ASSESSMENT OF DRINKING WATER QUALITY AND HUMAN HEALTH RISK FROM HOUSEHOLDS IN UHOLOR COMMUNITY, OFF UPPER EKEHAUN, BENIN CITY, EDO STATE.

BY

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LSC2003056

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 **Assessment Of Drinking Water Quality And Human Health Risk From Households In Uholor Community, Off Upper Ekehuan, Benin City** was carried out by **Anagwu, Jane Chisom** and presented to the Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, Benin City; in partial fulfillment 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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DECLARATION

I **Anagwu, Jane chisom** declare that **Assessment Of Drinking Water Quality And Human Health Risk From Households In Uholor Community, Off Upper Ekehuan, 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.

Jane Chisom Anagwu

…………………………

Date

DEDICATION

This project is dedicated, first and foremost, to Almighty God, who provided the strength and perseverance needed to complete this work.

ACKNOWLEDGEMENTS

The successful completion of this project, Assessment of Drinking Water Quality and Human Health Risk from Households in Uholor Community, Benin City, is the result of collaborative efforts and invaluable support from many individuals. This work is a testament to their patience and belief.

My deepest gratitude goes to my supervisor, Prof. (Mrs) I.H. Igbinosa. Thank you, not just for your academic expertise, but for your unwavering patience and profound belief in the environmental and public health importance of this study. Your critical feedback was truly instrumental, transforming raw data into meaningful findings and ensuring that my research remained rigorous and on the right track from start to finish.

To my extraordinary family, especially my parents, Mr. and Mrs. Felix Anagwu, and my siblings, I owe you all an immeasurable debt of gratitude. Thank you for the sacrifices, the constant prayers, and for instilling the emotional resilience that carried me through the toughest periods of this research. Your love was the indispensable support system that made everything possible.

To my dearest friends and colleagues, thank you for being the perfect balance to the stress of academia. Your timely distractions, shared moments of anxiety, and steadfast belief that I could finish served as a vital reset button. Your encouragement truly made the difference.

ABSTRACT

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Water is one of the most essential resources for sustaining human life, agriculture and ecosystems (Scanlon *et al*., 2023). Access to safe and quality water is fundamental human rights and is recognized as a key goal for sustainable development to be achieved by 2030 (Vaseashta, 2021). The quality of water is determined by its physical, chemical, biological and aesthetic properties which collectively its ability to protect human health and aquatic ecosystem. These properties are affected by various constituents both dissolved and suspended and can be influenced by natural processes as well as human activities (Luvhimbi *et al*., 2022).

Water security refers to a population's ability to ensure sustainable access to an adequate supply of safe drinking water, which is crucial for human well-being and socioeconomic growth (Pacheco *et al*., 2022). It also encompasses the protection against pollution and water-related disasters, alongside efforts to conserve ecosystems in a climate of peace and political stability (Mishra *et al*., 2021).

According to estimates from the World Health Organization (WHO), globally, there are nearly 1.7 billion cases of childhood diarrheal disease every year, which is one of the leading causes of waterborne illness (Alijanzadeh Maliji *et al*., 2023). A significant proportion of these illnesses can be prevented through safe drinking water and improved sanitation and hygiene practices (Bushen, Merga, and Tessema, 2022).

Contaminated water poses a serious threat to human health, as it may contain microorganisms from fecal matter, leading to different waterborne diseases such as cholera, diarrhea,

dysentery, and enteric fevers like typhoid fever (Tisha *et al*., 2025). The WHO established guidelines for acceptable drinking water quality, stating that coliform bacteria levels should be less than one (<1) colony-forming units per 100 mL and fecal coliforms should be absent (Guhad, 2022). The presence of these pathogens in treated drinking water indicates inadequate or ineffective water treatment methods. According to WHO guidelines, there are some primary water tests to detect these indicator organisms for pure, safe drinking water (World Health Organization, 2022).Despite existing guidelines, numerous reports from WHO and United Nations International Children Emergency Fund (UNICEF) have documented fecal contamination of drinking water sources, including treated source like pipe water, especially in low-income countries (Luvhimbi *et al.,* 2022). Water-related diseases continue to be a leading cause of high mortality rate among children under five especially in rural areas of developing nations. Additionally, emerging contaminants and disinfection by-products have been linked to chronic health issues in both developed and developing countries (Arman *et al*., 2021). Efforts by governmental and non-governmental organizations to ensure water security have often faltered due to unsustainable water supply infrastructures.

Water quality, particularly with regard to microbiological content, can deteriorate during collection, transport, and home storage (Manga *et al*., 2021). Common sources of contamination are open field defecation, animal wastes, economic activities (agricultural, industrial and businesses), and waste from residential areas as well as flooding (Singh, 2024). Thus, having access to a safe water source does not guarantee the quality of water consumed. In developing countries, drinking-water frequently becomes re-contaminated after collection and during house storage (Judah, 2022). Previous studies have shown a progressive increase in contamination levels, such as E. coli and total coliforms, from the source to the point of use in the households (Hasan *et al*., 2022). Factors contributing to this contamination include

the use of dirty containers, the type of water treatment employed, the duration of water storage and inadequate personal and domestic hygiene practices (Kagodo, 2024).

1.2 Justification of the Study

This study is important because no comprehensive assessment of drinking water quality and associated human health risks has been conducted specifically in Uholor community. While broader studies in Benin City indicate widespread contamination, local water quality is highly variable. This research will, therefore, fill an important data gap by establishing Uholor-specific baseline of physicochemical and microbiological parameters from water sources to the point of household consumption. By correlating these water quality results with the prevalence of waterborne diseases (e.g., typhoid, diarrhea) in the community, the study will directly quantify the public health risks. The findings will provide essential, evidence-based data necessary for local authorities and development partners to design and implement targeted effective public health interventions to safeguard the community's well-being.

1.3 Aim of the Study

This study aimed to assess the water quality and hygiene practices of households located in Ekehuan Barracks, Benin City.

1.4 Objectives of the Study

The overall objective of this study is to assess the drinking water quality and associated human health risks from selected sources and households in Uholor, Benin City.

The specific objectives were to:

i. Assess household water quality management and hygiene behaviors through a structured questionnaire survey;
ii. Analyze the physicochemical parameters of household drinking water;
iii. Determine the total heterotrophic bacterial load in household drinking water;

iv. Examine the distribution of heterotrophic bacteria in relation to different water sources.

v. Quantify the total coliform and *Escherichia coli* counts in household drinking water;

vi. Evaluate the distribution of total coliforms and *Escherichia coli* based on water sources.

CHAPTER TWO

LITERATURE REVIEW

2.1 Conceptual Review of Water Quality

Water quality is a multidimensional concept defined not only by its safety, the absence of hazardous chemical and microbial contaminants but also by consumer acceptability (Kekes and Kolliopoulos, 2023). It's fundamentally determined by a combination of physical, chemical, and microbiological parameters, as well as aesthetic characteristics like taste, odor, and color. These aesthetic qualities are important because they directly affect people's willingness to consume water (Addisie, 2022).

The Duality of Safety and Acceptability

The challenge in providing safe water lies in the duality between objective safety and subjective acceptability (Catherine *et al.,* 2023). A preference for the taste of water from an unimproved spring over that of chlorinated tap water, despite the spring's higher microbiological risk, underscores the complex challenge of providing water that is both safe and desirable (Crider, 2021). This demonstrates how consumers may knowingly choose unsafe water sources simply because of taste, smell, or appearance, prioritizing organoleptic qualities (Shomar and Hawari, 2017). The World Health Organization emphasizes this point, noting that consumers may perceive water to be unsafe if it is turbid, colored or has an unpleasant taste or odor, even when the water may actually be safe to drink (Spiridon, Ionete, and Ionete, 2021). Such rejection leads to reliance on alternative, often unimproved, sources, which increases the likelihood of exposure to waterborne diseases.

Water Safety and the Holistic Approach

The modern understanding of water quality moves beyond post-testing to a holistic, preventative approach. The WHO advocates for a Water Safety Plan (WPS) framework,

which aims to ensure water quality through risk management from the catchment area to the point of consumption (Majka, 2024; Baracho, Najberg, and Scalize, 2023). This conceptual shift is crucial as it acknowledges that quality failures can occur at any point in the supply chain from source contamination to household storage and handling. Consequently, water quality is not merely a laboratory result, but a function of the entire system's ability to protect the consumer from the point of origin to the final point of use (Wu *et al*., 2021). This holistic view is directly relevant to the Uholor community, where contamination is often linked to poor household-level handling rather than just the source itself.

2.2 Parameters of Drinking Water Quality: Physical, Chemical, and Microbiological

Water quality is a multifaceted concept evaluated by a combination of physical, chemical, and microbiological parameters (Sahu *et al.,* 2024). These characteristics are critical as they not only affect the safety of water but also its consumer acceptability, which in turn influences public health outcomes.

2.2.2 Aesthetic and Physical Parameters

Physical parameters are important indicators of water's suitability for use, as they relate to its aesthetic quality and can also signal the presence of contaminants (Verma *et al.,* 2025). The quality of water is influenced by its taste, odor, and color, along with other physical characteristics (Adams *et al*., 2022).

Taste and odor are frequent causes of consumer complaints, often arising from the presence of organic material, inorganic compounds (such as iron or hydrogen sulfide), and biological activity. The presence of any objectionable taste or odor may cause consumers to reject the water supply and seek alternative, potentially unsafe sources (Kozisek *et al*., 2024). This consumer-driven rejection increases the likelihood of exposure to waterborne pathogens.

Similarly, color in drinking water is typically caused by colored organic matter or metals like iron. The Nigerian Standard for Drinking Water Quality specifies that drinking water color should not exceed 15 TCU (true color unit) (Bezabih, 2021; Awogbami, 2023). The presence of color above this level is objectionable to consumers and suggests potential contamination.

In addition to aesthetics, physical parameters like pH, turbidity, and temperature are also vital. The pH of water determines its acidity or alkalinity, with the WHO recommending a range of 6.5–8.5 for drinking water (Arhin *et al*., 2023). Extreme pH values can cause pipe corrosion and affect the efficiency of chlorine disinfection. Turbidity, a measure of cloudiness caused by suspended solids, is a significant concern because it can provide a substrate for microorganisms to grow and shield them from disinfection methods (Mitiku, 2021). The U.S. Environmental Protection Agency notes that elevated turbidity is often associated with higher levels of disease-causing microorganisms (Erickson *et al*., 2025). Lastly, temperature plays a role in microbial ecology; higher temperatures can enhance microbial growth and reduce chlorine residuals, affecting the water's palatability and safety (Kennedy *et al*., 2021).

2.2.3 Microbiological Parameters

Microbiological quality is the most critical determinant of safe drinking water, as contamination from human and animal excreta poses the greatest risk to public health (World Health Organization, 2022). The assessment of this quality typically involves the detection of indicator organisms. E. coli remains the gold standard indicator of fecal contamination, as its presence indicates the likely presence of other enteric pathogens.

Both WHO guidelines and the Nigerian Standard for Drinking Water Quality (NSDWQ) state that E. coli or thermotolerant coliform bacteria must not be detectable in any 100 ml sample of drinking water. A systematic review on microbial water quality in low- and middle-income countries and that the prevalence of total coliforms was over 50%, with E. coli contamination

at 13.3%, highlighting the widespread nature of microbiological contamination. Access to safe drinking water is essential for protecting human health (Daba *et al*., 2025. Report shows that at least 1.7 billion people worldwide use a drinking water source contaminated with feces, leading to approximately 505,000 diarrheal deaths each year (Khan and Khan, 2024). In Nigeria, diarrheal diseases are the most significant outcome of unsafe drinking water (Salem-Bango *et al*., 2025). Furthermore, turbidity is strongly linked to health risks because pathogens can attach to suspended particles, which not only provides a substrate for microbial growth but also protects microorganisms from disinfection. The principal risk to human health derives from microbial contamination, underscoring the priority of monitoring and controlling microbial indicators for safe water provision (Mckee and Cruz, 2021).

2.2.2 Chemical Parameters

While microbiological contamination poses the most immediate risk to public health, chemical parameters are equally vital to assess, as long-term exposure to certain chemicals can lead to chronic health issues and also affect the aesthetic acceptability of the water (Villanueva *et al*., 2014). Chemical quality is broadly categorized into inorganic and organic constituents.

Inorganic Contaminants

Inorganic chemicals are a major concern, particularly in groundwater sources which are widely used in Nigeria (Kurwadkar, Kanel, Nakami, 2020). The presence of Heavy Metals such as Lead (Pb), Cadmium (Cd), Nickel (Ni), and Arsenic (As) constitutes a serious public health risk. These metals are non-biodegradable and tend to bioaccumulate in the human body, leading to chronic conditions like neurological damage, kidney disease, and cancer. Their presence often stems from industrial discharge, poor waste disposal, and leaching from geological formations or plumbing materials. A study on Lagos groundwater, for example,

reported non-permissible levels of Pb, Ni and Cd, highlighting this prevalent chemical risk (Yahaya *et al*., 2021).

Another significant inorganic issue is Nitrate and Nitrite contamination. Elevated concentrations of nitrate are typically an indicator of pollution from sanitary waste (septic systems, sewage) or agricultural runoff (fertilizers) (Khan *et al*., 2018). While nitrate itself is less toxic, its reduction to nitrite in the body, particularly in infants, can cause methemoglobinemia (blue baby syndrome), which impairs the blood's ability to carry oxygen (Fossen Johnson, 2022). Recognizing this vulnerability, the Nigerian Standard for Drinking Water Quality (NSDWQ) sets a strict maximum permissible limit for Nitrate (Ekejiuba, Amali, and Sule, 2023).

Beyond direct toxicity, certain inorganic chemicals compromise water palatability. These Aesthetic-Affecting Chemicals often lead to consumer rejection. Iron (Fe) and Manganese (Mn), common in Nigerian groundwater; cause reddish-brown or black staining, turbidity, and metallic tastes even at low concentrations (Obini, Afiukwa, and Samuel, 2023). Similarly, high concentrations of Hydrogen Sulfide can cause an unpleasant rotten egg odor in drinking water, prompting consumers to reject the supply and seek alternative, potentially unsafe sources (Adams *et al*., 2022).

Organic Contaminants

Organic contaminants are diverse and originate primarily from human activities. Pesticides and Herbicides are frequently introduced into drinking water sources through agricultural runoff, presenting toxic risks, particularly in rural and peri-urban areas where surface water is utilized (Khatri and Tyagi, 2015). A separate concern is the formation of Disinfection By-Products (DBPs). In systems using chlorine, the reaction between chlorine and natural organic matter (NOM) in the water can form trihalomethanes (THMs) and other (DBPs)

(Shen, 2021; Riyadh and Peleato, 2024). While disinfection is crucial for microbiological safety, prolonged exposure to high levels of (DBPs) is linked to potential cancer risks, requiring careful balance in treatment protocols (Kalita *et al*., 2024).

2.3 Importance of Water Quality to Public Health and Socio-Economic Development

Safe drinking water is fundamental to both human health and socio-economic development. The United Nations Sustainable Development Goal 6 recognizes that ensuring availability and sustainable management of water and sanitation for all is a prerequisite for public health and poverty reduction (Mujtaba *et al*., 2024).

2.4 The Water, Sanitation, and Health (WASH) Nexus

Access to clean water and proper sanitation is recognized as a basic human right and a fundamental pillar of public health and sustainable development (Shehu and Nazim, 2022). However, the chronic lack of these essential services particularly in informal settlements defined by overpopulation and subpar infrastructure creates severe health hazards and fuels the cycle of poverty and illness (Imarhiagbe *et al*., 2025). Globally, over a billion people, primarily in low- and middle-income nations, live in such conditions a challenge acutely felt across Sub-Saharan Africa where urbanization outpaces infrastructural provision (Bishoge, 2021).

2.4.1 Contamination Pathways and Health Risks in Informal Settlements

The absence of centralized urban planning and municipal service provision directly exposes residents to contaminated water sources. Due to a shortage of municipal water supply, residents often depend on unofficial or dangerous water sources, such as unmanaged shallow wells, rivers, and unlicensed water vendors, which are frequently contaminated by industrial discharge, human waste, or agricultural runoff (World Health Organization, 2022). This high

exposure to pathogens results in waterborne illnesses like cholera, typhoid fever, and diarrhea, with children and other vulnerable groups disproportionately affected. For instance, in Nigerian informal settlements like Ikpoba-Waterside in Benin City, households are forced to rely on tainted surface water or expensive private vendors, a dependence that increases both health hazards and economic disparities (Akinbile *et al.,* 2020). Furthermore, in many communities, water sources like the Ikpoba River are simultaneously used for household needs and for waste disposal, creating a severe public health risk as pathogens from human waste are rapidly reintroduced back into the drinking water supply (Omoregie, Omoregie, and Okoro, 2025).

2.4.2 Environmental and Socio-Economic Impact

Inadequate water and sanitation facilities create negative feedback loops that extend beyond direct illness, compounding socioeconomic challenges (Okesanya *et al*., 2024). The absence of official waste management leads residents to dispose of solid garbage in open landfills, rivers, or drainage channels. This environmental degradation creates breeding grounds for disease-carrying vectors like flies and mosquitoes, thereby increasing the prevalence of vector-borne illnesses such as dengue fever and malaria (Afolabi *et al*., 2021). Furthermore, blocked drainage systems exacerbate flooding during the rainy season, which disperses contaminated water across residential areas and significantly raises the risk of infection. Socio-economically, the dependence on expensive or hazardous water sources increases economic disparities, preventing communities from breaking the poverty cycle.

2.4.3 Intervention and Integrated Strategies

Community-led programs, such as Community-Led Total Sanitation (CLTS), have proven successful in lowering open defecation by enabling communities to assume shared

accountability for improved sanitation (Kar and Chambers, 2008). To achieve sustainable health outcomes, WASH initiatives must be integrated, ensuring that the provision of clean water (through affordable technology like community water kiosks and filtration systems) is combined with improved sanitation and hygiene education (John and Ajibade, 2024). By guaranteeing access to these three elements, communities like Uholor can feasibly lower the incidence of avoidable diseases and advance environmental sustainability.

2.5 Theoretical Framework: Human Health Risk Assessment

The U.S. Environmental Protection Agency defines risk assessment as the process used to evaluate the potential for adverse health effects resulting from human exposures to environmental hazards. The World Health Organization (World Health Organization, 2022) similarly views it as a systematic approach for characterizing the nature and likelihood of harm to human health from chemicals or other agents present in the environment.

2.5.1 Hazard Identification

Hazard identification establishes which microbial and chemical contaminants are of concern. While Westrell, (2004) focused on pathogens in centralized surface water systems, for Uholor, the primary hazards will be identified based on the presence of fecal indicator organisms (E. coli). The detection of these indicators establishes the likely presence of enteric pathogens (such as *Salmonella*, *Shigella*, and agents causing cholera and diarrhea) that pose an acute risk to health (Kumar *et al*., 2021). Chemical hazards, like heavy metals, must also be identified based on local geological conditions and potential anthropogenic pollution.

2.5.2 Exposure Assessment

Exposure assessment estimates how individuals within the Uholor community interact with the identified hazard. Unlike systems with extended distribution networks, the focus here shifts to household-level exposure points. Key areas for assessment include:

Source Consumption: The type of water source accessed (sachet water, borehole, and well water).

Water Handling and Storage: Contamination often occurs after collection, through unhygienic storage containers or handling practices within the home. This emphasizes the vulnerability of the consumer at the point of use, regardless of the initial source quality.

2.5.3 Dose–Response Assessment

Dose–response describes the relationship between the dose of pathogens or chemicals ingested and the likelihood of infection or adverse health effects. This quantitative step relies on established dose-response models for specific pathogens that can cause illness. While Westrell *et al*., (2003) used models for protozoa and viruses, this study will utilize applicable models to estimate the potential infection risk from the measured microbial levels found in Uholor's water.

2.6 Empirical Review of Drinking Water Quality And Health Risks In Nigeria

Access to drinking water in Nigeria is highly diversified, reflecting differences in geography, infrastructural availability and socio-economic status. These sources include groundwater (boreholes and wells), surface water (rivers, streams, ponds), and commercially packaged water (sachet and bottled). Each source presents unique quality concerns, with microbial contamination being the primary risk factor for public health in all categories.

2.6.1 Empirical Evidence of Groundwater Contamination in Benin City and Southern Nigeria

Groundwater, accessed through boreholes and hand-dug wells, is the most widely utilized household water supply in Nigeria, driven by urbanization and the failure of centralized public water distribution networks (Oyerinde and Jacobs, 2022). Numerous Nigerian studies have documented high levels of microbial contamination in these sources. For example, an

assessment in Port Harcourt showed boreholes near waste dumpsites contained significant faecal coliforms and other pathogenic bacteria, directly linking poor waste disposal practices to the degradation of groundwater quality (Abiye and Raimi, 2025). The national trend of contamination is notably pronounced in the Benin City urban aquifer. Studies across various Local Government Areas (LGAs) within the metropolis consistently report significant local vulnerabilities that directly inform the risks in Uholor:

Microbial Contamination: Local research, including that covering Egor and Oredo LGAs, frequently documents the presence of faecal coliforms and pathogenic bacteria in boreholes, with counts often exceeding WHO/NSDWQ standards (Bello, 2021). This contamination is directly linked to the poor siting and proliferation of wells in close proximity (<2km radius) to sanitation facilities like soak-away pits and septic tanks, as well as to solid waste dumpsites, a prevalent urban practice that facilitates contaminant transport (Bright, 2014).

Chemical Risk: A serious chronic health risk exists from chemical parameters. Multiple Benin City groundwater studies report abnormally high levels of Lead (Pb), Cadmium (Cd), and Chromium (Cr) in samples (Ezenwa *et al*., 2023; Adams, Ogedegbe and Tawari-Fufeyin, 2016). These concentrations frequently exceed both WHO and NSDWQ maximum permissible limits. This high heavy metal load is primarily attributed to leachate seepage from unregulated dumpsites and poor waste disposal practices, which readily percolates into the shallow aquifer (Haruna, 2022).

Overall, borehole water, although widely used and perceived as reliable, often fails to meet both microbiological and chemical safety standards, constituting a serious public health risk requiring localized assessment.

2.6.2 Quality Assessment of Commercial (Sachet/Bottled) and Surface Water Sources

Unsafe Surface Water Reliance

Surface water, including rivers, streams, and ponds, remains a critical source of household water, particularly in peri-urban and rural communities that lack piped infrastructure emphasize the high reliance on these unimproved sources, which are typically contaminated (Adeyeye, Gibberd and Chakwizira, 2020). Nigerian surface water resources are generally grossly polluted due to the discharge of untreated sewage, industrial effluents, and agricultural runoff (Chukwu, 2017). Bacteriological analysis consistently shows high levels of contamination; a study in Lagos found coliforms present in all samples, with E. coli levels far above permissible limits, indicating faecal contamination from nearby settlements and open defecation practices (Oluseyi and Nweke, 2020). Since estimated that nearly 50% of the rural population still depends on these unsafe sources, reliance on untreated surface water represents a significant and acute health risk due to the near-certain presence of bacteria, viruses, and protozoa.

Contaminants in Commercial Packaged Water

The proliferation of sachet water ("pure water") has become a key feature of the Nigerian water supply, offering affordability and convenience amid public water system inadequacy (Ezeudu *et al*., 2022). Despite its popularity, several studies indicate that many brands are microbiologically contaminated and fail to meet WHO standards. Contamination often occurs post-production during unhygienic storage, handling, and distribution by street vendors. Furthermore, chemical safety concerns have been raised with the detection of heavy metals such as Lead, Cadmium, and Chromium in some samples. While the National Agency for Food and Drug Administration and Control (NAFDAC) provides regulatory oversight, enforcement is often weak, allowing unregistered manufacturers to contribute to the variable and unreliable quality of sachet water (Oluwarotimi, 2025). Thus, the consumption of sachet

water remains a paradox: widely accepted for convenience, yet frequently unsafe due to microbial and chemical contamination.

2.6.3 Review of Point-of-Use Contamination and Waterborne Disease Incidence

The journey of drinking water from the source to the point of consumption often introduces a significant public health risk known as Point-of-Use (POU) contamination. In Nigeria, even water sourced from improved facilities (like boreholes or treated sachet water) frequently deteriorates in quality due to unhygienic household storage and handling practices, directly contributing to the nation's high incidence of waterborne diseases (Idigbe *et al*., 2024).

Point-of-Use Contamination at the Household Level

POU contamination occurs primarily when households collect water and store it in containers for extended periods to cope with intermittent supply, a common feature in both urban and rural settings (Thomas *et al*., 2020). Studies in various Nigerian states consistently show that clean water collected from a relatively safe source becomes microbiologically compromised before consumption. Water is typically stored in large high-density polyethylene (HDPE) tanks, plastic buckets, or clay pots (Kumpel *et al*., 2016). Many of these vessels are not cleaned regularly or thoroughly, leading to the formation of microbial biofilms that leach pathogens into the stored water (Manga *et al*., 2021). The lack of a proper seal or lid allows contaminants to enter the water via hands, utensils, or environmental dust. Furthermore, the use of shared, unwashed dipping utensils, or the dipping of unwashed hands into the storage container to retrieve water is a major route for transferring faecal-oral pathogens from the user's environment to the water. Lastly, research indicates that the concentration of faecal indicator bacteria like *E. coli* increases significantly over the duration of storage, particularly after the first few days (Thomas *et al*., 2020).

Incidence of Waterborne Diseases

The failure to maintain water quality at the household level, coupled with poor sanitation, directly fuels the spread of waterborne diseases, which represent a major public health crisis and a substantial proportion of the disease burden in Nigeria (World Health Organization, 2022).

Diarrhoea is the most prevalent water-related ailment, causing significant morbidity and mortality, particularly among children under five; its primary attributed risk factors are faecal contamination from unimproved water sources and poor hygiene or sanitation practices (Mokomane *et al*., 2018; Bain *et al*., 2014). Another critical threat is Typhoid Fever, caused by Salmonella typhi. Outbreaks of this disease are frequently linked to the consumption of water and food contaminated by faecal matter (Boakye Okyere *et al*., 2025), largely attributable to contaminated surface water and inadequate water treatment. Cholera presents a persistent challenge; with recurrent, devastating outbreaks often occurring during the rainy season when flooding contaminates water supplies with sewage. This cycle is driven by poorly managed water sources and a lack of adequate sanitation infrastructure. Finally, a range of other common infectious diseases, including Hepatitis A, Dysentery, and Giardiasis, are also tied to faecal-contaminated water sources and poor hygiene practices, largely due to unsafe water storage and poor personal hygiene.

The relationship between water quality and illness is statistically significant: studies in urban slums, for instance, have shown a direct correlation, where having an unimproved water source or practicing poor household water handling significantly increases the odds of a family member experiencing diarrhoea.

2.7 Water Quality Standards

Drinking water quality standards are indispensable for evaluating whether water is safe for human consumption and for protecting public health. For this study, the quality of household water in the Uholor community will be assessed by comparing the analytical results against two primary and internationally recognized benchmarks: the WHO Guidelines and the official Nigerian Standard.

2.7.1 WHO Guidelines for Drinking-Water Quality

The WHO Guidelines for Drinking-Water Quality provide a global, scientific basis for managing water safety and for countries to establish their own national standards (World Health Organization, 2022). Their fundamental aim is to protect public health by assessing and mitigating the risks posed by microorganisms and chemicals in drinking water. The microbial standard is exceptionally stringent, requiring that E. coli or thermotolerant coliform bacteria must not be detectable in any 100ml of water intended for drinking (Nedelkova *et al.*, 2019). For physical parameters, the guidelines recommend that drinking water should ideally maintain a turbidity of less than 1 NTU and should not exceed 5 NTU to ensure effective disinfection and consumer acceptability; the WHO standards serve as the universal reference for best practice in water quality management (World Health Organization, 2022).

2.7.2 Nigerian Standard for Drinking Water Quality (NSDWQ)

The Nigerian Standard for Drinking Water Quality (NSDWQ), developed by the Standards Organization of Nigeria (SON), sets the mandatory and guideline limits for all constituents and contaminants in water within Nigeria (Nwinyi *et al.*, 2020). The NSDWQ was formulated by closely considering and adapting the WHO guidelines to local environmental and economic conditions (World Health Organization, 2022). It specifies that water is considered safe only when it is free from disease-causing microorganisms, hazardous chemicals, and any other substances that would be harmful to health or discourage

consumption (Ezugwu and Osarumwanse, 2022). Because it is the official national guideline, the NSDWQ will be the primary legal and regulatory benchmark for assessing the acceptability of household water quality in the Uholor community.

CHAPTER THREE

MATERIALS AND METHODS

The methodology for this research study was designed to achieve the stated objectives through the collection and analysis. The focus was necessitated by the absence of prior water quality assessments specific to Uholor Community.

3.1 Study Area

This study was conducted in Benin City, the capital of Edo State, situated in the southern region of Nigeria.

3.2 Sample Location

The research focused on households within Upper Ekehuan Barracks, located in Uholor Community, Oredo Local Government Area of Edo State. Although the area is primarily occupied by military personnel, the study respondents comprised mainly small-scale business owners, artisans, and students who are relatives of the personnel.

3.3 Questionnaire Survey

A structured questionnaire was administered to assess household practices influencing drinking water quality. The questionnaire was designed to collect information on water sources, storage conditions, treatment methods, and sanitation behaviors that could affect water safety. Respondents were selected through a random sampling method to ensure fair representation across different households. The collected data were coded and analyzed using descriptive and inferential statistical techniques to identify patterns and risk factors associated with drinking water quality. A total of 100 households participated in the survey.

3.4 Sample Collection

Twenty-five (25) drinking water samples were collected from various households using sterile plastic containers.

Table 0.1: Coordinates of Samples taken from each Household

S/N	Sample Codes	Sample Sources	Latitude	Longitude
1	UHR-AH-01	Sachet Water	6.283175” N	5.54472” E
2	UHR-AH-02	Sachet Water	6.2979700” N	5.5195990” E
3	UHR-AH-03	Sachet Water	6.283503” N	5.537029” E
4	UHR-AH-04	Borehole Water	6.265638” N	5.539418” E
5	UHR-AH-05	Sachet Water	6.287222” N	5.539886” E
6	UHR-AH-06	Sachet Water	6.283508” N	5.53703” E
7	UHR-B-01	Sachet Water	6.283175” N	5.54472” E
8	UHR-B-02	Borehole Water	6.283175” N	5.544428” E
9	UHR-B-03	Sachet Water	6.283177” N	5.544474” E
10	UHR-SC-01	Sachet Water	6.284290” N	5.539731” E
11	UHR-SC-02	Borehole Water	6.284316” N	5.540057” E
12	UHR-SC-03	Sachet Water	6.284290” N	5.540165” E
13	UHR-SC-04	Sachet Water	6.284062” N	5.540322” E
14	UHR-SC-05	Sachet Water	6.284290” N	5.539948” E
15	UHR-SC-06	Sachet Water	6.284303” N	5.540165” E
16	UHR-SC-07	Sachet Water	6.284316” N	5.539840” E
17	UHR-AU-01	Sachet Water	6.278741” N	5.544656” E
18	UHR-AU-02	Sachet Water	6.287115” N	5.54172” E
19	UHR-AU-03	Bottled Water	6.286644” N	5.542268” E
20	UHR-AU-04	Borehole Water	6.286461” N	5.541316” E
21	UHR-AU-05	Sachet Water	6.287374” N	5.541960” E
22	UHR-AU-06	Sachet Water	6.287278” N	5.54188” E
23	UHR-AU-07	Sachet Water	6.286457” N	5.541149” E
24	UHR-AU-08	Sachet Water	6.284041” N	5.541659” E
25	UHR-AU-09	Sachet Water	6.285789” N	5.5406379” E

Each sample was carefully labeled with a unique identifier and promptly transported under aseptic conditions to the laboratory for analysis. The collection procedures were designed to prevent contamination and to ensure proper assessment of the microbial and physicochemical quality of the water.

3.5 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. This medium was used to assess the general microbial load of drinking water samples. 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 continuous stirring until completely dissolved. The CCA medium was not autoclaved or overheated for differentiation and enumeration of coliforms and *Escherichia coli*.

3.6 Determination of Physicochemical Parameters

The physicochemical characteristics of household drinking water including pH, temperature, electrical conductivity, salinity, and total dissolved solids (TDS) were measured using a digital water quality tester (MWC-TDS2355, China) according to the manufacturer's protocol. The instrument was calibrated using standard buffer solutions before use. Following calibration, the electrode was rinsed with distilled water, immersed in each water sample, and allowed to stabilize for 2–5 minutes to ensure accurate readings.

3.7 Material/ Apparatus

Field Sampling Equipment:

i. Sterile sampling bottles (50ml)
ii. Cooler box with ice pack
iii. Labels, waterproof marker, and sample logbook

Laboratory Equipment:

i. Autoclave
ii. Magnetic stirrer
iii. Incubators
iv. Analytical balance
v. Colony counter
vi. Refrigerator (4C) for media and sample storage
vii. Volumetric glassware (flasks, cylinders, pipettes)

Plate 3.7.1: micro pipette

Plate 0.1: sample Bottle

3.8 Enumeration of Total Heterotrophic Bacteria

The total heterotrophic bacterial count, an indicator of overall microbial quality, was determined using the spread plate technique. Undiluted water samples (200 µL each) were aseptically inoculated onto sterile Nutrient Agar plates (Lab M, Lancashire, United Kingdom) and evenly spread with a sterile glass spreader. The plates were incubated at 37°C for 18–24 hours to allow colony development. After incubation, distinct colonies were enumerated, and the results were expressed as mean colony-forming units per millilitre (CFU/mL).

3.9 Enumeration of Total Coliforms and *Escherichia coli*

The microbiological quality of household drinking water was further evaluated by determining total coliform and Escherichia coli counts using the spread plate method. A 200 µL aliquot of each water sample was evenly spread on sterile Chromogenic Coliform Agar (CCA) plates (Lab M, Lancashire, United Kingdom) with a sterile glass spreader. Plates were incubated at 44°C for 18–24 hours to promote selective bacterial growth. After incubation, colonies were counted, and results were expressed as colony-forming units per millilitre (CFU/mL).

Distinct blue or violet colonies were identified as presumptive *E. coli* (fecal coliforms) while pink or red colonies represented non-fecal coliforms. Presumptive isolates were purified by sub culturing on Nutrient Agar plates and stored on Nutrient Agar slants for further confirmatory analysis.

3.10 Biochemical Characterization of Coliform Bacteria

Presumptive coliform isolates obtained from the CCA plates were subjected to standard biochemical tests for confirmation and characterization. These included the potassium hydroxide (KOH) test, catalase test, and oxidase test. For KOH test, a small quantity of bacterial culture was mixed with 2–3 drops of 3% KOH on a glass slide. The formation of a viscous or stringy solution indicated a positive reaction, confirming Gram-negative bacteria.

For catalase test, a few drops of 3% hydrogen peroxide were added to a bacterial smear on a glass slide. The release of oxygen bubbles indicated a positive catalase reaction, suggesting the presence of aerobic or facultative anaerobic organisms. For oxidase test, a filter paper moistened with oxidase reagent was used to test bacterial colonies. The appearance of a purple-blue coloration within 10 seconds denoted a positive oxidase reaction, while the absence of color indicated a negative result. Isolates that were KOH-positive, catalase-positive, and oxidase-negative were categorized as presumptive coliforms including *E. coli*.

3.11 Data Analysis

All data obtained were analyzed to assess the quality of household drinking water. Physicochemical and bacteriological results were entered into Microsoft Excel and analyzed using the Statistical Package for the Social Sciences (SPSS) version 22.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were used to summarize the findings and results were expressed as mean ± standard deviation (SD).

CHAPTER FOUR

RESULTS

4.1 Demographics and Environmental Observations of Households

The demographic and environmental characteristics of the surveyed household, as presented in Table 4.1. Out of the 100 households, majority of respondents were female (69%), while males constituted 31%. Regarding age distribution, respondents were predominantly young adults aged 18–27 years (33%), followed by 28–37-year range (26%). Marital status was single (46%) and married (46%), with 8% widowed. In terms of religion, Christianity (89%) was the predominant faith, followed by Islam (11%). Educational status showed that 67% of respondents have tertiary education, 20% (secondary school), (2%) primary education, vocational training (4%), no formal education (6%), and Quranic education (1%).

Occupationally, the majority were artisans or skilled workers (27%) and traders or business owners (25%). The students were (19%), private sector employees (14%), retirees (9%), civil servants (3%), and unemployed individuals (3%). Household size data show that most households comprised 4–6 members (67%), followed by 1–3 members (17%) and 7–9 members (16%). When considering household income, a majority (64%) declined to state their monthly earnings, while 24% reported earning ₦150,000 or more, 9% earned between ₦100,000–₦149,999, and only 3% earned between ₦50,000–₦99,999. No respondents reported earning less than ₦49,999. Environmental observations revealed that 35% of households were located near a waste dump site, while 65% were not. Among those with nearby waste dumps, 42% were situated within 50 meters, 28% within 50–100 meters, and 30% beyond 100 meters. Additionally, 12% was observed to have open sewage or stagnant water near their homes, whereas 88% did not. The general condition of the household

surroundings could be described as moderately clean in 51% of the households, clean in 41%, and dirty in 8%.

Table 0.1: Demographics and Environmental Observations of Households

Parameters		Frequency(n=100)	Percentage (%)
Sex	Male	31	31.0
	Female	69	69.0
Age in years	18-27	33	33.0
	28-37	26	26.0
	38-47	19	19.0
	48-57	9	9.0
	58 and above	13	13.0
Marital status	Single	46	46.0
	Married	46	46.0
	Widowed	8	8.0
Religion	Christianity	89	89.0
	Islam	11	11.0
	Traditional	0	0.0
Educational Level Attained	No Formal Education	6	6.0
	Vocational	4	4.0
	Quranic	1	1.0
	Primary School	2	2.0
	Secondary School	20	20.0
	Tertiary Education	67	67.0
Occupation	Student	19	19.0
	Private sector Employee	14	14.0
	Trader/Business Owner	25	25.0
	Civil Servant	3	3.0
	Artisan/Skilled Worker	27	27.0
	Unemployed	3	3.0
	Retired	9	9.0
Household Size	1-3	17	17.0
	4-6	67	67.0
	7-9	16	16.0
	10 and above	0	0.0
Monthly Household Income (₦)	≤49,999	0	0.0
	50,000-99,999	3	3.0
	100,000-149,999	9	9.0
	≥150,000	24	24.0
	Can't say	64	64.0
Is there a waste dump site near the household?	Yes	35	35.0
	No	65	65.0
If yes, what is the estimated distance of their residence to the	<50m	42	42.0
	50-100m	28	28.0
	>100m	30	30.0

nearest waste dump site			
Is there any open sewage or stagnant water nearby?	Yes	12	12.0
	No	88	88.0
General condition of the surroundings	Clean	41	41.0
	Moderately clean	51	51.0
	Dirty	8	8.0

4.2 Water Source and Quality Assessment of Households

Table 4.2 presents showed that the main source of drinking water for most respondents was sachet water (73%), then borehole water (18%) and bottled water (9%). In terms of proximity, most respondents (64%) had their main water source within 100 meters, while 32% was reported 100–500 meters and 4% reported 501–1000 meters. Majority (74%) do not treat their water before drinking, whereas 26% treat their water. Among those who did, boiling (88.5%) was the most common method, with a few combining boiling and filtration (3.8%) or using alum (7.7%). Approximately half of the respondents (49%) stored water, while 51% did not. For those who stored drinking water, most used covered containers (23%), followed by jerry cans (8%), overhead tanks (6%), sachet containers (6%), refrigerators (5%), and uncovered containers (1%). In terms of water retrieval from storage, nearly all respondents (96.0%) used a cup with handles. Regarding cleaning frequency of storage containers, most respondents (49%) cleaned weekly, followed by 30.6% who cleaned monthly, 18.4% who cleaned rarely, and only 2% who did so daily.

With respect to source reliability, 65% reported that their water source was available year-round. Furthermore, 61% indicated that they had faced problems with their water supply recently, whereas 39% had not. Among those reporting issues, the most frequent was intermittent supply (82%), followed by poor taste (13.1%), contamination (3.3%), and poor taste with bad odour (1.6%). It was revealed that 66% of respondents believed people could get sick from their drinking water, while 34% disagreed. Correspondingly, 45% reported that

their households had experienced water-related illnesses in the previous six months. Among these, typhoid fever (80%) was the most prevalent, followed by diarrhea (15.6%) and cholera (4.4%). Finally, 85% of respondents reported no unpleasant physical characteristics in their drinking water, while 11% complained of taste issues, and 4% noted colour changes.

Table 0.2: Water Source and Quality Assessment of Households

Parameters		Frequency (n=100)	Percentage 2(%)
Main source of drinking water?	Borehole	18	18.0
	Sachet Water	73	73.0
	Bottled Water	9	9.0
Secondary source of drinking water?	Borehole	39	39.0
	Bottled Water	3	3.0
	Sachet Water	56	56.0
	Rain Water	1	1.0
	Well Water	1	1.0
Distance of main source of drinking water from home?	<100m	64	64.0
	100-500m	32	32.0
	501-1000m	4	4.0
	>1000m	0	0.0
Do you treat your water before drinking?	Yes	26	26.0
	No	74	74.0
If yes, what treatment method do you use?	Boiling	23	88.5
	Boiling and Filtration	1	3.8
	Use of Alum	2	7.7
Do you store water for drinking purpose?	Yes	49	49.0
	No	51	51.0
If yes, how do you store your drinking water?	Covered container	23	23.0
	Jerry can	8	8.0
	Uncovered container	1	1.0
	Overhead tank	6	6.0
	Sachet container	6	6.0
	Refrigerator	5	5.0
How do you collect water from the storage container?	Cup with handles	47	96.0
	Cup without handles	1	2.0
	Bowl	1	2.0
How frequently do you clean your water storage containers?	Daily	1	2.0
	Weekly	24	49.0
	Monthly	15	30.6
	Rarely	9	18.4
Is your source available year-round?	Yes	65	65.0
	No	35	35.0
Have you faced any problem with your	Yes	61	61.0

water supply recently?	No	39	39.0
If yes, what kind of problems?	Contamination	2	3.3
	Poor taste	8	13.1
	Intermittent supply	50	82.0
	Poor taste, Bad odour	1	1.6
Can people get sick with the water they	Yes	66	66.0
drink?	No	34	34.0
Have your household experienced water-	Yes	45	45.0
related illness in the past 6 months?	No	55	55.0
If yes, which illness(es)?	Diarrhea	7	15.6
	Typhoid	36	80.0
	Cholera	2	4.4
Any unpleasant physical characteristics	No	85	85.0
associated with your water? If yes, name	Colour	4	4.0
them	Taste	11	11.0

In Table 4.3, the findings indicated that nearly all respondents (98%) had access to a flush toilet, while 2% used a pit latrine, and none practiced open defecation. The reports on toilet floor showed 91% had tiled toilets and 9% had concrete floors. In terms of toilet sharing, 17% of households shared their facilities with other households, while 83% had private toilets. Access to hand washing facilities near toilets was available to only 76% of respondents. Regarding toilet cleaning frequency, 88% of households reported cleaning their toilets weekly, while 8% cleaned them daily and 4% on a monthly basis. When it comes to hand washing after toilet use, 54% reported washing their hands always, while 46% did so sometimes. Similarly, when asked about hand washing before food preparation, 60% always washed their hands, while 40% sometimes did. A notable proportion (74%) of respondents were unsure how often they washed their hands daily, while 23% washed their hands whenever dirty and 3% reported 4–6 times per day. Concerning soap use, only 45% reported always using soap when washing hands, 19% used soap sometimes, and 36% used it only when available.

All respondents (100%) reported bathing daily. With respect to household waste disposal, 58% relied on waste management services, while others resorted to less sanitary methods

such as burning (21%), dumping in open spaces (20%), or burying waste (1%). In terms of cleaning surroundings, 65% cleaned weekly, 17% cleaned daily, and 18% did so occasionally. Awareness of safe water, sanitation, and hygiene (WASH) revealed that 51% were being somewhat aware and 35% being very aware, while 14% had no awareness. Only 5% of respondents reported that there had been recent water quality testing programs in their area, while 82% said no and 13% were unsure. However, 92% of households expressed willingness to have their water source tested.

Table 0.3: Sanitation and Hygiene Practices of Households

Parameters		Frequency (n=100)	Percentage (%)
What type of toilet facility is available to your household?	Flush toilet	98	98.0
	Pit latrine	2	2.0
	Open defecation	0	0.0
Type of floor in the toilet?	Concrete	9	9.0
	Wooden	0	0.0
	Tiles	91	91.0
Is the toilet shared with other households?	Yes	17	17.0
	No	83	83.0
Do you have access to regular handwashing facility near the toilet?	Yes	76	76.0
	No	24	24.0
How often is the toilet facility cleaned?	Daily	8	8.0
	Weekly	88	88.0
	Monthly	4	4.0
How often do you wash your hands after using the toilet?	Always	54	54.0
	Sometimes	46	46.0
How often do you wash your hands per day?	1-3 times	0	0.0
	4-6 times	3	3.0
	Whenever hands are dirty	23	23.0
	Not sure	74	74.0
How often do you wash your hands before preparing food?	Always	60	60.0
	Sometimes	40	40.0
How often do you use soap when you wash your hands?	Always	45	45.0
	Sometimes	19	19.0
	When available	36	36.0
Do you bath daily?	Yes	100	100.0
	No	0	0.0
How do you dispose your household waste?	Waste management services	58	58.0
	Dump in Open Space	20	20.0
	Burned	21	21.0
	Buried	1	1.0
How often do you clean your surroundings?	Daily	17	17.0
	Weekly	65	65.0
	Occasionally	18	18.0
Are you aware of the importance of safe water, sanitation, and hygiene (WASH)?	Very aware	35	35.0
	Somewhat aware	51	51.0
	Not aware	14	14.0
Have there been any water quality testing programs in your area recently?	Yes	5	5
	No	82	82
	Don’t know	13	13
Would you consent to having your water source tested for quality parameters?	Yes	92	92.0
	No	8	8.0

Table 4.4 presents the physicochemical characteristics of household drinking water samples. The recorded temperatures ranged between 26.5°C and 29.8°C, with an overall mean of 27.7°C (±0.9). This temperature range falls within the natural ambient range typical of tropical regions and is suitable for drinking water. The pH values varied from 5.9 to 8.0, with a mean of 7.0 (±0.5), indicating that most water samples were neutral to slightly alkaline. Only one sample (UHR-AH-01) recorded a slightly acidic pH of 5.9. The Total Dissolved Solids (TDS) values ranged from 21 mg/L to 81 mg/L, with a mean of approximately 40.3 mg/L (±15.7). The Electrical Conductivity (EC) values ranged from 32 to 90 µS/cm, with an average of 60.0 µS/cm (±17.5). Salinity was recorded as 0.00% across all samples. The Oxidation-Reduction Potential (ORP) ranged between 132 mV and 272 mV, with an overall mean of 232.5 mV (±31.5). The Hydrogen concentration ranged between 0.0 and 0.5 ppb, with a mean of 0.17 ppb (±0.15). The Specific Gravity was consistently 1.0 (±0.0) across all samples, which is the expected value for pure water at ambient temperature. The Resistivity values ranged from 59 to 133 Ω·m, with a mean of 95.5 Ω·m (±19.7).

In Table 4.5, borehole water recorded the highest range of counts, from 45 to 63 CFU/mL $\times10^0$. Sachet water exhibited a broader but lower range of counts, varying from 0 to 31 CFU/mL $\times10^0$. Several sachet water samples had no detectable heterotrophic bacteria (0 CFU/mL). Bottled water consistently recorded no detectable bacterial growth (0 CFU/mL $\times10^0$).

The mean total heterotrophic bacterial counts varied significantly across the different drinking water sources. Borehole water had the highest mean heterotrophic bacterial count of 55.3 CFU/mL $\times10^0$. Sachet water, in contrast, had a much lower mean count of 14.7 CFU/mL $\times10^0$. However, bottled water demonstrated the lowest mean bacterial count of 0 CFU/mL $\times10^0$, indicating absence of heterotrophic bacteria. in all tested samples.

Table 0.4: 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 .m)
UHR-AH-01	26.5±1.2	5.9±0.3	21±2.8	42±2.0	0.00±0.0	132±2.5	0.0±0.0	1.0±0.0	104±2.4
UHR-AH-02	27.5±0.7	6.8±0.9	38±1.9	35±2.2	0.00±.0.0	205±.3.7	0.0±0.0	1.0±0.0	120±.3.4
UHR-AH-03	27.5±0.3	7.4±0.4	35±2.0	51±1.9	0.00±0.0	214±5.4	0.2±0.0	1.0±0.0	131±2.3
UHR-AH-04	28.9±0.8	7.2±0.5	58±1.6	63±2.6	0.00±0.0	232±3.0	0.0±0.0	1.0±0.0	133±2.0
UHR-AH-05	28.1±0.5	6.9±0.3	33±2.0	44±1.8	0.00±0.0	207±3.8	0.5±0.0	1.0±0.0	112±2.1
UHR-AH-06	28.4±0.2	7.0±0.4	40±0.7	51±2.7	0.00±0.0	231±3.9	0.2±0.0	1.0±0.0	104±2.9
UHR-B-01	27.5±0.5	7.0±0.3	59±1.6	42±2.3	0.00±0.0	223±3.1	0.0±0.0	1.0±0.0	88±2.5
UHR-B-02	28.3±0.6	7.9±0.3	68±2.8	72±3.4	0.00±0.0	232±3.4	0.3±0.0	1.0±0.0	101±3.3
UHR-B-03	28.9±0.2	7.3±0.4	47±3.3	64±2.5	0.00±0.0	198±3.2	0.0±0.0	1.0±0.0	115±2.5
UHR-SC-01	27.2±0.3	7.2±0.3	39±2.5	57±3.0	0.00±0.0	251±3.1	0.0±0.0	1.0±0.0	92±3.1
UHR-SC-02	27.3±0.1	7.1±0.3	54±4.1	54±1.5	0.00±0.0	245±2.7	0.2±0.0	1.0±0.0	94±3.2
UHR-SC-03	26.8±0.5	7.4±0.3	81±3.6	52±2.4	0.00±0.0	261±4.6	0.0±0.0	1.0±0.0	91±1.7
UHR-SC-04	28.4±0.3	6.8±0.4	37±3.1	32±1.8	0.00±0.0	272±3.7	0.1±0.0	1.0±0.0	63±3.7
UHR-SC-05	26.6±0.4	7.5±0.5	24±1.8	67±2.5	0.00±0.0	238±4.3	0.0±0.0	1.0±0.0	94±2.4
UHR-SC-06	27.2±0.4	6.7±0.5	36±2.1	67±2.1	0.00±0.0	241±3.6	0.3±0.0	1.0±0.0	101±4.2
UHR-SC-07	26.5±0.5	7.3±0.4	30±1.6	72±3.3	0.00±0.0	266±3.2	0.0±0.0	1.0±0.0	82±3.7
UHR-AU-01	27.3±0.5	6.6±0.7	26±2.0	88±2.8	0.00±0.0	245±2.7	0.0±0.0	1.0±0.0	78±4.3
UHR-AU-02	29.8±0.2	7.0±0.2	44±3.1	61±3.1	0.00±0.0	228±3.0	0.4±0.0	1.0±0.0	104±4.9
UHR-AU-03	28.1±0.8	7.2±0.3	33±1.4	38±2.3	0.00±0.0	271±2.9	0.0±0.0	1.0±0.0	98±4.2
UHR-AU-04	27.9±0.4	8.0±0.6	51±2.0	65±2.4	0.00±0.0	223±3.7	0.2±0.0	1.0±0.0	96±3.1
UHR-AU-05	28.1±0.3	6.5±0.3	29±1.8	79±2.5	0.00±0.0	242±3.2	0.3±0.0	1.0±0.0	73±3.3
UHR-AU-06	27.4±0.5	6.6±0.4	35±2.3	66±2.1	0.00±0.0	189±5.6	0.5±0.0	1.0±0.0	66±2.1
UHR-AU-07	27.7±0.3	7.1±0.5	31±1.8	61±2.2	0.00±0.0	220±4.1	0.0±0.0	1.0±0.0	59±2.4
UHR-AU-08	27.5±0.2	7.2±0.5	28±2.0	85±2.5	0.00±0.0	251±2.5	0.2±0.0	1.0±0.0	91±3.6
UHR-AU-09	27.0±0.5	7.4±0.3	30±2.3	90±3.1	0.00±0.0	242±3.8	0.0±0.0	1.0±0.0	96±4.1

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

Table 0.5:Mean Total Heterotrophic Counts of Drinking Water Samples from Households

Sample Code	Sample Source	Mean Counts of Heterotrophic Bacteria CFU/mL $\times 10^0$
UHR-AH-01	Sachet Water	25±2.5
UHR-AH-02	Sachet Water	0±0.0
UHR-AH-03	Sachet Water	22±2.3
UHR-AH-04	Borehole Water	53±2.1
UHR-AH-05	Sachet Water	22±1.6
UHR-AH-06	Sachet Water	0±0.0
UHR-B-01	Sachet Water	18±0.9
UHR-B-02	Borehole Water	63±2.1
UHR-B-03	Sachet Water	0±0.0
UHR-SC-01	Sachet Water	20±3.3
UHR-SC-02	Borehole Water	57±1.9
UHR-SC-03	Sachet Water	0±0.0
UHR-SC-04	Sachet Water	21±2.0
UHR-SC-05	Sachet Water	0±0.0
UHR-SC-06	Sachet Water	18±2.5
UHR-SC-07	Sachet Water	22±3.3
UHR-AU-01	Sachet Water	20±4.2
UHR-AU-02	Sachet Water	31±5.3
UHR-AU-03	Bottled Water	0±0.0
UHR-AU-04	Borehole Water	45±2.5
UHR-AU-05	Sachet Water	19±1.3
UHR-AU-06	Sachet Water	25±2.4
UHR-AU-07	Sachet Water	0±0.0
UHR-AU-08	Sachet Water	0±0.0
UHR-AU-09	Sachet Water	27±2.5

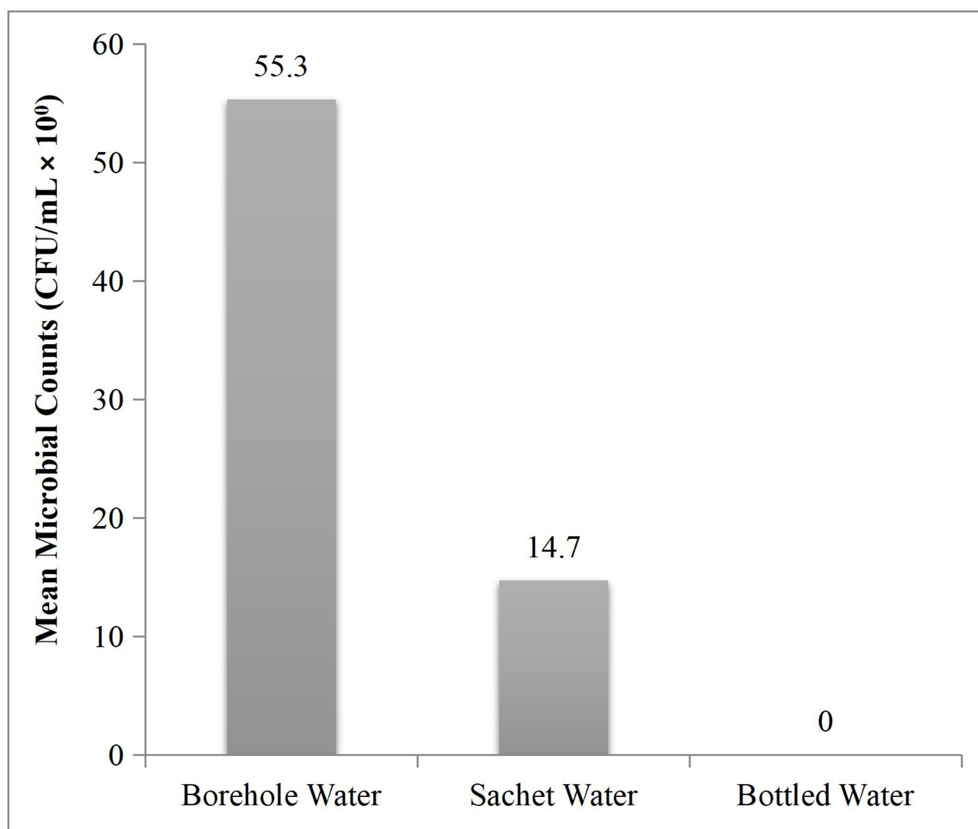

Figure 0.1: Mean Distribution of Heterotrophic Bacterial Based on Sample Sources

The results presented in Table 4.6 reveal variations in total coliform counts across the different household water sources, while *Escherichia coli* counts remained undetectable (0 CFU/mL $\times 10^0$) in all samples. For sachet water, total coliform counts ranged from 0 to 28 CFU/mL $\times 10^0$, with a mean value of 3.1 CFU/mL $\times 10^0$. In borehole water, total coliform counts ranged from 0 to 17 CFU/mL $\times 10^0$, with a mean of 10.0 CFU/mL $\times 10^0$. Bottled water showed no detectable coliforms or *E. coli* (0 CFU/mL $\times 10^0$) across all samples.

Table 0.6: Coliforms and Escherichia coli Counts in Water Samples from Households

Sample Codes	Sample Sources	Total Coliform Count (CFU/mL $\times 10^0$)	*Escherichia coli* Count (CFU/mL $\times 10^0$)
UHR-AH-01	Sachet Water	11±1.3	0±0.0
UHR-AH-02	Sachet Water	0±0.0	0±0.0
UHR-AH-03	Sachet Water	9±1.5	0±0.0
UHR-AH-04	Borehole Water	0±0.0	0±0.0
UHR-AH-05	Sachet Water	0±0.0	0±0.0
UHR-AH-06	Sachet Water	0±0.0	0±0.0
UHR-B-01	Sachet Water	0±0.0	0±0.0
UHR-B-02	Borehole Water	17±1.2	0±0.0
UHR-B-03	Sachet Water	0±0.0	0±0.0
UHR-SC-01	Sachet Water	10±2.3	0±0.0
UHR-SC-02	Borehole Water	0±0.0	0±0.0
UHR-SC-03	Sachet Water	0±0.0	0±0.0
UHR-SC-04	Sachet Water	0±0.0	0±0.0
UHR-SC-05	Sachet Water	0±0.0	0±0.0
UHR-SC-06	Sachet Water	0±0.0	0±0.0
UHR-SC-07	Sachet Water	0±0.0	0±0.0
UHR-AU-01	Sachet Water	0±0.0	0±0.0
UHR-AU-02	Sachet Water	28±1.5	0±0.0
UHR-AU-03	Bottled Water	0±0.0	0±0.0
UHR-AU-04	Borehole Water	13±2.3	0±0.0
UHR-AU-05	Sachet Water	0±0.0	0±0.0
UHR-AU-06	Sachet Water	18±2.1	0±0.0
UHR-AU-07	Sachet Water	0±0.0	0±0.0
UHR-AU-08	Sachet Water	0±0.0	0±0.0
UHR-AU-09	Sachet Water	0±0.0	0±0.0

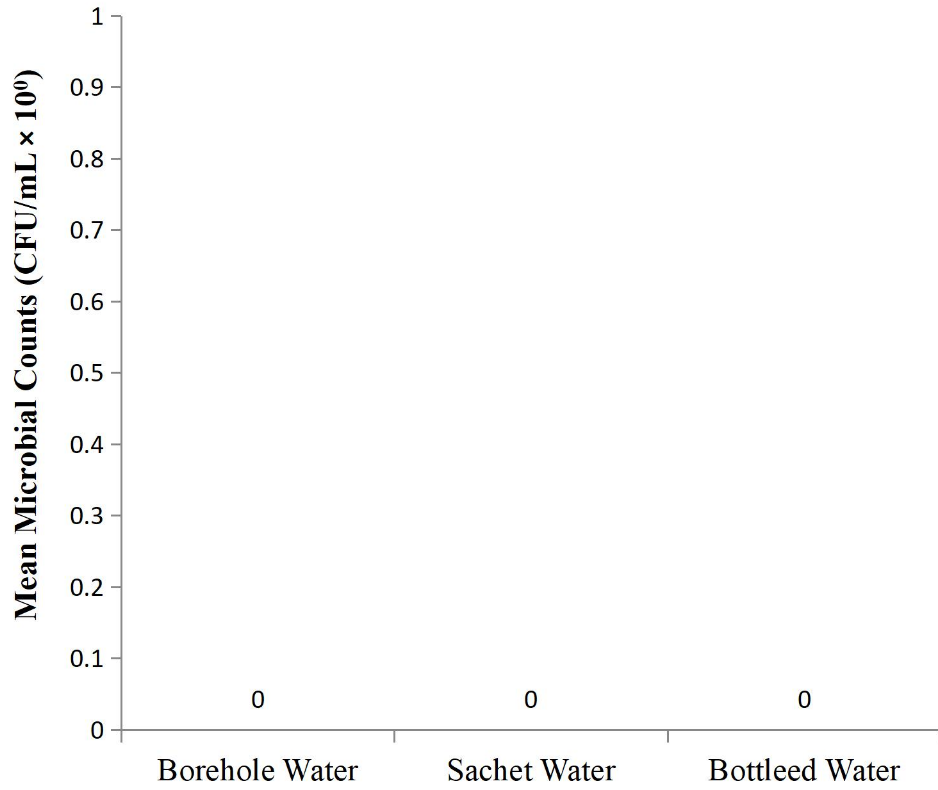

Figure 0.2: Mean Distribution of Escherichia coli in Drinking Water Samples from Households

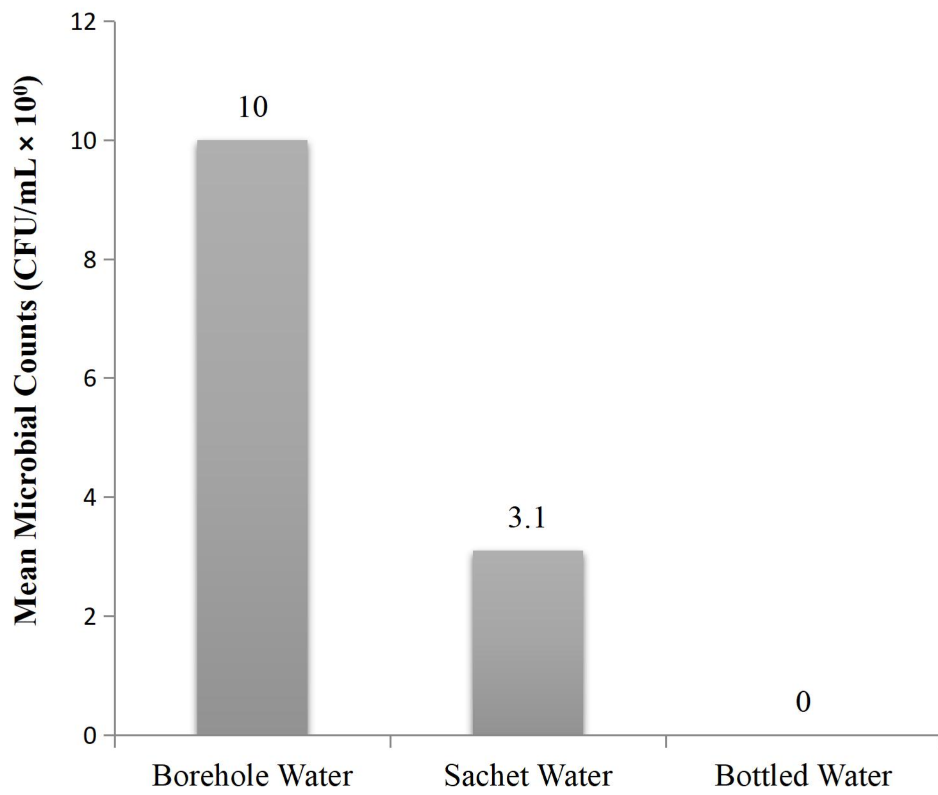

Figure 0.3: Mean Distribution of Total Coliforms Based on Sample Sources

CHAPTER FIVE

DISCUSSION

The current study assessed the quality of household drinking water and hygiene practices among residents of Uholor community, Benin City, Edo State, integrating physicochemical, bacteriological, and questionnaire data

Physicochemical Water Quality: Acceptable but Requires Vigilance

The physicochemical characteristics of the drinking water sources were largely satisfactory and fell within the permissible limits set by the World Health Organization and Nigerian Standard for Drinking Water Quality, the temperature (Mean = 27.7 °C) was typical for tropical groundwater, posing no direct health implications, though it can promote microbial proliferation if water is stored improperly, consistent with Dignum *et al*. (2023) in Benin City. The pH (Mean = 7.0; Range = 5.9–8.0) indicated neutral to slightly alkaline water, within the acceptable range (6.5–8.5). However, one slightly acidic sample (pH 5.9) suggests potential contamination from dissolved CO_2 or leaching from poor-quality plastic containers. Total Dissolved Solids (TDS) (Mean = 40.3 mg/L) and electrical conductivity confirmed low mineral content and excellent portability, well below the WHO limit of 500 mg/L. Similar low values in sachet water were reported by Odeyemi *et al*. (2024), affirming the good initial chemical quality of the region's rain-fed groundwater.

Bacteriological Quality: Significant Health Risk from Contamination

Despite the excellent physicochemical results, the bacteriological analysis revealed significant contamination, indicating a persistent microbial health risk. Heterotrophic bacterial counts were highest in borehole water (mean =55.3 x 100 CFU/mL), significantly

greater than in sachet water (mean =14.7 x 100 CFU/mL). The elevated counts in boreholes are likely due to poor maintenance of pumps/storage tanks and seepage contamination from surface runoff, consistent with findings by Diala *et al*., (2025) and Aminu and Udeze (2023). These counts, while not directly pathogenic, suggest biofilm formation and inadequate treatment. Crucially, Total coliforms were detected in both sachet (up to 28 x 100 CFU/mL) and borehole water (up to 17 x 100 CFU/mL), exceeding the WHO guideline of 0 CFU/100 mL. This suggests significant post-production or storage contamination. The absence of *E. coli* (an indicator of faecal contamination) in all samples is a positive finding, but the presence of coliforms still signals an unhygienic supply chain and potential risk of pathogen exposure.

Hygiene Practices and Sanitation Gaps: Perpetuating the Risk

Questionnaire findings highlighted common hygiene lapses and poor environmental sanitation practices that are likely perpetuating the microbial contamination observed. Sachet water was the primary source (73%), yet a critical finding was that 74% of respondents did not treat their water before drinking, reflecting low awareness and mirroring low treatment rates reported in southwestern Nigeria (Adewole *et al*., 2021). Of those who treated, the method was mainly boiling. While nearly half the households' stored water in covered containers, infrequent container cleaning was common (only 49% cleaned weekly). Unclean containers are a documented source of microbial increase (Diala *et al*., 2025). Furthermore, the presence of waste dumps (35%) and open sewage (12%) near some households strongly suggests environmental contamination pathways, aligning with correlations between poor sanitation and cholera risk found by Olanrewaju *et al*. (2025). Although sanitation coverage is high (98% uses flush toilets), significant gaps exist in personal hygiene: shared toilet use (17%) and limited hand-washing facilities (76%) are major concerns. Only 54% consistently

washed hands after toilet use and 45% used soap, increasing the likelihood of cross-contamination and household disease transmission, consistent with findings in Lagos slums (Aminu and Udeze, 2023).

Public Health Implications: Urgent Need for WASH Interventions

The study confirms that microbial contamination, not chemical safety, is the critical public health concern in Uholor community, a trend similar to Ado Ekiti (Odeyemi *et al*., 2024). The detection of heterotrophic bacteria and coliforms indicates a potential exposure risk to gastrointestinal pathogens. Typhoid fever (80%) and Diarrhoea (15.6%) were the most reported water-related illnesses, aligning with patterns observed in other Nigerian states (Aminu and Udeze, 2023; Wada *et al*., 2021). The findings underscore the urgent need for integrated WASH (Water, Sanitation and Hygiene) interventions focusing on improving storage hygiene, promoting household water treatment, enhancing environmental sanitation, and communicating effective personal hygiene practices.

5.2 Conclusion

The comprehensive assessment in Uholor community definitively concludes that, despite the observed physicochemical parameters of drinking water sources such as pH, TDS, and temperature falling well within acceptable WHO and SON limits, the water is fundamentally microbially compromised. The study established a critical failure in quality assurance, evidenced by the pervasive detection of Total coliforms and significantly high heterotrophic bacterial counts in both borehole and sachet water samples, thereby violating the zero-tolerance WHO guideline for microbial indicators. This clear bacteriological failure pinpoints post-source contamination and breaches in the supply and handling chain as the primary safety hazard.

Crucially, these microbial risks are deeply entrenched by poor community practices. The overwhelming majority of residents do not practice household water treatment (74%) and exhibit lapses in hygiene, including infrequent cleaning of water storage containers and inconsistent hand washing with soap. Furthermore, environmental determinants, such as the proximity of waste dumps and open sewage, create persistent pathways for recontamination.

The public health consequences of this sustained microbial exposure and inadequate hygiene are confirmed by the high self-reported prevalence of Typhoid fever (80%) and Diarrhea (15.6%), demonstrating a direct translation of microbial risk into significant community morbidity. Consequently, the water in Uholor is chemically palatable yet epidemiologically unsafe. This situation necessitates immediate and integrated Water, Sanitation, and Hygiene (WASH) intervention focused on enforcing safe water handling, promoting behavioral change, and strategically improving sanitation infrastructure to sustainably mitigate waterborne disease transmission.

5.3 Recommendation

The study's findings necessitate immediate and integrated Water, Sanitation, and Hygiene (WASH) interventions to address the critical public health risk posed by microbial contamination. The key focus must be on mitigating microbial risk. Authorities must strictly enforce the zero-tolerance WHO guideline for microbial indicators, especially Total coliforms, in both sachet and borehole water supplies. To prevent recontamination, strategies must be implemented to stop post-production and post-source contamination, including regular maintenance and proper sealing of borehole pumps and storage tanks. Crucially, an urgent public health campaign must be launched to promote and educate residents on effective household water treatment (HWT) methods, such as boiling, as a critical 74% of residents do not currently treat their water. Storage practices must also improve through an

awareness campaign to enforce the cleaning of water storage containers at least weekly and ensure all water is stored in clean, covered containers.

Sanitation and Environmental Management

Environmental hazards that perpetuate microbial risk must be removed. This requires a strategic effort to address determinants like the proximity of waste dumps (35%) and the proper closure of open sewage (12%) near households to eliminate pathways for recontamination. While sanitation coverage is generally high (98% flush toilets), targeted interventions are needed to reduce health risks associated with shared toilet use (17%).

Personal Hygiene and Behavioral Change

Significant behavioral change is required to break the transmission cycle. Targeted campaigns are necessary to improve personal hygiene, focusing specifically on consistent handwashing with soap after toilet use, as current rates are low (54% consistently wash hands and 45% use soap). Furthermore, authorities must ensure that all households and public areas have easily accessible hand-washing facilities with soap and running water to support this behavioral change.

These integrated measures are essential for transitioning the water supply from chemically palatable to epidemiologically safe, thereby reducing the high community morbidity associated with Typhoid fever (80%) and Diarrhea (15.6%).

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