Table 4.4. Temperature values ranged between 25.7°C and 29.7°C, with a mean around 27.8°C. The pH values varied between 4.6 and 8.0. However, samples such as UPM08 (pH 5.3) and UPM29 (pH 4.6) were slightly acidic. Total Dissolved Solids (TDS) ranged from 24 to 136 mg/L, indicating low levels of dissolved ions and overall good palatability. Electrical Conductivity (EC) values ranged from 44 to 219 μS/cm. All samples recorded zero salinity (0.00%), consistent with freshwater characteristics. Oxidation-Reduction Potential (ORP) values ranged from 183 to 285 mV, suggesting the presence of oxidizing conditions favourable for aerobic microbial processes, which are typical of well-aerated groundwater and packaged water. Hydrogen concentration remained minimal (0.0–0.6 ppb), and specific gravity was constant at 1.0 across all samples, indicating uniform water density. Resistivity values ranged between 45 and 162 Ω·cm, inversely correlating with conductivity and confirming low dissolved ionic content.

Table 4.5 presents the heterotrophic bacterial counts in different household drinking water sources. The heterotrophic counts ranged from 26×10^0 to 235×10^0 CFU/mL. Borehole water samples exhibited bacterial counts of 29×10^0 and 110×10^0 CFU/mL. Sachet water samples generally showed lower bacterial counts (ranging between 26×10^0 and 88×10^0 CFU/mL), reflecting better microbial quality compared to borehole and river sources. In contrast, river water samples (UPM27–UPM31) exhibited significantly elevated bacterial loads (ranging from 163×10^0 to 235×10^0 CFU/mL). These high counts in river sources suggest contamination from surface runoff, domestic waste, or direct human and animal activities along the riverbanks, making river water unsuitable for direct consumption without treatment.

Table 4.4. Physicochemical Profile of Drinking Water Samples from Households

Sample Codes	Parameters								
	Temperature (°C)	**pH**	**TDS (mg/L)**	**EC (µs/cm)**	**Salinity (%)**	**ORP (mv)**	**Hydrogen (ppb)**	**Specific Gravity**	**Resistivity (Ω .cm)**
UPM04	27.5±0.2	7.3±0.1	56±3.1	76±5.6	0.00±0.0	207±3.7	0.5±0.0	1.0±0.0	152±2.4
UPM05	26.1±0.3	7.2±0.1	61±2.0	64±4.2	0.00±.0.0	199±.3.2	0.0±0.0	1.0±0.0	121±.2.2
UPM06	28.5±0.2	7.0±0.3	37±3.5	78±2.7	0.00±0.0	223±3.9	0.3±0.0	1.0±0.0	162±4.1
UPM08	25.7±0.1	5.3±0.2	47±2.2	83±4.1	0.00±0.0	209±3.7	0.0±0.0	1.0±0.0	101±3.6
UPM10	28.2±0.1	6.6±0.2	29±4.0	92±7.2	0.00±0.0	268±2.6	0.0±0.0	1.0±0.0	123±3.6
UPM11	29.3±0.7	7.3±0.2	40±2.7	60±3.6	0.00±0.0	220±9.1	0.2±0.0	1.0±0.0	137±3.4
UPM12	27.0±0.2	6.7±0.1	56±2.1	92±3.5	0.00±0.0	246±4.9	0.0±0.0	1.0±0.0	115±3.7
UPM13	27.1±0.9	8.0±0.2	29±1.1	81±5.4	0.00±0.0	207±2.8	0.4±0.0	1.0±0.0	156±4.2
UPM14	28.6±0.3	7.2±0.1	115±4.3	104±6.3	0.00±0.0	183±6.0	0.0±0.0	1.0±0.0	83±3.9
UPM16	27.4±0.2	7.3±0.4	71±2.5	112±7.2	0.00±0.0	275±3.2	0.0±0.0	1.0±0.0	92±1.4
UPM20	28.7±0.5	7.9±0.0	24±6.1	44±3.9	0.00±0.0	195±3.5	0.1±0.0	1.0±0.0	97±2.6
UPM23	26.2±0.3	7.6±0.0	124±2.8	112±4.6	0.00±0.0	284±6.1	0.0±0.0	1.0±0.0	96±1.7
UPM24	28.3±0.0	6.2±0.2	105±4.6	141±3.2	0.00±0.0	211±3.5	0.0±0.0	1.0±0.0	45±3.7
UPM25	26.3±0.5	7.4±0.3	84±2.9	153±4.3	0.00±0.0	261±5.7	0.0±0.0	1.0±0.0	68±3.9
UPM26	27.4±0.3	6.2±0.2	46±4.8	97±5.1	0.00±0.0	273±6.2	0.0±0.0	1.0±0.0	110±3.3
UPM27	26.2±0.1	7.6±0.3	92±3.1	116±6.3	0.00±0.0	281±4.9	0.0±0.0	1.0±0.0	69±3.5
UPM28	27.6±0.2	6.5±0.2	63±2.7	210±4.3	0.00±0.0	271±3.0	0.0±0.0	1.0±0.0	89±4.0
UPM29	29.4±0.4	4.6±0.3	39±6.4	74±3.5	0.00±0.0	242±3.3	0.1±0.0	1.0±0.0	148±3.4
UPM30	26.2±0.2	7.6±0.4	46±2.1	105±3.6	0.00±0.0	261±3.9	0.1±0.0	1.0±0.0	88±5.0
UPM31	27.0±0.3	8.0±0.3	101±4.2	131±3.1	0.00±0.0	209±4.2	0.6±0.0	1.0±0.0	91±4.1
UPM34	28.1±0.1	6.7±0.4	104±4.6	219±6.1	0.00±0.0	223±4.2	0.2±0.0	1.0±0.0	53±4.9
UPM35	29.2±0.0	6.3±0.2	136±3.7	207±6.8	0.00±0.0	199±3.9	0.3±0.0	1.0±0.0	46±3.5
UPM37	28.4±0.0	7.5±0.2	133±3.1	201±4.2	0.00±0.0	242±6.1	0.0±0.0	1.0±0.0	49±3.8
UPM38	29.7±0.0	5.1±0.0	89±4.8	156±2.9	0.00±0.0	261±4.9	0.1±0.0	1.0±0.0	82±4.4
UPM39	28.0±0.02	7.6±0.3	96±3.6	217±3.2	0.00±0.0	203±2.7	0.1±0.0	1.0±0.0	91±3.6
UPM40	27.1±0.0	7.1±0.1	93±3.4	96±2.1	0.00±0.0	285±6.1	0.1±0.0	1.0±0.0	84±3.1
UPM41	28.1±0.2	8.0±0.5	77±3.1	83±6.1	0.00±0.0	237±5.2	0.0±0.0	1.0±0.0	95±4.5
UPM42	28.1±0.0	7.1±0.2	121±4.4	101±4.0	0.00±0.0	236±2.4	0.0±0.0	1.0±0.0	99±3.6
UPM43	29.0±0.0	6.7±0.0	96±2.3	203±3.1	0.00±0.0	210±8.2	0.2±0.0	1.0±0.0	72±5.3
UPM46	28.5±0.3	7.3±0.5	103±4.8	91±5.2	0.00±0.0	261±4.9	0.0±0.0	1.0±0.0	99±4.4

KEY: TDS = Total dissolved solids; EC= Electrical conductivity; ORP= Oxidation-Reduction Potential

Table 4.5. Mean Total Heterotrophic Counts of Drinking Water Samples from Households

Sample Code	Sample Source	Mean Counts of Heterotrophic Bacteria CFU/mL $\times 10^0$
UPM04	Borehole	201±6.2
UPM05	Borehole	82±4.1
UPM06	Borehole	88±5.1
UPM08	Sachet water	26±3.8
UPM10	Borehole	57±3.5
UPM11	Borehole	110±2.4
UPM12	Borehole	93±3.0
UPM13	Borehole	38±6.2
UPM14	Borehole	94±3.8
UPM16	Borehole	29±4.9
UPM20	Sachet water	31±3.5
UPM23	Borehole	94±4.6
UPM24	Borehole	90±3.1
UPM25	Borehole	66±3.7
UPM26	Sachet water	34±5.8
UPM27	River	189±3.0
UPM28	River	194±5.1
UPM29	River	163±7.9
UPM30	River	235±5.6
UPM31	River	231±8.1
UPM34	Borehole	69±4.1
UPM35	Borehole	72±5.2
UPM37	Borehole	98±2.9
UPM38	Borehole	38±5.8
UPM39	Borehole	88±4.3
UPM40	Borehole	40±4.7
UPM41	Borehole	71±3.2
UPM42	Sachet water	88±3.1
UPM43	Sachet water	37±2.9
UPM46	Borehole	75±3.4

Figure 4.1 illustrates the distribution of total heterotrophic bacterial counts across the different water sources sampled. The river water exhibited the highest mean bacterial load (202.4 × 10^0 CFU/mL), followed by borehole water (79.7 × 10^0 CFU/mL), while sachet water recorded the lowest bacterial count (43.2 × 10^0 CFU/mL). This distribution indicates the trend of River > Borehole > Sachet as highlighted for the varying degrees of microbial quality among water sources, with river water posing the greatest potential health risk to consumers if untreated.

Table 4.6 presents the distribution of total coliform and *Escherichia coli* (*E. coli*) counts in different household water samples. The total coliform counts varied across sources, with river water samples (UPM27–UPM31) recording the highest levels (ranging from 37 × 10^0 CFU/mL to 51 × 10^0 CFU/mL). Borehole samples showed moderate contamination in some cases, such as UPM04 (51 × 10^0 CFU/mL), UPM11 (30 × 10^0 CFU/mL), and UPM38 (46 × 10^0 CFU/mL), while other borehole and all sachet water samples had no detectable coliforms. Also, sachet water samples consistently showed zero coliform counts, reflecting a relatively safer microbiological quality.

Regarding *E. coli*, only one river water sample (UPM28) recorded a detectable count (2.6 × 10^0 CFU/mL), while all other samples had no detectable *E. coli*. This suggests that most water sources were free from recent fecal contamination. Figure 4.2 illustrates the mean distribution of *Escherichia coli* (*E. coli*) counts across the different water sources analyzed. The results show that both borehole and sachet water samples had a mean *E. coli* count of 0.0 CFU/mL × 10^0, indicating the absence of fecal contamination. In contrast, river water samples recorded a mean *E. coli* count of 0.5 CFU/mL × 10^0, signifying minor fecal contamination. The presence of *E. coli* in river samples suggests potential pollution from untreated domestic waste, livestock runoff, or human activities occurring along the riverbanks.

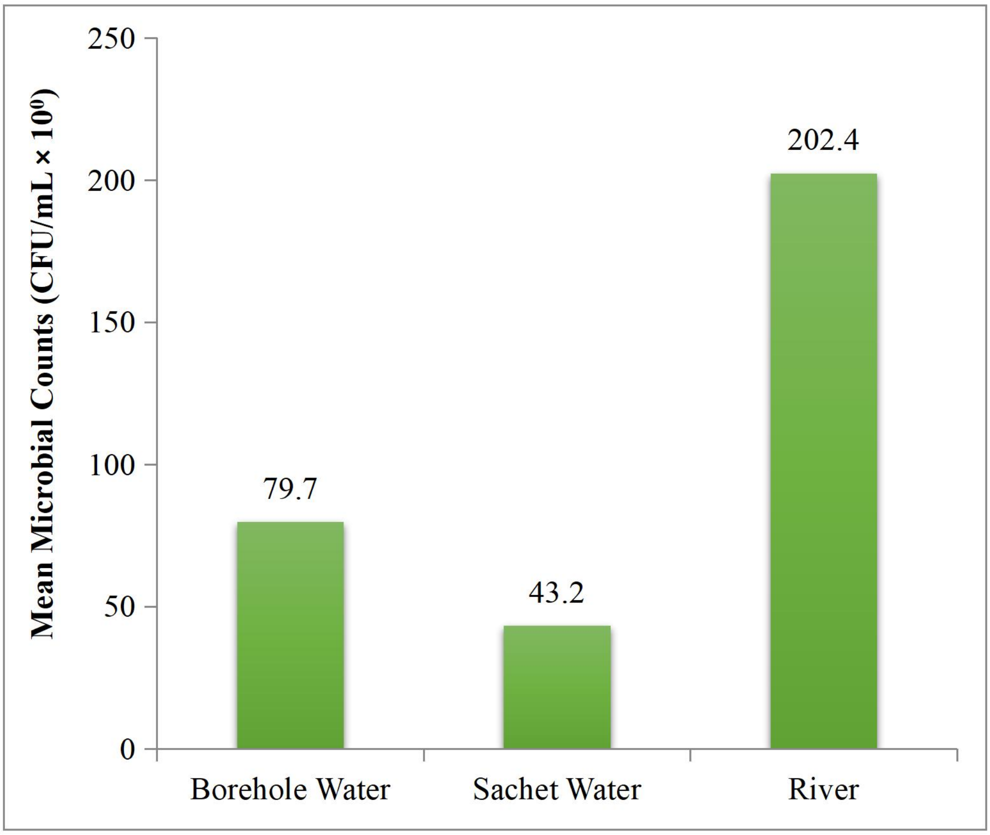

Figure 4.1. Distribution of Heterotrophic Bacterial Based on Sample Sources

Table 4.6. Coliforms and *Escherichia coli* Counts in Water Samples from Households

Sample Codes	Sample Sources	Total Coliform Count (CFU/mL ×10^0)	*Escherichia coli* Count (CFU/mL ×10^0)
UPM04	Borehole	51±4.2	0±0.0
UPM05	Borehole	0±0.0	0±0.0
UPM06	Borehole	23±3.3	0±0.0
UPM08	Sachet water	0±0.0	0±0.0
UPM10	Borehole	0±0.0	0±0.0
UPM11	Borehole	30±2.7	0±0.0
UPM12	Borehole	0±0.0	0±0.0
UPM13	Borehole	0±0.0	0±0.0
UPM14	Borehole	17±2.9	0±0.0
UPM16	Borehole	0±0.0	0±0.0
UPM20	Sachet water	0±0.0	0±0.0
UPM23	Borehole	0±0.0	0±0.0
UPM24	Borehole	19±2.1	0±0.0
UPM25	Borehole	0±0.0	0±0.0
UPM26	Sachet water	0±0.0	0±0.0
UPM27	River	51±2.6	0±0.0
UPM28	River	42±2.5	2.6±1.2
UPM29	River	44±3.7	0±0.0
UPM30	River	37±2.9	0.0±0.0
UPM31	River	39±6.2	0±0.0
UPM34	Borehole	0±0.0	0±0.0
UPM35	Borehole	0±0.0	0±0.0
UPM37	Borehole	31±4.1	0±0.0
UPM38	Borehole	46±2.8	0±0.0
UPM39	Borehole	0±0.0	0±0.0
UPM40	Borehole	30±2.0	0±0.0
UPM41	Borehole	0±0.0	0±0.0
UPM42	Sachet water	0±0.0	0±0.0
UPM43	Sachet water	0±0.0	0±0.0
UPM46	Borehole	27±3.2	0±0.0

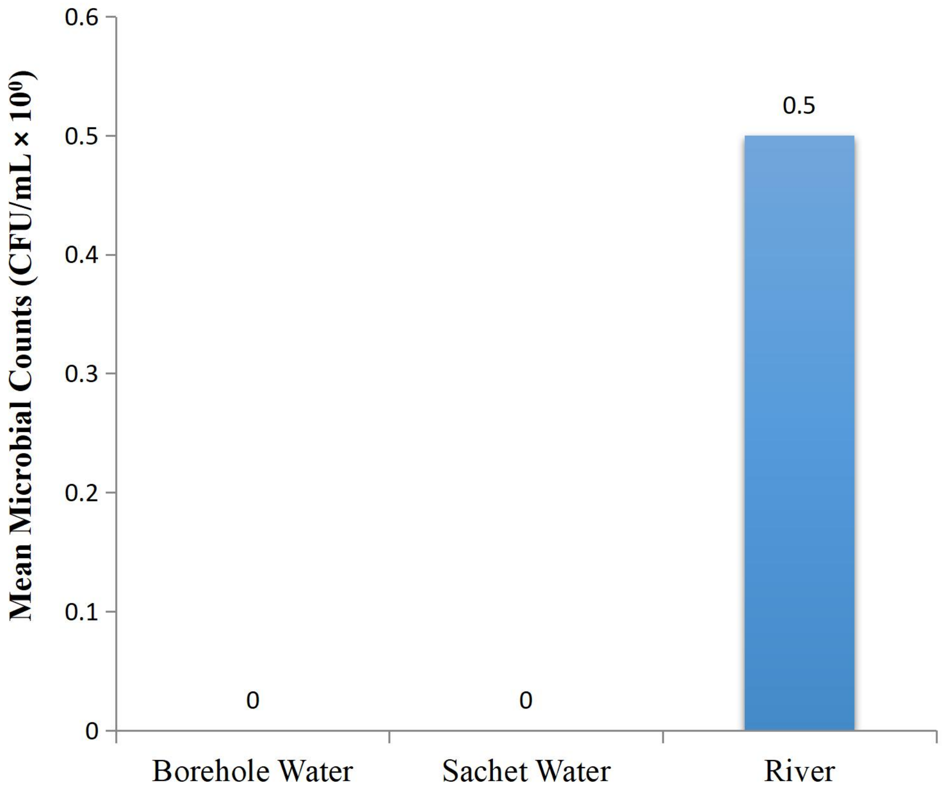

Figure 4.2. Distribution of *Escherichia coli* in Drinking Water Samples from Households

Figure 4.3 presents the mean distribution of total coliform counts in water samples. The borehole water samples recorded a mean coliform count of 24.9 CFU/mL × 10^0, while river water samples showed a higher mean value of 42.6 CFU/mL × 10^0. In contrast, sachet water samples recorded no detectable coliforms (0.0 CFU/mL × 10^0). The detection of coliforms in borehole and river water indicates possible contamination from environmental sources or infiltration of surface runoff into the water supply. The higher counts observed in river water may reflect direct exposure to wastes, and anthropogenic pollutants, which are typical of unprotected surface sources.

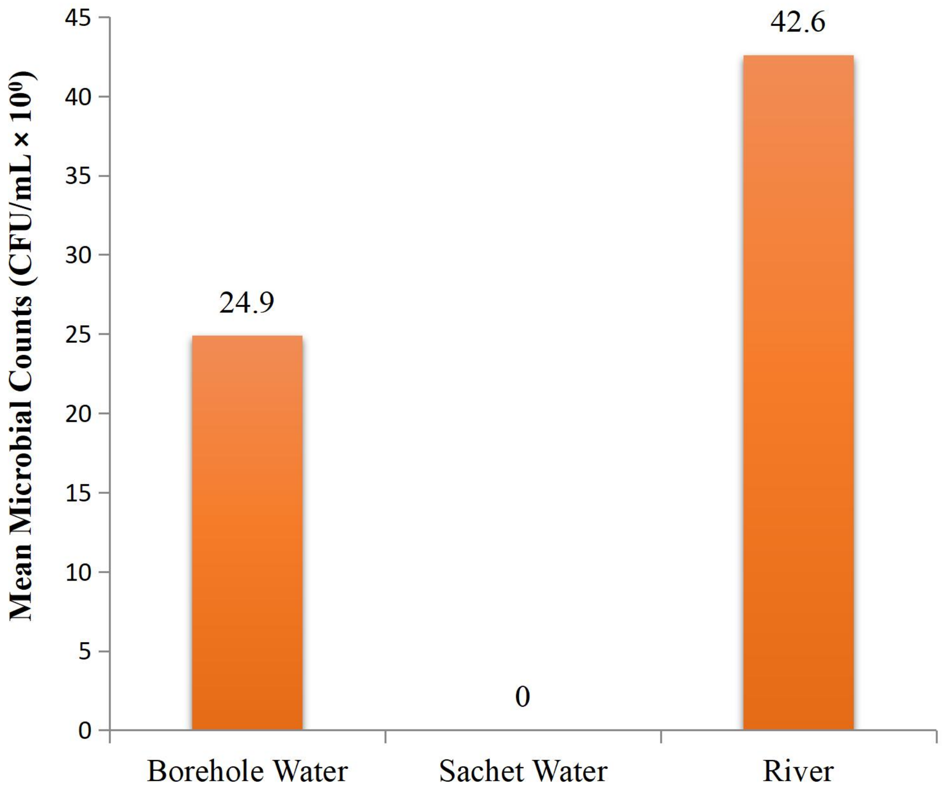

Figure 4.3. Distribution of Total Coliforms Based on Sample Sources

CHAPTER FIVE

5.0 DISCUSSION

5.1 Demographics and Environmental Observations of Households

The demographic profile of the surveyed households revealed a predominance of female respondents (65%), which is consistent with traditional household roles in Nigerian communities where women are typically responsible for water management and domestic hygiene practices. This finding aligns with the observations of Kaoje *et al.* (2018), who reported that women constitute the primary decision makers regarding household water usage and sanitation in urban Nigerian settings. The age distribution showed that the majority of respondents (78%) were within the 1837 years bracket, indicating a relatively young population that is economically active and potentially more receptive to health education interventions.

The high literacy rates observed in this study, with 72% of respondents having secondary or tertiary education, contrast sharply with findings from rural Nigerian communities where educational attainment is typically lower (Kaoje *et al.*, 2018). This educational advantage should theoretically translate to better WASH practices, yet survey reveal significant gaps between knowledge and practice, consistent with the "knowledge practice paradox" documented in similar urban settings (Nwosu *et al.*, 2024). The occupational distribution, dominated by traders and business owners (42%), reflects the commercial nature of the Upper Mission area and is consistent with the demographic patterns observed in peri-urban areas of Benin City.

The household income data showed that 44% of households earned ₦150,000 and above monthly, indicating a relatively middle income population. This income level influences access to improved water sources and sanitation facilities, as evidenced by the high proportion of households using sachet water (52%) and flush toilets (82%). Omoregie *et al.* (2023) noted that household income is a critical determinant of water source selection and treatment practices in Nigerian urban communities.

Environmental observations reveal concerning proximity patterns, with 38% of households located near waste dump sites and 60.5% of these within 50 meters of dumpsites. This spatial relationship significantly increases contamination risks for groundwater sources, particularly boreholes, which are vulnerable to leachate infiltration (Aluko *et al.*, 2022). The relatively low prevalence of open sewage (7%) suggests better environmental management compared to informal settlements, yet the moderate cleanliness rating (52%) indicates room for improvement in communitywide sanitation practices.

5.2 Water Source and Quality Assessment

The survey indicated a significant reliance on enhanced water sources within the community, with a majority of households depending on sachet water (52%) and boreholes (41%) for their drinking water. Accessibility was high overall, as more than 85% of respondents noted that both their primary and secondary water sources were situated within 100 meters of their homes. Nevertheless, a considerable vulnerability was recognized in the management of water safety: over 75% of households did not treat their water before consumption. This pattern was largely linked to the dependence on sachet water, which is usually pre-treated and regarded as safe for immediate consumption. The prevalence of sachet water as a primary source mirrors similar observations in West Africa, where packaged water is commonly utilized in areas with unreliable piped supplies. For instance, packaged water (which includes sachet water) is considered “a significant aspect of water security in various low and middle income countries,” although it is sometimes inconsistently categorized in surveys

(Vedachalam *et al*., 2017). Out of the 100 households surveyed, 41 reported boreholes as their principal source of drinking water. Among this group, only 11 households treated their water before drinking, while the remaining 30 did not. Furthermore, nine households that engaged in water treatment sourced their water from sachet and river sources. Those who relied on sachet water typically did not treat it directly but instead treated their alternative water sources, particularly borehole water. Among the few who undertook water treatment, boiling was the most commonly utilized method, followed by filtration. Importantly, a disconnect was noted between perception and risk, as many respondents who did not treat their water believed it posed no health risks. This belief implies a misleading sense of security concerning the safety of drinking water and underscores the potential dangers of contamination after the source, even when water is sourced from improved options. This observation aligns with broader knowledge-attitude-practice (KAP) studies in Nigeria, which reveal gaps in WASH knowledge and safe practices (Sridhar *et al*., 2020).

Water storage practices in households are largely positive, with the majority of respondents utilizing covered containers to safeguard their stored water. However, the methods used to retrieve this water create a significant risk of contamination. The common practice of using cups (with or without handles) and bowls to draw water from storage containers poses a high risk, as it often involves contaminated hands or utensils, thereby threatening the entire water supply. For instance, the 2014 research conducted in Ibadan indicated that using cups or ladles to scoop water from the container notably increased microbial levels in the stored drinking water (Onigbogi and Ogunyemi, 2014). Although the frequency of cleaning storage containers is typically good (mostly daily or weekly), the unsafe practices for extracting water undermine these efforts and highlight a critical area for public health initiatives aimed at preventing waterborne illnesses at the point of use.

5.3 Sanitation and Hygiene Practices

The community exhibits a strong level of sanitation facilities, with flush toilets being the most prevalent option, which often includes finished flooring like tiles. However, a notable concern is that many of these sanitation facilities are shared among several households, which can complicate upkeep and heighten the risk of pathogen exposure. An example can be found in Enugu, where households that share toilets experienced four to five times greater odds of diarrhoea (Nwokoro *et al*., 2020). In terms of personal hygiene, although most participants report consistently washing their hands after using the toilet, the effectiveness of this habit is compromised by irregular soap usage. Many individuals stated they use soap only "sometimes" or "when available." The main reason for handwashing appears to be a sensation of uncleanliness, rather than an established awareness of essential moments to wash hands (e.g., after defecation or before preparing food), suggesting that the quality of handwashing, not just its frequency, needs enhancement. This aligns with findings in Cross River State, where only 45.6% of respondents washed their hands with soap, and 53.9% washed with water only after defecation (Oka *et al*., 2019).

Although waste management is primarily handled by a formal agency, many households continue to burn or dump their waste in the open, which is hazardous to the environment and human health. For example, despite 95% of participants acknowledging the health concerns, 72% of participants in a study done in southwest Nigeria disposed of solid garbage at open dumpsites (Aluko *et al*., 2022). Regarding awareness, a significant number of participants stated that they were "very aware" or "somewhat aware" of the need of WASH. However, the adoption of safe behaviours, such as frequent water treatment or soap usage, is not often accompanied by this articulated awareness, highlighting a critical knowledge-action gap that requires targeted educational activities. There is a persistent gap between awareness/attitude and behaviour in Nigerian research. For instance, a survey found that although over 90% of respondents acknowledged appropriate trash disposal techniques, 66% still dumped rubbish in the open and 62% burned it (Adogu *et al*., 2015). Through focused educational initiatives, improved enforcement of environmental health laws, and the encouragement of behaviour change interventions that emphasize doable actions rather than just raising awareness, this disparity draws attention to a significant behavioural gap that needs to be closed.

5.4 Physicochemical Parameters of Drinking Water

The physicochemical assessment indicated that most parameters were within acceptable limits for drinking water, although some differences were noted among samples. The temperature ranged from 25.7°C to 29.7°C, which is characteristic of ambient conditions in tropical Nigeria and lies within the WHO's acceptable temperature range for drinking water. Temperature can impact the palatability of water and may affect microbial growth rates, with higher temperatures often promoting bacterial growth (Dignum *et al*., 2023). The pH levels varied from 4.6 to 8.0, with certain samples showing slight acidity. Specifically, samples UPM08 (pH 5.3) and UPM29 (pH 4.6) were acidic and fell below the WHO recommended range of 6.58.5 for drinking water (Okereke *et al*., 2022). Acidic water can lead to the corrosion of distribution systems and may influence the taste and smell of the water, potentially resulting in lower consumption rates. The slightly alkaline pH found in some borehole samples (pH 8.0) is typical for groundwater affected by carbonate minerals.

Total Dissolved Solids (TDS) ranged from 24 to 136 mg/L, all significantly below the WHO guideline limit of 500 mg/L. These low TDS values suggest low mineral content and good palatability of the water sources. The electrical conductivity (EC) values, which were between 44 and 219 µS/cm, correspondingly indicate the low ionic content of the water. The absence of salinity in all samples reinforces the freshwater nature and is in line with the hydrogeological conditions present in the study area. The Oxidation-Reduction Potential (ORP) values ranged from 183 to 285 mV, reflecting oxidizing conditions that are conducive to aerobic microbial activities. Though ORP is not a direct measure of water quality, higher values typically indicate better potential for disinfection and a lower chance of anaerobic bacterial contamination. The consistent specific gravity of 1.0 across all samples suggests that there are no significant dissolved solids affecting the water's density. The resistivity values, which have an inverse relationship with conductivity, further affirm the low ionic content in the water samples.

5.5 Microbiological Quality of Drinking Water

5.5.1 Total Heterotrophic Bacterial Counts

The counts of heterotrophic bacteria indicated a notable level of microbial contamination in all examined water sources, with values ranging between 26×10^{0} and 235×10^{0} CFU/mL. These figures surpass the WHO guideline threshold of 100 CFU/mL for heterotrophic bacteria in potable water, especially in river and various borehole samples. Elevated heterotrophic bacterial counts signify the existence of organic nutrients conducive to bacterial growth and suggest possible inadequacies in water treatment or the safeguarding of water sources. Recently, similar high levels of heterotrophic bacteria have been observed in Nigeria; for example, Okwelle *et al*. (2021) found total heterotrophic counts reaching up to 5.2×10^{3} CFU/mL in wells and streams within Rivers State — indicating that being classified as an “improved source” does not ensure microbiological safety.

River water samples showed the highest levels of bacterial contamination (ranging from 163×10^{0} to 235×10^{0} CFU/mL) with an average count of 202.4×10^{0} CFU/mL. This significant level of contamination aligns with the characteristics of surface water sources, which are susceptible to various pollutants such as domestic wastewater discharge, agricultural runoff, and direct exposure from human and animal activities (Adomi *et al*., 2025).

Borehole water samples exhibited moderate levels of bacterial contamination, presenting an average count of 79.7×10^0 CFU/mL, although individual sample counts varied between 29×10^0 and 201×10^0 CFU/mL. The discrepancies in borehole water quality may be indicative of differences in well construction, maintenance protocols, depth, and proximity to potential contamination sources. The notably high count in sample UPM04 (201×10^0 CFU/mL) points to possible surface water infiltration or insufficient well sanitation (Odeyemi *et al*., 2024).

Sachet water samples showed the highest microbiological quality among the three sources, with an average bacterial count of 43.2×10^0 CFU/mL (ranging from 26×10^0 to 88×10^0 CFU/mL). Although this level is lower than that of borehole and river waters, it still indicates the presence of heterotrophic bacteria. The relatively superior quality of sachet water is likely a result of industrial production methods that include filtration and, in certain cases, ultraviolet disinfection. However, recent studies in Nigeria indicate that sachet water still contains detectable levels of heterotrophic bacteria (e.g., Tenebe *et al*. (2023) identified significant THB levels in urban sachet water supplies), highlighting that contamination can occur postproduction during distribution and storage.

The observed distribution pattern of River > Borehole > Sachet water for bacterial contamination clearly illustrates the influence of water source protection and treatment on microbiological quality. This trend emphasizes the necessity for the protection of source water, particularly for boreholes and rivers, as well as the critical importance of household water treatment, especially for untreated borehole and surface water sources.

5.5.2 Total Coliform and *Escherichia coli* Contamination

The identification of total coliforms in various water samples indicates a potential risk of fecal contamination or contamination after treatment. River water samples exhibited the highest coliform counts (37×10^0 to 51×10^0 CFU/mL) with an average of 42.6×10^0 CFU/mL, confirming significant pollution from both environmental and human sources. The detection of coliforms in surface water is anticipated due to multiple sources of pollution, such as sewage disposal, farming practices, and wildlife (Alabi *et al*., 2024).

Borehole water samples displayed varying levels of coliform contamination, with some samples recording values as high as 51×10^0 CFU/mL (UPM04) and 46×10^0 CFU/mL (UPM38), while others showed no detectable coliforms. The average coliform count for borehole water was 24.9×10^0 CFU/mL. This inconsistency implies that certain boreholes may be affected by surface water infiltration or fecal contamination from nearby septic tanks. The closeness of waste disposal sites reported in the demographic data (38% of households) likely contributes to the contamination of groundwater through the movement of leachate. Similar patterns of contamination have been noted in various studies in Nigeria, where poor placement of boreholes and inadequate distances between water supplies and sanitation facilities have resulted in bacterial pollution of groundwater. Aminu and Udeze (2023) identified a significant link between the distance to septic tanks and the occurrence of waterborne illnesses in slums of Lagos, emphasizing the impact of poor sanitation water interactions on microbial contamination. Aluko *et al*. (2022) further highlighted the health risks associated with residing close to open dumps in Southwest Nigeria, indicating that leachate infiltration often undermines the microbiological safety of adjacent boreholes.

The absence of coliforms in all sachet water samples is a positive finding and indicates that industrial water treatment methods are typically successful in producing microbiologically safe products. This finding is consistent with research in Ebonyi State, where sachet-water

TCC measurements were "significantly below permissible limits" (Okpara *et al.*, 2024). However, consumers should remain mindful of storage conditions and expiration dates, as these factors can influence product quality.

The detection of *E. coli* in only one sample (UPM28, river water: 2.6×10^{0} CFU/mL) suggests that recent fecal contamination was restricted. *E. coli* serves as a specific marker for fecal contamination, and its presence, even in small amounts, presents a public health concern due to the possible presence of enteric pathogens. According to the WHO guideline, *E. coli* should not be found in any 100 mL water sample meant for human consumption (Odeyemi *et al.*, 2024). The low occurrence of *E. coli* in this study, despite the presence of total coliforms, implies that much of the coliform contamination may originate from environmental rather than fecal sources. Nevertheless, the absence of *E. coli* in numerous contaminated samples does not guarantee safety, as bacteria may have died during storage or transport, allowing more resistant pathogens to survive.

The mean distribution pattern of *E. coli* (Borehole: 0.0 CFU/mL, Sachet: 0.0 CFU/mL, River: 0.5 CFU/mL) indicates that river water carries the highest risk of fecal contamination. This highlights the urgent need to treat surface water prior to consumption and to safeguard water sources against contamination from human and animal waste (Alabi *et al.*, 2024).

5.6 Public Health Implications

The results of this research highlight significant public health issues related to the quality of household water and hygiene practices in Upper Mission, Benin City. The detection of heterotrophic bacteria and coliforms in drinking water samples, along with low rates of water treatment, creates a favouerable environment for the spread of waterborne diseases. The elevated bacterial levels in river water and inconsistent contamination in borehole water underscore the susceptibility of these water sources to pollution.

The gap between perception and reality is alarming, as 82% of respondents believed that drinking water does not lead to illness, despite the evidence of contamination. This misunderstanding could foster a lack of urgency regarding the adoption of water treatment and protection strategies. The reported low occurrence of water related diseases (10%) may not truly represent the actual disease burden, as many waterborne illnesses can manifest with nonspecific symptoms that might be misattributed to other ailments without appropriate diagnostic tests.

Poor handwashing habits, particularly the irregular use of soap (only 34% consistently use soap), notably heighten the risk of fecal-oral disease transmission. The combination of shared toilet facilities (51%) and the absence of handwashing stations close to toilets (58%) creates various routes for pathogen transmission within and among households. Recent national statistics indicate that merely 17% of households have access to basic hygiene services, and only 27% had soap visibly present at home (eWASH, 2022).

The closeness of waste disposal sites to residential neighbourhoods (38% of households) and the occurrence of open waste dumping (11%) introduce further contamination hazards to groundwater sources due to leachate infiltration. This environmental contamination route likely accounts for some of the variability seen in borehole water quality and highlights the connection between environmental sanitation and water quality.

5.7 Implications for Water Quality Management

The findings of this study emphasize the necessity for a comprehensive strategy to enhance household water quality in the examined region. Firstly, there is an immediate requirement for health education programs to increase awareness about water quality, waterborne illnesses, and the significance of water treatment, especially concerning borehole and surface water sources. Community driven initiatives that illustrate straightforward, cost effective treatment techniques such as boiling, chlorination, and filtration could considerably lower the risk of disease (Idigbe *et al.*, 2024; Aminu and Udeze, 2023).

Secondly, there should be an enhancement of regulatory supervision over sachet water production and distribution to uphold the currently acceptable quality standards (Durowoju *et al.*, 2022). Although sachet water exhibited the highest microbiological quality in this research, ongoing monitoring is essential to maintain consistent safety across varying brands and production periods.

Thirdly, standards for borehole construction and upkeep should be upheld to minimize contamination risks. This entails ensuring adequate depths, proper casings and seals, maintaining sanitary zones around boreholes, and conducting regular inspections and disinfections (Ikemitang, 2024). Households must be informed about appropriate borehole maintenance and the necessity of periodic water quality testing.

Fourthly, enhancements in environmental sanitation, particularly in waste management, are crucial for safeguarding water sources. Properly sited waste disposal facilities away from water sources, improved waste collection services, and the elimination of open dumping practices would diminish groundwater contamination risks (Rawlings and Seghosime, 2025).

Lastly, the creation of regular community water quality monitoring programs would facilitate ongoing oversight of water safety and allow for timely actions when contamination occurs. The relatively high percentage of respondents willing to agree to water testing (73%) indicates a community openness to such initiatives.

5.8 CONCLUSION

In conclusion, residents of Upper Mission, New Benin, maintain an unwarranted confidence in the quality of their water. A significant gap exists between the reasonably adequate sanitation facilities and the hazardous everyday actions associated with water treatment, storage, and hygiene practices. The interplay of microbiologically compromised source water, a prevalent absence of treatment, unsafe water-fetching methods, and inadequate handwashing contributes to a continuous cycle of vulnerability to waterborne illnesses.

To tackle these issues, public health initiatives such as community awareness programs should aim to highlight the microbial hazards linked to borehole and river water, utilizing local statistics to encourage regular point-of-use treatment, particularly through boiling or filtration methods. Additionally, households ought to be urged to opt for storage vessels with narrow openings and taps to minimize contamination from cups and hands. Efforts should be directed at installing handwashing stations (like "tippy-taps") close to bathrooms and kitchens while promoting hand hygiene at essential times, not solely when hands appear dirty. Although a more secure alternative, the quality of sachet water should be regularly assessed by local authorities to ensure compliance with manufacturing standards.

REFERENCES

Adelagun, R.O.A., Etim, E.E., and Godwin, O.E. (2021). Application of water quality index for the assessment of water from different sources in Nigeria. In: Moujdin I.A. and SummersJ.K. (eds.). *Promising Techniques for Wastewater Treatment and Water Quality Assessment*. Rijeka: IntechOpen, Chapter 14 doi.org/10.5772/intechopen.98696

Adogu, P.O.U., Uwakwe, K.A., Egenti, N.B., Okwuoha, A.P. and Nkwocha, I.B. (2015). Assessment of Waste Management Practices among Residents of Owerri Municipal Imo State Nigeria. Journal of Environmental Protection. *Journal of Environmental Protection*, **6**: 446456

Adomi, P.O., Anozie, A. J., Morka, E., and Odum, E. I. (2025). Microbial and Physicochemical Quality of River Water in Delta State, Nigeria. *World Journal of Environmental Biosciences,* **14**(1): 2128.

Agha A. A., Osuu C., Onalu; C. E. and Adewoyin Y. (2024). Rethinking CommunityLed Total Sanitation for Eradicating Open Defecation in Rural Ebonyi State Communities, Nigeria: practice considerations for social work practitioners and educators. *Journal of Water, Sanitation and Hygiene for Development*, **14** (3): 188–198.

Akhtar N., SyakirIshak M.I., Bhawani S.A., and Umar K. (2021). Various Natural and Anthropogenic Factors Responsible for Water Quality Degradation: A Review. *Water,* **13**: 2660

Alabi, O. S., Akintayo, I., Odeyemi, J. S., Oloche, J. J., Babalola, C. M., Nwimo, C., Popoola, O., Mogeni, O. D., Marks, F., and Okeke, I. N. (2024). Suboptimal Bacteriological Quality of Household Water in Municipal Ibadan, Nigeria. *The American journal of tropical medicine and hygiene*, **110**(2): 346–355.

Aleru, E.O., Bodunde, I.O., Deniran, I.A., Ajani, O.N., Aleru, O.O. and Fawole, A.O. (2023). WASH Practices Increased the Prevalence of Malnutrition Among UnderFive Children (6–59 months) in an Urban Slum Area in Ibadan, Nigeria. *Journal of Water, Sanitation and Hygiene for Development*, **13**(11): 910–920.

Aluko, O.O., Obafemi, T.H., Obiajunwa, P.O., Obiajunwa, C. J., Obisanya, O. A., Odanye, O. H., and Odeleye, A.O. (2022). Solid Waste Management and Health Hazards Associated with Residence Around Open Dumpsites in Heterogeneous Urban Settlements in Southwest Nigeria. *International journal of Environmental Health Research*, **32**(6): 1313–1328.

Aminu, F.O., and Udeze E. (2023). Relationship between Water, Sanitation, Hygiene Practices and the Incidence of Water Borne Diseases Among Urban Slum Households in Lagos State, Nigeria. *Journal of Agriculture, Food, Environment and Animal Sciences*, **4**(1): 120.

Asifat, O.A., Adenusi, A., Adebile, T.V., Aderinto, N., Azu E., Ivey-Waters, A., and Kersey X. K. (2025). Relationship between Unimproved Household Sanitation Facilities and

Malaria Infection Among Under-Five Children in Nigeria: Insights from Malaria Indicator Survey 2021. *Malaria Journal,* **24**:103.

Ayeki, J.A., Asikhia, M., and Ojeh, V.N. (2018). Seasonal and Spatial Variation in PhysicoChemical and Biological Quality of Rainwater in Benin City, Edo State. *Global Journal of HumanSocial Science: B (Geography, GeoSciences, Environmental Science and Disaster Management)*, **18**(5): 25–34.

Babalola, A., Kehinde, O., and Adebayo, A.M. (2025). Water Quality, Sanitation Practices, and Public Health Outcomes in Major Urban Areas of Nigeria (A Comparative Analysis). *International Journal of Research and Scientific Innovation*, **12**(15): 27–43.

Biswas, S., Adhikary, M., Alam, A., Islam, N., and Roy, R. (2024). Disparities in Access to Water, Sanitation, and Hygiene (WASH) Services and the Status of SDG6 Implementation Across Districts and States in India. *Heliyon*, **10**(18): e37646.

Bose, D., Bhattacharya, R., Kaur, T., Banerjee, R., Bhatia, T., Ray, A., Batra, B., Mondal, A., Ghosh, P., and Mondal, S. (2024). Overcoming Water, Sanitation, and Hygiene Challenges in Critical Regions of the Global Community. *WaterEnergy Nexus*, **7**: 277–296.

Cirella G.T., Iyalomhe F.O., and Adekola P.O. (2019). Determinants of Flooding and Strategies for Mitigation: TwoYear Case Study of Benin City. *Geosciences*, ***9***(3): 136.

Dignum, M., van der Wielen, P. W. J. J., Donocik, A., and Prest, E. I. (2023). Influence of Temperature on Growth of Four Different Opportunistic Pathogens in Drinking Water Biofilms. *Microorganisms*, **11**(6): 1574.

Durowoju, O. R., Desogan, A., Mustapha, M., Waziri, S. A., and Ibrahim, U. A. (2022). Assessment of Regulation Compliance and Quality of Sachet Water Factories in Ibadan North Local Government, Oyo State, Nigeria. *Arid Zone Journal of Engineering, Technology and Environment*, **18**(2).

Ejiohuo, O., Onyeaka, H., Akinsemolu, A., Nwabor, O.F., Siyanbola, K.F., Tamasiga, P., and AlSharify, Z.T. (2025). Ensuring Water purity: Mitigating Environmental Risks and Safeguarding Human Health. *Water Biology and Security*, **4**(2): 100341.

eWASH (2022). *Only 17 % of Households have Access Basic Hygiene Services – eWASH.* 28 October. Available at: https://washnigeria.com/2022/10/28/accesstohygieneservicesinnigeria2021/ (Accessed: 2 November 2025).

Ezeaka, N.B., and Bartholomew, C.E. (2025). Navigating Environmental Sanitation and Health Communication in Nigeria: Challenges and Prospects. *International Journal of Research and Innovation in Social Science*, **9**(1): 1–8.

Federal Ministry of Water Resources (FMWR), National Bureau of Statistics (NBS) and UNICEF, 2022. Water, Sanitation and Hygiene: National Outcome Routine Mapping (WASHNORM) 2021: A Report of Findings. Abuja, Nigeria: FMWR and NBS in collaboration with UNICEF. Available at:

www.unicef.org/nigeria/media/5951/file/2021%20WASHNORM%20Report%20.pdf (Accessed: 27 July 2025).

Heukelbach, J. (2023). Hygiene and Sanitation: The Cornerstones of Health and WellBeing. *Journal of Microbial Pathogenesis*, **7**(4).

Hlongwa, N., Nkomo, S.L., and Desai, S.A., (2024). Barriers to Water, Sanitation, and Hygiene in SubSaharan Africa: a mini review. *Journal of Water, Sanitation and Hygiene for Development*, **14**(7): 497–510.

Hutton, G., and Chase, C. (2017). Water Supply, Sanitation, and Hygiene. In: Mock C.N., Nugent R., Kobusingye O. and Smith K.R. (eds.). *Injury Prevention and Environmental Health.* Washington (DC): The International Bank for Reconstruction and Development / The World Bank, Chapter 9. Available at: www.ncbi.nlm.nih.gov/books/NBK525207/ (Accessed 5 May 2025).

Idigbe I., Cherian M., Salako A., Adewale B., Salako B., and Maffioli E. M. (2024). Safe Water Treatment Practices: A Qualitative Study on PointofUse Chlorination in Nigeria. *Journal of Global Health*, **14**: 04178.

Ihezie E. and Obaniyi F. (2023). The importance of clean water and sanitation in Nigeria. (online) Available at: https://southernvoice.org/theimportanceofcleanwaterandsanitationinnigeria/#:~:text=This%20article%20is%20based%20on,where%20the%20crisis%20is%20critical (Accessed 5 May 2025).

Ikemitang, S. (2024). *Indiscriminate boreholes drilling, threat to underground water and sustainable development.* Press release, Federal Ministry of Information and National Orientation. Available online at: https://fmino.gov.ng/indiscriminateboreholesdrillingthreattoundergroundwaterandsustainabledevelopment/?utm_source

Imarhiagbe, E.E., and Eghomwanre, A.F. (2023). Assessment of Water, Sanitation and Hygiene Conditions in Selected Markets in Benin City, Nigeria. *Journal of Applied Sciences and Environmental Management*, **27**(6): 1229–1235.

Israel O.K., Olotu A.A., Idowu A., Ojewuyi A.R., Odusan M.O., and Adeniji O.A. (2023). Biologic quality of households' drinkingwater in an urban local government area of Oyo State, Southwest, Nigeria. *Research Journal of Health Sciences,* **11**(4): 353362

Kaoje, A.U., Yahaya, M., Raji, M.O., Hadiza, S.M., Sylvanus, A., and Musa, T.M. (2018). Drinking Water Quality, Sanitation and Hygiene Practices in a Rural Community of Sokoto State, Nigeria. *International Journal of Medical Science and Public Health*, **7**(11): 1.

Mohammed, H., and Oguntola, I. (2022). The fight against open defecation: Can Nigeria meet the 2025 target? Nigeria Health Watch, (online) Available at: nigeriahealthwatch.com/thefightagainstopendefecationcannigeriameetthe2025target/ (Accessed 27 July 2025).

Mustapha, M., Okareh, O.T., Sridhar, M.K.C., and Aliyu, M.M. (2022). Households' Awareness and Practices on Water, Sanitation and Hygiene (WASH) in an Arid Region of Northwestern Nigeria – Sokoto State. *West African Journal of Applied Ecology*, **30**(2): 47–66.

Nwokoro, U.U., Ugwa, O., Onwuliri, C. D., Obi, I. F., Ngozi, O., and Agunwa, C. (2020). Water, Sanitation and Hygiene Risk Factors Associated with Diarrhoea Morbidity in a Rural Community of Enugu, South East Nigeria. *The Pan African Medical Journal*, **37**: 115.

Nwosu, N. I., Mmerem, J. I., Ozougwu, J. J., Nlewedim, P. I., Ugwa, O. M., Ugwunna, N. C., Nwosu, E. O., and Ndu, A. C. (2024). Knowledge of Hand Hygiene and Evaluation of Hand Washing Technique Among Nurses at the University of Nigeria Teaching Hospital. *BMC Nursing*, **23**(1): 872.

Odeyemi, D.F., Ogunniran, A.O., Omode, T.S., Ayeni, I.E., and Fagbure, A.F. (2024) Assessment of water quality from selected borehole locations in Ado Ekiti, Ekiti State, Southwest Nigeria. *World Journal of Advanced Research and Reviews*, **21**(2): 1161–1170.

Okereke, E. E., Obasi, K. O., Amadi, C. A., Ede, O. A., Aronu, C., Abonyi, I. C., Nwankwo, C. J., Eze, P. M., and Amadi, A. N. (2022). PhysicoChemical Quality of Drinking Water From Various Sources in Abia State. *Nigeria. Journal of Current Biomedical Research*, **2**(4): 350358.

Okesanya, O. J., Eshun, G., Ukoaka, B. M., Manirambona, E., Olabode, O. N., Adesola, R. O., Okon, I. I., Jamil, S., Singh, A., LuceroPrisno, D. E., Ali, H. M., and Chowdhury, A. B. M. A. (2024). Water, Sanitation, and Hygiene (WASH) Practices in Africa: Exploring the Effects on Public Health and Sustainable Development Plans. *Tropical Medicine and Health,* **52**(1): 68.

Okpara, O.G., Chukwueke, J.I., Nwenewo, E.C., Agbom, J.N., Menechukwu, K.C., Egbu, V.N., and Diala, E.C. (2024). Quality assessment of sachet water sold and consumed in Ishiagu, Ivo Local Government Area of Ebonyi State, Nigeria. *Open Access Library Journal*, **11**: 124.

Okwelle , A.A., Asikong, B.E., and Lennox, J.A. (2021). Bacteriological Quality Assessment of Well and Stream Water Sources from Ikwerre, Emohua and Etche Local Government Areas of Rivers State. *Microbiology Research Journal International*, **31**(8): 4255.

Omoregie, A.E., Omoregie, A.P., and Okoro, E.O. (2025). Assessment of Household Hygiene, Potable Water Sources, and Sanitation Practices in Ikpoba Okha Local Government Area, Edo State, Nigeria. *Journal of Applied Science and Environmental Management,* **29**(3): 879–887.

Onigbogi, O. and Ogunyemi, O. (2014). Effect of Storage Containers on Quality of Household Drinking Water in Urban Communities in Ibadan, Nigeria. *International Journal of Public Health Science (IJPHS), 3*(4): 253258.

Orimoloye E.O., Amadi C.O.A., Amadi A.N., Azuamah Y.C., Nwoke E.A., Zacchaeus, U., and Dozie I.N.S. (2015). Assessment of Water Sanitation and Hygiene Practices in Ibadan, Nigeria. *International Journal of Research*, **2**(2): 94100

Orivri, H., and Abigail OgwezzyNdisika. (2023). Application of Health Belief Model in Understanding Wash Behaviour Practices among Mothers of U5 Children in Lagos Urban Slums. *Journal of Humanities and Social Sciences Studies,* **5**(1): 91104.

Rawlings, A., and Seghosime, S. (2022). Evaluation of Water Supply, Sanitation and Hygiene Facilities in Ekosodin Community of Ovia NorthEast LGA, Benin City, Edo State, Nigeria. *Nigerian Journal of Technology,* **41**(4): 632–643.

Rawlings, A., and Seghosime, S. (2025*)* Effect of open dumping of municipal solid waste on groundwater quality in Ekurede Itsekiri, Warri South LGA, Delta State, Nigeria. *Journal of Engineering Research*, **9**(1): 3144.

Ross, I., Bick, S., Ayieko, P., Dreibelbis, R., Wolf, J., Freeman, M. C., Allen, E., Brauer, M., and Cumming, O. (2023). Effectiveness of Handwashing with Soap for Preventing Acute Respiratory Infections in LowIncome and MiddleIncome Countries: A Systematic Review and MetaAnalysis. *Lancet (London, England)*, **401**(10389): 1681–1690.

Sesay, B.P., Hakizimana, J.L., Elduma, A.H., and Gebru, G.N., 2022. Assessment of water, sanitation and hygiene practices among households, 2019 − Sierra Leone: A communitybased cluster survey. *Environmental Health Insights*, **16**: 1–11.

Sridhar, M. K. C., Okareh, O. T., and Mustapha, M. (2020). Assessment of Knowledge, Attitudes, and Practices on Water, Sanitation, and Hygiene in Some Selected LGAs in Kaduna State, Northwestern Nigeria. *Journal of environmental and public health*, **2020**: 6532512.

Tenebe I.T., Babatunde E.O., EddyUgorji C.C., Etu EE.E., Ogarekpe N.M., Ekeanyanwu C.V., Diekola O.A., Oladele O.S., and Ezeudu O.B. (2023) Bacterial Contamination Levels and Brand Perception of Sachet Water: A Case Study in Some Nigerian Urban Neighborhoods. *Water*, **15**(9): 1762.

Trevett, A. F., and Carter, R. C. (2008). Targeting Appropriate Interventions to Minimize Deterioration of DrinkingWater Quality in Developing Countries. *Journal of health, population, and nutrition*, **26**(2): 125–138.

UNICEF, 2021. Water, Sanitation and Hygiene: National Outcome Routine Mapping Report 2021. (online) UNICEF Nigeria. Available at: www.unicef.org/nigeria/reports/watersanitationandhygienenationaloutcomeroutinemappingreport2021 (Accessed 5 May 2025).

United Nations (UN), 2022. Ensure Availability and Sustainable Management of Water and Sanitation for All. (online) United Nations. Available at: www.un.org/sustainabledevelopment/waterandsanitation/#:~:text=In%202022%2C%202.2%20billion%20people,no%20handwashing%20facility%20at%20all (Accessed 5 May 2025).

UN-Water. (2025). Handwashing and Hand Hygiene, Water Facts. Geneva: UN-Water. Available at: www.unwater.org/waterfacts/handwashingandhandhygiene (Accessed: 2 August 2025).

Vedachalam, S., MacDonald, L. H., Omoluabi, E., OlaOlorun, F., Otupiri, E., and Schwab, K. J. (2017). The Role of Packaged Water in Meeting Global Targets on Improved Water Access. *Journal of Water, Sanitation, and Hygiene for Development*, **7**(3): 369.

Victor C., Kupoluyi J. A., Oyinlola F. F., and Sule V. O. (2025). Prevalence and Factors Associated with Water, Sanitation and Hygiene (WASH) Facilities Deprivation Among Children in Nigeria. *BMC Pediatrics,* **25**: 102.

Wolf, J., Hubbard, S., Brauer, M., Ambelu, A., Arnold, B. F., Bain, R., Bauza, V., Brown, J., Caruso, B. A., Clasen, T., Colford, J. M., Jr, Freeman, M. C., Gordon, B., Johnston, R. B., Mertens, A., PrüssUstün, A., Ross, I., Stanaway, J., Zhao, J. T., Cumming, O., … Boisson, S. (2022). Effectiveness of Interventions to Improve Drinking Water, Sanitation, And Handwashing with Soap on Risk of Diarrhoeal Disease in Children in LowIncome and MiddleIncome Settings: A Systematic Review and MetaAnalysis. *Lancet (London, England)*, **400**(10345): 48–59.

Yahaya T.O., Oladele E. O., Fatodu I. A., Abdulazeez A., and Yeldu A. (2020). The Concentration and HealthRrisk Assessment of Heavy Metals and Microorganisms in the Groundwater of Lagos, Southwest Nigeria. *Journal of Advances in Environmental Health Research*, **8**(3): 234242