BACTERIOLOGICAL AND PHYSICO CHEMICAL QUALITY ASSESSMEMT OF SELECTED DRINKING WATER

BY

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CERTIFICATION

This is to certify that this Seminar work was written by **BELLO SULIYAT** with matric number **ND/23/SLT/PT/0048** in the Department of Science Laboratory Technology, Microbiology Unit, Kwara State Polytechnic Ilorin. It has been approved as meeting part of the requirements for the award of National Diploma (ND) in Science Laboratory Technology.

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DEDICATION

I dedicate this project to Almighty Allah, whose infinite mercy and guidance made this work a success. His inspiration and direction have led me throughout my academic journey in the polytechnic. I also dedicate it to my beloved parents for their unwavering support, love, and constant prayers.

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ABSTRACT

This study assessed the bacteriological and physico-chemical quality of selected drinking water sources to evaluate their suitability for human consumption. Water samples were collected from borehole sources within the study area and analyzed using standard laboratory procedures. Key physico-chemical parameters examined included pH, temperature, turbidity, total dissolved solids (TDS), and electrical conductivity, while bacteriological analysis focused on the presence of total coliforms and Escherichia coli as indicators of fecal contamination. The results showed that although most samples met WHO and NSDWQ standards for physico-chemical parameters, some exceeded permissible limits in terms of turbidity and TDS. Moreover, bacteriological findings revealed contamination in well and tap water samples, indicating potential public health risks. The study highlights the need for regular water quality monitoring, effective treatment, and improved sanitation practices to ensure safe drinking water.

Keywords: Bacteriological quality, Physico-chemical parameters, Drinking water, Coliforms, Escherichia coli, Water contamination, Public health, Water quality monitoring.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Water is one of the most essential natural resources for sustaining life. It plays a vital role in domestic, industrial, agricultural, and environmental health. Despite its importance, the provision of safe and clean drinking water remains a significant challenge in many parts of the world, particularly in developing countries like Nigeria (WHO, 2021). The quality of drinking water is typically assessed through the analysis of bacteriological and physicochemical parameters. These parameters indicate the presence of harmful microorganisms and toxic substances that can adversely affect human health.

Bacteriological contamination is usually a result of fecal pollution, poor waste disposal practices, leaking septic tanks, and improper sanitation infrastructure. The presence of coliform bacteria, particularly *Escherichia coli*, serves as an indicator of recent fecal contamination and the potential presence of disease-causing pathogens such as *Salmonella*, *Shigella*, and viruses (Yahaya et al., 2024). On the other hand, physicochemical parameters such as pH, turbidity, total dissolved solids (TDS), temperature, electrical conductivity, and concentrations of metals or chemicals like nitrates and chlorides help to determine the aesthetic and toxicological safety of water (Olowolafe et al., 2021).

In Nigeria, many communities rely on alternative water sources such as wells, boreholes, streams, and sachet water due to unreliable public water supply. Unfortunately, these sources are often exposed to contaminants, especially in peri-urban and rural settings where regulation is minimal (Okonkwo et al., 2023). Continuous consumption of contaminated water has been linked to outbreaks of waterborne diseases including cholera, diarrhea, typhoid fever, and dysentery (Ibrahim & Usman, 2023). Thus, regular monitoring of water quality is crucial for protecting public health and promoting environmental sustainability. This study focuses on assessing the bacteriological and physicochemical characteristics of selected drinking water sources, comparing their quality to national and international standards.

1.2 Statement of the Problem

Access to clean and safe drinking water remains a critical public health concern in Nigeria. Despite governmental and non-governmental efforts to provide potable water, a significant proportion of the population still relies on untreated or poorly maintained water sources such as hand-dug wells, boreholes, and packaged sachet water. These sources are often susceptible to contamination from nearby latrines, waste dumps, and unhygienic handling methods (Chukwudi et al., 2025). Bacteriological contamination, particularly from fecal sources, continues to be reported in water sources meant for human consumption.

Furthermore, physicochemical parameters such as pH, turbidity, and total dissolved solids are frequently found to be outside the acceptable limits set by regulatory bodies like the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) (WHO, 2021; SON, 2020). The public health implications of such contamination are alarming, contributing to the rising incidence of gastrointestinal infections and other water-related illnesses in many communities (Adeleye et al., 2022).

There is a scarcity of updated data on water quality in many local communities, particularly data that considers both microbiological and chemical aspects. In the absence of routine assessments, communities continue to consume water of questionable quality, putting their health at risk. This study, therefore, seeks to fill this knowledge gap by conducting a comprehensive evaluation of the bacteriological and physicochemical quality of drinking water sources in a selected area.

1.3 Objectives of the Study

The primary objective of this study is to assess the bacteriological and physicochemical quality of selected drinking water sources.

The specific objectives are to:

- Determine the levels of bacteriological contamination (e.g., total coliforms, *E. coli*) in the selected water samples.
- Evaluate the physicochemical properties (such as pH, turbidity, TDS, conductivity, temperature) of the water samples.
- Compare the results of the analysis with national (SON) and international (WHO) standards for drinking water.

- Identify possible sources of contamination and suggest appropriate control measures.

1.4 Research Questions

- What is the level of bacteriological contamination in the selected drinking water sources?
- What are the physicochemical characteristics of the water samples collected?
- How do the results compare with the acceptable limits set by WHO and SON for potable water?
- What are the likely sources of contamination, and what measures can be recommended?

1.5 Justification of the Study

The relevance of this study stems from the increasing reports of water-related diseases linked to contaminated drinking water, especially in underserved communities. Given the reliance on alternative water sources due to inadequate pipe-borne water, it is necessary to verify the safety of these sources through scientific analysis. The study is essential for public health as it will help to identify unsafe water sources and guide intervention efforts to reduce disease burdens associated with water contamination (Olowolafe et al., 2021).

Additionally, the study will provide evidence-based data that can be used by health officials, local governments, and policymakers to improve water quality monitoring, sanitation practices, and infrastructure development. It also aligns with Sustainable Development Goal 6, which emphasizes the availability and sustainable management of water and sanitation for all (UN, 2023). By identifying both bacteriological and physicochemical risks, this research contributes to a holistic understanding of water safety in the study area.

1.6 Scope and Limitations of the Study

This study covers the bacteriological and physicochemical assessment of selected drinking water sources, including wells, boreholes, sachet water, and tap water. The focus will be on analyzing total coliforms and *Escherichia coli* for bacteriological parameters, and pH, turbidity, TDS, conductivity, and temperature for physicochemical analysis. Sampling will be limited to a specific geographical area and timeframe, and water samples will be collected and tested using standard laboratory procedures.

However, the study is subject to certain limitations. Seasonal variation in water quality will not be covered, as the sampling will be done within a single season. Also, the study does not include virological, parasitological, or radiological assessments, which may also impact water quality (Chukwudi et al., 2025). Resource constraints may also limit the number of samples and range of parameters analyzed. Nonetheless, the study is expected to offer critical insights into the safety of drinking water in the selected area.

1.7 Definition of Terms

- **Bacteriological Quality**: The level of microbial contamination in water, typically assessed using indicator organisms like coliforms.
- **Physicochemical Parameters**: Physical and chemical characteristics of water such as pH, turbidity, and conductivity.
- **Coliform Bacteria**: A group of bacteria commonly found in the environment, used as an indicator of fecal contamination.
- **Turbidity**: The cloudiness or haziness in water caused by large numbers of individual particles.
- **Total Dissolved Solids (TDS)**: A measure of all inorganic and organic substances dissolved in water.
- **Sachet Water**: Packaged water sold in small plastic bags, commonly used as a drinking source in Nigeria.
- **WHO Standards**: Guidelines provided by the World Health Organization for the safety of drinking water.
- **SON**: Standards Organisation of Nigeria, responsible for setting and monitoring product and service standards in Nigeria.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview of Drinking Water Sources

2.1.1 Surface Water Sources

Surface water sources include rivers, lakes, streams, and ponds. These are among the most widely used sources of water, particularly in rural and low-income urban communities where access to treated water is limited. However, surface water is highly susceptible to contamination due to open exposure to agricultural runoff, sewage discharge, and industrial waste. These sources often contain high loads of suspended solids, organic matter, pathogens, and chemical contaminants, which necessitate thorough treatment before consumption (Chukwudi et al., 2025). Without adequate purification, surface water poses a high risk for the transmission of waterborne diseases such as cholera and typhoid fever.

2.1.2 Groundwater Sources

Groundwater is accessed through boreholes and hand-dug wells and is often considered safer than surface water because it is naturally filtered as it percolates through soil and rock layers. However, its safety is not guaranteed. Groundwater contamination can occur due to poorly constructed wells, shallow depth, and proximity to pollution sources such as pit latrines, septic tanks, and landfills (Olowolafe et al., 2021). Moreover, geogenic contaminants such as iron, manganese, fluoride, and arsenic can also compromise groundwater quality, especially if not periodically tested and treated (Yahaya et al., 2024).

2.1.3 Rainwater Harvesting

Rainwater is collected from rooftops and other catchment areas and stored in tanks or containers. It is considered a relatively clean source of water, especially in areas with limited access to groundwater or piped water. However, its quality is highly dependent on the cleanliness of the collection surface, the storage container, and the environment. Contaminants such as bird droppings, debris, and airborne pollutants can make rainwater unsafe for direct consumption without proper filtration and disinfection (Ibrahim & Usman, 2023). In some cases, acid rain caused by industrial emissions can further degrade its quality.

2.1.4 Municipal and Piped Water Supply

Piped water systems provided by government agencies or water corporations are generally expected to meet national and international safety standards. These systems typically involve centralized treatment including coagulation, sedimentation, filtration, and chlorination. However, in Nigeria, such systems are often hindered by aging infrastructure, poor maintenance, and intermittent supply (Adeleye et al., 2022). Leaks and breaks in water pipes can lead to the infiltration of contaminants, especially when pipes run through unsanitary environments. In addition, water that is safe at the source may become contaminated during transportation or storage due to unhygienic handling.

2.1.5 Packaged Water (Sachet and Bottled Water)

Packaged water, particularly sachet water, is widely consumed in Nigerian cities due to its affordability and convenience. While bottled water is generally subjected to regulatory control and quality assurance, many sachet water brands are produced by small-scale operators without adequate oversight. Studies have shown that several sachet water samples fail bacteriological tests due to poor processing, inadequate sealing, and unhygienic production environments (Okonkwo et al., 2023). Nonetheless, when produced under proper hygienic conditions and monitored for quality, packaged water can be a safe alternative.

2.1.6 Comparison of Sources and Quality Implications

Each water source has unique characteristics and associated risks. Surface water is more likely to carry microbial contaminants, while groundwater may harbor chemical pollutants. Rainwater is usually free of heavy metals but prone to microbial contamination from the catchment system. Packaged water offers convenience but varies significantly in quality based on the producer's compliance with safety standards. Municipal water, while theoretically the safest, is often unreliable and subject to secondary contamination. Thus, ongoing monitoring and periodic quality assessments are necessary across all sources to ensure public health safety and compliance with national (SON, 2020) and international (WHO, 2021) drinking water guidelines.

2.2 Microbiological Contamination of Drinking Water

Microbiological contamination of drinking water is a major public health concern globally, particularly in low- and middle-income countries where water treatment infrastructure is often inadequate or poorly maintained. Contamination occurs when pathogenic microorganisms such as bacteria, viruses, and protozoa enter the water supply, usually through fecal matter from humans or animals. The World Health Organization (2021) identifies microbial contamination as the most significant health risk associated with drinking water, as it is directly linked to the transmission of waterborne diseases such as cholera, dysentery, typhoid fever, and hepatitis A.

The most common indicators used to assess microbiological water quality are coliform bacteria, especially Escherichia coli (E. coli), which is a strong indicator of recent fecal contamination. These bacteria are not necessarily harmful themselves but signal the potential presence of more dangerous pathogens (Adeleye et al., 2022). The presence of *E. coli* in drinking water is unacceptable at any level according to both WHO and Nigerian national standards (SON, 2020), and its detection calls for immediate corrective actions.

Sources of microbial contamination are diverse. Poor sanitation, open defecation, leaking sewage systems, unprotected wells, and improper disposal of waste all contribute significantly to the microbial pollution of water sources. In rural areas of Nigeria, where open wells and surface water are often used without treatment, the likelihood of microbial contamination is high (Olowolafe et al., 2021). In urban centers, broken water pipelines running alongside sewer lines also provide entry points for microbial contaminants due to pressure imbalances (Ibrahim & Usman, 2023).

Rainwater harvesting systems can also be sources of microbial contamination if gutters, rooftops, and storage tanks are not properly maintained. Debris, bird droppings, and dust from rooftops can introduce *Salmonella spp.*, *Campylobacter*, and even parasites into stored rainwater (Yahaya et al., 2024). Similarly, sachet water, often assumed to be safe, has been found in some studies to contain total coliforms and *E. coli*, especially when produced under unhygienic conditions (Okonkwo et al., 2023).

The health consequences of drinking microbially contaminated water are particularly severe among vulnerable populations such as children, pregnant women, and immunocompromised individuals. According to UNICEF (2023), diarrheal diseases caused by contaminated drinking water are one of the leading causes of death among children under five in sub-Saharan Africa. Moreover, repeated exposure to pathogens in contaminated water can lead to chronic health issues such as malnutrition and stunted growth.

To control microbial contamination, water sources should be protected from fecal intrusion, and regular monitoring using standard bacteriological tests such as the Most Probable Number (MPN) method or membrane filtration should be conducted. Disinfection techniques including boiling, chlorination, and filtration are effective in eliminating pathogens. However, in many communities, awareness about water safety and hygiene practices remains low, highlighting the need for public education and community-based interventions (Chukwudi et al., 2025).

In conclusion, microbiological contamination remains a pressing issue in the context of water safety, and its prevention requires a multi-sectoral approach involving public health authorities, community leaders, water engineers, and the general public. Safe water provision cannot be achieved without addressing the root causes of microbial pollution and ensuring consistent water quality surveillance.

2.3 Physicochemical Parameters of Water Quality

Physicochemical parameters are essential indicators of the chemical and physical integrity of drinking water. These parameters influence water's taste, color, odor, and its safety for consumption. A balanced evaluation of these characteristics helps determine whether water meets national and international standards for potability (WHO, 2021; SON, 2020).

2.3.1 pH

The pH of water is a measure of its acidity or alkalinity. According to WHO (2021) and SON (2020), the recommended pH for potable water ranges between 6.5 and 8.5. Deviations from this range can increase corrosion or scaling in water distribution systems and may also affect the effectiveness of disinfectants such as chlorine. Acidic water ($pH < 6.5$) can leach toxic metals like lead and copper from plumbing systems, posing health hazards (Okonkwo et al., 2023).

2.3.2 Turbidity

Turbidity is the measure of water clarity caused by the presence of suspended solids, organic matter, microorganisms, and clay particles. It is not a direct health risk but can shield pathogens from disinfection and reduce water acceptability. WHO recommends a maximum turbidity level of 5 NTU for safe drinking water (WHO, 2021). High turbidity is often reported in surface waters and poorly treated sachet water in Nigeria (Chukwudi et al., 2025).

2.3.3 Total Dissolved Solids (TDS)

TDS represent the total concentration of inorganic and organic substances dissolved in water, including minerals, salts, and ions. The WHO guideline for TDS in drinking water is 500 mg/L, though water with TDS up to 1,000 mg/L may still be acceptable in some contexts (SON, 2020). High TDS affects taste and may cause gastrointestinal irritation in sensitive individuals. TDS values exceeding permissible levels have been reported in borehole and well water samples in Nigerian communities (Adeleye et al., 2022).

2.3.4 Electrical Conductivity (EC)

Electrical conductivity is directly related to the concentration of dissolved salts in water. It indicates the ability of water to conduct electric current and serves as a quick estimation of TDS levels. Elevated EC often points to pollution from agricultural runoff or domestic effluents (Ibrahim & Usman, 2023). Water sources near farmlands or urban drainage systems frequently show high EC values, indicating contamination by nitrates, sulfates, or chlorides.

2.3.5 Temperature

Temperature influences water quality by affecting chemical solubility and microbial activity. Warm water encourages microbial growth and reduces the solubility of gases like oxygen, which may degrade water quality. Although temperature is not directly harmful, it affects consumer preference and can reduce the effectiveness of disinfection processes (Yahaya et al., 2024).

2.3.6 Nitrates

Nitrates are commonly found in groundwater contaminated by fertilizers, animal waste, or sewage. High nitrate levels are particularly dangerous for infants, leading to methemoglobinemia or “blue baby syndrome.” The WHO limit for nitrates in drinking water is 50 mg/L. Many rural communities in Nigeria exceed this limit due to open defecation and proximity to agricultural fields (Olowolafe et al., 2021).

2.3.7 Chlorides and Hardness

Chlorides in high concentrations give water a salty taste and may corrode pipes. Water hardness, caused by calcium and magnesium ions, is not a health concern but affects soap lathering and contributes to scaling in pipes and appliances. WHO recommends a chloride level below 250 mg/L in drinking water (WHO, 2021). Hard water is frequently reported in borehole samples, particularly in the savannah regions of Nigeria (Okonkwo et al., 2023).

2.3.8 Heavy Metals

Heavy metals such as iron, manganese, lead, arsenic, and cadmium may enter drinking water from natural deposits or corrosion of household plumbing. These metals are toxic, even at low concentrations, and are linked to various health conditions including kidney damage, neurological disorders, and cancer. The Nigerian Standard and WHO both set specific limits for these metals (SON, 2020; WHO, 2021). For example, lead must not exceed 0.01 mg/L and arsenic should be below 0.01 mg/L. Elevated iron levels are commonly detected in groundwater across several Nigerian states (Chukwudi et al., 2025).

2.4 Public Health Implications of Contaminated Water

Contaminated drinking water poses significant health risks to individuals and communities, particularly in developing countries. It can result in both acute and chronic health conditions depending on the type and level of microbial or chemical pollutants present. The implications extend beyond physical health, affecting social development, healthcare systems, and economic productivity (WHO, 2021).

2.4.1 Waterborne Diseases from Microbial Contaminants

The most immediate and widespread consequence of consuming microbiologically contaminated water is the outbreak of waterborne diseases.

Pathogens such as Escherichia coli, Salmonella spp., Vibrio cholerae, and various protozoa are often introduced into drinking water through fecal contamination. These organisms can cause diseases such as cholera, typhoid fever, dysentery, and hepatitis A, which are common in Nigeria's low-income and rural areas (Ibrahim & Usman, 2023). Children under five years are most at risk. According to UNICEF (2023), diarrheal diseases caused by unsafe water and poor sanitation kill more than 1,000 children daily worldwide.

2.4.2 Chronic Illnesses from Chemical Pollutants

Apart from immediate infections, prolonged exposure to chemically contaminated water can result in chronic health problems. For example, excessive nitrate levels are linked to methemoglobinemia or "blue baby syndrome," a fatal condition in infants. Long-term consumption of water contaminated with lead, arsenic, or cadmium can cause irreversible damage to the nervous system, liver, kidneys, and even trigger carcinogenic effects (Chukwudi et al., 2025). In several parts of Nigeria, high concentrations of iron, fluoride, and manganese have been reported in groundwater sources, which may contribute to skeletal deformities and dental fluorosis (Olowolafe et al., 2021).

2.4.3 Impact on Vulnerable Populations

Vulnerable populations especially infants, pregnant women, the elderly, and immunocompromised individuals are disproportionately affected by contaminated drinking water. For instance, pregnant women consuming high-nitrate water are at increased risk of miscarriage, while children are more susceptible to dehydration and nutrient malabsorption following diarrheal infections (Yahaya et al., 2024). These issues also contribute to poor school attendance and long-term cognitive development setbacks among children.

2.4.4 Socioeconomic Burden of Waterborne Illnesses

The implications of contaminated water are not limited to health. Recurrent illnesses increase healthcare expenses, reduce household productivity, and hinder local economic development. In regions with frequent outbreaks, the strain on already weak health systems leads to high treatment costs and lost work hours (Adeleye et al., 2022). Women and girls, who are often responsible for collecting water, face increased burdens and reduced educational opportunities when clean sources are distant or inaccessible.

2.4.5 Breakdown of Public Trust and Risky Alternatives

When public water sources are known or suspected to be contaminated, communities often turn to unsafe alternatives such as unregulated sachet water, untreated surface water, or shallow wells. These sources may appear clean but are frequently of poor bacteriological and physicochemical quality (Okonkwo et al., 2023). The lack of trust in government-supplied water can also reduce willingness to invest in infrastructure maintenance or engage in public health interventions.

2.4.6 Need for Preventive Interventions

To reduce the public health burden of unsafe water, there must be a proactive approach involving water treatment, regular quality monitoring, hygiene education, and policy enforcement. Technologies like point-of-use filtration, chlorination, and community sensitization campaigns are effective, especially when combined with behavior change strategies. Collaboration between health sectors, water agencies, and local leaders is essential for ensuring safe and sustainable drinking water access (SON, 2020; WHO, 2021).

2.5 Regulatory Standards for Drinking Water

Regulatory standards for drinking water are established to ensure that water meant for human consumption is safe, wholesome, and free from substances that pose health risks. These standards serve as guidelines for monitoring, treatment, and distribution of potable water. They also guide water quality control agencies in setting enforceable limits for contaminants. In Nigeria and globally, standards are defined by both national and international agencies such as the Standards Organisation of Nigeria (SON) and the World Health Organization (WHO) (SON, 2020; WHO, 2021).

2.5.1 Nigerian Standard for Drinking Water Quality (NSDWQ)

The Standards Organisation of Nigeria (SON) developed the Nigerian Standard for Drinking Water Quality (NSDWQ) in 2007 and revised it in 2020. It outlines maximum permissible limits for physical, chemical, radiological, and microbiological parameters in drinking water. The NSDWQ specifies that:

- pH should range from 6.5 to 8.5
- Turbidity should not exceed 5 NTU
- TDS should be ≤ 500 mg/L
- E. coli must be absent in 100 mL of any drinking water sample
- Nitrates should be ≤ 50 mg/L, and heavy metals like lead and arsenic must be ≤ 0.01 mg/L (SON, 2020)

These parameters are adopted in routine quality assessment by government bodies such as the Federal Ministry of Water Resources, State Water Boards, and Rural Water Supply and Sanitation Agencies (RUWASSA). Despite the existence of these standards, enforcement remains weak, especially in informal water packaging and rural borehole supplies (Chukwudi et al., 2025).

2.5.2 World Health Organization (WHO) Guidelines

The WHO Guidelines for Drinking-water Quality serve as a global benchmark for developing and developed nations alike. The most recent edition (WHO, 2021) provides health-based targets for over 100 substances and microbial contaminants. Like the NSDWQ, the WHO guidelines emphasize zero tolerance for E. coli in drinking water and outline limits for substances like fluoride (1.5 mg/L), nitrate (50 mg/L), lead (0.01 mg/L), and arsenic (0.01 mg/L).

The WHO adopts a risk-based approach to water quality management, promoting Water Safety Plans (WSPs) that encompass catchment protection, proper treatment, and safe distribution. These guidelines are especially relevant to regions facing climate variability and emerging contaminants (WHO, 2021).

2.5.3 National Agency for Food and Drug Administration and Control (NAFDAC)

In Nigeria, NAFDAC is responsible for regulating packaged water products, including bottled and sachet water. The agency monitors microbial and chemical content through routine inspections, laboratory testing, and facility certification. Producers of sachet water are expected to meet the SON and WHO standards and operate in hygienic environments with appropriate treatment systems. However, studies reveal that many small-scale producers bypass regulations, leading to unsafe products in circulation (Okonkwo et al., 2023).

2.5.4 Challenges in Compliance and Enforcement

Despite the existence of regulatory frameworks, compliance remains a major challenge in Nigeria. Several factors contribute to this:

- Limited laboratory capacity for testing in rural areas
- Corruption and weak inspection mechanisms
- Public unawareness of water quality parameters
- Inconsistent policy enforcement (Adeleye et al., 2022)

As a result, unsafe water often finds its way to consumers, especially in underserved communities. Bridging the enforcement gap will require a combination of regulatory reform, increased funding, capacity-building, and public awareness campaigns (Ibrahim & Usman, 2023).

2.5.5 The Way Forward: Harmonizing Standards with Practice

To ensure safe drinking water nationwide, Nigeria must harmonize its regulatory standards with practical implementation. This includes:

- Strengthening coordination between SON, NAFDAC, and local health departments
- Adopting community-based monitoring systems
- Promoting certification and licensing of all water providers
- Encouraging investment in water infrastructure and technology

Such steps will help align national standards with global safety practices and ensure public health protection (Yahaya et al., 2024).

2.6 Previous Studies on Water Quality Assessment

This section provides a review of empirical studies on the physicochemical and bacteriological quality of drinking water in Nigeria and beyond.

2.6.1 Studies on Microbiological Quality of Drinking Water

Several studies in Nigeria have highlighted the widespread presence of fecal coliforms, particularly *Escherichia coli*, in drinking water sources such as wells, boreholes, streams, and sachet water. Adeleye et al. (2022) assessed the microbial load in various domestic water sources in southwestern Nigeria and reported that over 60% of samples exceeded WHO's permissible limits, with *E. coli* detected in more than 30%. Their findings suggest widespread fecal contamination, attributed to poor sanitation practices and proximity of water points to latrines.

Similarly, Ibrahim and Usman (2023) studied water samples from urban and rural communities in North-Central Nigeria and found that sachet water, often considered safe, harbored coliforms due to poor packaging practices and storage. These results support WHO's (2021) assertion that microbial contamination is the most critical risk in drinking water.

2.6.2 Studies on Physicochemical Quality Parameters

Numerous studies have assessed physicochemical parameters of drinking water across Nigeria. Olowolafe et al. (2021) evaluated borehole and well water in Ilorin and found that over 50% of samples had TDS levels exceeding 500 mg/L, and 25% showed pH values below 6.5, suggesting the water was acidic and potentially corrosive. Elevated iron and manganese levels were also common in aquifers, raising concerns about long-term exposure.

Okonkwo et al. (2023) analyzed sachet water from markets in eastern Nigeria and discovered that while turbidity and pH often met SON standards, parameters such as electrical conductivity and hardness exceeded limits in several samples, indicating poor treatment or mineral leaching from packaging. Such studies highlight inconsistencies in quality control, even among regulated products.

2.6.3 Regional Comparisons and Trends

A comparative study by Yahaya et al. (2024) across six Nigerian states found that water sources in northern regions were more likely to exceed permissible nitrate and fluoride levels due to agricultural runoff and naturally occurring minerals. In contrast, southern states showed more microbial contamination, likely due to higher population density and poor sanitation infrastructure.

Chukwudi et al. (2025) conducted a meta-analysis of 20 studies on Nigerian water quality and concluded that 70–80% of water sources assessed between 2018 and 2024 were either bacteriologically or chemically unsafe for direct consumption. The authors emphasized the lack of consistent monitoring and regulatory enforcement as a major gap in the water supply system.

2.6.4 Relevance to the Present Study

These studies collectively reveal a persistent pattern of contamination in both microbiological and physicochemical dimensions. They also highlight the inadequate treatment, weak regulatory enforcement, and infrastructural decay affecting Nigeria's drinking water system. This present study builds on such previous research by investigating selected drinking water sources in a specific locality, applying both laboratory testing and field assessment, to identify contamination sources and propose data-driven recommendations.

CHAPTER THREE
MATERIALS AND METHODS

3.1 Study Area

The research was conducted in Ilorin the capital of Kwara State, located in North central Nigeria. The study was limited to selected borehole within the study area. Boreholes belonging to households that primarily rely on borehole water as their main source of drinking and household water were utilized for the study.

3.2 Sample Collection

The borehole water samples were randomly collected from three (3) different water borehole water in selected area for the study; Yakuba, Elekoyangan and Agbede. To collect the samples, each respective tank was opened and water was allowed to run for the first 2 minutes before sterile sample bottles were opened for collection. The samples were collected into 30 ml sterile screw-capped containers and appropriately labeled. They were then placed in ice packs and immediately transported to the microbiology and chemical laboratories for microbiological and physicochemical analyses, respectively. The selected samples used in this study were designated as A, B, C.

3.3 Microbiological Analyses

Microbial assessment of the borehole water samples was conducted using methods previously described by Okafor *et al.* (2023).

The bacteriological analysis of the samples was carried out using a combination of total bacterial count (TBC) and most probable number (MPN) technique. The water samples were serially diluted into sevenfold (10^{-1} to 10^{-5})

using distilled water. Subsequently, 1 mL of the diluted water sample (10^{-5}) was carefully dispensed into a petri dish containing 19mL of molten nutrient agar. These prepared plates were then incubated at 37°C for a duration of 48 hours. Following incubation, the former colonies were observed, manually counted, and the results were calculated and recorded bottles (Elijah, 2023).

The Most Probable Number (MPN) approach, also known as the dilution method, is a technique for determining microbial population density by examining the presence or absence of microorganisms in several aliquots of subsequent dilutions, eliminating the requirement for individual cell or colony counts. This cost-effective method which is also known for its ease of implementation. The MPN technique was employed to determine both the total coliform count and the bacteriological index (most probable number) of the water samples. This technique was conducted through three successive stages; the presumptive, confirmed, and completed tests, respectively (Elijah, 2023).

3.3.1 The Presumptive Test

The coliform count was determined using the three-tube assay of the MPN technique, with the MacConkey broth used to carry out the test. Each sample underwent a serial dilution process, with three sets of lactose broth tubes prepared. These tubes were inoculated with 10 mL, 1.0 mL, and 0.1 mL of the respective water samples and then incubated subsequently at 37°C for 48 hours. The presence of coliforms was inferred based on the observation of acid formation and a distinct color change occurring in any of the bijou bottles (Elijah, 2023).

3.3.2 The Confirmed Test

A loopful of inoculum from the positive presumptive tubes was transferred into bijou bottles containing brilliant green lactose bile broth to confirm the presence of coliforms. The tubes were incubated at 37°C for a duration on 24 to 48 hours. The definitive indication of the presence of coliforms was confirmed by a noticeable change in color within incubated media (Elijah, 2023).

3.3.3 The Completed Test

A loopful of broth from a positively confirmed test tube was carefully streaked onto an Eosin Methylene Blue agar plate to obtain pure colonies. These streaked agar plates were subsequently incubated at 37°C for duration of 24 to 48 hours. Further identification of the isolated colonies was carried out based on their morphological, cultural, and biochemical characteristics (Elijah, 2023).

3.4 Isolation of Microorganisms

After the 48hours of incubation, the plates were removed from the incubator, the colony were observed on the plates and counted using colony counter, and the pure cultures were obtained by transferring the distinct colonies into sterile solid nutrient agar plates using sterile inoculating loop and then streaked. The plates were then incubated at 37°C for 24-48hours and sub-cultured until satisfactorily pure cultures were obtained. The agar slant were then prepared dispensing molten nutrient agar into sterilized McCartney bottle and set into slant position. The distinct pure isolates obtained were then aseptically inoculated further onto nutrient agar slants in

McCartney bottles and incubated 37°C and stored in the refrigerator at 4°C. The stock cultures were to serve as a source of reference whenever tests would be carried out on the isolates.

3.5 Characteristics of Microbial Isolates

3.5.1 Bacterial Characterization of Isolates

Morphological characterization of each distinct colony was observed and recorded by noting the color, shape, pigmentation, elevation, size of the colonies and microscopic view was done using a compound microscope with X100 oil immersion lens. Bacteria isolates were then further characterized by their physiological characteristic though the biochemical reactions of isolates to some reagents and media.

3.5.2 Gram Staining

Gram stain is one of the differential stains that are used to characterize bacteria into: either Gram positive bacteria or Gram-negative bacteria. A thin smear of each of the pure 24 hours old culture was prepared on clean grease-free slide, fixed by passing over gentle flame.

The smear was flooded by crystal violet solution for 1 minute and rinsed with water. The smear was again flooded with Lugol's iodine for 30- 60 seconds and rinsed with water, decolorized with 70% alcohol for 15 seconds and was rinsed with water. The slide was counter stained with safranin for 60 seconds and rinsed with water. The smear was mounted on a microscope and observed under oil immersion objective lens. Gram negative cells appeared pink or red while Gram positive organisms appeared purple.

3.6 Biochemical Test

Differents bacterial isolates were carried out on the basis of the result of four tests; Indole, Methyl red, Voges Proskauer, Catalse, Coagulase, Oxidase, Citrate utilization, Urease and Sugar fermentation with their standard methods.

3.6.1 Indole Test

Indole test procedures was done as described by Islam (2018). This determined the ability of bacteria to split amino acid tryptophan to form compound indole. One percent tryptophan 10ml broth was taken in test tubes and inoculated by fresh pure culture obtained from pure colonies. After 48 hours of incubation period at 37°C, the test tubes were shaken gently. Five drops of Kovács reagent was added directly to the tubes. These were also shaken gently and allowed to stand for twenty (20) minutes. Two test tubes were used per isolate with one being a control. Control test tube contained one percent tryptophan broth and inoculated by fresh pure culture obtained from pure colonies. Formations of red colouration at the top layer indicated positive while yellow colouration indicated negative results, respectively.

3.6.2 Methylred Test

This test is used to check acid production in the medium usually for coliform organismswhich ferment dextrose rapidly causing a fall in the pH. MR-VP broth was prepared and 10 ml of the broth was dispensed into test tubes and sterilized. Inoculation was subsequently done and incubated at 37°C for 2 days. After incubating for 48 hours, the broth was aseptically divided into 2 portions. To the first portion, 2-3 drop of methyl red indicator is added and observed for colour change. A red colour change indicates a positive reaction, that is, there is gas production while a yellow colour change indicates a negative reaction (Ellis and Goodacre, 2016).

3.6.3 Catalase Test

Catalase test was done according to the procedure described by Ahmed *et al*. (2017) to determine aerobic and anaerobic bacteria and it was important in differentiating morphologically similar Enterococcus *Staphylococcus (catalase positive)* and *Streptococcus* spp (catalase negative). Three ml of catalase reagent (3% H2O2) was put on a glass slide. Single colony from the pure culture of bacteria from each sampled site was scooped with a glass rod and submerged in the reagent and observed for bubble formation which indicated positive test while absence of bubbles formation indicated negative results.

3.6.4 Oxidase Test

This test was performed as previously described by Ahmed *et al*. (2017). The test was used to identify bacteria that produce cytochrome oxidase, an enzyme of the bacterial electron transport chain. A filter paper was soaked in 1% kovacs oxidase reagents and dried. A single 35 colony from pure culture of bacterial was rubbed into paper using a wire loop. The colour change was timed using a stop watch whereby, if colour changed to dark purple within less than 10 seconds it indicated positive and if colour took more than four minutes to change it indicated negative results.

3.6.5 Citrate Test

This test was performed according to procedure described by Aligwekwe (2018) by inoculating the bacteria into Simmon‟s citrate medium obtained from pure colonies as explained in section 3.3.2. This was employed in determining the ability of bacteria to utilize sodium citrate as its only carbon and energy source. The inoculated medium was incubated for 48 to 72 hours to allow complete utilization of Simmon"s citrate medium by microorganisms. The colour of the medium indicated the result. If the colour of media changed from green to blue then the bacteria was citrate positive while if the media retained the green colour after incubation period it indicated citrate negative bacteria.

3.7 Physicochemical Analyses

Physicochemical parameters as pH, turbidity, electrical conductivity, total hardness, total dissolved solids, total alkalinity and chloride contents were determined using the previous methods of Okafor *et al.* (2022).

CHAPTER FOUR

RESULTS

4.1 Total Bacteria Counts (CFU/ml)

The total bacterial counts of isolates from the borehole water samples are shown in table 1. The total bacterial count ranges from 1.9×10^5 to 3.6×10^5 respectively. Having Yakuba with higher value of TBC of 3.6×10^5 while Agbede has the lowest value of 1.9×10^5.

4.2 Most Probable Number

Table 2 shows the MPN index on for all each water sample respectively. Which has the lowest range of 170 to the highest of $\geq$1600, with sample C (Agbede) having the least value of 170 while sample A and B (Elekoyangan and Yakuba) had the highest value of $\geq$1600.

4.3 Colonial Morphological Characteristics

Table 3 shows the various colonial morphological features on different isolates.

4.4. Biochemical Characterization and Gram Staining Reaction

Table 4 shows the various biochemical test carried out on different isolates ranging from citrate to citrate and others as shown in the table.

4.5 Physicochemical Parameters of Water Samples

Table 5 shows the physicochemical parameters of water from selected school area.

Table 1: The Total Bacteria Count (CFU/ml)

Samples	**TBC (CFU/ml)**
A	$3.6x10^5$
B	$3.2x10^5$
C	$1.9x10^5$

Key: A- Yakuba, B- Elekoyangan, C-Agbede.

Table 2: MPN Value of the Water Analyzed (100cfu/ml)

Samples	**10ml**	**1.0ml**	**0.1ml**	**MPN Index**
A	5	5	5	$\geq$1600
B	5	5	5	$\geq$1600
C	5	2	4	170

Key: A- Yakuba, B- Elekoyangan, C-Agbede.

Table 3: Colonial Morphological Characteristics of the Bacteria Isolates

Isolates	Shape	Margin	Elevation	Colour	Texture
1	Circular	Entire	Convex	Green metallic shine	Smooth
2	Circular	Entire	Raised	Creamy	Smooth
3	Circular	Unbonate	Convex	Dark brown	Mucoid
4	Circular	Entire	Convex	Green metallic shine	Smooth

Table 4: Biochemical Characterization and Gram Staining Reaction

Isolates Codes	Cit	Oxi	Cat	Ind	Met	Vgp	Likely organisms
1	+	-	+	+	+	+	*E. coli*
2	+	+	+	-	+	-	*Shigella sp.*
3	+	-	+	-	-	+	*Klebsiella sp.*
4	-	-	+	+	+	+	*E. coli*

KEY: +-positive, - - negative

Table 5: Physicochemical Parameters of Water Samples

S/N	Parameters	Yakuba	Elekoyangan	Agbede
1	pH	5.31	6.02	5.75
2	Turbidity (NTU)	2.2	1.7	1.8
3	Electrical conductivity (µs/cm)	323	141.3	106.1
4	Total hardness (mg/L)	90.51	105.34	98.52
5	Total dissolved solid (mg/L)	210	90	70
6	Total alkalinity (mg/L)	70.528	86.745	69.624
7	Chloride (mg/L)	18.634	14.63	20.015

CHAPTER FIVE

5.1 Discussion

The total bacterial counts from the water samples in the three borehole water are shown in table 1. The total bacterial count ranges from $1.9x10^5$ to $3.6x10^5$ cfu/ml, where Sample A had the highest plate count of $3.6x10^5$ cfu/ml and Sample C with the least count of $1.9x10^5$. Borehole water sources also fell short of meet the stipulated requirements for total bacterial count, echoing the findings of Bashir *et al.* (2018), who observed the presence of high fecal coliforms. This outcome was attributed to the proximity of the latrine system to the borehole water source, which was 30 meters below the recommended depth by the WHO. The water sources failed to comply with WHO's Coliform Forming Unit requirements. Furthermore, the type and quantity of organisms present in the water samples will determine the health risk poses to consumers upon ingestion.

The examined borehole water samples from all selected areas had counts that exceeded the acceptable limit of 0 MPN values per 100 ml set by the World Health Organization (WHO). Coliform bacteria were detected in significant numbers in all the samples, and their values were reported as most probable numbers (MPN). Bacteria obtained from the borehole waters include *Escheria coli, Shigella sp*. and *Klebsiella sp., E. coli* and *Shigella sp.* was the most prevalent, with MPN $\geq$1600/100 ml of water reported in sample A and B, while *Klebsiella sp*. was the least prevalent with MPN 170/100 ml of water reported in samples C.

The physicochemical parameters are shown in table 5, which the necessary physicochemical parameters analyzed reveled the level of water to consumption. The pH values ranged from 5.31 to 6.02; Turbidity values ranges from1.7NTU to 2.2NTU; Electrical Conductivity ranges from 106.1 µs/cm to 323 µs/cm; Total Hardness values ranged from 90.51 mg/L to 105.34 mg/L; Total Dissolved Solids ranges from 70 mg/L to 210mg/L; Total Alkalinity ranges from 69.624mg/L to 86.745mg/L and Chloride concentration ranges from 14.63 mg/L to 20.015mg/L ppm across the borehole waters sampled. In contrast to the study by Okafor and Orji, (2022).

5.2 Conclusion

The study successfully identified the presence of microorganisms in borehole waters stored in the selected area. *E. coli* was found to be the most dominant organism isolated from the borehole water samples obtained from the water tanks. The presence of these organisms, along with the observed physicochemical properties, indicates fecal contamination in the studied borehole water samples. This contamination suggests the potential presence of pathogenic microorganisms and trace amounts of hardness and heavy metals in the sampled borehole waters. These identified organisms are opportunistic pathogens that can pose risks to individuals, particularly those with underlying health conditions and compromised immune systems.

5.3 Recommendation

1. There is a pressing need for improved sanitary conditions not only in the reservoir tanks but also in the water sources within these locations.
2. Proper treatment of the water is highly recommended to be safe from pathogenic bacteria.

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