

WATER QUALITY ASSESSMENT AND HEALTH STATUS OF DRINKING WATER FROM
HOUSEHOLDS IN BDPA COMMUNITY, UGBOWO, BENIN CITY, EDO STATE.

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.

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CERTIFICATION

This is to certify that this research titled **Water Quality Assessment And Health Status of Drinking Water From Households In Bdpa Community, Ugbowo, Benin City, Edo State** was carried out by **Amadasun, Jessica Osasenaga** 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 **Amadasun, Jessica Osasenaga** declare that **Water Quality Assessment And Health Status of Drinking Water From Households In Bdpa Community, Ugbowo, Benin City, Edo State** was carried out by **Amadasun, Jessica Osasenaga** 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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Date

DEDICATION

I dedicate this project report first and foremost to God Almighty, the giver of life, wisdom, and knowledge, who has guided and sustained me throughout this journey. To my dear parents, Mr Osamudiamen Amadasun and Mrs Edith Amadasun, whose love, support, and prayers have been my strength and inspiration, I also dedicate this work, grateful for their unwavering commitment to my success.

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ABSTRACT

Access to safe drinking water remains a critical public health challenge in many urban communities, with contaminated water sources posing significant health risks to residents. This study assessed the human health risks associated with household drinking water quality and hygiene practices among residents of BDPA Community, Ugbowo, Benin City, Edo State. A mixed-methods approach combined structured questionnaire surveys of 100 households with physicochemical and microbiological analyses of 30 water samples from borehole, sachet, and bottled water sources. Parameters examined included pH, temperature, turbidity, total dissolved solids, electrical conductivity, total heterotrophic bacterial counts, total coliforms, and *Escherichia coli*. The study revealed a predominantly young, educated population demonstrating high personal hygiene awareness, yet significant environmental sanitation deficits persisted, with over half of households located near waste dumps or open sewage systems. Borehole water exhibited the highest contamination risk, recording mean heterotrophic bacterial counts of 58.3 colony forming units per milliliter and total coliform counts of 12.3 colony forming units per milliliter, exceeding acceptable safety standards. Sachet water showed moderate contamination with intermittent coliform presence, while bottled water remained consistently safe. *Escherichia coli* was absent in all samples. A critical behavioral gap emerged as 64% of residents consumed borehole water without treatment, correlating with 24% self-reported water-related illnesses, predominantly typhoid fever. Poor local sanitation infrastructure enables contaminant infiltration into untreated water sources, creating tangible public health threats. Municipal authorities must enforce Nigerian water quality standards and improve community sanitation infrastructure. Public health campaigns should urgently encourage residents, particularly borehole users, to consistently boil or chlorinate drinking water before consumption to prevent disease outbreaks.

CHAPTER ONE

INTRODUCTION

1.1 Background of study

Water's quality is defined by its physical, chemical, biological and aesthetic characteristics which also affects its suitability for various applications such as safeguarding human health and aquatic ecosystem (Verma *et al.*, 2025). According to the World Health Organization in 2017, safe drinking water or potable water is water that does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. Whether it is to be used for drinking, domestic use, food production or recreational purposes, safe and readily available water is important for public health. The United Nations General Assembly (UNGA) has listed availability of clean water and sanitation for all as one of the goals to be achieved by the year 2030 for sustainable development (United Nations, 2018). Although, the world's population have access to water but the available water is seldom safe for human consumption and not obtainable in sufficient quantities to meet basic health needs (Mendelson *et al.*, 2024). Poor sanitation and contaminated water is linked to a rise in transmission of waterborne diseases such as cholera, diarrhoea, dysentery, typhoid and other gastrointestinal infections. Nigeria, with a population of over 199 million (Ewuzie *et al.*, 2021), faces significant challenges in water quality, impacting both its surface and groundwater resources (Egbueri *et al.*, 2025).

Industrial, residential, and agricultural activities, commercial slaughterhouses, mining, and petroleum exploration are some of the factors that contribute to water pollution in Nigeria

(Ighalo and Adeniyi, 2020). Therefore, in order to Identify pollution issues and develop effective prevention and mitigation strategies, regular monitoring and assessment of water quality should be carried out(Ighalo and Adeniyi, 2020). According to the World Health Organization (WHO), contaminated water causes approximately 485,000 diarrheal deaths every year(WHO, 2023). Ensuring good water quality by keeping water clean and safe is crucial for preventing these diseases and maintaining a healthy community.

In Nigeria, limited access to improved drinking water remains a major contributing factor to high morbidity and mortality rates among children under 5 years of age (UNICEF, 2021).The use of contaminated drinking water enhances vulnerability to waterborne diseases including diarrhoea which leads to the death of more than 70,000 children under the ages of 5 years annually (UNICEF, 2021). Report shows that about 62% of Edo State's population (representing 1,346,649 persons) lack access to safe drinking water (Idogho *et al.*, 2013). Edo State is clearly facing significant challenges in providing safe drinking water. Therefore, continuous monitoring of drinking water supply is essential to gather accurate data that will support sustainable improvements in drinking water supply (Rawlings and Seghosime, 2022).

In this study, physicochemical and microbiological analyses will be conducted to evaluate the safety of drinking water. These tests will measure physical properties (such as pH, temperature and turbidity) and biological contaminants (Total coliform and E-coli). Standardized methods recommended by the World Health Organization (WHO) and the Standard Methods for the Examination of Water and Wastewater (APHA) will be used. Results will be compared to establish health guidelines to determine if the water meets safety standards for consumption.

1.2 Problem Statement

The safety of the primary drinking water sources, packaged (bottled and sachet) water and boreholes in the BDPA community of Edo State is uncertain due to a lack of empirical data. This absence of water quality evaluation creates a risk of unnoticed contamination, potentially contributing to adverse health outcomes within the community and highlighting a critical need for investigation to inform public health intervention.

1.3 Justification of the Research

This project aims to evaluate household drinking water quality and related health risks in BDPA, providing essential data for targeted interventions. The findings will enable policymakers and stakeholders to allocate resources efficiently and raise community awareness on safe water practices to reduce health risks.

1.4 Aim and Objectives

This study aims to assess the potential human health risks associated with household drinking water quality and hygiene practices among residents of BDPA Community, Ugbowo, Benin City.

The specific objectives of the study are to:

- i. Examine household water handling, treatment, and hygiene behaviors that may influence the risk of waterborne diseases using a structured questionnaire survey.
- ii. Analyze the physicochemical characteristics of household drinking water to identify parameters that may pose health concerns.
- iii. Determine the total heterotrophic bacterial load in household drinking water as an indicator of microbial contamination.

- iv. Investigate the distribution of heterotrophic bacteria across different water sources to identify potential high-risk sources of contamination.
- v. Quantify the total coliform and *Escherichia coli* counts in household drinking water to assess associated public health risks; and
- vi. Evaluate the distribution of total coliforms and *Escherichia coli* across various water sources to determine the relative human health risk linked to each source.

CHAPTER TWO

LITERATURE REVIEW

2.1 PREAMBLE

Water quality studies are important in environmental studies as they ensure that water is suitable for various human activities such as manufacturing, farming, building or construction, household activities, and consumption (Ewuzie *et al.*, 2021). Most people in Nigeria lack access to safe drinking water. Of the people residing in urban and semi-urban regions, only about 42 % have access to safe water, compared to 71 % of those living in rural communities (Ehinomen *et al.*, 2018). Access to safe and clean drinking water is crucial for human health yet many communities in Nigeria including BDPA community in Edo state face challenges with water quality. Contaminated water poses health risks, thereby requiring safety evaluation of drinking water sources (Yahaya *et al.*, 2020). As a result of the growing global correlation between contaminated water and disease, it is essential that every community must have its supplies of drinking and household water thoroughly analyzed for safety (Yahaya *et al.*, 2020).

Microbial contamination of drinking-water as a result of contamination with faeces poses the greatest risk to drinking-water safety which can therefore transmit diseases such as diarrhoea, cholera, dysentery and typhoid and is also estimated to cause approximately 505 000 diarrhoeal deaths each year (WHO, 2023). Safe and sufficient water improves the practice of hygiene, which is a key measure to prevent not only diarrhoeal diseases, but acute respiratory infections and numerous neglected tropical diseases (Okesanya *et al.*, 2024).

Water quality issues in Edo State arises primarily from anthropogenic activities, leading to pollution of groundwater and surface water through waste disposal, agricultural runoff, oil

exploration, and sewage contamination (Sam-Uroupa and Ogbeibu, 2020). Common issues including heavy metal contamination, microbial pollution, and acidic water, often result in water that is unsuitable for drinking and thereby causing public health concern (Rath 2021). This review aims to highlight the critical need to assess and improve household drinking water quality in the BDPA community of Ugbowo, Edo State, to safeguard public health and inform effective interventions.

2.2 Sources of Household Drinking Water

Household drinking water comes from various sources that differ by location and availability; common sources include bottled water, sachet water, boreholes, wells, tap water, streams and rain water and each source has its unique benefits and risks linked to reliability and contamination (WHO 2023). In BDPA community, the most common sources of household drinking water are bottled water, sachet water and borehole water as they are believed to be safe sources of drinking water compared to other sources such as wells, rain water and streams or rivers (Imarhiagbe *et al.*, 2025). The various sources of household drinking water peculiar to Edo state environment are discussed below:

2.2.1 Packaged water (bottled and sachet water)

Packaged Water means water that is sealed in bottles, packages, or other containers and offered for sale for human consumption, including mineral water and spring water sometimes referred to as product water (SKNBS, 2016). Packaged water includes sachet water (packaged in nylon), bottled water (packaged in plastics or glass) and water dispensers; it usually treated to remove contaminants and may be disinfected to ensure it remains safe and clean until it's consumed (WHO 2022). Packaged water is often preferred in Edo state due to the benefit of convenience and reduced level of contamination compared to other sources (Agbasi *et al.*, 2024). However, it

carries significant health risks, including contamination with microplastics, BPA, and phthalates from plastic bottles, which can disrupt hormones, and promote inflammation, while also posing risks from bacterial or chemical contamination (CDC, 2024).

2.2.2 Boreholes

A borehole is a hydraulic structure which when properly designed and constructed, permits the economic withdrawal of water from an aquifer (Ukpong and Okon, 2013). A study by Ogundele, 2010 revealed that well and borehole water are the primary sources of water in Akure, Ondo State. Groundwater is generally considered safer and more reliable for domestic use and agricultural irrigation than surface water (Zige *et al.*, 2018). However, borehole water can be easily contaminated as a result of contributing factors such as proximity of pit latrines, landfills, and graves to boreholes, poor agricultural practices, improper well construction, as well as indiscriminate waste disposal (Abdulsalam *et al.*, 2019).

2.2.3 Wells

Well water is defined as water sourced from underground aquifers, which is typically protected from surface contamination. It can contain varying levels of minerals and generally has good microbiological quality (Nolan, 2017). Although well water provides nutrients and minerals, health problems could arise from drinking contaminated well water. Well water contaminants are associated with several illnesses including gastrointestinal illnesses, cancer, reproductive issues, and neurological disorders due to contamination from sources such as septic systems or agricultural runoffs (Villanueva *et al.*, 2014).

2.2.4 Rainwater Harvesting

Rainwater harvesting is defined as the collection and storage of rainwater for agricultural and domestic use, which has been historically practiced in arid regions to supplement water supply and enhance agricultural yield (Prewitt 2025). Although it is believed that rainwater can improve hair health and boost the immune system, these benefits aren't well proven and are outweighed by safety concerns. Drinking untreated rainwater can expose people to dangerous contaminants like bacteria, viruses, parasites, heavy metals, and chemicals such as PFAS, which can lead to infections and serious health problems. To drink rainwater safely, it needs to be collected hygienically and treated using methods like boiling, filtration, or UV disinfection to remove harmful impurities.

2.2.5 Rivers/Streams

Inland waterways and rivers provide various human needs, such as fish and other river biota, food sources, irrigation functions, mobility, recreation, drinking, washing, and sanitation (Chabib *et al.*, 2025). Generally, river/stream is considered an unsafe source of drinking water due to the presence of contaminants such as bacteria, viruses, parasites and chemicals usually from sources such as agricultural runoffs, industrial waste, sewage and animal wastes.

2.3 WATER QUALITY PARAMETERS

Water quality parameters are measured indicators of water's physical, chemical, and biological state. These include physical aspects like temperature, clarity, and color; chemical aspects such as pH, oxygen levels, and nutrients like nitrates as well as biological markers like bacteria, algae, and viruses. These parameters help assess water suitability for drinking, farming, or recreation, and track pollution and ecosystem health.

2.3.1 Physical parameters

Temperature: This refers to the degree of hotness or coldness of a body or substance. Temperature is a significant parameter because it affects the amount of dissolved oxygen in water. The amount of oxygen that will dissolve in water increases as temperature decreases. Water at 0°C will hold up to 14.6 mg of oxygen per litre, while at 30°C, it will hold only up to 7.6 mg/L. The ideal temperature range for drinking water is typically between 50–60°F (10–16°C).

Turbidity: Turbidity is a measure of the ability of light to pass through water, that is, a measure of the water's murkiness. Measuring murkiness gives an estimate of suspended solids in the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances. Turbidity can be caused silt, sand and mud, bacteria and other germs and chemical precipitates. Turbidity is measured in Nephelometric Turbidity Units (NTU's). It is very important to measure the turbidity of domestic water supplies, as these supplies often undergo some type of water treatment which can be affected by turbidity.

Colour: Water is typically expected to be colorless and transparent. However, the presence of dissolved or suspended substances can impart various colors to it. Color affects the aesthetic quality of water, particularly for drinking purposes. Elevated color levels may also indicate the presence of organic contaminants.

Taste: Taste refers to the sensory perception experienced in the mouth when consuming water. It is primarily caused by substances dissolved in the water. Natural minerals (such as chlorides and sulfates), microbial metabolites, dissolved metal ions (like iron and manganese), as well as various organic and inorganic pollutants, can all affect the taste of water.

2.3.2 Chemical Parameters

pH: pH is one of the fundamental chemical parameters in water quality, indicating the acidity or alkalinity of water. It represents the negative logarithm of the hydrogen ion (H^+) activity in water, typically ranging from 0 to 14. pH not only affects chemical reactions and the stability of treatment processes but also determines the health of aquatic ecosystems. The ideal pH level for drinking water is 6.5 to 8.5. Values outside this range may cause corrosion, release of heavy metals, or biological stress.

Dissolved Oxygen (DO): The amount of oxygen in water, to a degree, shows its overall health. That is, if oxygen levels are high, one can presume that pollution levels in the water are low. Conversely, if oxygen levels are low, one can presume there is a high oxygen demand and that the water is not of optimal health. The concentration of dissolved oxygen depends on various factors, primarily salinity, pressure, and temperature.

Nutrients: The principal limiting nutrients in water include free ammonia, organic nitrogen, nitrites, nitrates, organic phosphorus and inorganic phosphorus. Nitrogen and phosphorus are important because these two nutrients are responsible for the growth of aquatic plants. All living organisms require varying amounts of some trace elements, such as iron, copper, zinc and cobalt, for proper growth. These are widely present in natural water, drinking water, wastewater, and industrial water, directly affecting hardness, alkalinity, corrosion potential, and conductivity. Nutrient contamination in ground water which is a major source of drinking water in Edo state can be harmful, even at low levels.

Total Dissolved Solids (TDS): Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc. These minerals produce unwanted taste and dilute color in appearance

of water. This is an important parameter for the use of water. Water with high TDS value indicates that water is highly mineralized. High values of TDS in ground water are generally not harmful to human beings, but high concentration of these may affect persons who are suffering from kidney and heart diseases. Water containing total dissolved solids may cause laxative or constipation effects (Onuigbo and Madu, 2013).

2.3.3 Biological Parameters

Bacteria: Bacteria are microscopic single-celled organisms, some of which come from fecal contamination (like *E. coli* and total coliforms). Their presence often indicates poor sanitation and possible harmful pathogens. While many bacteria are harmless, certain types cause diseases like cholera, typhoid, and dysentery.

Total Coliforms: These are either motile or non-motile Gram-negative, non-spore forming bacilli that possess β -galactosidase to produce acids and gases under their optimal growth temperature of 35–37 °C (Yusuf *et al.*, 2025). Coliform bacteria are often used as indicators of poor sanitation in food, water, and milk. Although they don't typically cause severe illness, their presence suggests potential contamination with disease-causing pathogens like bacteria, viruses, or parasites (Meller *et al.*, 2024). Testing for coliform bacteria is crucial to ensure drinking water safety. Typical Genera of Coliforms includes *Enterobacter*, *Klebsiella*, *Citrobacter* and *Escherichia*.

E. Coli: *Escherichia coli* (*E. coli*) can be distinguished from most other coliforms by its ability to ferment lactose at 44 °C in the fecal coliform test, and by its growth and color reaction on certain types of culture media (Abu-sini *et al.*, 2023). *Escherichia coli* have an incubation period of 12–72 hours with the optimal growth temperature being 37 °C. Unlike the general coliform group, *E.*

coli are almost exclusively of fecal origin and their presence is thus an effective confirmation of fecal contamination (Maes *et al.*, 2025). Most strains of E. coli are harmless, but some can cause serious illness in humans. Infection symptoms and signs include bloody diarrhea, stomach cramps, vomiting and occasionally, fever (Kumari *et al.*, 2022).

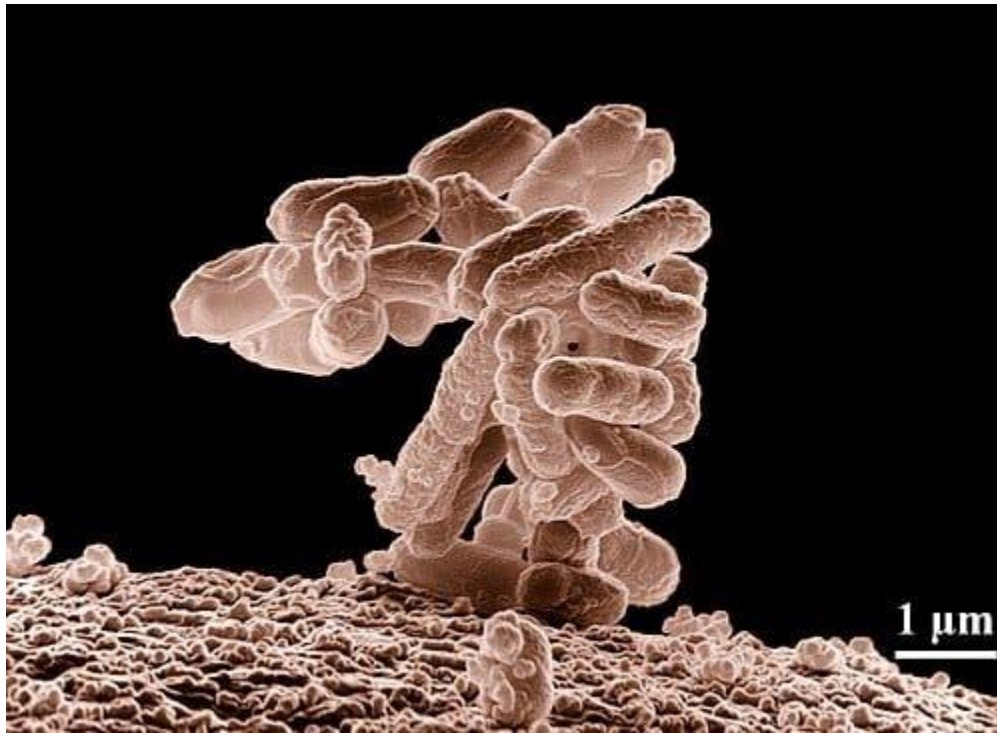


Plate2.3.3.1: A cluster of E. Coli magnified 10,000 times

Photo Credit: Eric Erbe, 2005.

Viruses: Viruses in drinking water are tiny infectious agents that come mainly from fecal contamination by humans or animals (Kristanti *et al.*, 2022). They don't grow in water but survive long enough to infect people when they drink or use the water. Common waterborne viruses include enteroviruses, noroviruses, and hepatitis A, causing illnesses like gastroenteritis,

hepatitis, and other infections. Their presence indicates serious contamination and health risks because some are highly infectious even at low levels (Lanrewaju *et al.*, 2022).

Protozoans: These are tiny single-celled parasites like Giardia and Cryptosporidium. They cause diseases such as diarrhea and stomach cramps. These protozoa are tough and they can survive some water treatments and can spread where sanitation is poor. Their presence signals serious contamination and health risks that need careful water treatment (Vaisusuk and Saijuntha, 2021).

Algae: Algae are tiny aquatic plants or microorganisms. While most algae aren't harmful, some types can produce toxins affecting water taste, smell, and safety. Their presence often indicates nutrient pollution and can lead to problems like algal blooms, which may harm aquatic life and affect the quality of drinking water (Wu *et al.*, 2022).

2.4 Health Risks from Contaminated Water

Contaminated water and poor sanitation are linked to transmission of diseases such as cholera, diarrhoea, dysentery, hepatitis A, typhoid and polio (Kristanti *et al.*, 2022). Absent, inadequate, or inappropriately managed water and sanitation services exposes individuals to health risks that are preventable (Wolf *et al.*, 2023). Common waterborne diseases include Cholera, Typhoid, Hepatitis A, Giardiasis, Cryptosporidiosis, and Dysentery (Nwabor *et al.*, 2016). These diseases are caused by pathogens transmitted through contaminated drinking water, food, and poor sanitation practices, often leading to symptoms such as diarrhea, cramps, and fever (Ali *et al.*, 2021).

2.4.1 Common waterborne diseases

The following are examples of waterborne diseases:

Cholera is a bacterial infection of the small intestine caused by *Vibrio cholerae* that causes severe diarrhea and can be life-threatening (Kamarany *et al.*, 2025).

Typhoid and Paratyphoid Fevers are bacterial diseases spread by *Salmonella* bacteria, often found in contaminated water and food (Manesh *et al.*, 2021).

Hepatitis A is a viral infection that affects the liver and can be contracted by ingesting water or food contaminated with the hepatitis A virus (Foster 2021).

Dysentery is a severe form of diarrhea, often with blood and mucus in the stool, caused by bacteria or parasites that contaminate water (Anyiam *et al.*, .2024).

Giardiasis is a parasitic infection caused by the *Giardia* parasite, which can contaminate water supplies and lead to symptoms like watery diarrhea (Morsy *et al.*, 2024).

Cryptosporidiosis (or "crypto") is a parasitic disease caused by the *Cryptosporidium* parasite, spread through contaminated water (Helmy and Hafez, 2022).

2.4.2 Causes of waterborne disease associated with poor water quality

Waterborne diseases are conditions or adverse effects on human health, such as death, disability, illness or disorders caused by pathogenic micro-organisms that are transmitted by water (Shayo *et al.*, 2023). These diseases can be spread while bathing, washing, drinking water, or by eating food exposed to contaminated water (Mahant and Biswal, 2022). Lack of clean water supply, sanitation and hygiene (WASH) are major causes for the spread of waterborne diseases in a community (Okesanya *et al.*, 2024). The fecal–oral route is a common disease transmission pathway for waterborne diseases (Shayo *et al.*, 2023). Another cause of waterborne diseases is poverty as it also increases the risk of communities to be affected by waterborne diseases (Hora *et al.*, 2021). For example, the economic level of a community impacts their ability to have

access to clean water. Other causes of waterborne diseases includes environmental factors such as flooding, consumption of untreated or inadequately treated water and lack of proper waste disposal systems near water sources (Chan *et al.*, 2021).

2.5 ASSESSMENT OF HOUSEHOLD WATER QUALITY

2.5.1 Water sampling strategies:

A well-designed water sampling strategy is a systematic process that ensures the data collected accurately represents the true quality of the water source. It involves careful planning, precise field techniques, and strict quality control, all guided by the specific objectives of the study. The foundation of any sampling program is a clear goal. The key is to select a sampling design that minimizes bias and ensures samples collected are representative of the entire water body.

The table below summarizes common sampling techniques:

Table 2.5.1: Common sampling techniques

S/N	Sampling techniques	Core principles	Best use cases
1.	Random sampling	Here, every location in the study area has an equal chance of being selected	<ol style="list-style-type: none"> 1. Homogeneous water bodies where spatial variability is low; helps eliminate bias. 2. Getting one overall estimate for a homogenous community

2.	Systematic sampling	Samples are taken at fixed intervals (e.g., every 10 meters along a transect or every 3 hours).	Identifying patterns or gradients (e.g., from a pollution source downstream) or for routine monitoring.
3.	Stratified sampling	The water body is divided into distinct zones (strata) based on a characteristic (e.g., depth, proximity to shore). Samples are taken from each stratum.	<p>1. Heterogeneous environments with distinct sub-areas (e.g., a lake with deep and shallow regions, or a river with agricultural and urban runoff areas).</p> <p>2. Ensuring representation and enabling comparisons between subgroups</p>
4.	Grab sampling	A single sample collected at a specific location and point in time.	Provides a "snapshot" of conditions at that moment. Suitable for stable parameters or detecting acute contamination events
5.	Composite sampling	Multiple grab samples collected over time or space	Provides an average measurement over time or

		are mixed together.	across an area, which can be more cost-effective for understanding general conditions.
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2.6 Relevant Case Examples

1. Morka *et al.*, (2021) conducted a study in Edo State, Nigeria, to assess the potability of borehole water for human consumption. The researchers collected and analyzed two hundred and forty (243) borehole water samples from nine sites, examining physical (pH, total solids, DO, COD and BOD), chemical (NO3, SO4, PO4, chloride and metallic ions) and bacteriological (total bacteria count and total coliform count) parameters. The results were compared with standards prescribed by the World Health Organization (WHO) and Federal Ministry of Environment (FMEnv), Nigeria. The values of all the physicochemical parameters of the borehole water analyzed in the study were below the limits recommended by FME and WHO. The bacteriological analysis of the water revealed that the total bacterial count ranged from 1.78±0.33 to 3.92±0.32× 10³cfu/ml while coliform counts ranged from 0.65±0.32 to 2.75±0.20× 10³ cfu/ml. These values were above acceptable limits. Thus, the borehole water from the studied localities across the three senatorial districts were considered unfit for consumption and it was therefore recommended that home water purification such as boiling and filtration should be practiced among the inhabitants before consumption.

2. Ijioma *et al.*, (2025) conducted a study that applied Water Safety Plan (WSP) to assess water quality, health risks, and the effects of harmful environmental practices in Aba, Nigeria, where

the waterworks infrastructure is dysfunctional. The datasets used were collected from physicochemical, chemical, and bacteriological analyses of drinking water samples (natural sources: n = 60, secondary sources: n = 19), along with household surveys (120) and semi-structured expert interviews (10). Findings from the study revealed that groundwater is the primary source of drinking water, with most facilities classified as improved sources. However, poor sanitation practices, particularly improper septage disposal, were identified as major contributors to water contamination. Bacteriological analysis showed severe contamination in the Aba River, while sachet water posed significant health risks due to the presence of *E. coli* and total coliform bacteria in some cases.

3. Rawlings and Seghosime (2022) evaluated the water supply, sanitation and hygiene facilities of Ekosodin community in Ovia North-East LGA, Benin city, Edo State. Four hundred and twenty (420) semi-structured questionnaires were administered to households in Ekosodin Community. Three hundred and ninety seven (397) copies were retrieved and thus analysed. The study found that Ekosodin communities have poor access to adequate WASH facilities/services, especially those related to water treatment, toilet and waste management. Poor hygiene practice was observed among households; poor maintenance of water storage containers and hand washing practice at indiscriminate times.

4. Okereke *et al* (2022) evaluated the physicochemical quality of drinking water from various sources in 24 randomly selected communities throughout Abia State, Nigeria. These communities were selected from 8 Local Government Areas within the 3 senatorial zones of Abia State. Using sterile universal containers, water samples were collected from the major drinking water sources in the selected communities. On-site evaluation of the pH, electrical conductivity (EC), total dissolved solids (TDS) and temperature of the water samples was carried out using a

HI9813-6 pH/EC/TDS/Temperature meter. The pH values of the water samples from all sampled communities ranged between 4.1 and 5.9, and the acidic pH levels of the water samples were not within the Nigerian Industrial Standard's (NIS) approved range of 6.5-8.5. Furthermore, the water sources in the selected communities were found to have ambient temperatures ranging from 25.8-31.8oC. The average electrical conductivity (0.04 μ S/cm) and total dissolved solids (36.4 mg/L) of water samples from all senatorial zones studied were both within acceptable limits of 1000 μ S/cm and 500 mg/L respectively.

5. Ekejiuba *et al.*, (2023) conducted a study in Achusa community, Benue State, Nigeria. They assessed the physicochemical and bacteriological properties of hand-dug wells and boreholes. The research analyzed 16 water samples from four boreholes, four brands of sachet water, and four hand-dug wells. Key findings included:

Physicochemical Parameters:

-Sachet water samples largely met World Health Organization (WHO) and Nigerian Standards for Drinking Water Quality (NSDWQ) guidelines.

-Borehole samples exceeded standard iron levels (0.32-0.41 mg/l).

- Well samples had higher mean values for turbidity (6.0-39.85 mg/l), chloride (327.50 mg/l), and nitrite (2.07 mg/l).

Bacteriological Properties:

-Sachet water samples met WHO/NSDWQ standards.

-Well samples had high total viable counts (128-131 cfu/100ml) and total coliform counts (20 cfu/100ml).

-Borehole samples had lower total coliform counts (12-15 cfu/100ml).

Pathogenic Bacteria Isolates:

E. coli, faecal streptococcus, *Salmonella* species, *Pseudomonas* species, *Bacillus* species, and *Vibrio cholerae* were detected.

6. Luvhimbi *et al.*, (2022) conducted a study that evaluated the physico-chemical and bacteriological quality of drinking water supplied by the municipality from source to the point of use at Thulamela municipality, Limpopo Province, South Africa. They assessed the community practices regarding collection and storage of water and determined the human health risks associated with consumption of the water. Assessment of water quality was carried out on 114 samples. Questionnaires were used to determine the community's practices of water transportation from source to the point-of-use and storage activities. Many of the households reported constant water supply interruptions and the majority (92.2%) do not treat their water before use. While *E. coli* and total coliform were not detected in the water samples at source (dam), most of the samples from the street taps and at the point of use (household storage containers) were found to be contaminated with high levels of *E. coli* and total coliform. The levels of *E. coli* and total coliform detected during the wet season were higher than the levels detected during the dry season.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of Study Area

The study was conducted in Benin City, the capital of Edo State, southern Nigeria. Benin City is an urban area where variations in water quality and sanitation practices may influence public health and the risk of waterborne diseases (Archibong *et al.*, 2025).

3.2 Sample Location

The sample location is BDPA (Bendel Development and Property Authority) Community, Ovia Northeast, Benin city, Edo state and is located 320 kilometers (200 miles) East of Lagos and about 40 kilometers (25 miles) North of the Benin River with coordinates of 6°20'00"N 5°37'20"E and located in the southern part of Nigeria (Imarhiagbe *et al.*, 2025). BDPA Community is situated opposite the University of Benin main gate, and land use predominantly features businesses and student residential areas and a lesser percentage of family residential areas (Onwuanyi *et al.*, 2023). The estate was designed in the late 1970s by the BDPA, an agency of the then government of Bendel State (which was split into Edo and Delta states in 1991); the Authority was founded in 1968 to execute property management, property development and urban planning functions and though figures are not available, the population is observed to increase over the years (Onwuanyi *et al.*, 2023). The area is predominantly inhabited by students.

Table3.2.1: Coordinates of Samples taken from each Household

S/N	Sample Codes	Sample Sources	Latitude	Longitude
1	BDPA02	Borehole	6°39'930"N	5°60'505"E
2	BDPA03	Sachet water	6°40'078"N	5°60'424"E
3	BDPA05	Borehole	6°40'094"N	5°60'421"E
4	BDPA06	Sachet water	6°40'124"N	5°60'548"E
5	BDPA10	Sachet water	6°40'040"N	5°60'180"E
6	BDPA11	Borehole	6°39'971"N	5°60'189"E
7	BDPA20	Borehole	6°40'440"N	5°60'471"E
8	BDPA21	Borehole	6°40'196"N	5°60'311"E
9	BDPA22	Sachet water	6°39'723"N	5°60'766"E
10	BDPA23	Borehole	6°39'709"N	5°60'765"E
11	BDPA24	Borehole	6°39'848"N	5°60'690"E
12	BDPA25	Borehole	6°39'705"N	5°60'770"E
13	BDPA26	Borehole	6°39'683"N	5°60'776"E
14	BDPA29	Borehole	6°39'730"N	5°60'675"E
15	BDPA33	Sachet water	6°39'892"N	5°60'394"E
16	BDPA37	Sachet water	6°39'721"N	5°60'665"E
17	BDPA40	Borehole	6°39'744"N	5°60'767"E
18	BDPA42	Borehole	6°39'744"N	5°60'766"E
19	BDPA43	Bottled water	6°39'709"N	5°60'765"E
20	BDPA49	Sachet water	6°39'705"N	5°60'770"E
21	BDPA52	Sachet water	6°39'683"N	5°60'776"E
22	BDPA55	Borehole	6°39'664"N	5°60'770"E
23	BDPA57	Sachet water	6°39'847"N	5°60'740"E
24	BDPA60	Sachet water	6°39'755"N	5°60'658"E
25	BDPA62	Sachet water	6°39'749"N	5°60'667"E
26	BDPA69	Borehole	6°39'739"N	5°60'662"E
27	BDPA73	Bottled water	6°39'721"N	5°60'665"E
28	BDPA77	Sachet water	6°39'831"N	5°60'607"E
29	BDPA79	Borehole	6°39'731"N	5°60'564"E
30	BDPA91	Sachet water	6°39'731"N	5°60'570"E

3.3 Questionnaire Survey

A structured questionnaire was employed to assess household water quality management and hygiene practices with a focus on identifying behaviors that may influence the risk of waterborne diseases. The instrument was designed to gather information on water sources, storage and treatment methods, as well as sanitation and hygiene habits that could impact human health.

Respondents were selected using a random sampling technique to ensure fair representation across households.

One on one interviews were conducted to reduce response misinterpretation and bias. Data obtained were coded, and analyzed using descriptive and inferential statistical methods to identify potential links between water handling practices and health risks. A total of 100 households participated in the survey.

3.4 SAMPLE COLLECTION

Water samples were collected from various household sources within BDPA Community, including sachet water, bottled water, and boreholes where available. Thirty (30) drinking water samples were collected using sterile plastic containers. Each sample was properly labeled and immediately transported to the laboratory for analysis. Collection was done following standard procedures to avoid contamination.

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. 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.

3.6 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 (MWC-TDS2355, 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.

3.7 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 200 µL 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).

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

Total coliform and *Escherichia coli* counts were determined using the spread plate method. A 200 µL 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 colony-forming 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 subculturing on Nutrient Agar plates and subsequently maintained on Nutrient Agar slants for further analysis.

3.9 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 color change indicated a negative result. Presumptive coliform isolates were characterized as KOH-positive, catalase-positive, and oxidase-negative.

3.10 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 \pm standard deviation (SD).

3.11 SAMPLE EQUIPMENTS

The study utilized various laboratory equipments for water quality analysis. Physical parameters like turbidity and pH were measured using a 10-in- one water quality meter probe. For microbiological tests, Nutrient Agar and Chromocult Coliform Agar powder were used. Other essential tools included:

- i. Sterile sampling bottles for collecting water samples from households
- ii. Insulating cooler for preserving the integrity of the samples
- iii. Sterile petri dishes for culturing

- iv. Sterile inoculating loops
- v. Distilled water
- vi. Absolute ethanol for sterilization
- vii. 10-in-1 water quality meter probe
- viii. Pipette
- ix. Temperature controlled incubator
- x. Autoclave

CHAPTER FOUR

RESULTS

4.1 Socio-demographic Characteristics of Respondents

Table 4.1 presents the demographic characteristics and environmental observations of the 100 households surveyed. The findings indicate a predominance of female respondents (61%), compared to males (39%). The age distribution shows that the majority of respondents (55%) were between 18 and 27 years, followed by 28–37 years (18%), 38–47 years (16%), and smaller proportions above 47 years. This distribution implies that most respondents were young adults, possibly with greater exposure to education on sanitation and hygiene practices. In terms of marital status, 61% of the respondents were single, while 37% were married and 2% divorced. The dominance of single respondents may relate to the high proportion of students (45%). Other major occupations included traders/business owners (17%), private sector employees (14%), civil servants (8%), artisans/skilled workers (7%) and unemployed (8%).

Regarding educational attainment, a significant 79% of respondents had tertiary education, while 12% completed secondary school, and only 6% had no formal education. Majority of respondents were Christians (88%), with 11% Muslims and 1% traditionalists. Household size

data revealed that 52% of households had 4–6 members, 46% had 1–3 members, and only 2% had 7–9 members. In terms of income, a large proportion (45%) of respondents declined to disclose their monthly income, while 25% earned ₦150,000 and above, and smaller percentages fell into lower income brackets. Environmental observations revealed that 54% of households were located near waste dump sites, and of these, 30% were within 50 meters of such sites. Additionally, 29% of respondents reported the presence of open sewage or stagnant water near their homes. Despite these, 52% of households were classified as moderately clean, 32% as clean, and 16% as dirty.

Table 4.1.1: Demographics and Environmental Observations of Households

Parameters		Frequency (n=100)	Percentage (%)
Sex	Male	39	39.0
	Female	61	69.0
Age in years	18-27	55	55.0
	28-37	18	18.0
	38-47	16	16.0
	48-57	7	7.0
	58 and above	4	4.0
Marital status	Single	61	61.0
	Married	37	37.0
	Divorced	2	2.0
	Widowed	0	0.0
Religion	Christianity	88	88.0
	Islam	11	11.0
	Traditional	1	1.0
Educational Level Attained	No Formal Education	6	6.0
	Vocational	1	1.0
	Primary School	2	2.0
	Secondary School	12	12.0
Occupation	Tertiary Education	79	79.0
	Student	45	45.0
	Private sector Employee	14	14.0
	Trader/Business Owner	17	17.0
	Civil Servant	8	8.0
	Artisan/Skilled Worker	7	7.0
	Farmer	1	1.0
	Unemployed	8	8.0
Household Size	1-3	46	46.0
	4-6	52	52.0
	7-9	2	2.0
	10 and above	0	0.0
Monthly Household Income (₦)	<20,000	5	5
	20,000-49,999	3	3
	50,000-99,999	11	11

	100,000-149,999	11	11
	≥150,000	25	25
	Can't say	45	45.0
Is there a waste dump site near the household?	Yes	54	54.0
	No	46	46.0
If yes, what is the estimated distance of their residence to the nearest waste dump site	<50m	30	30.0
	50-100m	22	22.0
	>100m	2	2.0
Is there any open sewage or stagnant water nearby?	Yes	29	29.0
	No	71	71.0
General condition of the surroundings as observed	Clean	32	32.0
	Moderately clean	52	52.0
	Dirty	16	16.0

4.2 Water Source and Quality Assessment of Households

Table 4.2.1 showed that majority of households (54%) identified sachet water as their main source of drinking water, then borehole water (35%), bottled water (10%), and underground well water (1%). Notably, 26% of households reported borehole water as their secondary source. In terms of accessibility, the majority of respondents (87%) had their primary water source located within 500 meters of their homes, 40% within 100 meters, 47% within 100–500 meters while 13% have distance more than 500 meters. Regarding water treatment, only 36% of households reported treating their water before drinking, while 64% consumed it untreated. Among those who practiced treatment, boiling (24%) was the most common method, followed by chlorination (6%), filtration (4%), and minimal use of alum (1%) or water guard (1%).

Most households (71%) stored water for drinking purposes, mainly in covered containers (34%), jerry cans (22%), and in uncovered containers (3%). Storage in overhead tanks (5%), small plastic containers (3%), and refrigerators (4%) was also observed. Water retrieval practices showed that 63% used cups with handles while smaller proportions used cups without handles (3%) or bowls (5%). Cleaning frequency varied, with 36% cleaning weekly, 23% monthly, and only 9% daily, while 3% rarely cleaned their containers. A high proportion (91%) of respondents reported that their water source was available throughout the year. Nevertheless, 46% reported

problems with their water sources, including intermittent supply (20%), poor taste (11%), contamination (10%), and bad odor and color (3%). Concerning health implications, 33% of households believed that people could get sick from their drinking water, and 24% had experienced water-related illness in the preceding six months. Of those cases, typhoid fever (87.5%) was the most frequently reported illness, followed by diarrhea (8.3%) and cholera (4.2%). Finally, 86% of respondents reported no unpleasant physical characteristics in their drinking water, while 11% cited taste issues and 3% stated color changes.

Table 4.2.1: Water Source and Quality Assessment of Households

Parameters		Frequency (n=100)	Percentage (%)
Main source of drinking water?	Borehole	35	35.0
	Sachet Water	54	54.0
	Underground Well	1	1.0
	Bottled Water	10	10.0
Secondary source of drinking water?	Borehole	26	26.0
	Bottled Water	15	15.0
	Sachet Water	48	48.0
	Well	1	1.0
Distance of main source of drinking water from home?	<100m	40	40.0
	100-500m	47	47.0
	>500m	13	13.0
Do you treat your water before drinking?	Yes	36	36.0
	No	64	64.0
If yes, what treatment method do you use?	Boiling	24	24.0
	Filtration	4	4.0
	Chlorination	6	6.0
	Use of Alum	1	1.0
	Water Guard	1	1.0
Do you store water for drinking purpose?	Yes	71	71.0
	No	29	29.0
If yes, how do you store your drinking water?	Covered container	34	34.0
	Jerry can	22	22.0
	Uncovered container	3	3.0
	Overhead tank	5	5.0
	Small plastic container	3	3.0
	Refrigerator	4	4.0
How do you collect water from the storage container?	Cup with handles	63	63.0
	Cup without handles	3	3.0
	Bowl	5	5.0
How frequently do you clean your water storage containers?	Daily	9	9.0
	Weekly	36	36.0
	Monthly	23	23.0
	Rarely	3	3.0
Is your source available year-round?	Yes	91	91.0

	No	9	9.0
Have you faced any problem with your water supply recently?	Yes	46	46.0
	No	54	54.0
If yes, what kind of problems?	Contamination	10	10.0
	High cost	2	2.0
	Intermittent supply	20	20.0
	Poor taste	11	11.0
	Bad odour and Colour	3	3.0
Can people get sick with the water they drink?	Yes	33	33.0
	No	67	67.0
Have your household experienced water-related illness in the past 6 months?	Yes	24	24.0
	No	76	76.0
If yes, which illness(es)?	Diarrhea	2	8.3
	Typhoid	21	87.5
	Cholera	1	4.2
Any unpleasant physical characteristics associated with your water? If yes, name them	No	86	86.0
	Colour	3	3.0
	Taste	11	11.0

4.3. Sanitation and Hygiene Practices of Households

Table 4.3 results reveal that vast majority (98%) of respondents reported using flush toilets, while 2% relied on pit latrines, and none practiced open defecation. The predominance of tiled toilet floors (79%) also reflects hygienic standards and maintenance convenience, whereas concrete (19%) and wooden (2%) floors. Despite these, 42% of respondents shared toilets with other households. Notably, 73% of households reported access to a handwashing facility near the toilet, which supports good hygiene. Cleaning practices were commendable, with 62% of toilets cleaned weekly and 33% daily while only 5% cleaned monthly. Regarding handwashing after toilet use, 68% reported always doing so, while 32% admitted to sometimes. When asked about handwashing frequency per day, 51% reported washing whenever hands are dirty, 32% were not sure, and 17% washed between 1–6 times daily. Awareness of handwashing before food preparation was high with 77% reported to always but 23% claimed they wash only sometimes. Moreover, while 56% always used soap, 25% did so sometimes, and 19% only when available.

Daily bathing was universal (100%), reflecting strong personal hygiene norms. However, waste disposal practices varied with 50% relying on formal waste management services, while 23%

resorted to burning and 27% to open dumping. In terms of environmental hygiene, 42% cleaned their surroundings weekly, while 29% did so daily and another 29% occasionally. Awareness of safe water, sanitation, and hygiene (WASH) was notably high, with 80% being very aware and 17% are somewhat aware. Nonetheless, community-level participation in water quality monitoring appeared limited as only 9% reported awareness of any water quality testing programs, while 33% said no such programs existed, and 58% were unsure. When asked about willingness to water testing, 58% expressed consent, while 42% declined.

Table4.3.1.: 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	19	19.0
	Wooden	2	2.0
	Tiles	79	79.0
Is the toilet shared with other households?	Yes	42	42.0
	No	58	58.0
Do you have access to regular handwashing facility near the toilet?	Yes	73	73.0
	No	27	27.0
How often is the toilet facility cleaned?	Daily	33	33.0
	Weekly	62	62.0
	Monthly	5	5.0
How often do you wash your hands after using the toilet?	Always	68	68.0
	Sometimes	32	32.0
How often do you wash your hands per day?	1-3 times	6	6.0
	4-6 times	11	11.0
	Whenever hands are dirty	51	51.0
	Not sure	32	32.0
How often do you wash your hands before preparing food?	Always	77	77.0
	Sometimes	23	23.0
How often do you use soap when you wash your hands?	Always	56	56.0
	Sometimes	25	25.0
	When available	19	19.0
Do you bath daily?	Yes	100	100.0
	No	0	0.0
How do you dispose your household waste?	Waste management services	50	50.0
	Burning	23	23.0
	Buried	0	0.0
	Dump in Open Space	27	27.0
How often do you clean your surroundings?	Daily	29	29.0
	Weekly	42	42.0
	Occasionally	29	29.0
Are you aware of the importance of safe	Very aware	80	80.0

water, sanitation, and hygiene (WASH)?	Somewhat aware	17	17.0
	Not aware	3	3.0
Have there been any water quality testing programs in your area recently?	Yes	9	9.0
	No	33	33.0
	Not sure	58	58.0
Would you consent to having your water source tested for quality parameters?	Yes	58	58.0
	No	42	42.0

4.4 Physicochemical Profile of Drinking Water Samples from Households

Table 4.4 presents the physicochemical characteristics of drinking water samples collected from various households. Water temperature ranged from 26.1°C to 29.7°C, with a mean of approximately 28°C. The pH values ranged between 4.6 and 8.6 with most samples falling within the acceptable range of 6.5–8.5. However, some samples such as BDPA06 (pH 5.3), BDPA42 (pH 4.6), and BDPA60 (pH 5.1) were acidic. Also, slightly alkaline samples “BDPA21 and BDPA73” are typically not harmful but may affect taste. TDS values ranged from 11 to 96 mg/L. Electrical conductivity varied from 31 to 217 $\mu\text{S}/\text{cm}$, with most samples exhibiting low to moderate conductivity. The correlation between TDS and EC is consistent samples with higher TDS tend to show higher EC. Salinity across all samples was 0.00%, suggesting the absence of saline intrusion or contamination from seawater. Oxidation-Reduction Potential (ORP) values ranged from 199 to 369 mV. The hydrogen concentration in most samples was negligible (0.0–0.5 ppb). All water samples recorded a specific gravity of 1.0, which aligns perfectly with the standard for pure water. Resistivity values ranged from 93 to 306 $\Omega\cdot\text{m}$, inversely related to conductivity, as expected.

4.5 Mean Total Heterotrophic Counts of Drinking Water Samples from Households

Table 4.5 presents the mean total heterotrophic bacterial counts (THBC) of drinking water samples obtained from different household sources. The total heterotrophic bacterial counts

among the samples ranged from 4 ± 4.6 CFU/mL $\times 10^0$ to 113 ± 3.0 CFU/mL $\times 10^0$. Borehole water samples exhibited the highest mean heterotrophic counts, with values ranging between 4 CFU/mL $\times 10^0$ and 113 CFU/mL $\times 10^0$. Several borehole samples exceeded 70 CFU/mL, suggesting possible microbial recontamination after collection or not cleaning overhead tank frequently. Sachet water samples demonstrated moderate heterotrophic bacterial counts, ranging from 24 ± 1.3 to 58 ± 3.4 CFU/mL $\times 10^0$. The bottled water samples recorded the lowest heterotrophic bacterial counts among all sources, with mean values of 10 ± 1.6 CFU/mL $\times 10^0$ and 23 ± 2.7 CFU/mL $\times 10^0$ respectively.

Table4.4.1: 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)
BDPA02	29.1±0.3	7.6±0.4	12±3.1	88±2.7	0.00±0.0	207±2.4	0.4±0.0	1.0±0.0	211±3.1
BDPA03	27.2±0.2	7.1±0.5	34±2.0	31±2.4	0.00±0.0	199±3.2	0.0±0.0	1.0±0.0	181±3.2
BDPA05	28.1±0.4	7.5±0.6	39±3.3	48±2.7	0.00±0.0	278±3.9	0.1±0.0	1.0±0.0	131±3.1
BDPA06	28.7±0.5	5.3±0.4	45±3.1	71±3.1	0.00±0.0	289±2.8	0.0±0.0	1.0±0.0	101±3.6
BDPA10	27.1±0.2	6.5±0.5	62±3.6	91±4.3	0.00±0.0	238±2.6	0.0±0.0	1.0±0.0	123±2.7
BDPA11	28.4±0.3	7.6±0.7	43±2.5	57±1.9	0.00±0.0	220±9.1	0.0±0.0	1.0±0.0	253±5.1
BDPA20	26.1±0.2	6.8±0.3	67±2.2	88±3.1	0.00±0.0	246±4.9	0.0±0.0	1.0±0.0	165±4.2
BDPA21	27.7±0.4	8.1±0.5	73±1.3	69±3.1	0.00±0.0	207±2.8	0.4±0.0	1.0±0.0	198±3.7
BDPA22	28.6±0.2	7.5±0.3	25±4.2	40±2.6	0.00±0.0	313±5.1	0.0±0.0	1.0±0.0	93±2.8
BDPA23	29.1±0.9	7.3±0.5	71±2.4	101±4.7	0.00±0.0	275±3.2	0.0±0.0	1.0±0.0	122±2.4
BDPA24	26.4±0.6	7.8±0.5	24±6.1	73±1.9	0.00±0.0	245±4.2	0.4±0.0	1.0±0.0	253±4.7
BDPA25	28.7±0.4	7.3±0.8	94±1.8	99±3.2	0.00±0.0	284±4.2	0.0±0.0	1.0±0.0	168±2.3
BDPA26	28.2±0.7	6.2±0.5	85±1.6	101±4.1	0.00±0.0	211±2.5	0.0±0.0	1.0±0.0	245±3.5
BDPA29	27.1±0.3	7.4±0.6	84±2.9	113±2.3	0.00±0.0	261±3.4	0.0±0.0	1.0±0.0	127±3.9
BDPA33	28.1±0.2	6.2±0.3	26±2.7	72±3.6	0.00±0.0	273±4.1	0.0±0.0	1.0±0.0	189±2.6
BDPA37	28.1±0.6	7.6±0.2	21±2.1	91±2.5	0.00±0.0	281±4.9	0.0±0.0	1.0±0.0	139±2.7
BDPA40	29.0±0.2	6.5±0.7	63±2.7	111±3.8	0.00±0.0	271±4.0	0.0±0.0	1.0±0.0	135±4.4
BDPA42	28.5±0.3	4.6±0.3	39±6.4	84±2.6	0.00±0.0	242±4.5	0.2±0.0	1.0±0.0	148±3.7
BDPA43	26.2±0.2	7.6±0.5	11±1.1	51±3.9	0.00±0.0	261±2.3	0.0±0.0	1.0±0.0	231±5.5
BDPA49	27.0±0.3	8.0±0.2	41±1.2	101±5.0	0.00±0.0	209±4.2	0.4±0.0	1.0±0.0	191±5.2
BDPA52	28.1±0.1	6.7±0.7	54±1.6	113±3.6	0.00±0.0	273±4.2	0.0±0.0	1.0±0.0	193±3.7
BDPA55	29.2±0.5	6.3±0.3	86±3.7	217±4.1	0.00±0.0	369±3.9	0.3±0.0	1.0±0.0	306±2.5
BDPA57	27.4±0.2	7.5±0.2	33±1.2	156±2.1	0.00±0.0	292±6.1	0.0±0.0	1.0±0.0	139±3.2
BDPA60	29.7±0.3	5.1±0.1	19±2.8	123±3.4	0.00±0.0	281±4.9	0.4±0.0	1.0±0.0	212±3.3
BDPA62	28.0±0.8	7.2±0.6	36±2.6	99±3.2	0.00±0.0	273±2.7	0.3±0.0	1.0±0.0	191±4.8
BDPA69	27.1±0.3	7.2±0.3	93±3.4	91±3.1	0.00±0.0	295±6.1	0.5±0.0	1.0±0.0	184±4.2
BDPA73	28.1±0.2	8.6±0.3	17±2.1	93±4.1	0.00±0.0	242±5.2	0.0±0.0	1.0±0.0	195±5.6
BDPA77	28.1±0.2	7.7±0.7	26±4.4	84±5.2	0.00±0.0	256±2.4	0.0±0.0	1.0±0.0	209±5.7
BDPA79	29.0±0.5	6.5±0.5	96±2.3	114±2.6	0.00±0.0	218±8.2	0.0±0.0	1.0±0.0	212±6.1
BDPA91	28.5±0.3	7.1±0.5	73±2.5	83±3.2	0.00±0.0	277±4.9	0.0±0.0	1.0±0.0	199±4.2

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

Table4.5.1: Mean Total Heterotrophic Counts of Drinking Water Samples from Households

Sample Code	Sample Source	Mean Counts of Heterotrophic Bacteria CFU/mL $\times 10^0$
BDPA02	Borehole	34 \pm 2.2
BDPA03	Sachet water	24 \pm 1.3
BDPA05	Borehole	58 \pm 5.1
BDPA06	Sachet water	26 \pm 3.8
BDPA10	Sachet water	27 \pm 3.5
BDPA11	Borehole	80 \pm 4.1
BDPA20	Borehole	113 \pm 3.0
BDPA21	Borehole	58 \pm 6.2
BDPA22	Sachet water	34 \pm 2.4
BDPA23	Borehole	69 \pm 2.3
BDPA24	Borehole	41 \pm 3.5
BDPA25	Borehole	4 \pm 4.6
BDPA26	Borehole	90 \pm 3.1
BDPA29	Borehole	66 \pm 3.7
BDPA33	Sachet water	34 \pm 3.1
BDPA37	Sachet water	29 \pm 2.7
BDPA40	Borehole	45 \pm 5.1
BDPA42	Borehole	24 \pm 2.3
BDPA43	Bottled water	10 \pm 1.6
BDPA49	Sachet water	32 \pm 3.2
BDPA52	Sachet water	30 \pm 2.1
BDPA55	Borehole	70 \pm 1.2
BDPA57	Sachet water	28 \pm 2.4
BDPA60	Sachet water	38 \pm 2.7
BDPA62	Sachet water	58 \pm 3.4
BDPA69	Borehole	43 \pm 3.1
BDPA73	Bottled water	23 \pm 2.7
BDPA77	Sachet water	48 \pm 2.5
BDPA79	Borehole	57 \pm 1.9
BDPA91	Sachet water	35 \pm 2.3

Figure 4.1 illustrates the mean distribution of total heterotrophic bacterial counts across the different water sources sampled. Borehole water exhibited the highest mean bacterial count with a value of $58.3 \text{ CFU/mL} \times 10^0$. Sachet water revealed a mean value of $35.4 \text{ CFU/mL} \times 10^0$. These values indicate that sachet water is generally safe for consumption, though slight variations suggest possible contamination during packaging, storage, or distribution. Bottled water with a mean value of $16.5 \text{ CFU/mL} \times 10^0$. Bottled water recorded the lowest mean bacterial count.

The findings in Table 4.6 revealed that total coliforms were detected in several borehole and sachet water samples, while bottled water showed no contamination. The total coliform counts in borehole samples ranged between 13 ± 1.4 and $32 \pm 2.1 \text{ CFU/mL} \times 10^0$. Some borehole samples, however, showed no detectable coliforms, suggesting that those particular sources might have been properly constructed or well maintained. Sachet water samples were largely free of coliforms, though a few exhibited counts between 10 ± 1.9 and $27 \pm 3.2 \text{ CFU/mL} \times 10^0$. In contrast, bottled water samples showed no presence of coliforms. A significant observation across all samples was the complete absence of *Escherichia coli*, with counts recorded as $0 \pm 0.0 \text{ CFU/mL} \times 10^0$. Nonetheless, the presence of total coliforms in certain samples still raises concerns.

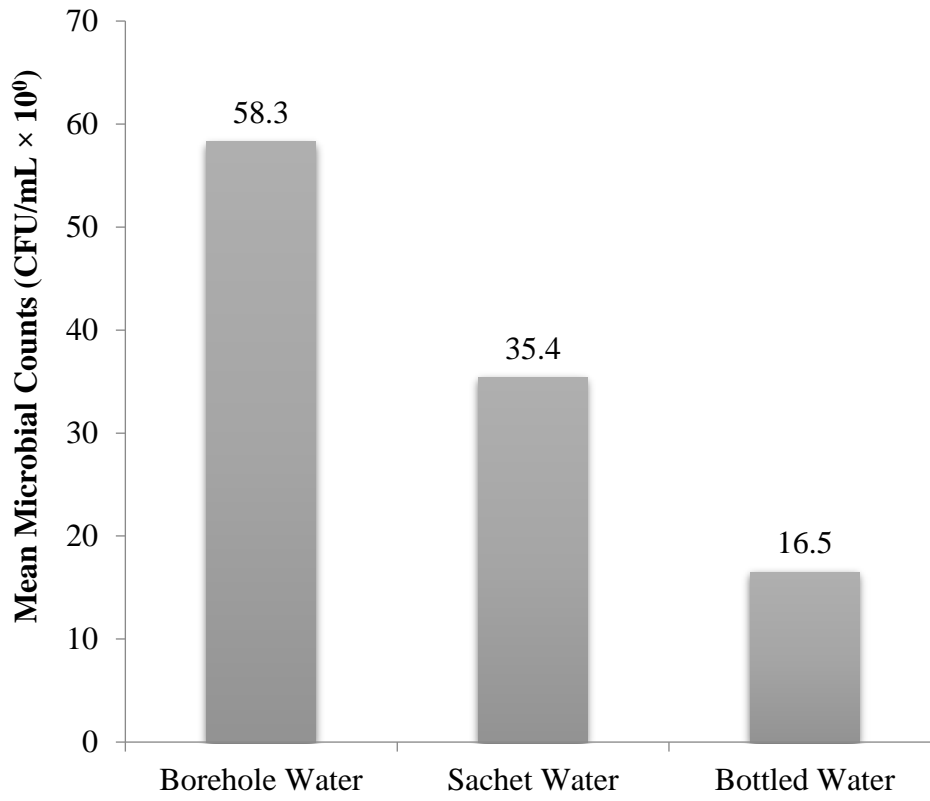


Figure 4.1: Distribution of Heterotrophic Bacterial Based on Sample Sources

Table4.6.1: Coliforms and *Escherichia coli* Counts in Water Samples from Households

Sample Codes	Sample Sources	Total Coliform Count (CFU/mL × 10 ⁰)	<i>Escherichia coli</i> Count (CFU/mL × 10 ⁰)
BDPA02	Borehole	31±1.7	0±0.0
BDPA03	Sachet water	0±0.0	0±0.0
BDPA05	Borehole	13±1.4	0±0.0
BDPA06	Sachet water	0±0.0	0±0.0
BDPA10	Sachet water	11±1.2	0±0.0
BDPA11	Borehole	30±2.7	0±0.0
BDPA20	Borehole	0±0.0	0±0.0
BDPA21	Borehole	0±0.0	0±0.0
BDPA22	Sachet water	0±0.0	0±0.0
BDPA23	Borehole	0±0.0	0±0.0
BDPA24	Borehole	27±1.3	0±0.0
BDPA25	Borehole	0±0.0	0±0.0
BDPA26	Borehole	0±0.0	0±0.0
BDPA29	Borehole	0±0.0	0±0.0
BDPA33	Sachet water	0±0.0	0±0.0
BDPA37	Sachet water	0±0.0	0±0.0
BDPA40	Borehole	32±2.1	0±0.0
BDPA42	Borehole	21±1.3	0±0.0
BDPA43	Bottled water	0±0.0	0±0.0
BDPA49	Sachet water	19±6.2	0±0.0
BDPA52	Sachet water	0±0.0	0±0.0
BDPA55	Borehole	0±0.0	0±0.0
BDPA57	Sachet water	0±0.0	0±0.0
BDPA60	Sachet water	10±1.9	0±0.0
BDPA62	Sachet water	0±0.0	0±0.0
BDPA69	Borehole	31±1.3	0±0.0
BDPA73	Bottled water	0±0.0	0±0.0
BDPA77	Sachet water	0±0.0	0±0.0
BDPA79	Borehole	0±0.0	0±0.0
BDPA91	Sachet water	27±3.2	0±0.0

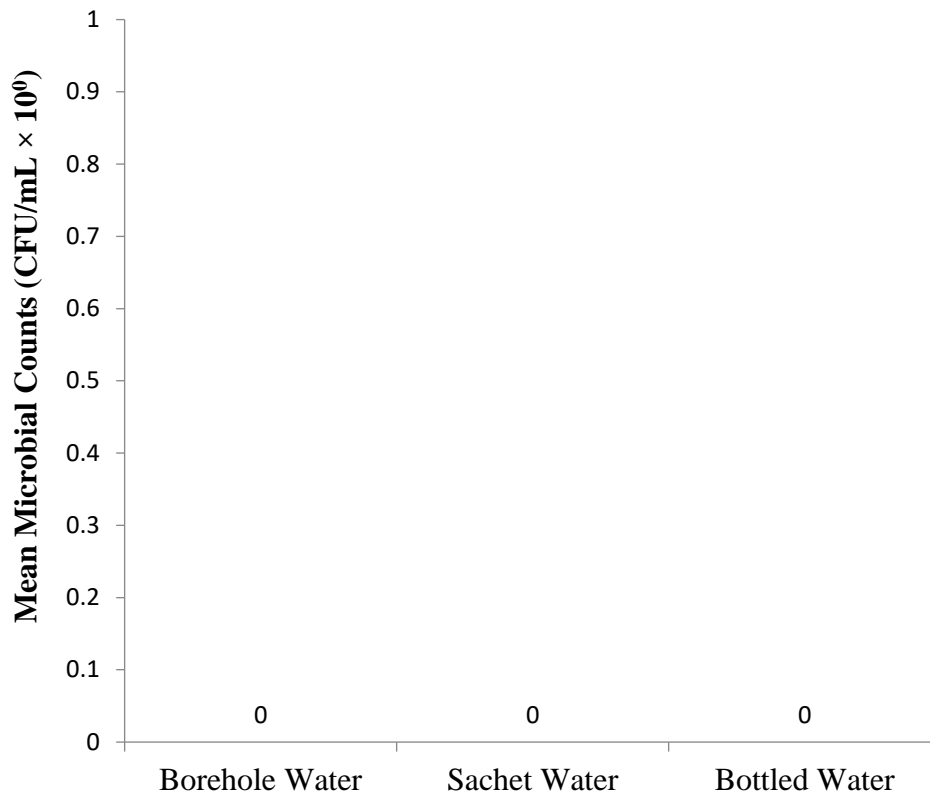


Figure 4.2: Distribution of Escherichia coli in Drinking Water Samples from Households

Figure 4.2 revealed that *Escherichia coli* counts were consistently 0 CFU/mL $\times 10^0$. Figure 4.3 presents the mean distribution of total coliform counts in water samples. It revealed that borehole water had the highest mean total coliform count of 12.3 CFU/mL $\times 10^0$. Sachet water had a lower mean count of 5.2 CFU/mL $\times 10^0$ while bottled water showed no detectable coliforms.

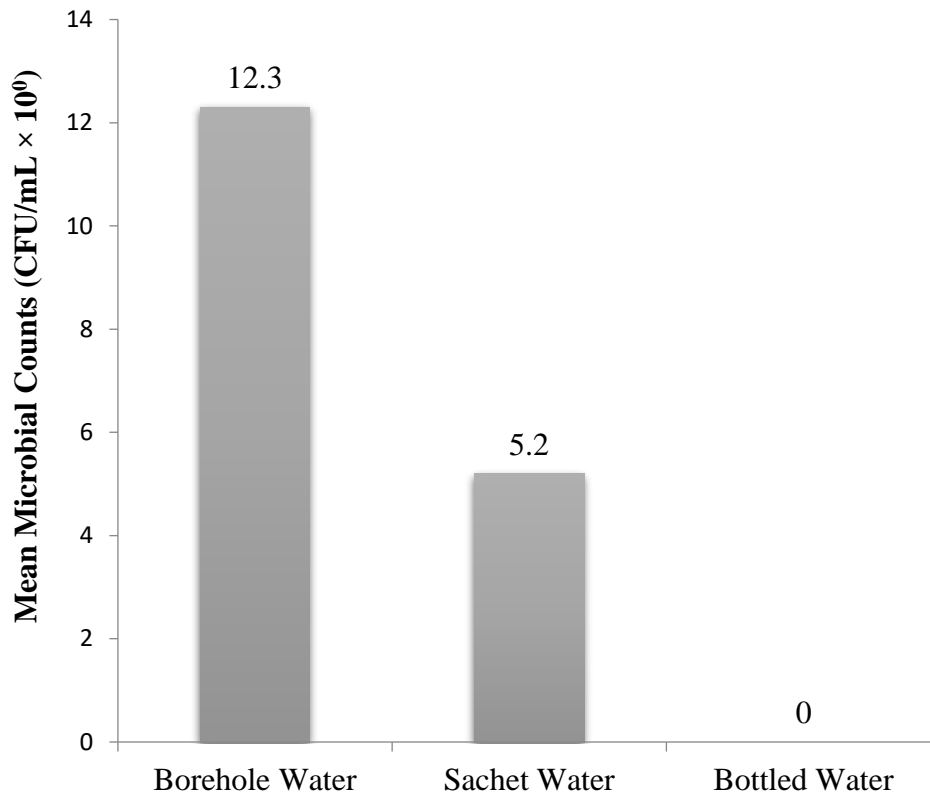


Figure 4.3: Distribution of Total Coliforms Based on Sample Sources

CHAPTER FIVE

DISCUSSION

5.1 This study aimed to assess the potential human health risks associated with household drinking water quality and hygiene status among residents of BDPA Community, Ugbowo, Benin City. The findings reveal a complex situation where high personal hygiene awareness contrasts sharply with significant environmental sanitation deficits and tangible risks from drinking water sources.

5.1.1 Demographic and Environmental Context: The study population is predominantly young, educated, and single, with a large student contingent. This demographic profile aligns with the high level of reported awareness regarding safe water, sanitation, and hygiene (WASH), with 80% of respondents reporting being "very aware". This awareness is reflected in strong personal hygiene practices: 98% use flush toilets, 100% bathe daily, and a high percentage always wash hands after toilet use (68%) and before food preparation (77%). However, a significant disconnect exists between this high personal awareness and the community's environmental condition. Over half of the households (54%) are located near waste dump sites, and 29% are near open sewage or stagnant water. Furthermore, waste disposal practices are poor, with 27% resorting to open dumping and 23% to burning. This poor environmental sanitation creates a high-risk setting, providing ample pathways for contaminants to infiltrate water sources, particularly boreholes (Selim *et al.*, 2024).

5.1.2 Water Sources, Handling, and Treatment Practices: The community's reliance on sachet water (54%) and borehole water (35%) as primary drinking sources highlights a lack of dependable municipal water (Oyerinde and Jacobs, 2022). A critical finding is that a majority of households (64%) do not treat their water before drinking. This practice indicates a high level of trust in the safety of these sources, particularly sachet and borehole water. Among the minority who do treat water, boiling (24%) is the preferred method. While most households (71%) store water, and retrieval methods are generally safe (63% use cups with handles), the cleaning frequency of storage containers is suboptimal (36% weekly, 23% monthly). This, combined with storage in overhead tanks, presents a significant risk for microbial recontamination after collection (Manga *et al.*, 2023).

5.1.3 Physicochemical Water Quality: The physicochemical analysis presented a generally acceptable profile for most parameters. Total Dissolved Solids (TDS), Electrical Conductivity (EC), and Salinity (0.00%) were all within safe and acceptable limits, suggesting the water is not subject to significant chemical or saline pollution. The main parameter of concern was pH. While most samples were within the 6.5–8.5 range, several samples were notably acidic, such as BDPA42 (pH 4.6) and BDPA06 (pH 5.3). Acidic water can be corrosive and may affect taste, indicating a potential water quality issue that warrants further investigation (Adams *et al.*, 2022).

5.1.4 Microbiological Water Quality: The microbiological assessment is the most critical component of this study, revealing clear health risks.

- i. Total Heterotrophic Bacteria (THBC): These counts, which indicate the general microbial load, were highest in borehole water (mean 58.3 CFU/mL $\times 100$), with some samples reaching very high levels (e.g., 113 CFU/mL $\times 100$). This suggests that borehole sources are either contaminated or that contamination is introduced during storage, possibly in overhead tanks that are not frequently cleaned (Okafor *et al.*, 2023). Sachet water also showed moderate THBC levels (mean 35.4 CFU/mL $\times 100$), indicating that it is not sterile and contamination may occur during production or handling (Agbasi *et al.*, 2024). Bottled water was clearly the safest source, with the lowest mean THBC (16.5 CFU/mL $\times 100$).
- ii. Coliforms and *Escherichia coli*: The most significant finding was the complete absence of *E. coli* in all 30 samples tested. This is a positive outcome, as it suggests the water is free from recent and direct fecal contamination (Nowicki *et al.*, 2021)..
- iii. Total Coliforms: Total coliforms are environmental indicators; their presence signals a breakdown in water treatment, a breach in the integrity of the water source, or post-collection contamination (Too 2023). . Borehole water again performed the worst, with the highest mean coliform count (12.3 CFU/mL $\times 100$) and counts as high as 32 CFU/mL $\times 100$ in some samples. This is a strong indicator of contamination, likely linked to the poor environmental sanitation (proximity to waste and sewage). Sachet water also showed contamination, with a mean count of 5.2 CFU/mL $\times 100$ and some samples having counts as high as 27 CFU/mL $\times 100$. This is a serious concern given that 54% of households rely on it as their main source. Bottled water was the only source to show a complete absence of total coliforms.

5.1.5 Water quality vs. Standards

5.1.5.1 Microbiological Quality vs. Standards: The most critical finding of this study is the widespread microbiological contamination of the primary water sources, which directly violates national and international health standards.

- i. **Total Coliforms:** The WHO and NSDWQ standards are unequivocal; the maximum acceptable limit for total coliforms in drinking water is 0 CFU/100 mL; the presence of any coliforms indicates a breach in the water system's integrity or inadequate treatment (Adamu *et al.*, 2024). Borehole water, used by 35% of households, failed the standard significantly, with a mean coliform count of 12.3 CFU/100 mL and individual samples as high as 32 CFU/100 mL. Sachet water, the most popular source (54% of households), also failed the standard, showing a mean of 5.2 CFU/100 mL and counts up to 27 CFU/100 mL. Bottled water was the only source that consistently met the standard, with 0 CFU/100 mL of total coliforms.
- ii. ***Escherichia coli*:** Both WHO and NSDWQ set a mandatory limit of 0 CFU/100 mL for *E. coli* and as *E. coli* is a direct indicator of recent fecal contamination, its absence is non-negotiable. A positive finding of the study was the complete absence of *E. coli* in all borehole, sachet, and bottled water samples tested. While this suggests no recent fecal contamination, it does not mean the water is safe. The presence of other coliforms (as noted above) still indicates a pathway for contamination exists, posing a risk for pathogens like *Salmonella Typhi* (which causes typhoid).
- iii. **Total Heterotrophic Bacteria (THBC):** While less of a direct health-risk indicator, THBC (or HPC) is a measure of general water quality. The WHO suggests counts should not exceed 100 CFU/mL. The reported counts for borehole (mean 58.3 CFU/100 mL) and

sachet water (mean 35.4 CFU/100 mL), even the highest borehole sample (113 CFU/100 mL), are generally within acceptable limits. This suggests the issue is not a high load of general bacteria, but a specific contamination by coliforms, which is a more serious treatment failure.

5.1.5.2 Physicochemical Quality vs. Standards: The primary physicochemical parameter of concern was pH. The acceptable range for drinking water under both WHO and NSDWQ (NIS 554:2015) guidelines is 6.5 to 8.5. Water outside this range can be corrosive and have an unpleasant taste. The study found that while most samples were compliant, several were not. Samples like BDPA06 (pH 5.3), BDPA42 (pH 4.6), and BDPA60 (pH 5.1) were acidic and fell well below the minimum 6.5 standard. This indicates potential water quality issues and could lead to the leaching of metals from pipes.

5.1.6 Health Implications and Risk Perception: The study successfully links these microbiological findings to tangible health outcomes. A considerable portion of the population (33%) believes their water can cause sickness. This perception is supported by the fact that 24% of households reported a water-related illness in the preceding six months. The most striking finding is that among those reporting illness, 87.5% identified it as typhoid fever. While *E. coli* was absent, typhoid is caused by *Salmonella Typhi*, another bacterium transmitted via the fecal-oral route. The presence of total coliforms in borehole and sachet water confirms that a pathway for such pathogens to enter the water supply exists. The combination of contaminated water sources (especially boreholes), poor environmental sanitation, and the widespread practice of not treating water creates an ideal environment for the transmission of waterborne diseases like typhoid.

5.2 Recommendations

A public health campaign should be organized in order to address the gap between hygiene awareness and water treatment practices. Residents, particularly borehole users, must be strongly encouraged to boil or chlorinate their water before consumption. Municipal authorities must also enforce the NSDWQ by investigating the sources of contamination for both the community boreholes and the sachet water brands circulating in the area. Furthermore, environmental sanitation must be improved to protect water sources from contamination from waste and sewage.

5.3 Conclusion

This study concludes that while the residents of BDPA Community demonstrate high levels of personal hygiene awareness, they face significant and unaddressed public health risks from their drinking water. This conclusion is likely based on the failure of these sources to meet the mandatory microbiological standards set by the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ). The risk varies by source in that the three main water sources show a clear hierarchy of risk. Bottled water was found to be the only consistently safe source, free of coliforms and with low bacterial counts. Borehole water poses the highest risk, showing significant contamination with both heterotrophic bacteria and total coliforms. Sachet water, the most popular source, is not sterile and carries a moderate risk, with intermittent coliform contamination. The microbiological risks are not merely theoretical. They correlate directly with a high self-reported incidence of water-related illness (24%),

overwhelmingly identified as typhoid fever. Furthermore, the primary risks stem from two key failures; environmental failure such as poor community-level sanitation, including proximity to waste dumps and open sewage which likely contaminates groundwater and, by extension, borehole sources and behavioral failure such as the widespread practice of consuming water (especially borehole water) without any form of treatment (64% of households) directly exposes the population to these microbial contaminants.

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