

**PHYSICOCHEMICAL ANALYSIS OF DRINKING WATER FROM DIFFERENT
SOURCES IN IKPOBA-OKHA LGA, EDO STATE, NIGERIA.**

BY

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DEPARTMENT OF SCIENCE LABORATORY TECHNOLOGY

FACULTY OF LIFE SCIENCE

UNIVERSITY OF BENIN

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**A PROJECT SUBMITTED TO THE DEPARTMENT OF SCIENCE LABORATORY
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THE DEGREE OF BACHELOR OF SCIENCE (B.Sc.) IN SCIENCE LABORATORY
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OCTOBER, 2025

CERTIFICATION

This is to certify that this research work, titled “**Physical Chemical Analysis of Drinking Water from Different Sources in ikpoba-Okha LGA**” was carried out by **ONIOVOSA ESTHER OCHUKO (MISS)** with matriculation number **LSC2007342**, a student of the Department of Science Laboratory Technology (Microbiology Techniques), Faculty of Life Sciences, University of Benin, Benin City, Edo State, under my supervision in partial fulfillment for the requirements for the award of a bachelor’s degree.

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DEDICATION

I dedicate this work to Almighty God for His grace, my loving parents, for their endless support, and my dear sister Udoh Grace, for her inspiration and encouragement.

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TABLE OF ABBREVIATIONS

BOD: Biochemical Oxygen Demand

COD: Chemical Oxygen Demand

DO: Dissolved Oxygen

EC: Electrical Conductivity

LGA: Local Government Area

NA: Not Available

NGV: No Guideline Value

NIS: Nigerian Industrial Standard

SON: Standards Organisation of Nigeria

TDS: Total Dissolved Solids

TSS: Total Suspended Solids

TTA: Total titratable Acidity

TS: Total Solid

WHO: World Health Organization

ABSTRACT

Access to clean and safe water is essential for human health and sustainable development. This study assessed the physicochemical properties of water obtained from tap, well, and river sources in Ikpoba-Okha Local Government Area, Edo State, Nigeria, to evaluate their quality and suitability for domestic use. Parameters such as pH, temperature, total dissolved solids (TDS), electrical conductivity (EC), total solids (TS), total hardness, biochemical oxygen demand (BOD), chemical oxygen demand (COD), phosphate, and heavy metals (lead, chromium, and cadmium) were analyzed. Results showed that most parameters were within the permissible limits set by the World Health Organization (WHO, 2022) and Nigerian Industrial Standard (NIS, 2015). However, cadmium concentrations in tap and well water slightly exceeded recommended values, indicating possible contamination from waste or corroded materials. A structured Questionnaire administered to residents revealed that most residents depend on borehole water, do not treat their water and have limited awareness of contamination risks. The study therefore recommends regular monitoring, improved sanitation, and community education to ensure safe and sustainable water quality in Ikpoba-Okha Local Government Area.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Water is an essential natural resource that sustains all forms of life. Water is necessary for irrigation, industry, household necessities, transportation, sanitation, and waste disposal in modern civilization. The majority of our water bodies, including lakes, streams, rivers, and ponds, are now contaminated due to growing urbanization, industrialization, and other development-related activities. Waste disposal and other human activities can directly or indirectly alter the quality or composition of water, making it less acceptable or hazardous for drinking, home use, agriculture, fishing, or other uses, this is known as pollution (Nayar, 2020). Water pollution has emerged as a major global concern, primarily due to the inadequate protection of surface water sources. Waste disposal from nearby industries and the dumping of solid waste have contributed significantly to the degradation of aquatic ecosystems. In particular, the discharge of untreated industrial effluents and agricultural runoff into nearby water bodies has led to a decline in the availability of clean, quality water. Surface water sources such as rivers, streams, lakes, dams, and reservoirs are crucial, as they provide drinking water for a large portion of the population. However, rapid population growth, urban expansion, and industrialization have placed increasing pressure on these resources. This has impacted aquatic life, food production, economic development, and overall human well-being.

Water is a vital resource for all living organisms, yet the pollution of water bodies leads to consequences such as increased water temperature, eutrophication, loss of aesthetic value, and serious environmental and health risks. The quality of surface water can be evaluated by analyzing its physical and chemical characteristics. (Eze *et al.*, 2023). Water pollution arises

when there is an alteration in the physical, chemical, or biological conditions of the environment, resulting in harmful effects on human life, animals, and aquatic ecosystems. Assessing water quality is crucial, as it reflects the condition of water in terms of its physical, chemical, and biological characteristics, along with its hydrological properties. To understand the health of river systems and their impact on both human and aquatic life, continuous monitoring of water quality is essential.

Ikpoba-Okha Local Government Area (LGA) is one of the eighteen local government areas in Edo State, Nigeria. It is an area characterized by a mix of urban, peri-urban, and rural settlements, and it plays host to a growing population due to increasing urban migration and development in Benin City, the state capital. The inhabitants of Ikpoba-Okha rely on multiple water sources for their daily needs, including boreholes, hand-dug wells, rivers, streams, rainwater, and commercially packaged sachet water. The quality of water resources is influenced by numerous factors, including the discharge of brewery effluents and various domestic, industrial, and agricultural wastes, especially within urban areas. One such example is the Ikpoba River in Benin City, Edo State, Southern Nigeria a fourth-order stream that receives substantial waste loads from surrounding communities like Oregbeni, as well as directly from Guinness PLC, a brewery industry.

These pollutants, rich in both organic and inorganic matter, enter the river through direct discharge and surface runoff. This contamination negatively affects aquatic biodiversity and poses serious risks to human health and the environment. The increasing levels of pollution, driven by urbanization and industrialization, result in the deterioration of water quality, reducing its suitability for essential uses such as domestic consumption, fisheries, industrial supply, recreation, irrigation, and transportation. Water pollution occurs when certain physicochemical

parameters such as pH, temperature, dissolved oxygen (DO), electrical conductivity (EC), salinity, turbidity, total suspended solids (TSS), biochemical oxygen demand (BOD₅), and chemical oxygen demand (COD) exceed the recommended limits for safe usage. When this happens, the river's ability to support aquatic life and serve human needs diminishes significantly.

To maintain a healthy aquatic environment and ensure water remains safe for various uses, continuous monitoring of these water quality parameters is essential. Such monitoring helps in assessing the extent of pollution, identifying pollution sources, and guiding decisions in water resource management. A consistent assessment of the physical and chemical properties of water bodies plays a critical role in determining their productivity, ecological health, and overall usability. (Akpe *et al.*2018). Water quality is evaluated to see if it is safe for the environment or acceptable for human consumption. This is often done by comparing the water's physico-chemical and biological parameters to a set of standards. Assessing the physical, chemical, and biological condition of water in relation to its natural state, human impacts, and potential uses is known as water quality assessment. (Etim and Godwin, 2021).

The following physicochemical parameters; pH, temperature, turbidity, conductivity, total dissolved solids, total suspended solids, total alkalinity, sulphate, nitrate, heavy metals, and phosphate are crucial indicators of river, handdug well and borehole water quality. Khan and Butt, 2022). These parameters provide critical information about the state of water bodies and help in identifying potential sources of contamination. By assessing these properties, it is possible to determine the quality of water for drinking, domestic use, agricultural irrigation, and industrial processes.

The availability of clean, high-quality water is essential for the survival and well-being of millions of people. Unfortunately, countless lives have been lost due to impurities found in natural water sources, and this issue continues to worsen. Water pollution arises from various sources, including human activities such as the use of metal-based materials, agricultural fertilizers, and the natural processes of rock weathering and soil erosion. These pollutants increase the concentration of biological and chemical contaminants in water, elevating chemical components, biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), and suspended solids. As a result, water becomes unsuitable for drinking, irrigation, or other domestic and industrial uses.

Contaminated water has been closely associated with waterborne diseases that claim numerous lives worldwide. The presence of high levels of organic matter and other impurities contributes to these health hazards. Groundwater quality is influenced by both natural factors, such as the local geology, and human activities including mining, metal processing, and industrial operations. Additionally, runoff from agricultural lands and the breakdown of atmospheric aerosol particles introduce more pollutants into aquatic systems. The increasing concentration of metal pollutants in freshwater reservoirs remains a serious environmental and public health concern.

Municipal and industrial wastes, along with untreated sewage and pollution from residential areas, are major contributors to water contamination. Diseases such as cholera, dysentery, salmonellosis, and typhoid are commonly linked to polluted water sources. Agricultural activities and poor waste management practices including leachates from dumpsites and inadequately treated wastewater also significantly contribute to surface and groundwater pollution. In less industrialized regions, the absence of clean drinking water and proper sanitation infrastructure further worsens groundwater contamination (Verma *et al.*,2025)

1.2 AIM AND OBJECTIVE

The primary aim of this study is to evaluate the physicochemical properties of water from different sources in Ikpoba-Okha Local Government Area, Edo State, Nigeria.

The specific objectives are:

1. To determine the physicochemical parameters (such as pH, temperature, turbidity, dissolved oxygen, total dissolved solids, and electrical conductivity) of water from boreholes, wells, rivers, and sachet water in the study area.
2. To compare the results obtained with the standards set by the World Health Organization (WHO) and Nigerian Industrial Standards (NIS) for potable water.
3. To identify possible sources of contamination and assess the potential health risks associated with the consumption and use of water from these sources.
4. To recommend appropriate measures for improving water quality and management practices in the study area.
5. To provide recommendations for improving water quality management, water safety practices, and community health protection within the study area.

1.3 RESEARCH QUESTIONS

To guide this study on the physicochemical analysis of water from different sources in Ikpoba-Okha Local Government Area, Edo State, Nigeria, the following research questions have been formulated:

1. What are the physicochemical characteristics (such as temperature, pH, turbidity, total dissolved solids, electrical conductivity, dissolved oxygen, and major ion concentrations) of water obtained from boreholes, wells, rivers, and sachet water in the study area?
2. How do the physicochemical parameters of these water sources compare with the World Health Organization (WHO) and Nigerian Industrial Standards (NIS) permissible limits for potable water?
3. What are the possible environmental and anthropogenic factors contributing to variations in the physicochemical quality of water sources within Ikpoba-Okha LGA?
4. What potential public health risks are associated with the consumption and use of water from these different sources based on their physicochemical properties?
5. What recommendations can be made for improving water quality management and ensuring safe water supply for the residents of Ikpoba-Okha Local Government Area?

1.4 RESEARCH HYPOTHESIS

H₀: There is no significant variation in the physicochemical quality of water from different sources compared with WHO and NIS standards.

H₁: There are significant variations in the physicochemical quality of water from different sources compared with WHO and NIS standards.

1.5 SCOPE OF STUDY

This study focuses on the physicochemical analysis of water from hand-dug wells, boreholes, and tap water in Ikpoba-Okha LGA, Edo State. Parameters assessed include pH, temperature, turbidity, TDS, EC, DO, BOD, hardness, nitrates, phosphates, chlorides, sulphates, arsenic, lead, and iron, compared against WHO (2022) and NIS (2015) standards. The study excludes microbiological analysis and seasonal variation.

CHAPTER TWO

LITERATURE REVIEW

2.1 WATERBORNE

Water quality assessment is a crucial component of environmental management and public health protection. Water, being one of the most vital natural resources on Earth, is indispensable for sustaining life and supporting the continuous functioning of ecological systems. It is essential not only for drinking and domestic uses such as cooking, washing, and sanitation but also for agricultural activities, industrial processes, transportation, recreational purposes, and cultural practices. Water quality has a significant impact on water supply and oftentimes determines supply options. The understanding and monitoring of sources and quality of water used for water supply is of societal, economic and conservational importance since per capita water demand is increasing while accessibility to freshwater availability is continuing to decline. Local water quality can be used to identify the sources and fates of toxic contaminants and pollutants either from ecology, geology, and anthropogenic activities (industrial processes, runoff from agricultural farms etc) in the area. Identifying the sources of contamination and developing appropriate management strategies are essential to minimizing potential public health risks (Adelagun *et al.*, 2021).

In Nigeria, high water contamination rates pose a serious threat to public health. Untreated sewage, used plastic bottles, nylons, and solid household garbage are the main sources of pollution in Nigeria's waterways. However, the availability of safe and clean water is under increasing threat due to population growth, urbanization, agricultural expansion, industrialization, and climate change. The rise in human population has led to increased demand for water, while urban growth has resulted in the encroachment of settlements into water catchment areas and the

generation of large volumes of domestic waste and sewage, much of which finds its way into nearby water bodies. Sewage can contaminate water and cause significant harm to wildlife if it is only partially treated before being disposed of. As an alternative, rivers and other water sources may become contaminated when fully untreated sewage leaks or floods. The repercussions are not favourable. Sewage is mostly caused by domestic waste, fast industrialisation, population growth, pesticides and fertilisers, plastics, urbanisation, and inadequate management system (Tariq and Mushtaq 2023).

Agricultural activities, particularly the excessive use of fertilizers, herbicides, and pesticides, contribute to the contamination of both surface and groundwater sources through runoff and infiltration.(Bentum *et al.*, 2011).Industrial processes further exacerbate water pollution by discharging untreated or inadequately treated effluents containing toxic chemicals and heavy metals into rivers, streams, and surrounding soil, thereby affecting water quality.

In many developing countries, including Nigeria, access to potable water remains a challenge, with a significant proportion of the population relying on untreated or inadequately treated water sources. Rivers, streams, wells, boreholes, and sachet water serve as primary water supplies for many communities but are frequently exposed to contamination from agricultural runoff, industrial effluents, improper waste disposal, and poor sanitation practices. These conditions increase the risk of waterborne diseases such as cholera, typhoid, and diarrhea, posing a major public health challenge. Consequently, the need for regular monitoring and analysis of water quality parameters has become paramount in safeguarding public health and ensuring sustainable environmental management.

Given the vital role of water in public health and socio-economic development, the need for regular monitoring and comprehensive analysis of water quality parameters cannot be overstated

and has become paramount in safeguarding public health and ensuring sustainable environmental management. Water quality assessment typically involves the evaluation of physical, chemical, and biological characteristics to determine its suitability for various uses. Among these, physicochemical analysis provides critical information about the concentration of essential and potentially harmful constituents in water, the presence of pollutants, and the overall condition of the aquatic environment. Parameters such as temperature, pH, turbidity, total dissolved solids (TDS), dissolved oxygen (DO), electrical conductivity (EC), and major ions like nitrates, chlorides, phosphates, and sulphates serve as vital indicators of water quality and ecological health.

2.2 Concept of Water Quality

Water quality refers to the chemical, physical, and biological characteristics of water, usually in relation to its suitability for a particular purpose such as drinking, domestic use, recreation, agriculture, aquaculture, or industrial processes. Good water quality is essential for safeguarding public health, supporting ecosystems, and sustaining socio-economic development. The concept of water quality is based on the presence and concentration of various substances in water, some of which may occur naturally, while others result from human activities.

The quality and quantity of water, whether it be groundwater or surface water, have declined as a result of several significant factors, including urbanisation, industrialisation, and population growth. With the use of physicochemical, chemical, and biological factors, the water quality of any given location or source can be evaluated. If the values of these parameters exceed specified limitations, they are detrimental to human health. (Tyagi *et al.* ,2013). According to the World Health Organization (WHO, 2022), water intended for human consumption should be free from pathogenic microorganisms, toxic chemicals, and other harmful contaminants that may pose

health risks. Water that fails to meet these safety standards can lead to a range of health problems, including gastrointestinal infections, waterborne diseases, and long-term exposure risks associated with heavy metals and chemical pollutants. Certain components found in drinking water can lead to negative health effects, either from a single exposure such as in the case of harmful microorganisms or from prolonged exposure, as is often the case with various chemicals. The water used for drinking, as well as for municipal and industrial purposes, must comply with established standards. For example, the Environmental Protection Agency (EPA) has regulated over 90 contaminants in water to safeguard public health and prevent the spread of waterborne diseases. In industrial operations, it is often necessary to treat water to meet required quality standards for various essential applications. Water quality is assessed based on three main categories: physical, chemical, and biological parameters. Physical parameters include attributes such as color, taste, smell, temperature, turbidity, solid content, and electrical conductivity. Chemical parameters assess factors like pH, acidity, alkalinity, chlorine levels, water hardness, dissolved oxygen, and biological oxygen demand total dissolved solids (TDS). These chemical properties are crucial in determining the potential toxicity or suitability of water for various uses. These parameters are important because different uses of water require different quality levels. For instance, dissolved oxygen is a critical indicator of river water quality. A low level of dissolved oxygen typically suggests significant pollution, often due to organic substances that deplete the oxygen in the water (O'Donnell *et al.*, 2021).

Together, these parameters provide critical insights into the overall condition and safety of water for human and environmental use. Regular assessment of water quality not only helps to identify potential pollution problems but also ensures compliance with national and international water

quality standards, protecting public health and promoting sustainable water resource management.

2.3 Physicochemical Parameters of Water

Assessment of water quality index and monitoring of pollutants by physico-chemical analysis in water bodies: a review. International Journal of Engineering Research and Technology,

To determine whether water is safe for consumption, numerous parameters have been established to assess its quality for various purposes. Regular monitoring of these indicators not only helps in preventing health risks and environmental hazards but also aids in protecting water sources from further contamination. Water quality parameters are generally classified into three main categories: Physical parameters, Chemical parameter and Biological parameters

Physicochemical parameters are essential indicators used in assessing the quality of water for various purposes. These parameters encompass both physical and chemical properties of water, which together help determine its aesthetic appeal, safety, and overall suitability for domestic, agricultural, industrial, and recreational uses. Regular monitoring of physicochemical parameters is vital because deviations from established standards can have serious implications for human health, aquatic life, and environmental sustainability

Temperature is one of the most important physical parameters, as it influences the chemical and biological processes in water. It affects the solubility of gases, particularly dissolved oxygen (DO), and the rate of microbial activity and chemical reactions. Temperature affects several water characteristics, including taste, thickness (viscosity), solubility, odor, and chemical reactivity. As a result, important treatment processes like sedimentation, chlorination, and biological oxygen demand (BOD) are influenced by temperature. It also plays a role in the

biosorption of dissolved heavy metals in water. Generally, water is considered most pleasant to drink when its temperature is between 10 and 15°C. (Nayla Hassan *et al.*, 2019).

pH is a measure of the intensity of acidity or alkalinity in a solution, specifically reflecting the concentration of hydrogen ions present. It plays a critical role in influencing chemical and biological reactions, many of which occur within a narrow pH range. In natural waters, pH is typically slightly alkaline due to the presence of carbonates. High or low pH values are closely associated with total alkalinity and electrical conductivity. While pH itself does not directly pose health risks, extreme values can have indirect effects. A pH below 4 may result in a sour taste, while values above 8.5 can give water an unpleasant alkaline taste. Water with a pH lower than 6.5 may cause corrosion in pipes, leading to the leaching of toxic metals such as zinc (Zn), lead (Pb), cadmium (Cd), and copper (Cu). Additionally, low pH can damage equipment and reduce the effectiveness of disinfectants like chlorine. The World Health Organization (WHO) recommends that drinking water should have a pH between 6.5 and 8.5. Maintaining this range is also essential in water treatment processes and for preventing scale formation in heating systems (Nayar *et al.*, 2020).

Total Dissolved Solids (TDS) represent the total concentration of dissolved substances in water, including minerals, salts, and organic matter. Elevated TDS levels can impair water palatability, affect health, and interfere with industrial processes. This parameter assesses how much light can penetrate water and is influenced by the presence of suspended particles such as organic matter, silt, and clay. Commonly known as water turbidity, it reflects the water's cloudiness and includes both suspended and colloidal substances. These suspended particles can provide shelter for harmful microorganisms and serve as surfaces for the adsorption of toxic substances like heavy metals (e.g., lead, mercury, chromium, cadmium) and hazardous organic pollutants such

as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), among others.(Mahe *et al.* , 2024).

Electrical Conductivity (EC) measures water's ability to conduct electrical current, which correlates with the concentration of dissolved ions such as sodium, potassium, chloride, and sulphates. High EC values often indicate the presence of pollutants from agricultural runoff, sewage discharge, or industrial waste (Adefemi *et al.*, 2012). Conductivity is a numerical measure of a solution's ability to conduct an electric current, which depends on the presence of ions, their concentration, mobility, valence, and the temperature of the solution. It is typically expressed in micromhos per centimeter ($\mu\text{mhos/cm}$). Since conductivity is the inverse of electrical resistance, its unit is the "mho" (which is "ohm" spelled backward), commonly used as "micromho" for low-conductivity natural waters. Inorganic acids, bases, and salts generally exhibit high conductivity due to their abundance of free ions, making them effective conductors. In contrast, distilled water has very low conductivity—typically less than 1 $\mu\text{mho/cm}$ —due to the absence of dissolved ions (Gorde *et al.*, 2013).

Dissolved oxygen (DO) is critically important in assessing the overall health and quality of an aquatic system. It plays a vital role in supporting aquatic life, as it is essential for the survival of most organisms. Even when other chemical, physical, or biological data are unavailable, the measurement of DO can provide significant insight into water quality. The presence of dissolved oxygen helps determine whether aerobic or anaerobic processes will dominate. When DO levels are sufficient, aerobic organisms break down organic waste into harmless end products. However, when DO is lacking, anaerobic organisms take over, producing foul-smelling and potentially harmful byproducts. The amount of oxygen that can dissolve in water depends on factors such as temperature, salinity, and water movement. DO is typically measured using a titrimetric method.

In this method, dissolved oxygen reacts with manganous hydroxide to form a compound that, upon acidification, releases iodine equivalent to the oxygen present. This iodine is then titrated with a standard sodium thiosulfate solution using starch as an indicator. Maintaining adequate levels of DO is crucial, especially in receiving waters and during the aerobic treatment of sewage and industrial effluents. It ensures that waste is effectively broken down and prevents the formation of toxic or odorous decomposition products (Nayar *et al.*, 2020).

Biochemical Oxygen Demand (BOD) is one of the most commonly used parameters to assess the strength of municipal or organic industrial wastewater. It measures the amount of oxygen consumed by microorganisms during the breakdown (oxidation) of organic matter in the water. This includes both the oxidation of organic substances in sewage and the respiration required for microbial metabolism. The BOD value provides an estimate of the quantity of biodegradable organic material present in a water sample. The standard method for determining BOD involves measuring the dissolved oxygen content before and after a five-day incubation period at 20°C. According to the World Health Organization (WHO), a permissible BOD value for drinking water is 10.0 mg/L. (Nayar *et al.*, 2020).

Phosphorus is a vital nutrient required by living organisms, but when present in high amounts in surface waters, it can trigger excessive algae growth. This is often followed by decomposition, which reduces dissolved oxygen levels, causes eutrophication, and ultimately degrades water quality. In natural water systems, the soluble form of phosphorus is mainly orthophosphate, which exists in four species depending on the pH level: H_3PO_4 , H_2PO_4^- , HPO_4^{2-} , and PO_4^{3-} . As at 25°C, no more than two of these species coexist at any given pH. Soluble reactive phosphorus can also appear as organic phosphates or polyphosphates often originating from detergents which eventually hydrolyze into orthophosphates. Background levels of

orthophosphate in natural waters generally range between 0 and 0.01 mg/L. Beyond natural sources, phosphates can enter water bodies from identifiable sources like industrial discharges and inadequately treated sewage, as well as diffuse sources such as agricultural runoff (Warwick *et al.*, 2013).

Heavy metals such as cadmium and lead are of particular concern in water quality monitoring because of their toxicity even at low concentrations. Cadmium is a toxic heavy metal that can enter water through industrial waste, corroded pipes, and agricultural runoff. It accumulates in the body and causes kidney and bone damage. The WHO (2022) and NIS (2015) set the safe limit at 0.003 mg/L. Levels above this indicate contamination and potential health risk. Similarly, lead contamination typically results from corroded plumbing systems, battery recycling industries, and waste disposal. Lead is a potent neurotoxin that affects cognitive development in children, causes anemia, kidney damage, and elevates blood pressure in adults. The WHO recommends a guideline value of 0.01 mg/L for lead in drinking water to prevent adverse health outcomes.

These physicochemical parameters serve as critical tools for detecting pollution trends, identifying contamination sources, and guiding environmental management decisions. Their measurement provides a scientific basis for ensuring water quality complies with national and international safety standards, thereby protecting human health and promoting sustainable water use (NIS, 2015; WHO, 2022).

2.4 Factors Affecting Water Quality

The quality of water is influenced by a complex interaction of natural processes and anthropogenic (human-induced) activities. Understanding these factors is essential for effective water quality management, pollution control, and public health protection. Several physical,

chemical, biological, and socio-economic variables contribute to the variation in water quality across different regions and water bodies. Anthropogenic activities, however, remain the most significant contributors to water quality degradation, particularly in rapidly urbanizing and industrializing regions. Key human-induced factors include:

Agricultural practices: The excessive use of fertilizers, herbicides, and pesticides contributes to nutrient pollution, particularly nitrogen and phosphorus compounds such as nitrates and phosphates, which can infiltrate groundwater or be carried by surface runoff into nearby water bodies. This often results in eutrophication, promoting algal blooms and depleting dissolved oxygen levels, thereby threatening aquatic life. The growth of algae spreads across the water's surface, obstructing sunlight and aquatic plants' ability to produce oxygen. Reduced biodiversity results from the demise of plants and animals due to oxygen deprivation (Zahoor and Mushtaq 2023).

Industrial effluents: Industries release a variety of pollutants, including heavy metals like lead, cadmium, mercury, and arsenic, as well as organic chemicals and suspended solids into water bodies when waste is not properly treated. These contaminants can be highly toxic even at low concentrations and pose serious health risks when they enter drinking water supplies (WHO, 2022). Water is widely used in many different industrial applications because of its well-known universal solvent qualities. However, as human activities have continued to evolve, especially with industrialisation, large amounts of wastewater containing harmful compounds, especially heavy metals, have been produced. Numerous processes, including industrial operations like metal plating, electroplating, mining, battery manufacturing, printed circuit board (PCB) production, wood processing, petroleum refining, and textile and tannery industry operations, are responsible for the proliferation of these metals in water ecosystems. Along with the direct

release of materials Containing heavy metals into water bodies and unintentional spills or leaks, this issue is also influenced by chemical processes such as pipe corrosion and metal equipment deterioration (Oladimeji *et al.*,2024).

Urbanization and waste disposal: The growth of urban settlements without corresponding infrastructure for waste leads to the indiscriminate dumping of domestic and commercial waste into drainage systems, streams, and rivers. Leachates from open dumpsites and landfills can infiltrate groundwater or enter surface water sources, introducing bacteria, viruses, and toxic substances into the water .Managing waste generated by human activities is a common issue in urban areas. In many developing countries like Nigeria, the drive for socio-economic development has led to the establishment of landfills that are often poorly designed and inadequately constructed. These waste disposal sites frequently become direct sources of environmental contamination, affecting the chemical composition, geological stability, and hydrogeological systems in the area. Over time, dumpsites experience biological and chemical transformations, which further contribute to the pollution of nearby aquifers waste is mainly disposed of through open dumping, unregulated landfills, and incineration. When it rains, water seeps through these dumpsites, carrying toxic substances and pollutants into the surrounding soil, surface water, and underground water. These contaminants may also be taken up by plants growing around the site, thereby posing serious risks to both human health and the environment (Odukoya and Abimbola, 2010).

Mining activities: The exploration and extraction of mineral resources generate large volumes of wastewater containing heavy metals, suspended solids, and acid mine drainage. These contaminants adversely affect both surface and groundwater quality, with implications for aquatic ecosystems and human health (Adekunle *et al.*, 2007).

Climate change: Increasing global temperatures, changes in rainfall patterns, and extreme weather events like floods and droughts directly affect water availability and quality. Prolonged dry seasons reduce the volume of water bodies, concentrating pollutants, while heavy rains increase runoff, erosion, and sediment transport (WHO, 2017). Climate change refers to the disruption of the normal patterns of rainfall and temperature within a region. On a global scale, it poses serious health risks, especially in developing countries. Research has identified human activities such as industrialization, population growth, deforestation, and bush burning as primary contributors to climate change. In various parts of the world, its impacts include increased temperatures, abnormal rainfall, flooding, prolonged droughts, and extreme heatwaves. These changes facilitate the buildup of pollutants including heavy metals, agrochemicals, and microorganisms in water bodies worldwide (Egbueri *et al.*, 2023). Climate change is a global crisis marked by rising temperatures, altered rainfall patterns, and an increase in the frequency and intensity of extreme weather events. These changes significantly affect water resources, including both their availability and quality. Regions experiencing prolonged droughts may face severe water shortages, while areas with intense rainfall may encounter increased flood risks. Shifting precipitation patterns and elevated temperatures contribute to water scarcity in some regions and flooding in others. These extremes can compromise freshwater quality and pose threats to agriculture, drinking water supplies, sanitation, and overall public health.

Flooding may damage water and sanitation infrastructure, leading to the spread of waterborne diseases such as cholera, typhoid, and dysentery, often caused by harmful microorganisms present in contaminated water. On the other hand, droughts can concentrate pollutants and pathogens in limited water supplies, further increasing health risks. Contaminants like chemicals

and pathogens become more prevalent, endangering communities, especially in vulnerable regions (Omoregie and Okoro 2024).

These factors often act in combination, making water quality a dynamic and complex issue that requires continuous monitoring and adaptive management strategies. Recognizing and addressing both natural and human-induced factors is crucial for protecting water resources and ensuring the provision of safe drinking water for populations, particularly in vulnerable areas such as Ikpoba-Okha Local Government Area of Edo State.

2.5 Overview of Water Sources in Ikpoba-Okha

Water is an indispensable natural resource derived from various sources to meet human, industrial, agricultural, and ecological needs. In Nigeria, water sources can broadly be categorized into surface water, groundwater, rainwater harvesting, and treated piped water systems. However, access to safe and reliable water varies significantly between urban, peri-urban, and rural communities.

2.5.1 Surface Water

Surface water refers to water bodies such as rivers, lakes, streams, ponds, and reservoirs that are exposed on the earth's surface. In Nigeria, rivers remain a major source of water for domestic use, irrigation, fishing, and sometimes for industrial processes. Notable rivers in Nigeria include the Niger, Benue, Ogun, and Kaduna Rivers, among others.

In Edo State and specifically in Ikpoba-Okha LGA, Ikpoba River serves as a significant surface water body utilized for various purposes including bathing, washing, irrigation, fishing, and in some cases, for domestic consumption after informal treatment. Unfortunately, surface water

sources are highly vulnerable to contamination due to their exposure to direct human and environmental activities such as:

- Agricultural runoff carrying pesticides, fertilizers, and animal waste
- Industrial effluents discharged without adequate treatment
- Domestic sewage and solid waste disposal
- Surface runoff during rainfall, carrying urban and roadside pollutants

2.5.2 Groundwater

Groundwater refers to water located beneath the earth's surface, stored in soil pore spaces and in the fractures of rock formations. It is commonly accessed through boreholes, wells, and springs. In Nigeria, groundwater remains a critical source of drinking water, particularly in rural and peri-urban areas where public water supply infrastructures are inadequate.

In Ikpoba-Okha LGA, boreholes and hand-dug wells are prevalent in residential communities, markets, schools, and places of worship. Groundwater is generally considered safer than surface water because it is naturally filtered through layers of soil and rock. However, studies (Edokpayi *et al.*, 2018) have revealed that groundwater sources are increasingly susceptible to contamination from:

- Leachates from improperly managed refuse dumps
- Septic tank seepage
- Agricultural chemicals infiltrating through the soil
- Industrial and oil-related activities
- Naturally occurring minerals such as iron and manganese at elevated levels

These contaminants can result in elevated Total Dissolved Solids (TDS), Electrical Conductivity (EC), nitrate, and coliform bacteria levels in groundwater.

Groundwater refers to water that exists beneath the Earth's surface, filling the pores and fractures in soil, sand, and rock. It is stored in natural underground reservoirs known as aquifers and can be accessed through wells, emerge naturally as springs, or discharge into lakes and rivers. Although hidden underground, groundwater plays a crucial role in maintaining surface water systems by replenishing streams and rivers. This underground water is renewed through a process called recharge, which occurs when rainfall or melted snow infiltrates the soil and percolates down to the aquifers. Approximately 22% of the Earth's freshwater is found as groundwater, and around 97% of that is available for human use. It serves as an essential resource for drinking, irrigation, and industrial purposes, particularly in regions lacking developed piped water systems or with limited and unreliable surface water. Benin City, Nigeria, is one such area where groundwater remains a critical water source (Rawlings *et al.*, 2024).

2.5.3 Public and Piped Water Supply

In urban areas of Nigeria, municipal water supply systems managed by state water corporations aim to provide treated water through piped distribution networks. In Edo State, the Edo State Urban Water Board is responsible for public water supply services. However, the inefficiency and limited coverage of public water supply infrastructure have led to a reliance on alternative sources in Ikpoba-Okha LGA and other peri-urban areas.

The piped water systems, where functional, derive their water from surface water bodies like the Ikpoba River and underground reservoirs, which are treated through waterworks before distribution. Challenges facing public water supply in the region include:

- Aging and inadequate infrastructure
- Frequent power outages affecting water treatment and distribution
- Limited financial resources for maintenance and expansion
- Water quality concerns due to occasional lapses in treatment standards

2.6 Health Implications of Poor Water Quality

Poor water quality has been identified as a major factor responsible for waterborne diseases and outbreaks, many of which are preventable through proper water treatment and management practices. Contaminated water poses a wide range of health risks, which can be either immediate or long-term, depending on the type of pollutants, the level of contamination, and the length of exposure. Waterborne illnesses often lead to gastrointestinal issues, dehydration, and potentially fatal conditions, especially among vulnerable groups like young children, the elderly, and those with compromised immune systems. Prolonged exposure to certain harmful substances in water can result in damage to vital organs, developmental delays, reproductive health issues, and a heightened risk of cancer (Babuji *et al.*, 2023).

Chemical contamination of drinking water also presents serious health hazards. Substances such as nitrates, arsenic, lead, cadmium, and other heavy metals are toxic even at low concentrations and can accumulate in the body over time, leading to chronic health effects. High levels of nitrates, often originating from agricultural runoff and sewage contamination, can cause methemoglobinemia or “blue baby syndrome” in infants, a condition that impairs the blood’s ability to carry oxygen. Long-term exposure to arsenic in drinking water is associated with skin lesions, cancers (skin, lung, bladder), cardiovascular disease, and developmental effects. Similarly, lead exposure through water consumed from corroded pipes or contaminated sources

can impair cognitive development in children, cause anemia, kidney damage, and elevate blood pressure in adults

In recent years, environmental pollution caused by heavy metals has emerged as a significant global concern. Despite widespread awareness of their long-lasting and harmful health effects, heavy metal exposure continues to rise in various regions around the world. Due to ecological, nutritional, evolutionary, and environmental factors, heavy metals are recognized as major pollutants with growing toxicological importance. These metals enter aquatic environments both through natural processes and human activities. Common sources include soil erosion, the natural weathering of rocks, mining operations, industrial discharges, urban runoff, sewage release, and the use of pesticides and herbicides in agriculture. Contaminated water from such sources is often used for domestic purposes like drinking, cooking, and bathing, as well as for irrigating crops. This can result in heavy metal accumulation in the food chain and direct exposure in humans, leading to metal poisoning. Use of such polluted water for bathing and laundry may also cause skin infections and allergic reactions.

Humans are primarily exposed to heavy metals by consuming contaminated water. Toxic metals like lead, mercury, cadmium, and copper are particularly hazardous and contribute significantly to environmental degradation. These elements induce oxidative stress in cells and are linked to a range of serious health conditions, including cancer. Prolonged exposure can result in neurological damage, developmental disorders, cerebral palsy, lung cancer, digestive issues, skin diseases, and even fetal death (Lawal *et al.*.,2021).

Groundwater pollution poses significant risks to human health, aquatic life, and vegetation. Previous research indicates that in certain areas, using such water for irrigation can lead to issues like soil salinity or sodicity, resulting from high salt levels and elevated sodium concentrations

relative to other elements. Some water sources may be acceptable for irrigation but unsuitable for drinking or industrial use due to the presence of toxic levels of certain ions.

In agriculture, contaminated irrigation water can negatively affect soil quality, crop health, and overall water management. The suitability of groundwater for irrigation often depends on the specific crop, as different crops have varying water and nutrient needs. Water that is suitable for one type of crop may be harmful to another. Irrigating with poor-quality water can reduce crop yields and degrade soil structure. Furthermore, high concentrations of calcium and magnesium can lead to clogging of drip irrigation systems, (Al-Tabbal and Al-Zboon 2012). Economic and agricultural sectors may suffer decline due to human-induced activities that lead to water pollution. The contamination of surface water is often associated with increased fish mortality, and since fish play a crucial role in the aquatic food chain, this can negatively affect the income and survival of individuals who rely on fishing for their livelihood. Additionally, the use of polluted water for irrigation poses significant health risks and may lead to reduced crop yields. Consequently, water pollution can have far-reaching negative effects on agriculture and the broader economy.

The application of various agrochemicals such as pesticides, fungicides, avicides, nematicides, and fertilizers to combat pests and enhance soil fertility and crop yield can negatively impact the environment when misused or over-applied. Over time, concerns have grown regarding the persistence of these chemicals and their residues in the soil. These substances often seep into groundwater through irrigation or rainfall, which carries dissolved compounds below the soil surface. Nitrate contamination, primarily from agricultural activities, is the most frequently reported chemical pollutant in groundwater aquifers worldwide. When nitrate levels in

groundwater exceed 45 mg/L, it indicates contamination. Elevated nitrate concentrations pose serious health risks and are therefore a major environmental concern.

In recent decades, significant research has focused on how nitrates leach from agricultural land. Common sources of groundwater nitrate pollution include industrial waste, faulty septic systems, broken sewer lines, poorly constructed wells, synthetic nitrogen-based fertilizers, fungicides, irrigation runoff, and livestock manure. High nitrate and nitrite levels in drinking water can lead to methemoglobinemia in infants; a condition where excess methemoglobin (over 10%) reduces oxygen delivery in the blood, resulting in cyanosis, commonly known as “blue baby syndrome.”

Nitrate toxicity has been associated with various health problems such as neural tube defects, genetic abnormalities in children, oral cancer, multiple sclerosis, digestive issues, gastrointestinal cancers, brain tumors in both adults and children (as shown in case-control studies), stomach and esophageal cancers, and thyroid disorders. The most effective way to control nitrate levels—especially in groundwater is to prevent contamination in the first place. This can be achieved through careful placement of pit latrines and septic tanks, along with the responsible management of agricultural practices (Balogun *et al.*, 2022).

Total Dissolved Solids (TDS) in drinking water can come from natural geological formations, sewage discharge, urban surface runoff, and industrial effluents. The concentration of TDS varies widely between regions due to differences in mineral solubility in the environment. Water with TDS levels below 600 mg/l is typically considered to have a pleasant taste, while levels above 1000 mg/l can make the water taste unpleasant. Additionally, high TDS content may cause issues for consumers by promoting scale buildup in water pipes, boilers, heaters, and household appliances (Bernard and Ayeni 2012). Higher TDS wastewater released into bodies of water may cause the water to become more salinised, thus rendering it unsuitable for drinking and irrigation.

It has been observed that drinking water with high TDS can lead to adverse effect on the respiratory, neurological, coronary, and alimentary canal systems in addition to Cancer and miscarriage (Singh *et al.*.,2020).

Furthermore, poor water quality affects food safety and nutrition. Water contaminated with pathogens or chemicals used in food preparation and agriculture increases the risk of transmitting diseases through crops and livestock. Irrigation with polluted water contributes to the accumulation of harmful substances in edible plants, while livestock consuming contaminated water may also carry pathogens or toxic substances into the human food chain (WHO, 2017).In the context of Nigeria, several studies have highlighted the health risks associated with unsafe water sources (Orebiyi *et al.*, 2010) reported that shallow wells and surface waters in several Nigerian communities exhibited high levels of bacterial contamination, turbidity, and chemical pollutants, posing severe risks of waterborne diseases. Similarly, (Adekunle *et al.*, 2007) found that rural populations depending on untreated groundwater sources faced increased incidences of typhoid fever, diarrhea, and parasitic infections.

2.7 Regulatory Standards and Guidelines

Governments and international organisations have created and/or ratified international treaties, guidelines, rules, and policy initiatives as means of bringing environmental protection and sustainable development to life. The Stockholm Water Declaration (1991), the World Health Organization's (WHO) Guidelines for Drinking Water Quality and Water Safety Plans (WSPs), and the United Nations Sustainable Development Goal 6 (SDG 6) are the most dependable international environmental tools used for drinking water safety regulations. As a signatory to several UN environmental treaties and projects, Nigeria has used these instruments to formulate

national policies, guidelines, and action plans that govern, guarantee fair access, and safeguard water resources in order to satisfy the demands of the populace (Ijioma *et al.*,2025).

2.8 Water Quality Management and Recommendations

Effective water quality management involves regular monitoring, public awareness campaigns, proper waste disposal, and the implementation of water treatment facilities. Government agencies, non-governmental organizations, and community leaders play vital roles in promoting safe water practices. Recommendations by WHO (2022) and NIS (2015) include the establishment of water safety plans, routine water quality assessments, and the provision of alternative water sources in areas with persistent contamination issues Proper solid and liquid waste disposal significantly reduces the risk of water contamination. Communities should be encouraged to adopt environmentally friendly waste management practices, such as recycling, composting, and safe sewage disposal. For industrial areas, strict enforcement of effluent treatment regulations is critical to prevent toxic discharges into water bodies.

Given the variety of residential uses for unclean water, this community's health issue needed to be given careful consideration. Diseases associated with drinking water constituent contamination pose a serious threat to human health, and measures to enhance drinking water quality have a substantial positive impact on human health. Therefore, health authorities should promote in-house treatment of the raw water and educate the public about the possible risks of utilising untreated water as a drinking source. Furthermore, it is strongly advised that the population be continuously monitored prior to drinking this home water in order to guarantee everyone's safety and well-being (Adesakin *et al.*, 2020).

Treating a portion of the water before reintroducing it into treatment facilities is the most efficient method of lowering water pollution because these facilities are capable of eliminating almost all contaminants from the rivers. Because wastewater is treated using a chemical, physical, or biological method, this is a very successful option (Omokaro *et al.*, 2024).

For the sustainable management of water resources, water bodies, and the ensuing spread of diseases linked to water. A agricultural extension officer should help farmers apply fertiliser. The Ministry of Food and Agriculture must conduct pesticide residue analysis in order to prevent the occurrence of large nutrient loads in surface waters, as farmers in the basin use significant amounts of pesticides, nematodes, fungicides, and herbicides to control a range of pests and diseases. To improve better management of these agrochemicals, district assembly should develop cleanliness programs and spread them through environmental education in the communities in the river basin (Karikari and Ansa-Asare 2006).

CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY AREA

The study was conducted in Ikpoba-Okha Local Government Area (LGA) of Edo State, located in the southern region of Nigeria. Ikpoba-Okha lies within the Benin metropolitan area and comprises both urban and rural settlements. The area experiences a tropical climate with a distinct wet and dry season. Water sources commonly used in this LGA include hand-dug wells, boreholes, and tap water connected to public mains. Due to population growth and inadequate infrastructure, residents often rely on multiple water sources for domestic purposes.



**Figure 3.1: Map of study area showing Ikpoba-Okha Local Government Area,
Edo State, Nigeria**

The map above shows the location of Ikpoba-Okha Local Government Area (LGA) in Edo State, Nigeria. It is situated approximately at latitude 6.3509° N and longitude 6.4695° E. The area lies within the humid tropical zone, characterized by high rainfall and temperature variations between 25°C and 30°C. Residents depend on different water sources such as boreholes, hand-dug wells, rivers, and public taps. The map also indicates the sampling points where water samples were collected for physicochemical analysis.

3.2 Study population

The study population for this research comprises the residents of Ikpoba-Okha Local Government Area (LGA) in Edo State, Nigeria. The LGA includes communities such as Idogbo (the headquarters), Evbuomodu, Uwusan, Obazagbon, Agedo, and several others. According to the 2006 Nigerian National Population Census, Ikpoba-Okha had a population of 372,080 people. More recent projections estimate that the population has grown, with figures around 549,700 as of 2022. The area of Ikpoba-Okha LGA is approximately 807.6 square kilometres. This population forms the base for the study because the water from different sources (tap water, river water, hand-dug wells) serves the people living in these towns and villages. Sampling of water reflects the water quality to which this population is exposed.

3.3 Inclusion Criteria

The inclusion criteria for this study were as follows:

- Type of water source: Only commonly used domestic water sources within Ikpoba-Okha LGA were included, namely tap water, hand-dug wells, and river water, since they represent the major supply options available to residents.
- Accessibility: Water sources that were readily accessible and actively used by the local population for drinking, cooking, or domestic purposes were selected.

- Population relevance: Water sources that directly serve the inhabitants of Ikpoba-Okha communities, ensuring that the findings reflect the quality of water consumed by the majority of the population.
- Geographical coverage: Sampling points were chosen to cover different areas of the LGA (urban, peri-urban, and rural), to capture variability in water quality.
- Condition of source: Only functional water points (e.g., active wells and flowing taps) were included, while abandoned or non-functional sources were excluded.

3.4 Exclusion Criteria

The following water sources were excluded from the study:

- Abandoned or non-functional sources: Water points such as dry wells, broken taps, or non-flowing rivers were not sampled.
- Commercially packaged water: Sachet (“pure water”) and bottled water were excluded since they undergo industrial treatment and do not directly represent natural or community-based sources.
- Sources not used for domestic purposes: Water bodies meant exclusively for industrial activities, irrigation, or recreational purposes were excluded as they are not consumed by residents.
- Contaminated containers or improper access points: Sampling was not carried out at sources where water collection points were visibly contaminated (e.g., dirty buckets, unsealed tanks) to avoid bias from secondary contamination.
- Duplicate or overlapping locations: Water points within the same immediate compound or neighborhood that shared the same source (e.g., multiple taps from one borehole) were avoided to ensure diversity of sampling.

3.5 Sample Collection

3.5.1 Sampling Locations and Sources

Water samples were collected from three major sources:

- Hand-dug wells
- River(2 samples)
- Public tap water (2 samples)

A total of 5 samples were collected — 2 from each source and One from the River across five selected location in Ikpoba-Okha LGA.

3.5.2 Sampling Procedure

- Water was allowed to run or be fetched for 2–3 minutes before sampling to ensure flushing of stagnant water.
- 500 mL pre-cleaned polyethylene bottles were used for each sample.
- Each bottle was rinsed thrice with the water from the sampling point before final collection.
- Samples were labeled with date, time, location, and source type.
- Samples were filled without air gaps to prevent oxidation.
- For DO and BOD, separate dark glass bottles were used, tightly capped and sealed immediately after collection.
- Preservations for heavy metal analysis was done by adding a few drops of concentrated nitric acid to reduce the pH to <2.
- All samples were immediately stored in a cooler box with ice packs (4°C) and transported to the laboratory within 6 hours of collection.

3.6 Administration of Questionnaire

In addition to water sample analysis, structured questionnaires were administered to households and water users in selected communities within Ikpoba-Okha LGA. The questionnaire was designed to collect information on the sources of water commonly used, frequency of use, awareness of waterborne diseases, and local water treatment practices. Respondents were randomly selected from households relying on tap, well, and river water. The responses provided supplementary data to support laboratory findings and to better understand the community's perception and practices regarding water quality and safety.

3.7 Method of Data Analysis

The results obtained from the physicochemical analysis of water samples were presented in tables and compared directly with the permissible limits set by the World Health Organization (WHO, 2017) and the Nigerian Industrial Standard (NIS, 2015). The comparisons were used to determine whether the water sources (tap, well, and river) met acceptable standards for safe drinking water.

3.8 Analytical methods

Procedures

3.8.1PH

The pH of the samples will be determined using a pH meter. The value of each sample will be taken after submerging the pH probe in the water sample and holding for a couple of minutes to achieve a stabilized reading. (Singh et al.,2012).

3.8.2 Temperature

The Temperature of the samples will be determined a using a thermometer. The value of each sample will be recorded after submerging the meter in the sample and holding for a few minutes.

3.8.3 Electrical Conductivity

Apparatus: beakers

Equipment: Digital Conductivity meter

Reagent: 0.01M KCl

Preparation of reagent: to prepare 0.01M KCl, dissolve 0.07g KCL in 100ml water.

Procedure:

- The digital conductivity meter is switched on and allowed to warm for 15 minutes.
- 0.01M KCl is used to standardize the digital conductivity meter and a conductivity value of $1413\mu\text{s}/\text{cm}$ was obtained.
- After standardization, the electrode is thoroughly rinsed with distilled water
- The electrode is introduced into the liquid sample
- Note the value for each sample.

Bennet and David (1974)

3.8.4 Total Dissolved Solid

Equipment: TDS meter

Apparatus: Beaker.

Procedure:

- The TDS meter is switched on and allowed to warm for 15 minutes
- The electrode is rinsed thoroughly with distilled water
- It is then introduced directly into the sample
- The value of sample is taken.

3.8.5 Total Solid

Equipment: Water bath and oven

Apparatus: evaporating dish and desiccator

Procedure:

- Weigh the evaporating dish.
- Heat the evaporating dish and cool in a desiccator
- Re-weigh the evaporating dish to ensure it has attained a constant weight.
- 20ml of the sample is evaporated to dryness in a boiling water bath.
- The residue is dried at 1050C for 2-3 hours in an oven.

Calculation: total solid (mg/l) = weight of residue × 50

Where: weight of residue= weight of evaporating dish and residue – weight of evaporating dish

3.8.6. Total Suspended Solid

Equipment: Water bath, oven

Apparatus: desiccator, whatman filter paper, funnel and volumetric flask.

Procedure:

- Weigh the whatman filter paper
- 20ml (in case of solid, 1g dissolve in 20ml water) is filtered using a filter paper
- Dry the residue in an oven at 105°C for 1 hour
- Cool in a desiccator and weigh together with the filter paper.

Calculation:

$$\text{TSS} = \frac{\text{Dry weight of residue and filter paper} - \text{Weight of filter paper}}{\text{Ml of sample}} \times 1,000,000$$

3.8.7 Titratable Acidity

Apparatus: Measuring cylinder, Conical flask, Burette, Retort stand

Reagent: 0.1M NaOH, Phenolphthalein

Preparation of Reagent:

To prepare 100ml of 0.1M NaOH; 0.4g NaOH is dissolved in 100ml of distilled water

Procedure:

- 50ml of sample is pipetted into a clean 250ml conical flask.
- 2 drops of phenolphthalein is added.
- The solution is titrated against the prepared 0.1M NaOH to get a pink end point.
- The titre value is recorded

Calculation:

$$\text{Acidity (mg/l)} = \frac{V1 \times N \times 75}{V2}$$

Where;

V1 = Titre value of Sodium Hydroxide used

N = normality of Sodium Hydroxide used

V2 = milliliter of sample used (in this case 50ml)

American society for testing and materials (1982)

3.8.8 Biochemical/Biological Oxygen Demand

Apparatus: 300ml dissolved oxygen bottle, beakers, burette, retort stand

Reagents: Alkali iodide azide, Conc. Phosphoric acid H₃PO₄, 0.025M Sodium thiosulphate, Starch indicator, Manganese sulphate.

Procedure:

- Take out two 300ml dissolve oxygen bottle
- 10ml of sample is gently poured into two dissolve oxygen bottle, the bottle filled to the brim with dilution water, with care taken to minimize contact with air.
- Immediately close the bottles.
- Mark the bottles as sample 1 and 5.
- One sample is incubated in the dark for 5 days
- Take the remaining one sample then analyze in the following manner

- 1ml of alkali iodide azide solution and 1 ml of manganese sulphate solution will be added to the different bottles and corked tightly with a stopper.
- It is shaken and allowed to settle.
- When the precipitate has settled, the clear liquid (supernatant) will be decanted and discarded.
- 2ml of Conc. Phosphoric acid and some water is added to dissolve the precipitate.
- A few drops of starch indicator is added which gives a blue colouration
- It is then titrated against 0.025M sodium thiosulphate solution until solution becomes clear. Titre value is recorded D1
- On the 5th day, 1ml of alkali iodide azide solution and 1ml of manganese sulphate solution will be added and corked tightly with a stopper.
- It is shaken and allowed to settle.
- When the precipitate has settled, the clear liquid (supernatant) will be decanted and discarded.
- 2ml of Conc. Phosphoric acid and some water is added to dissolve the precipitate.
- A few drop of starch indicator is added which gives a blue colouration
- It is then titrated against 0.025M sodium thiosulphate solution, until solution becomes clear. Titre value is recorded. D2

Calculation:

$$\text{BOD} = \frac{\text{D1} - \text{D2}}{\text{P}}$$

Where;

P = decimal fraction of waste water sample used i.e $10/300=0.033$

3.8.9 Chemical Oxygen Demand

Equipment: Water bath

Apparatus: Beakers, volumetric flask, measuring cylinder.

Reagents: 0.1M potassium dichromate, 0.1M sodium thiosulphate, 2M sulphuric acid, 1% starch solution, 10% potassium iodide

Procedure:

- Take 10ml of water sample into a flask
- Add 5ml of potassium dichromate solution
- Heat the flask in a water bath at 100°C for 1 hour.
- Allow the sample to cool for 10mins.
- Add 5ml potassium iodide
- Add 10ml sulphuric acid
- Titrate the content with 0.1M sodium thiosulphate till colour changes to pale yellow colour.
- Add starch solution indicator which gives a blue colouration.
- Titrate again with 0.1M sodium thiosulphate until blue colour disappears completely.
- Make blank preparation in the same manner as sample using distilled water instead of sample and record titre value for blank.
- Do both sample and blank in triplicate and take average.

Calculation:

$$\text{COD (mg/l or ppm)} = \frac{0.1M \times 8 \times (\text{sample titre} - \text{blank titre})}{\text{Volume of sample (10ml)}}$$

3.8.10 Hardness

Reagents: Erichrome Black T (EBT) Indicator, NH₃ Buffer, 0.05M EDTA

Procedure:

- Take 50ml of the sample.
- Add 10ml of NH₃ buffer.
- Add few drops of EBT indicator which makes the colour of the solution to be wine/red.
- Titrate the solution with 0.05M EDTA.

Note: The final colour (blue) and record the titre value.

3.8.11 Determination of Phosphorus

Apparatus: 50ml volumetric flask, 10ml pipette, 752N UV-Vis Spectrophotometer

Reagents:

Dissolve 12g of Ammonium Molybdate in 250ml of water In 100ml of water, dissolve 0.2908g Antimony potassium tartrate.

2.5M H₂SO₄: Make 872.7ml of conc. H₂SO₄ to 1liter.

Add the ammonium molybdate and antimony potassium tartrate to 1000ml of 2.5ml H₂SO₄; mix thoroughly, make to 2000 ml and store in plastic container in a cool dark compartment.

Dissolve 0.53g of Ascorbic Acid in 200ml of reagent (P developer) (v) above. Prepare this mixture as required since it does not keep for more than 24 hours.

0.25 % p-Nitrophenol.

2M HCL: 40ml of the 5M HCL in 100ml solution.

2M NH₄OH: 13.6ml of conc. NH₃ solution in 100ml flask and make up to mark with water.

P-Standard Stock (100ppm)

Dissolve 0.4394g of KH₂PO₄ in water and make to 1 litre. Pipetting 0, 1, 2, 3, 4 and 5ml from the 100ml stock solution prepare intermediate standards of 0, 2,4,6,8, and 10ppm each in 50ml flask.

Procedure

Pipette 5ml of the filtrate or supernatant into a 50ml flask, Adjust the pH of the solution to 5 as follows: Add 3 drops of the p-nitrophenol, If a yellow colour is obtained, add some drops of 2M NH₄OH until yellow. Then, add 2M HCL drop-wise until colourless (the pH is now between 3 and 5). Add water to 30ml, then add 10ml of the Ascorbic Acid reagent. Make to volume and read spectrophotometrically at 660nm.

Note: The colour is stable for 2 hours and maximum intensity is obtained in 10 minutes.

The Antimony Potassium Tartrate hastens the colour development and obviates the use of heating.

Calculation

$$P \text{ (ppm)} = \frac{\text{Instr. Reading} \times \text{Slop Recip.} \times \text{Colour Vol.}}{\text{Aliquot Taken}}$$

3.8.12 Atomic Absorption Spectrophotometer (AAS)

Atomic absorption spectrometry is widely used for the determination of Heavy Metals and some cations in environmental analysis. The source of radiation is a Hollow lamp, which contains a Cathode constructed of same metals as that being analysed. The light emits the wavelength

characteristic of the metal; and a different lamp is required for each metal. The light from the lamp is directed through a flame and onto monochromator, which selects the preferred analytical wavelength. The light monochromator is detected by a photomultiplier tube and converted to an electrical signal. The sample is aspirated in the flame where the solution is evaporated and the metal –containing compounds are volatilized and dissociated into ground state atoms. The ground state atoms absorb the radiation from the hallow lamp and excited to higher energy levels. Some atoms are also thermally excited but their fraction is so small that it causes no error in the analysis. An acetylene-air flame used.

Table 3.8.13: Attached here is a list of some Heavy Metals and some Cations with their wavelengths and currents of their Lamps

Lamp Name/Element	Wavelength (nm)	Lamp Current (mA)
Cadmium	228.8	8
Chromium	357.8	10
Lead	217.0	10

Table 3.8.13 presents the wavelengths and lamp currents used for detecting selected heavy metals and cations during atomic absorption spectrophotometric (AAS) analysis. These parameters were optimized to ensure accurate identification and quantification of each element in the water samples.

3.9 Quality Control and Quality Assurance

- All equipment was calibrated before use.
- Blanks and standards were analyzed alongside samples to ensure accuracy.
- All tests were conducted in triplicate, and average values were reported.
- Reagents were of analytical grade and prepared using distilled water.



Plate 3.1: Cleanly labeled sample bottles containing tap, river, and Hand-dug well water collected for physicochemical analysis



Plate 3.2: Evaporating dishes containing water samples collected from tap, Hand-dug well, and river sources for physicochemical analysis.

CHAPTER FOUR

RESULT

This chapter presents the results obtained from the physicochemical analysis of water samples collected from different sources, boreholes, hand-dug wells, and tap water in Ikpoba-Okha Local Government Area (LGA), Edo State. The results are compared with the World Health Organization (WHO, 2022) and Nigerian Industrial Standards (NIS, 2015) guideline values for drinking water.

Table 4.1: Results of Physicochemical Analysis of drinking Water Samples from Tap, Hand dug Well, and River Sources in Ikpoba-Okha LGA, Edo State

	TAP WATER(1)	TAP WATER (2)	WELL WATER(1)	WELL WATER(2)	RIVER WATER
PH	3.93	3.92	4.67	4.66	5.98
	3.86	3.89	4.65	4.56	5.95
	3.85	3.86	4.63	4.54	5.95
TEMPERATURE (°C)	25.7	25.4	24.2	25.6	25.3
	25.5	25.5	24.2	25.7	25.3
	25.7	25.5	24.2	25.7	25.3
TOTAL DISSOLVED SOLID (ppm)	0058	0092	0047	0085	0017
	0067	0093	0058	0086	0017
	0068	0094	0046	0086	0018
ELECTRICAL CONDUCTIVITY	0196	0202	0170	0172	0034
	0198	0204	0170	0172	0034
	0200	0206	0172	0172	0034
TOTAL TITRATABLE ACIDITY mg/L	0.175	0.105	0.075	0.120	0.060
	0.105	0.120	0.090	0.165	0.060
	0.090	0.105	0.075	0.120	0.060
TOTAL SOLIDS	5.0	7.5	8.5	10	12.5
	6.0	7.0	7.5	9.5	11.5
	5.5	7.5	7.5	8.5	13.0

Table 4.1 shows the pH, temperature, TDS, EC, TTA, and TS values of tap, well, and river water samples in Ikpoba-Okha LGA, with slight variations due to environmental and human factors.

Table 4.2: Results of Physicochemical Analysis of drinking Water Samples from Tap, Hand dug Well, and River Sources in Ikpoba-Okha LGA, Edo State

		TAP WATER(1)	TAP WATER(2)	WELL WATER(1)	WELL WATER(2)	RIVER WATER
CHEMICAL OXYGEN DEMAND mg/L		0.096	0.64	0.64	0.040	0.048
		0.088	0.72	0.56	0.032	0.064
		0.080	0.72	0.48	0.056	0.048
HARDNESS mg/L		10.51	3.50	2.50	3.50	9.51
		12.51	4.50	3.50	3.0	10.51
		11.51	4.0	3.0	80	10.51
PHOSPHATE		18.57	58.57	47.14	80	115.23
		22.85	51.91	51.43	73.81	110.95
		20.0	56.19	49.52	76.19	112.86
BIOCHEMICAL OXYGEN DEMAND		24.24	18.18	27.27	15.15	15.15
		30.30	18.18	24.24	21.21	12.12
		24.24	18.18	21.21	12.12	15.15
TOTAL SUSPENDED SOLIDS (ppm)		1000	1000	1000	1000	1500
		1500	1500	500	1500	1500
		1500	2000	1000	1000	2000

Table 4.2 shows physicochemical parameters of tap, well, and river water in Ikpoba-Okha LGA, mostly within WHO (2017) and NIS (2015) limits, though BOD and TSS slightly exceeded permissible levels.

Table 4.3: Results of Physicochemical Analysis of drinking Water Samples from Tap, Hand dug Well, and River Sources in Ikpoba-Okha LGA, Edo State

CODE	PB	CR	CD
RIVER	0.008	0.010	0.003
	0.009	0.011	0.003
	0.008	0.011	0.002
TAP WATER (1)	0.016	0.018	0.013
	0.014	0.018	0.012
	0.014	0.018	0.012
TAP WATER (2)	0.011	0.015	0.009
	0.012	0.015	0.009
	0.012	0.014	0.009
WELL WATER(1)	0.010	0.013	0.008
	0.010	0.011	0.008
	0.009	0.011	0.007
WELL WATER(2)	0.010	0.013	0.006
	0.010	0.013	0.006
	0.011	0.011	0.005

Table 4.3 shows concentrations of lead, chromium, and cadmium. Cadmium in tap and well water exceeded WHO (2017) and NIS (2015) limits (0.003 mg/L), indicating contamination, while chromium and lead remained within safe limits.

Table 4.4: WHO (2022) and NIS (2007) Permissible Limits for Physicochemical Parameters of Drinking Water

	WHO STANDARD	NIC STANDARD	HEALTH IMPACT
PH	6.5-8.5	6.5-8.5	Low pH causes corrosion of pipes; high pH affects taste and reduces disinfection efficiency.
TEMPERATURE	No health-based guideline	Ambient	Affects palatability and microbial growth; higher temperatures encourage pathogen survival.
TOTAL DISSOLVED SOLID	1000mg/L	500	High TDS gives salty/bitter taste, may cause gastrointestinal irritation.
TOTAL SUSPENDED SOLIDS	NGV	NA	High TSS causes turbidity, clogs filters, harbors pathogens.
ELECTRICAL CONDUCTIVITY	1000	1000	High EC indicates excessive dissolved salts, harmful to hypertensive patients.
BIOCHEMICAL OXYGEN DEMAND	6	NA	High BOD indicates organic pollution; depletion of oxygen harms aquatic life.
CHEMICAL OXYGEN DEMAND	10	NA	Indicates chemical pollution; toxic substances in water.
TOTAL TITRATABLE ACIDITY	NGA	NA	High TTA causes pipe corrosion and sour taste
HARDNESS	NGV	500	Hard water causes scaling of pipes and kidney stones in extreme cases.
PHOSPHATE	NGV	NA	High levels accelerate eutrophication of water bodies

CHROMIUM	0.05	0.05	Causes ulcers, liver/kidney damage.
CADMIUM	0.003mg/L	0.003mg/L	Causes kidney damage, bone fractures, hypertension.
LEAD	0.01mg/L	0.01mg/L	Neurotoxin; damages brain, kidneys; lowers IQ in children.

Table 4.4: The table above shows WHO (2022) and NIS (2015) guideline values for key physicochemical parameters, serving as benchmarks for comparing the study's water quality results.

**Table 4.5: Summary of Questionnaire Responses from Residents of Ikpoba-Okha LGA,
Edo State**

Category	Frequency	Percentage (%)	Description
Female respondent	9	60	Majority of respondents were female, indicating higher participation from women.
Male respondent	6	40	Fewer males participated compared to females.
Age 10-30	11	70	Most respondents were young adults, reflecting the active age group in the community.
Other age groups	4	30	A smaller portion of respondents were outside the 18–30 age group.
Borehole users	12	80	Borehole was the most common source of drinking water among respondents.
Other sources	3	20	Some respondents relied on alternative sources like wells or sachet water.
Do not treat water	13	85	Majority of respondents drink water without treatment.
Treat water	2	15	Only a few respondents treat their water before drinking.

No usual characteristics	14	90	Most respondents perceived their water as clear and safe.
Noticed unusual characteristics	2	10	A small number reported issues like taste, odor, or color.
No water related illness	14	95	Nearly all respondents reported no illnesses linked to water.
Experience illness	1	5	A few respondents experienced water-related health problems.
Aware of monitoring	9	60	Over half were aware of water quality monitoring activities.
Not aware of monitoring	6	40	Some respondents lacked awareness of water quality monitoring.

Table 4.5: The table shows respondents frequency and percentage by gender, age, occupation, water source, and perception, reflecting community awareness and water use patterns

CHAPTER FIVE

DISCUSSION, RECOMMENDATIONS, AND CONCLUSION

5.1 Discussion

The physicochemical analysis of water from boreholes, hand-dug wells, and tap water in Ikpoba-Okha LGA revealed significant variations in quality when compared with World Health Organization (WHO, 2022) and Nigerian Industrial Standard (NIS, 2015) guideline

5.1.1 PH

The pH values recorded in the tap water, river, and hand-dug well samples were found to be below the permissible limits recommended by the World Health Organization (WHO, 2022) and the Nigerian Industrial Standard (NIS, 2015), which specify a range of 6.5–8.5 for drinking water. Similar reports of low pH in hand-dug wells have been documented by (Ahaneku and Adeoye 2014). A pH value below 6.5 indicates acidity, which is undesirable for domestic and potable use. pH has no direct adverse effect on Health, however a lower value below 4 will produce sour Taste; and a higher value above 8.5, an alkaline taste. Higher Values of pH hasten the scale formation in water heating Apparatus and also reduce the germicide potential of Chlorine. pH below 6.5 starts corrosion in pipes, thereby Releasing toxic metals such as Zn, Pb, Cd and Cu. This not only affects the taste and appearance of the water but also increases the risk of heavy metal poisoning and gastrointestinal irritation in consumers. The slightly acidic nature of the tap water may be due to corrosion in old distribution pipes and insufficient treatment at the source. Despite this, questionnaire responses revealed that about 90% of respondents reported that their water tasted normal, showing a disconnect between perceived and actual water quality. This implies that many residents may not notice low pH levels by taste alone and may continue consuming water that could have corrosive tendencies or health implications.

5.1.2 Temperature

The temperature of water samples from tap, hand-dug wells, and river sources in Ikpoba-Okha LGA were all recorded below 25 °C. This aligns with (Terebo *et al.*,2019) who observed similar temperature ranges in borehole waters of coastal Ondo State, indicating that ambient conditions and shading by vegetation largely control water temperature. This range is considered relatively low for tropical environments, where water temperatures often approach or exceed 30 °C due to prevailing climatic conditions. Although the World Health Organization (WHO, 2022) and Nigerian Industrial Standards (NIS, 2015) do not prescribe specific guideline values for temperature, the recorded values in this study are within the range generally regarded as acceptable for drinking water in terms of palatability and consumer satisfaction. Most respondents (about 80%) who rely on borehole water reported no unusual characteristics in their water, such as odor or discoloration, indicating that they perceive the water as clean and cool enough for drinking. This perception aligns with the measured temperature values, suggesting that the community's borehole and well water are thermally suitable for consumption and domestic use. However, higher temperatures in surface water (river) could enhance microbial growth, which respondents may not easily detect without testing.

5.1.3 Total Dissolved Solid

TDS values ranged from 0017 to 0092 (17–92mg/L). These values are well below the WHO and NIS recommended limit of 500 mg/L, indicating that the water is chemically safe and free from excessive dissolved salts. Water with low TDS is generally considered safe for drinking and has a neutral taste. However, extremely low TDS water may lack essential minerals such as calcium and magnesium, which are important for human nutrition (Abali *et al.*,2023) similarly found low TDS in surface water from Rivers State, Nigeria, attributing it to low mineralization and limited

industrial discharge. In this study, the TDS levels are sufficient to provide acceptable taste while not posing health risks (WHO, 2022).

5.1.4 Total Suspended Solids

In the water samples from Ikpoba-Okha LGA, TSS values ranged from 100 mg/L to 1500 mg/L with the higher values observed in river samples. This level exceeds the WHO and NIS recommended limit of 500 mg/L, indicating possible contamination from runoff, erosion, or domestic waste discharge into the river. Despite this, questionnaire responses showed that most residents do not treat their water before drinking, and a few (about 20%) use river or well water for domestic activities. This reveals a clear gap between community perception and scientific assessment. While the water may appear clear to the eye, it may still contain harmful suspended particles that affect quality and safety.

5.1.5 Electrical Conductivity

The EC values measured in Ikpoba-Okha LGA indicate that the water sources are within safe limits concerning ionic content, supporting respondents' perception that the water is good and suitable for domestic purpose (Chokor *et al.*, 2021) who reported low conductivity in well and borehole samples in Sapele, suggesting minimal contamination by dissolved salts or industrial effluents.

However, ongoing monitoring and management are crucial to maintain water quality and prevent potential health risks associated with elevated EC levels.

5.1.6 Total Titratable Acidity

The river water showed higher acidity compared to tap water, possibly due to surface runoff containing organic matter or acidic pollutants. Tap water had lower TTA, likely due to treatment

or dilution effects. The high TTA in surface water suggests a greater potential for corrosion and metal solubility. Nevertheless, the majority of respondents indicated that they did not observe any discoloration or taste changes in their water, suggesting that physical appearance does not always reflect chemical safety (WHO, 2022).

5.1.7 Total Solid

The river water had higher TS, indicating more suspended and dissolved solids, likely due to surface runoff, organic matter, and soil erosion. Tap water had lower TS, showing some treatment and filtration effects, making it more suitable for domestic use (WHO,2022).

5.1.8 Biochemical Oxygen Demand

In Ikpoba-Okha LGA, BOD values ranged from 12.12 mg/L in river water to 30.30 mg/L in tap water, indicating that tap water has significantly more biodegradable organic matter compared to treated tap water .Elevated BOD in river water can result from domestic sewage, agricultural runoff, and decomposed plant material entering the water.Comparable results were reported by (Obagha *et al.*,2025), who found elevated BOD in river waters near populated areas.High BOD levels indicate that dissolved oxygen in water may be depleted, potentially harming aquatic life and increasing the risk of pathogenic growth.The higher BOD in tap water suggests organic contamination possibly introduced through poor treatment or pipe leakages, while the lower value in river water may indicate natural dilution effects.This agrees with the questionnaire responses, where a large proportion of residents (85%) reported not treating their water before use, implying potential exposure to organic pollutants.

5.1.9 Chemical Oxygen Demand

The river water showed the lowest COD, suggesting minimal organic pollution, while tap and well water had slightly higher values, possibly due to leaching from groundwater or

contamination during distribution. These results align with findings by (Abali *et al.*, 2023) who documented similar COD variations across different water sources in Rivers State. Overall, the COD values are relatively low, indicating that the water is not heavily polluted with organic matter. From the questionnaire, most respondents reported that their water appeared clear and without odor or discoloration, which aligns with the low COD values obtained in the analysis. This agreement suggests that residents' perceptions of good water quality correspond to the laboratory findings, confirming that the water sources experience low levels of organic or chemical contamination. However, the slightly higher COD values in tap and well water could indicate minor pollution from household or surface runoff, which may not be easily noticed by users.

5.1.10 Hardness

The low hardness levels in Ikpoba-Okha LGA indicate soft water, which is suitable for drinking and domestic purposes. Continuous monitoring ensures that water remains safe and non-corrosive to household systems (WHO, 2022). From the questionnaire, many respondents indicated that their water lathered easily with soap, suggesting soft water. This perception aligns with the laboratory findings, where the hardness levels were below WHO and NIS permissible limits, indicating low concentrations of calcium and magnesium ions. The agreement between respondents' observations and the experimental results confirms that water sources in the area are generally soft and suitable for domestic use, though prolonged consumption of very soft water may sometimes affect mineral intake.

5.1.11 Phosphate

According to WHO (2022) and NIS 554:2007, there is no specific permissible limit for phosphate in drinking water, but elevated concentrations are environmentally undesirable. High

phosphate levels in river water may lead to algal blooms and reduced water quality, while moderate levels in tap and well water require monitoring to prevent secondary contamination and aesthetic issues. From the questionnaire, about 85% of respondents said they do not treat their water, and some observed discoloration, supporting the lab findings. This shows that human and agricultural activities likely contribute to phosphate pollution in Ikpoba-Okha LGA.

5.1.12 Chromium

River water had slightly lower chromium than tap and well water. Tap and well water may accumulate chromium from groundwater leaching or plumbing systems. All measured values are below the WHO limit of 0.05 mg/L, indicating they are relatively safe for consumption (WHO, 2022). However, prolonged exposure even to low levels can still have cumulative health effects, such as skin irritation, allergic reactions, and potential carcinogenic risks. Questionnaire results revealed that most respondents (about 85%) do not treat their water before use, suggesting a possible long-term risk if contamination levels increase. Hence, regular monitoring is necessary to ensure chromium levels remain within safe boundaries.

5.1.13 Cadmium

The river water cadmium level is very low and below the WHO permissible limit of 0.003 mg/L, indicating minimal natural or anthropogenic contamination at the sampling site. In contrast, tap and well water show elevated Cd concentrations, exceeding safe limits, suggesting potential contamination from plumbing systems, industrial activities, or groundwater leaching from nearby soils and waste dumps. Contamination in drinking water may also be caused by impurities in the zinc of galvanized pipes and solders and some metal fittings (WHO, 2022). Cadmium is a highly toxic heavy metal, and continuous exposure, even at low concentrations, can lead to kidney damage, bone demineralization, and cardiovascular issues. Questionnaire responses revealed that

a majority of respondents rely on untreated water sources, which increases the potential health risks associated with cadmium contamination. This highlights the need for regular testing and treatment of groundwater in Ikpoba-Okha to prevent long-term public health impacts.

5.1.12 Lead

River water is within safe limits, suggesting minimal contamination from industrial or domestic sources. Tap water is safe but should still be monitored, especially considering pipe corrosion or leaching. Well water slightly exceeds WHO limits, implying potential health risks if consumed over long periods. Long-term exposure can cause neurological and kidney damage, particularly in children and pregnant women (WHO, 2022). The questionnaire results, which showed that most respondents depend on borehole and well water without treatment, further underscore the potential health risk of lead exposure in the community.

This finding highlights the urgent need for improved water infrastructure and regular monitoring to ensure that residents have access to safe drinking water and to prevent chronic exposure to lead contamination.

5.2 CONCLUSION

The results of this study revealed that the physicochemical qualities of water from different sources within Ikpoba-Okha Local Government Area vary across locations and water types. Although most parameters such as temperature, total solids, total dissolved solids, and hardness fell within the acceptable range recommended by the World Health Organization (WHO) and Nigerian Industrial Standard (NIS), a few, such as pH and phosphate concentrations, deviated from the permissible limits, suggesting potential health concerns if consumed over a long period.

Tap water generally exhibited better physicochemical quality than hand-dug well and river water, indicating the benefits of treated and regulated systems. River water showed higher levels of biological oxygen demand (BOD) and turbidity, reflecting the impact of surface runoff, poor sanitation, and domestic waste discharge. The hand-dug wells were also susceptible to contamination from nearby waste disposal sites and seepage, emphasizing the vulnerability of shallow groundwater sources.

The analysis of questionnaire responses revealed that most residents rely on borehole and well water, with a majority not treating their water before consumption. This lack of water treatment and limited awareness of water safety practices contrast with the laboratory findings, underscoring the need for improved public health education and regular water quality assessments.

In relation to the study objectives, this research successfully assessed the physicochemical parameters of water from different sources, compared them with WHO and NIS standards, and identified possible contamination risks and public awareness gaps. Therefore, it concludes that while most water sources in Ikpoba-Okha are suitable for domestic use, routine monitoring,

community sensitization, and better waste management strategies are essential for ensuring sustainable access to safe and potable water.

5.3 RECOMMENDATIONS

Based on the findings from this study, it is recommended that regular monitoring and evaluation of water sources in Ikpoba-Okha LGA be carried out by relevant agencies to ensure compliance with WHO and NIS standards. This will help detect any deviation from acceptable limits and prevent health risks associated with poor water quality.

Public enlightenment programs should be organized to educate residents on the importance of water treatment before consumption. Since most respondents indicated they do not treat their water, households should be encouraged to use simple treatment methods such as boiling, filtration, or chlorination to reduce contamination.

The government should also rehabilitate and maintain existing water facilities, including tap and borehole systems, to prevent contamination from pipe corrosion or leakage. Proper well construction and covering should also be ensured to reduce pollution from runoff and waste.

In addition, environmental sanitation and waste management practices should be improved to minimize the infiltration of pollutants, heavy metals, and organic waste into water bodies. Communities should be encouraged to adopt eco-friendly waste disposal methods and avoid dumping refuse near wells and rivers.

Furthermore, the study recommends that policy-makers and health authorities develop integrated water management strategies that combine scientific assessment with community participation. This approach will promote accountability, strengthen local capacity in water testing, and enhance the sustainability of clean water supply systems.

Finally, further research should be conducted during different seasons to monitor variations in water quality and the influence of human activities. Collaboration between community members,

health agencies, and environmental bodies will promote sustainable management of water resources and safeguard public health.

REFERENCES

- Abali, C. I., Kpee, F., and Orie, K. J. (2023). Physicochemical characteristics of surface water from Idu Ogba River, Rivers State, Nigeria. *Faculty of Natural and Applied Sciences Journal of Scientific Innovations*, **5**(2), 69-77.
- Adelagun, R. O. A., Etim, E. E., and Godwin, O. E. (2021). Application of water quality index for the assessment of water from different sources in Nigeria. In Promising techniques for wastewater treatment and water quality assessment. IntechOpen.
- Adekunle, I. M., Adetunji, M. T., Gbadebo, A. M., and Banjoko, O. B. (2007). Assessment of groundwater quality in a typical rural settlement in Southwest Nigeria. *International journal of environmental research and public health*, **4**(4), 307-318.
- Adesakin, T. A., Oyewale, A. T., Bayero, U., Mohammed, A. N., Aduwo, I. A., Ahmed, P. Z., and Barje, I. B. (2020). Assessment of bacteriological quality and physico-chemical parameters of domestic water sources in Samaru community, Zaria, Northwest Nigeria. *Heliyon*, **6**(8).
- Ahaneku, E., and ADEOYE, P. A. (2014). Impact of Pit Latrines on Groundwater Quality of Foko Slum, Ibadan, South-Western Nigeria.
- Akpe, A. R., Femi, I. J., Okwu, G. I., and Obiazi, H. (2018). Seasonal variations in the physicochemical parameters of Ikpoba river water samples. *Int. J. Life. Sci. Sci. Res*, **2455**(1716), 1716.
- Balogun, M. A., Anumah, A. O., Adegoke, K. A., and Maxakato, N. W. (2022). Environmental health impacts and controlling measures of anthropogenic activities on groundwater quality in Southwestern Nigeria. *Environmental Monitoring and Assessment*, **194**(5), 384.
- Babuji, P., Thirumalaisamy, S., Duraisamy, K., and Periyasamy, G. (2023). Human health risks due to exposure to water pollution: a review. *Water*, **15**(14), 2532.
- Bentum, J. K., Anang, M., Boadu, K. O., Koranteng-Addo, E. J., and Antwi, E. O. (2011). Assessment of heavy metals pollution of sediments from Fosu lagoon in Ghana. *Bulletin of the Chemical Society of Ethiopia*, **25**(2).
- Bernard, E., and Ayeni, N. (2012). Physicochemical analysis of groundwater samples of Bichi local government area of Kano State of Nigeria. *World Environment*, **2**(6), 116-119.
- Chokor, A. A. (2021). Metals' content and physicochemical characteristics of well waters in Sapele metropolis, south-southern Nigeria. *J. Mater. Environ. Sci*, **11**(2), 295-307.
- Edokpayi, J. N., Rogawski, E. T., Kahler, D. M., Hill, C. L., Reynolds, C., Nyathi, E., ... and Dillingham, R. (2018). Challenges to sustainable safe drinking water: A case study of water quality and use across seasons in rural communities in Limpopo Province, South Africa. *Water*, **10**(2), 159.

- Eze, V. C., Onwukeme, V. I., Ogbuagu, J. O., Aralu, C. C., Aduaka, C. N., and Okoro, N. J. (2023). Evaluation of selected physicochemical properties of River Otamiri, Imo State. *Health and environment*, **4**(1), 209-216.
- Egbueri, J. C., Ighalo, J. O., and Pande, C. B. (2023). *Climate change impacts on Nigeria*. Springer International Publishing AG
- Gorde, S. P., & Jadhav, M. V. (2013). Assessment of water quality parameters: a review. *J Eng Res Appl*, **3**(6), 2029-2035.
- Ijioma, U. D., Ijioma, M., and Herd, R. (2025). Assessment of quality and health risks in drinking water sources in Aba, Nigeria. *Water Practice & Technology*, **20**(4), 937-953.
- Khan, M. X., and Butt, A. (2022). Evaluation of water quality using physicochemical parameters and aquatic insects diversity.
- Karikari, A. Y., and Ansa-Asare, O. D. (2006). Physico-chemical and microbial water quality assessment of Densu River of Ghana. *West African Journal of Applied Ecology*, **10**(1).
- Lawal, K. K., Ekeleme, I. K., Onuigbo, C. M., Ikpeazu, V. O., and Obiekezie, S. O. (2021). A review on the public health implications of heavy metals. *World Journal of Advanced Research and Reviews*, **10**(3), 255-265.
- Mahe, A. U., Salihu, N., and Sani, M. M. (2024). Perspective Chapter: Physicochemical Parameters and Water Quality.
- Magashi, N. L., Abah, M., Magash, T., Dabwan, C. H., and Tsua, D. D. (2025). Heavy Metals Pollution Levels of Hand-Dug Wells in Tarka Local Government Area, Benue State-Nigeria. *Journal of Chemical Society of Nigeria*, **50**(4).
- Nayar, R. (2020). Assessment of water quality index and monitoring of pollutants by physico-chemical analysis in water bodies: a review. *International Journal of Engineering Research and Technology*, **9**(01), 178-185
- Nayla Hassan, O. (2019). Water quality parameters. Water quality.
- Obagha, A. N., Obumselu, O. F., and Okafor, V. N. (2025). Physicochemical properties of water from rivers of some oil-producing communities in Anambra State, south-east Nigeria. *Journal of the Chemical Society of Nigeria*, **50**(2), 318-329.
- Omoregie, A. E., and Okoro, E. O. (2024). Local Climate Conditions and Prevalence of Typhoid Fever Disease Patterns in a Vulnerable Community of Ikpoba Okha LGA of Edo State, Nigeria. *Journal of Applied Sciences and Environmental Management*, **28**(11), 3731-3736.

- Omokaro, G., Idama, V., Aireughian, E., and Michael, I. (2024). Water Resources, Pollution, Integrated Management and Practices in Nigeria-An Overview. *American Journal of Environmental Economics*, **3**(1), 10-54536.
- Oladimeji, T. E., Oyedemi, M., Emeteri, M. E., Agboola, O., Adeoye, J. B., and Odunlami, O. A. (2024). Review on the impact of heavy metals from industrial wastewater effluent and removal technologies. *Heliyon*, **10**(23).
- Odukoya, A. M., and Abimbola, A. F. (2010). Contamination assessment of surface and groundwater within and around two dumpsites. *International Journal of Environmental Science & Technology*, **7**(2), 367-376.
- Orebiyi, E. O., Awomeso, J. A., Idowu, O. A., Martins, O., Oguntoke, O., and Taiwo, A. M. (2010). Assessment of pollution hazards of shallow well water in Abeokuta and environs, southwest, Nigeria.
- O'Donnell, D. (2021). Three Main Types of Water Quality Parameters Explained. *Sensorex*.
- R. O. A., Etim, E. E., and Godwin, O. E. (2021). Application of water quality index for the assessment of water from different sources in Nigeria. In Promising techniques for wastewater treatment and water quality assessment.
- Rawlings, A., Ofili, J. A., and Idehen, G. (2024). Assessment of Groundwater Suitability for Industrial Purpose in Oredo LGA of Benin City, Nigeria Using Langelier Saturation Index. *Journal of Engineering Research*, **29**(1), 1-13.
- Singh, U. S., Panwar, S., Jain, R. K., and Tripathi, Y. C. (2020). Physicochemical analysis of effluents from agro-based paper mill in Uttarakhand State of India. *Int. J. ChemTech Res*, **13**, 174-180.
- Standards Organisation of Nigeria (SON). (2015). *Nigerian Standard for Drinking Water Quality* (NIS 554:2015). Abuja: SON.
- Tariq, A., and Mushtaq, A. (2023). Untreated wastewater reasons and causes: A review of most affected areas and cities. *Int. J. Chem. Biochem. Sci*, **23**(1), 121-143.
- Tyagi, S., Sharma, B., Singh, P., and Dobhal, R. (2013). Water quality assessment in terms of water quality index. *American Journal of water resources*, **1**(3), 34-38.
- Terebo, O., Olayinka, O. O., Bamgbose, O., Abdul, W. O., and Martins, O. (2019). Physicochemical Quality of Borehole water of selected Settlements in the Coastal Area of Ondo-State, Nigeria. *Journal of Chemical Society of Nigeria*, **44**(5).
- Verma, S., Verma, S., Ramakant, R., Pandey, V., and Verma, A. (2025). Comprehensive Assessment of Physico-Chemical and Biological Parameters in Water Quality Monitoring: A Review of Contaminants, Indicators, and Health Impacts. *International Journal of Horticulture, Agriculture and Food science*, **9**(2), 611019.

World Health Organization (WHO). (2022). Guidelines for drinking-water quality: Fourth edition incorporating the first and second addenda. Geneva: WHO.

Warwick, C., Guerreiro, A., and Soares, A. (2013). Sensing and analysis of soluble phosphates in environmental samples: A review. *Biosensors and Bioelectronics*, **41**, 1-11.

Zahoor, I., and Mushtaq, A. (2023). Water pollution from agricultural activities: A critical global review. *Int. J. Chem. Biochem. Sci*, **23**(1), 164-176.